Evaluation of Three Non-Metric Traits in Maxillary Central Incisors for Population and Sex Estimations: A Cross-Sectional Study using the Turner-Scott Dental Anthropology System

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ABSTRACT The expressions of non-metric traits are commonly used for population or ancestry estimation. This present study explored the role of dental non-metric data from Gujarat state in India for population and sex estimation. The three non-metric traits namely, labial curvature, shoveling, and *tuberculum dentale* traits in permanent maxillary central incisors in distinct population subgroups from different geographical and community backgrounds were compared. The dental traits in right and left central incisors of 1299 school children, with a mean age of 13.97 years ± 1.70 were examined and recorded using the Turner-Scott standard dental anthropology plaques. There was no significant difference in the distribution of all three traits between sides. There was a significant difference in the overall distribution of the traits between the different population subgroups (p<0.001). Nearly 21% of the overall population was correctly classified district-wise using the non-metric dental traits in the maxillary central incisor. Only the shoveling trait showed significant gender differences in the study population. Using the discriminant function, 75% of the girls and 29%of the boys were correctly classified. The percentage of correct prediction of sex based on the discriminant function ranged from 57.9% to 70.9% in all the districts.

Forensic profiling plays an integral part in the human identification process. Parameters like age, sex, and ancestry are some of the important components of forensic profiling. The potential unique characteristics or personal information of an individual can also be derived by properly analyzing the dental structures. Furthermore, teeth are known to vary morphologically between and within populations and the sexes (Scott and Turner, 2008). Particularly, dental non-metric traits have shown affinities and variations among different population groups (Scott and Turner, 1997; Vargiu et al., 2009). The teeth, thus, can be used to provide an estimate of the ancestry and sex of an unidentified individual. Dental non-metric traits show different degrees of expression among different populations (Turner, 1991; Kelley and Larsen, 1991; Jernvall and Jung, 2000). This grading system places the trait expression into an ordinal scale based on the extent of expression of the traits (Turner, 1991). The frequencies of expressions of such traits are used to distinguish the population variations (Edgar, 2013; Lukacs, 1987). The most commonly studied traits in the tooth are cusp number, cusp size, groove patterns, root length, and number. Genetic and environmental influences have also been hypothesized to play an important role in the phenotypic manifestation of dental traits (Townsend et al., 2009).

For sex estimation, odontometric measures also have proved to be a more reliable method than the tooth morphologic parameters (Nagpal et al., 2017). Among the non-metric traits, the canine distal accessory ridge has shown a significant sex difference (Pilloud and Scott, 2020). The unique dental features and the evidence of dental treatments

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on teeth have their role in human identification or linking the accused to the victim or the crime. There are instances where the single incisor tooth has been used as an exhibit from the crime scene and sent for forensic odontology investigations like age and sex estimations. Though the expressions of non-metric traits have no role in age estimation, they play a significant role in estimating the ancestry and sex of the unidentified decedent. Thereby, dental traits help in generating the biological profile of the deceased.

According to G. Richard Scott and Christy Turner, only a few traits like shovel-shaped incisors, Carabelli's cusp, and lower molar cusp number have been characterized on a worldwide scale. However, in some geographic locations like India, dental morphologic traits have not been studied in detail (Scott et al., 2018). The application of dental non-metric traits in forensic human identification cases is very limited. However, from research and anthropological points of view, dental traits are being explored to study population variation. Such population-based studies in Gujarat, a state in the western part of India are also lacking. The principal author (JP), having more than 25 years of experience in teaching dental anatomy and histology in Gujarat observed variations in maxillary central incisors of his students who represent different parts of Gujarat. In the maxillary central incisor, the labial curvature, shoveling, and *tuberculum dentale* are the easily identifiable traits. The present population-based study was designed to explore the variations in the expression of these three traits among the eight geographically distinct populations using the standard Turner-Scott/Arizona State University Dental Anthropology System (ASUDAS). Another objective of the study was to explore the variations in these traits between sexes. There is hardly any study examining the expressions of these non-metric traits used for population and sex estimation, especially in this part of India. Hence, the present study was conducted to generate the population-based data from eight different districts of Gujarat and to explore the differences in the expression between populations and sexes.

Materials and Methods

One thousand two hundred and ninety-nine school children from eight different districts of Gujarat in the age group of 10 to 17 years were examined from August to November 2019 in their respective schools. The study subjects included 620 (47.7%) boys and 679 (52.3%) girls. The institutional ethical committee's approval was obtained before the start of the study (IEC/ GDCH/S.2/2019). The necessary permissions from the school authorities of the respective districts were obtained for this study. All the students were residents of Gujarat since birth and were basically of Gujarati origin in terms of their surname/family name and mother tongue. The clinical evaluation of the children was performed by the principal investigator (JP) using mouth mirrors and probes under good illuminations and the supervision of their respective class teachers. The ASUDAS plaques of three traits in the maxillary central incisors were used as standards (Figure 1).

The extent of labial curvature, the prominence

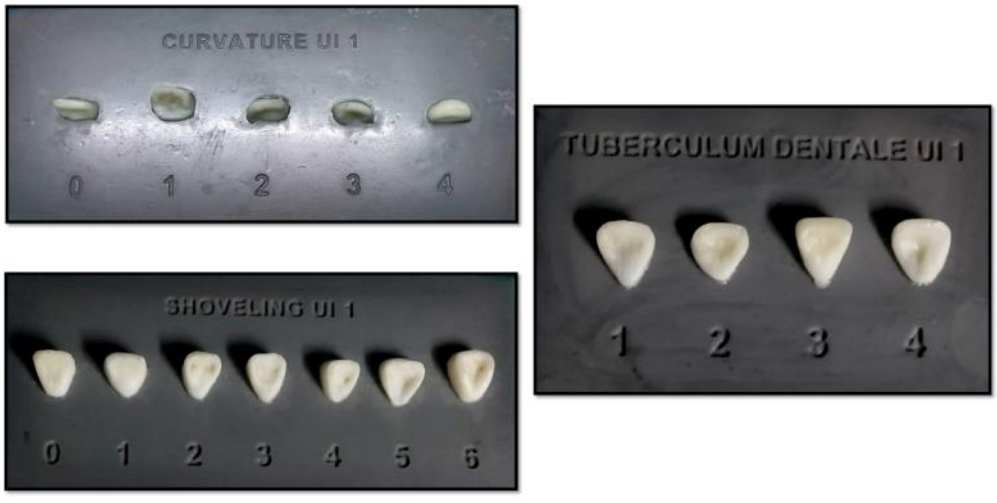

Figure 1. Non-metric traits in the permanent maxillary central incisor in the ASUDAS.

of mesial and distal marginal ridges, and the extent of projection of cingulum on the lingual surface of the maxillary central incisor were the morphological parameters used in the study. There are 5 scores of labial curvature (score 0-4) and 7 scores for grading the expression of shoveling in upper central incisors according to the ASUDAS plaques. For grading *tuberculum dentale*, there are 4 scores (Score 1-4) The grading of the traits were noted in the prescribed proforma and then entered in the Microsoft Excel sheet. The intra-observer error in grading the traits was tested before the start of the study by the same author (JP) with a subsample of 50 dental students in his institute.

Statistical analysis

The data were analyzed using the Statistical Package for the Social Sciences (SPSS) software (version 23; SPSS, Inc., Chicago, USA). The intra-observer error in grading the traits was tested using the Cohen's Kappa coefficient of agreement. The descriptive statistics included mean, standard deviation, and frequency distribution in percentages. The Wilcoxon Signed-Rank test was used to test the difference in the expression of the traits between sides. The Spearman correlation coefficient was used to correlate the expressions of traits between right and left central incisors. The nonparametric Kruskal-Wallis was used to test the difference in the expression of the trait among the eight districts' populations. The independent samples Mann-Whitney U test was used in assessing the graded data between sexes. The discriminant function analysis (DFA) using the traits as independent or predictor variables and the population groups as dependent or grouping variables was carried out using the Canonical discriminant function. The prior probabilities were set to compute from group sizes and using the within-group covariance matrix. The level of significance was set at $p \leq 0.05$ for all statistical analyses.

Results

Sample characteristics

The study included a sample of 1299 Gujarati school students aged 10 to 17 years from 8 districts of Gujarat (Figure 2). The mean age of the sample was 13.97 years ± 1.70. The Cohen's Kappa coefficient ranged between 0.84 to 0.96 for all the three traits when testing the intra-observer variations in grading the traits in the subsample. This result revealed an almost significant intra-observer agreement in grading the traits (Landis and Koch, 1977). The frequency distribution of the scores of the three non-metric traits in the overall sample is shown in Table 1. The labial surface of incisors was slightly curved and not exactly straight (Score 1) in around 82% of the overall cases. The shoveling was absent in 36.5% of the overall sample and 37% of the cases the *tuberculum dentale* trait was absent and the cingulum was smooth. There was no significant difference in the expression of the traits between right and left central incisors (see Table 1). There was also excellent intra-trait correlation between the right and left sides with the Spearman correlation coefficient ranging between 0.995 to 0.998. Hence, the data of one of the sides (right side), was considered for further analysis. The distribution of the samples according to the scores in all eight districts is shown in Table 2. The independent samples Kruskal-Wallis test revealed a significant difference in the distribution of the scores of all the three traits across the districts (see Table 2). The results of the pair-wise comparison of the expression of the traits between the districts are shown in Figure 3. This figure shows which of the two districts significantly differ from each other (yellow line) concerning the expression of the traits. Among the three traits studied, only the shoveling trait showed a significant difference in its expression between boys and girls. More boys were showing the expression of this trait than girls. (Table 3).

Discriminant function analysis

The discriminant function that best separates or discriminates between the groups is reported here. The discriminant function to classify the district-wise population using the dental non-metric traits in maxillary central incisors revealed a canonical correlation of 0.333 with a variance of 69.7%. There was a significant relationship between the discri-

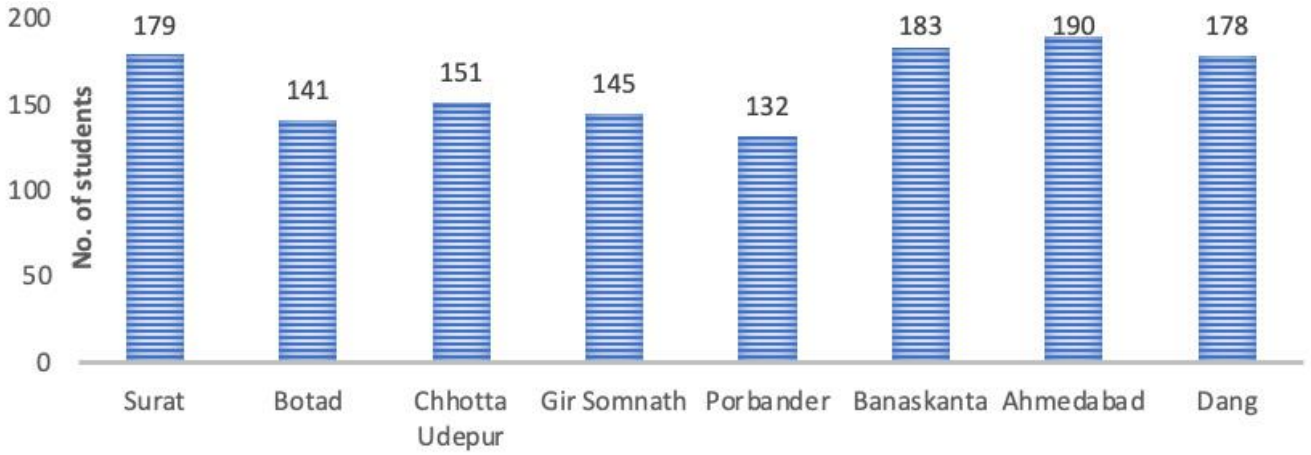

Figure 2. Graph showing the district-wise frequency distribution of the study subjects.

Table 1. Table showing the frequency distribution of the scores of the three traits in permanent maxillary central incisors on both sides.

Traits	Score	Right		Left		Wilcoxon Signed Rank test Sig.*
		n	%	n	%	
Maxillary Incisor Labial Curvature (UI1LC)	**0**	96	7.4	96	7.4	0.317
	1	1068	82.2	1069	82.3	
	2	127	9.8	126	9.7	
	3	8	0.6	8	0.6	
Maxillary Incisor Shovel shape (UI1SS)	**0**	471	36.3	467	36.0	0.257
	1	550	42.3	555	42.7	
	2	278	21.4	277	21.3	
Maxillary Incisor *Tuberculum Dentale* (UI1TD)	**0**	488	37.6	487	37.5	0.655
	1	719	55.4	720	55.4	
	2	88	6.8	88	6.8	
	3	4	0.3	4	0.3	

*Significant at $p<0.05$

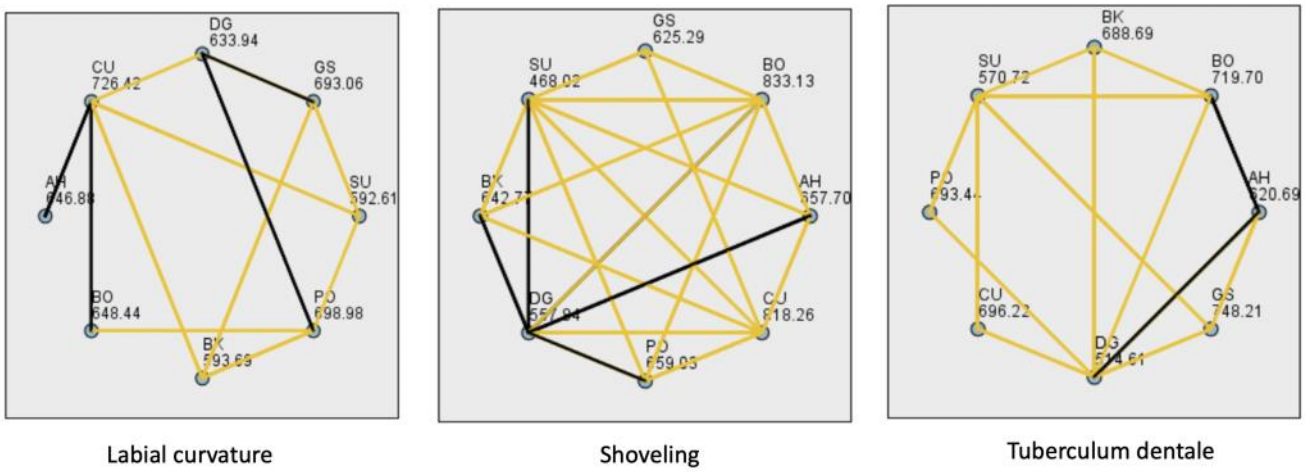

Figure 3. Figure showing the results of the pair-wise comparisons of the district populations for all the three traits. The yellow lines show significant difference (adjusted by Bonferroni correction) and the black lines represent the insignificant difference between the pairs of districts and the nodes represent the mean rank values, according to the independent Kruskal-Wallis test.

Table 2. Table showing the district-wise distribution of the scores of expressions of the three traits in maxillary central incisors.

District Code	Score	UI1 LC (Rt.)		UI1 Shoveling (Rt.)		UI1 *Tuberculum Dentale* (Rt.)	
		n	%	n	%	n	%
ST	0	25	14.0	109	60.9	87	48.6
	1	141	78.8	56	31.3	85	47.5
	2	13	7.3	14	7.8	6	3.4
	3	0	0.00	0	0.0	1	0.6
BO	0	9	6.4	15	10.6	38	27
	1	119	84.4	78	55.3	91	64.5
	2	13	9.2	48	34	12	8.5
	3	0	0.00	0	0	0	0
CU	0	13	8.6	25	16.6	46	30.5
	1	102	67.50	69	45.7	93	61.6
	2	28	18.50	57	37.7	12	7.9
	3	8	5.30	0	0	0	0
GS	0	7	4.80	62	42.8	32	22.1
	1	116	80.00	49	33.4	101	69.7
	2	22	15.20	34	23.4	12	8.3
	3	0	0.00	0	0	0	0
PO	0	5	3.80	51	38.6	48	36.4
	1	107	81.10	46	34.8	63	47.7
	2	20	15.20	35	26.5	19	14.4
	3	0	0.00	0	0	2	1.5
BK	0	28	15.30	68	37.2	57	31.1
	1	139	76.00	77	42.1	113	61.7
	2	16	8.70	38	20.8	13	7.1
	3	0	0.00	0	0	0	0
AH	0	8	4.20	59	31.1	81	42.6
	1	169	88.90	99	52.1	95	50
	2	13	6.80	32	16.8	13	6.8
	3	0	0.00	0	0	1	0.5
DG	0	1	0.60	82	46.1	99	55.6
	1	175	98.30	76	42.7	78	43.8
	2	2	1.10	20	11.2	1	0.6
	3	0	0.00	0	0	0	0
Chi-Square		43.084		135.815		68.400	
df.		7		7		7	
Sig.*		0.000		0.000		0.000	

*Significant at $p<0.05$

Table 3. Table showing the frequency distribution of the scores of the three traits in permanent maxillary central incisors in boys and girls.

Traits	Score	Boys (n=620)		Girls (n=679)		Mann-Whitney U test Sig.*
		n	%	n	%	
Maxillary Incisor Labial Curvature (UI1LC)	**0**	41	6.6	55	8.1	0.502
	1	514	82.9	554	81.6	
	2	63	10.2	64	9.4	
	3	2	0.3	6	0.9	
Maxillary Incisor Shovel shape (UI1SS)	**0**	174	28.1	297	43.7	0.000
	1	301	48.5	249	36.7	
	2	145	23.4	133	19.6	
Maxillary Incisor *Tuberculum Dentale* (UI1TD)	**0**	227	36.6	261	38.4	0.171
	1	338	54.5	381	56.1	
	2	51	8.2	37	5.4	
	3	4	0.6	0	0	

minant function and the grouping variables (Wilks Lambda = 0.843; $c^2 = 221.293$ *df=21, p<0.001).* The inter-trait correlation revealed a 27.6% correlation between shoveling and *tuberculum dentale* and a weak correlation between labial curvature and *tuberculum dentale* (8.1%). Between labial curvature and shoveling the correlation was 18.6%. The shoveling trait revealed a maximum discriminating power (94.4%) followed by *tuberculum dentale* (49.2%) and labial curvature (40.4%). Only 21.3% of the overall population was correctly classified using this function. The percentage of correct classification was maximum for the Surat district (Table 4).

The discriminant function for classifying sex based on the variables also revealed a significant relationship between the discriminant function and the grouping variables with a canonical correlation of 0.132. (Wilks Lambda= 0.983, $c^2 = 22.764$ *df=3, p<0.001).* The shoveling trait has more discriminant power followed by the *tuberculum dentale* trait (Table 5). The classification statistics revealed 53.2% of the original cases were correctly classified. The percentage of correct classification was more for girls (75.1%) when compared to boys (29.2%). The district-wise results of the discriminant function analysis in sex estimation using the three traits revealed an overall correct classification in the range of 57.9% to 70.9%. However, the function was significant only for three districts (Table 6).

Discussion and Conclusions

The present study observed the expression of three different non-metric traits in the permanent maxillary central incisors in eight different geographic locations in Gujarat. Gujarat is a state in western India with a population of nearly 67 million. The population is diverse based on caste, culture, tradition, occupation, geography, etc. The Gujarati population in the present study represents the ancestral North Indian gene that appears to be much more diverse than other South Asian populations (Silva et al., 2017). This study is the first of its kind in India which was conducted in a large population using the ASUDAS to discriminate the population subgroups based on the expression of non-metric traits in the tooth and also on sex estimation. However, as there are possible biases in recording the traits, the estimation of population just based on teeth is difficult and has to be undertaken very cautiously (Acharya and Sherawat, 2021). In the present study, around 82% of the population had slight curvature (score 1), a trait which is characteristic of Asian and Asian-derived populations. A study on labial curvature among 20 worldwide populations has shown that moderate curvature was seen in Europeans and American Indians (Nichol et al., 1984). The study also showed that

Table 4. The results of the discriminant function analysis performed to discriminate the populations based on the non-metric trait parameters in maxillary central incisors.

Variables	Unstandardized coefficients	Standardized coefficients	Absolute size of correlation	Constant	Wilks Lambda	Sig.	% of correct classification		
							District	%	Overall %
UI LC	0.528	0.229	0.404				ST	58.10	
UI SS	1.179	0.834	0.944	-1.839	0.843	0.000	BO	30.50	21.30
UI TD	0.413	0.244	0.492				CU	21.20	
							GS	5.50	
							PO	0.00	
							BK	20.20	
							AH	0.00	
							DG	29.80	

Table 5. The results of the discriminant function analysis performed to discriminate the sex based on the non-metric trait parameters in maxillary central incisors.

Variables	Unstandardized coefficients	Standardized coefficients	Absolute size of correlation	Constant	Centroids		Wilks Lambda	Sig.	% correct classification		
					M	F			M	F	Overall
UI LC	-0.285	-0.126	0.094	-0.943	0.139	-0.127	0.983	0.00	29.20	75.10	53.20
UI SS	1.343	0.992	0.990								
UI TD	0.136	0.082	0.367								

Table 6. The results of the discriminant function analysis in sex estimation using the traits parameter in all the districts.

District	Eigenvalue	Canonical correlation	Wilks Lambda	Chi-Square	Sig.	% of correct classification		
						M	F	Overall
1	0.221	0.425	0.819	35.038	0.000	60.5	80.6	70.9
2	0.019	0.135	0.982	2.522	0.471	16.4	93.0	63.1
3	0.030	0.17	0.971	4.304	0.23	74.4	36.2	57.0
4	0.094	0.293	0.914	12.72	0.005	30.2	84.8	64.8
5	0.049	0.216	0.954	6.117	0.106	15.4	93.5	70.5
6	0.012	0.109	0.988	2.160	0.540	75.5	43.5	60.7
7	0.006	0.079	0.994	1.171	0.760	100.0	0.0	57.9
8	0.049	0.216	0.953	8.326	0.040	80.4	30.9	57.90

labial curvature does not exhibit sexual dimorphism. This finding is similar to the results of the present study. The shoveling trait in the incisors is a characteristic dental feature of North Asian and North/South American populations. It is very commonly seen in the Native American populations, South East Asians, and derived populations like Polynesians and Micronesians (Nichol et al., 1984). Grades of shoveling may be observed in both upper and anterior teeth. In the present study, this trait was observed in 64% of the study population. In the Tamil population in Southern India, the shoveling trait was present in 8% of the population (Shrivastav et al., 2018). However, that study did not grade the expression of traits as done in the present study. The same trait in a study on the Malayalee population showed a frequency of 6.7% (Uthaman et al., 2015). There is a clear-cut genetic demarcation between the Kerala population and the Gujarati population (D'Cuna et al., 2017). However, in another study on the Kerala population, the shoveling trait was observed in 69.12% of the population which was similar to the results of the present study (Baby et al., 2017). In the Bangalore population study, the shoveling of incisors was observed in 65.7% of the population and double shoveling in 66.6%. The shoveling of incisors was noted comparatively lower in the south Indian population, while 81% of East Indian and 85% of West Indian population showed shoveling of incisors (Nagaraj et al., 2015). A study by Lukacs and Pal (2013) demonstrated weak incisal shoveling in the early Holocene foragers in the mid-Ganga plains in North India. The district-wise comparisons showed a significant difference among all the districts except the Chottaudepur district. The expression of *tuberculum dentale* is more common in upper lateral incisors (20% - 50%).

The expression of ridge form of *tuberculum dentale* varies in size and number. There are 7 scores (Score 0-6) for grading the expression of *tuberculum dentale* (Edgar, 2017). However, in the ASUDAS, only 4 sores (score 1-4) were considered. The expressions of these three traits significantly differed among the populations. The study populations analyzed in the present study represented different geographical and community backgrounds. The present study also applied DFA to estimate population based on the three traits. The overall per cent of correct classification is only 21.3%. This is because only one tooth (i.e., the central incisor) is being considered here. Similar functions using multiple teeth may also be attempted in the future.

The present study also applied DFA to estimate sex based on the three variables. Among the three traits, shoveling was found to be more powerful in estimating sex and also the population. It was also observed in the present study that the females were more correctly classified than the males. Just based on the visual examination of the teeth, it may not be possible to exactly estimate the sex of an individual (Radlanski, 2012). Sex estimation accuracy rate of 53-65% was earlier reported using the shape analysis of upper arch incisors and canine (Horvath et al., 2012). However, odontometric parameters may be useful in some cases. Perhaps, a few traits like Carabelli's cusp and canine distal accessory ridge have shown evidence of sexual dimorphism (Pilloud and Scott, 2020). Carabelli's trait and the molar cusp number traits have shown an accuracy in the range of 70.2%- 74.8% in sex estimation in children (Adler et al., 2012).

In the present study, only the permanent maxillary central incisor tooth was considered and its three characteristic traits were used as independent variables to explore their role in population and sex estimations. Though there is a potential role of non-metric traits in sex estimation, it needs to be applied very carefully because there is always a possibility of subjective error in grading the traits. This mandates a need for intensive training for handling the standard plaques and identifying the expression grades accurately. In India, the dental curriculum needs to focus on dental anthropological aspects for the undergraduate and postgraduate students, by incorporating practical training on grading the traits using dental models and clinical subjects. Such exercise may minimize the inter-observer grading errors and increase the scope of application of the non-metric traits in population-based studies and sex estimation. Also, there is a need to incorporate dental morphology details including the non-metric trait details during the recording of the post-mortem dental findings during the dental autopsy procedures.

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