 DOI: 10.18231/2395-6194.2017.0037

Determination of sex by discriminant function analysis of lateral radiographic cephalometry using angular, linear and proportional cephalometric variables in Western Maharashtrian population

Amit Mathur[1], Abhijeet Sande[2,*], Mukund Risbud[3], Praveenkumar Ramdurg[4], Ashwinirani SR[5]

[1]Reader, Vaidik Dental College, Daman, [2,5]Senior Lecturer, School of Dental Sciences, KIMSDU, Karad, Maharashtra, [3]Professor, Vasantdada Patil Dental College & Hospital, Sangli, Maharashtra, [4]Reader, Dept. of Oral Medicine & Radiology, PNMN Dental College, Bagalkot, Gujarat

***Corresponding Author:**
Email: sandeabhijeet@gmail.com

Abstract

Sex determination of skeleton represents an important stage in the execution of forensic anthropological examination. Skull is considered the second best region of the skeleton after pelvis to determine the sex. Radiographic cephalometry is ideal for the skull examination as it gives details of various anatomical points in a single radiograph. Discriminant function analysis is a statistical technique that enables the researcher to examine the relationship among two or more groups based on any number of variables simultaneously.

Aims of the Study: To evaluate the sex determination technique from skull with the help of radiographic cephalometry and discriminant function analysis.

Materials and Method: Total 100 patients (50 males, 50 females) were recruited for the study. Lateral cephalographs were taken on the Cephalostat of MEDI TRONICS ARCOGRAPH ZEUS RH using standardized technique. Each radiograph was traced with 0.05 mm black lead pencil. All angular variables were marked using 0.05 mm blue lead pencil and all linear variables were marked using 0.05 mm red lead pencil.

Statistical Analysis Used: Unpaired *t*-test.

Results: Total 80 cases were classified into two sexual groups with 100% accuracy in our study. From our study we also observed that Frontal Bone Prominence (G-Sg-M), Supraorbital Ridges (G-SgN) and GPI Index are highly reliable variables for sex identification.

Conclusion: The radiographic cephalometric technique and discriminant function analysis is a useful technique to determine sex from skull and seems a promising, less expensive and readily available tool in forensic and anthropological investigations for sex identification.

Keywords: Forensic Anthropology, Sex determination, Cephalometry, Discriminant function analysis, Indian population survey

Introduction

Sex determination of skeleton represents an important stage in the execution of forensic anthropological examination. If the entire skeleton is available, sex can be assessed with 100% accuracy, 92% when using the skull alone and 98% when using the pelvis and skull.[1,2] Skull is probably the second best region of the skeleton after pelvis to determine the sex. In general male skulls have more robust suprastructures than the female skulls, as evident by bony ridges, crests and processes are more prominent in the male skulls than in the female skulls, especially true for the temporal line, mastoid processes, nuchal lines, external occipital protuberance and superciliary arches or ridges. The lack or weaker development of frontal sinuses, external occipital protuberance and mastoid process, also gives a fairly characteristics difference in the profile of female and male crania.[3]

Determination of sex from skull can be established by using either morphologic or morphometric methods. The methods based on morphometric traits are considered more reliable, as they use measurements and statistical analysis, whereas morphological methods are more subjective and depends on experience of the investigator.[4,5]

Radiographic cephalometry is ideal for the skull examination as it gives details of various anatomical points in a single radiograph. Studies conducted by Patil et al.[4] for central Indian population and Naikmasur et al.[6] for south Indian population for sex determination using the skull showed 99% and 81.5% accuracy respectively. In this background the present study was designed to evaluate the sex determination using radiographic cephalometry and discriminant function analysis in western Maharastra population of India**.**

Materials and Method

The present study was conducted in Department of Oral Medicine, Diagnosis and Radiology. The subjects were taken randomly from the patients attending the Department. The study group consisted of 100 subjects, comprising of 50 males and 50 females in the age range of 6 to 35 years. They were further divided into three age groups like 6 to 15 years, 16 to 25 years and 26 to 35 years. The selected subject was explained about the study and written consent was taken. Pregnant patients,

Patients undergoing radiotherapy and mentally disabled patients were excluded from the study**.** Lateral cephalographs were taken on the Cephalostat of MEDI TRONICS ARCOGRAPH ZEUS RH using standardized technique.

After exposure all radiographs were coded, as not to reveal the sex of the subject to either of two observers during tracing of radiographs. Each radiograph was traced with 0.05 mm black lead pencil on acetate tracing paper of 50 micron thickness under ideal viewing conditions and following cephalometric landmarks were traced. All angular variables were marked using 0.05 mm blue lead pencil and all linear variables were marked using 0.05 mm red lead pencil by both observers. Both observers traced and recorded their findings separately. Average values of both examiners were taken as the actual measurements to eliminate inter-observer variations. Out of 100 radiographs nine radiographs were reselected randomly and reanalyzed to eliminate intra- observer variations.

All landmarks selected for the study were cranial landmarks, hence stationary and remained unaltered because of any dental anomaly. As all cephalometric radiographs were made on the same machine hence magnification factor remained constant. Table 1 and Fig. 1 shows all cephalometric landmarks and variables which were taken into consideration.

Statistical Analysis: The data was analyzed using Microsoft Excel 2007 and SPSS (Statistical Procedure for Social Services) –Version 16 statistical software program. Unpaired T- test was used for statistical analysis with discriminant function analysis.

Results

Descriptive analysis of mean, standard deviation and unpaired T- Test of the difference between gender for all fifteen variables for three age groups. (Table 2)

First age group showed only two out of fifteen variables had significant mean differences (p-values <0.05), whereas second and third age groups showed thirteen and twelve respectively. This suggests that this method of sex determination was not significant before puberty, when the growth is not completed, hence for further analysis first age group was not included.

Comparison of two age groups 16-25years and 26-35years according to different variables.(Table 3)

The mean differences by unpaired T-Test between the variables of second and third age groups of males and females on the basis of age were not significant (p-value > 0.05) except one parameter hence further analysis was carried for 80 subjects (41 males and 39 females) by clubbing second and third age groups.

Five functions were developed by combination of fifteen cephalometric variables to create discriminant function analysis and results were tabulated. (Table 4)

Table 1: Cephalometric Landmarks and Variables

B (Bregma)	Point at sagittal and coronal sutures meet
M (Metopion)	Point at highest points of the frontal eminences
G (Glabella)	Most anterior point in the midsagittal plane between the superciliary arches
Sg (Supraglabellare)	Most posterior midline point in the supraglabellar fossa
N (Nasion)	Most anterior point on the frontonasal suture in the mid saggital plane
V1 & V2	Upper & lower parameter of the frontal sinus
H1 & H2	Anterior & Posterior parameter of the frontal sinus cavity on Bregma to Nasion
S (Sella)	Mid point of sella turcica, hypophyseal fossa
Or (Orbitale)	Lowest point on the lower margin of the bony orbit
Po (Porion)	Top of the external auditory meatus
Op (Opisthocranion)	Most prominent point of the occipital bone in the midline
I (Inion)	Most prominent point of the external occipital protuberance
Ba (Basion)	Most inferior posterior point on the anterior rim of the foramen magnum
Ma (Mastoidale)	Lowest point of the mastoid process
B1 & B2	Anterior & Posterior parameter of the mastoidal width at cranial base
Angular variables	IOp-BaN, GM-BaN, GM-OrPo, GM-SN, G-Sg-M
Linear variables	G-SgN, Ma-SN, FSWd (H1H2), FSHt (V1V2), MaWd (B1B2), MaHt (Ma-B1B2), SgGM, G-Op, Ma-OrPo
GPI (Glabella Projection Index)	(Glabella to Supraglabellare Nasion) x 100/(Supraglabellare to Nasion)

Table 2: Descriptive analysis of means, standard deviation and unpaired t-test of the differences between gender for all fifteen variables for three age groups

Variables	*6-15 Years*						*16-25 Years*						*26-35 Years*					
	Male		**Female**		**t-value**	**p-value**	**Male**		**Female**		**t-value**	**p-value**	**Male**		**Female**		**t-value**	**p-value**
	Mean	**SD**	**Mean**	**SD**			**Mean**	**SD**	**Mean**	**SD**			**Mean**	**SD**	**Mean**	**SD**		
IOp – BaN	75.6944	5.5082	77.1364	9.3751	-0.4064	0.6892	75.8426	5.8549	76.6500	6.5658	-0.4687	0.6413	77.0357	4.9350	77.2679	5.8429	-0.1136	0.9105
GM-BaN	115.7778	7.9022	117.1364	4.5940	-0.4811	0.6363	100.7593	5.3071	107.4400	4.1062	-5.0476	0.0000*	101.3214	7.3376	113.4286	12.2974	-3.1634	0.0039*
GM-OrPo	89.3611	7.3507	91.7727	3.9202	-0.9404	0.3595	74.7222	3.7662	81.5200	4.4988	-5.9243	0.0000*	75.3571	4.0284	83.7679	5.6479	-4.5363	0.0001*
GM-SN	98.0833	8.1029	100.5455	3.9966	-0.8880	0.3863	81.8889	4.5082	88.7000	4.9329	-5.2026	0.0000*	81.9286	4.9190	89.7857	6.1134	-3.7467	0.0009*
G-Sg-M	180.0278	4.0475	179.8636	3.0421	0.1036	0.9186	175.2037	3.8736	180.7700	3.6657	-5.3122	0.0000*	174.0714	4.6775	177.7500	1.6496	-2.7751	0.0101*
G-SgN	2.3889	1.0977	1.9091	0.4779	1.3116	0.2061	5.0463	0.9041	2.6300	0.6296	11.0975	0.0000*	4.5357	1.0136	2.5179	0.6238	6.3436	0.0000*
Ma-SN	42.5833	5.9948	38.0909	3.8133	2.0381	0.0565	48.7407	4.5258	42.6200	6.0057	4.1702	0.0001*	47.6950	5.6567	42.4000	5.6665	4.6762	0.0785
H1H2	10.2778	3.3668	8.0909	2.4680	1.6766	0.1109	13.8426	3.2219	11.8600	2.6975	2.3956	0.0204*	12.8214	1.9647	10.1607	2.5012	3.1301	0.0043*
V1V2	29.0556	6.2372	22.3636	5.2026	2.6186	0.0174*	36.3148	5.7074	32.1700	5.9755	2.5581	0.0136*	35.1071	5.2858	29.9286	6.3613	2.3428	0.0271*
B1B2	13.0556	2.7861	12.5455	2.0821	0.4689	0.6448	18.0833	9.2531	16.2300	2.7537	0.9622	0.3406	17.7857	3.5786	16.9464	4.2190	0.5676	0.5752
Ma-B1B2	7.2222	1.4708	6.3864	1.1256	1.4411	0.1667	9.0648	2.0646	7.7600	1.8463	2.3951	0.0204*	8.8214	1.9573	8.2143	1.9187	0.8288	0.4147
BaN	106.1389	6.4361	100.6364	4.6157	2.2260	0.0390*	114.2593	5.0917	107.7700	4.2463	4.9693	0.0000*	112.5536	5.6255	105.1429	2.6049	4.4728	0.0001*
G-Op	187.2222	10.3776	180.5000	7.8422	1.6513	0.1160	198.5093	8.3501	186.9100	5.3740	5.9031	0.0000*	194.8214	10.5112	184.5000	6.2481	3.1583	0.0040*
Ma-OrPo	30.0278	3.6837	27.8864	3.1011	1.4127	0.1748	35.2315	3.3512	30.4700	2.7370	5.5848	0.0000*	34.9107	3.0423	30.7500	3.1117	3.5773	0.0014*
GPI	8.2361	2.5877	7.5641	1.4837	0.7297	0.4750	15.5752	2.4909	9.1544	2.1580	9.8986	0.0000*	15.1350	3.0898	8.7332	2.0021	6.5059	0.0000*

*$p < 0.05$ (significant at 5% level of significance)

Table 3: Comparison of two age groups 16-25years and 26-35years according to different variables by unpaired t-test

Variables	16-25years		26-35years		t-value	p-value
	Mean	Std. Dev.	Mean	Std. Dev.		
IOp –BaN	76.2308	6.1586	77.1518	5.3082	-0.6684	0.5058
GM-BaN	103.9712	5.8012	107.3750	11.6935	-1.7439	0.0851
GM-OrPo	77.9904	5.3401	79.5625	6.4430	-1.1672	0.2467
GM-SN	85.1635	5.7983	85.8571	6.7565	-0.4814	0.6316
G-Sg-M	177.8798	4.6754	175.9107	3.9183	1.8971	0.0615
G-SgN	3.8846	1.4455	3.5268	1.3182	1.0883	0.2798
Ma-SN	45.7981	6.0787	47.1786	5.3795	-1.0074	0.3169
H1H2	12.8894	3.1172	11.4911	2.5896	2.0255	0.0462*
V1V2	34.3221	6.1468	32.5179	6.3157	1.2403	0.2186
B1B2	17.1923	6.9349	17.3661	3.8625	-0.1225	0.9028
Ma-B1B2	8.4375	2.0519	8.5179	1.9268	-0.1706	0.8650
BaN	111.1394	5.6939	108.8482	5.7221	1.7137	0.0905
G-Op	192.9327	9.1313	189.6607	9.9806	1.4796	0.1430
Ma-OrPo	32.9423	3.8757	32.8304	3.6887	0.1253	0.9006
GPI	12.4883	3.9809	11.9341	4.1415	0.5856	0.5598

*p<0.05 (significant at 5% level of significance)

Table 4: Discriminant functions analysis percentage of correctly classified subjects with all five functions

	Discriminant function	% of correct classification
Function 1	Only Angular Variables	88.75%
Function 2	Only Linear Variables	98.75%
Function 3	Proportional Parameter	95.00%
Function 4	All Variables	98.75%
Function 5	Significant Variables	100.00%

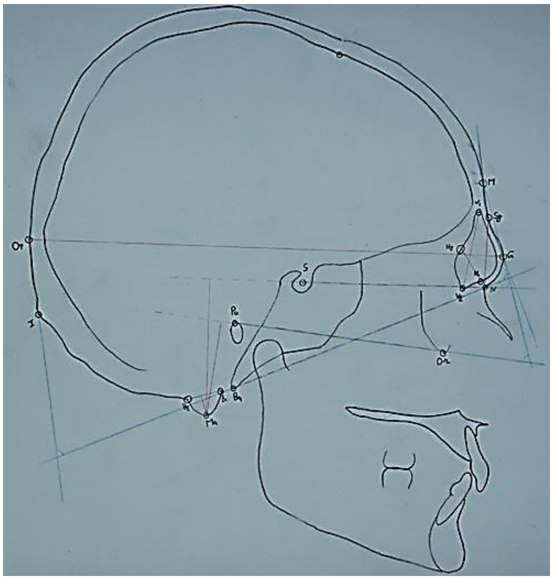

Fig. 1: Cephalometric markings of landmarks showing angular and linear Variables

Function 1 developed with all angular variables, classified 87.80% male and 89.74% females correctly. Total percentage of correctly classified subjects with all angular variables was 88.75%. Function 2 developed with all linear variables, classified 97.56% male and 100% females correctly. Total percentage of correctly classified subjects with all linear variables was 98.75%. Function 3 developed with only proportional index, which classified 92.68% male and 97.44% females correctly. Total percentage of correctly classified subjects with proportional index was 95%. Function 4 developed with combination of all variables, which classified 97.56% male and 100% females correctly. Total percentage of correctly classified subjects with all variables was 98.75%. Function 5 developed with combination of only significant variables, classified 100% male and 100% females correctly. Total percentage of correctly classified subjects with only significant variables was 100%. Analysis showed that, Accuracy increases up to 98.75% when all variables are involved and it is 100% when only significant variables are involved.

Discussion

Use of radiography in forensic science soon followed the announcement of the discovery of X- rays by Sir Wilhelm Conrad Roentgen. Validation study of matching skull radiographs for forensic use was first reported by Thorne et al in 1953. In the year 1958 Ceballos[(7)] first conducted a study to determine sex from the skull radiographs with 88% accuracy. Since then cepahlographs are extensively used for sex determination. In his article Funayama et al[(8)] reported that Fisher in 1936 introduced the specific statistical procedure known as "Discriminant Function Analysis" in taxonomic studies. In 1963 Giles[(9)] first used this procedure for sex determination from crania. Discriminant function analysis is a statistical technique that enables the researcher to examine the relationship among two or more groups based on any number of variables simultaneously. This is a two step process, first step tests significance of a set of discriminant functions and step two determines percentage of correctly classified subjects. When many variables are taken, some of them may be significant and others may not be that significant, those variables which are significant potentiate the efficiency of other not so significant variables. Presently this is the most preferred statistical method among the majority of anthropologists for determining sex using morphometric methods.[(10)]

In our study according to discrimant function created from fifteen established variables a total of 80 cases were classified into two sexual groups with 100% accuracy, which is similar to accuracy obtained by Hsiao et al[(3)] in the similar study. In our study mean values obtained for all angular variables were higher in the males as compared to females whereas the mean values of all linear variables and proportional parameter were higher in the females, which are also similar to them. In a similar study conducted by Patil et al[(4)] by using only ten liner variables found, all ten linear measurements were significantly greater in males as compared to females and accuracy was found 99% in diagnosing sex correctly using lateral cephalograph and discriminant function analysis. In two similar studies using lateral radiographic views and discriminant function analysis for sex variation, Packard et al[(11)] and Inoue[(12)] found 93.2% and 85% respectively. In another cephalometric study conducted by Bibby et al[(13)] found male skulls are 8.5% times larger than female skulls, with all linear dimensions are significantly greater in males then females which is similar to our study. The present study indicates that cephalometric variables significantly differentiate the sex using discriminant function analysis. However further studies with larger sample size should be done to establish the level of accuracy with different populations.

Conclusion

Based on the results of the present study it can be concluded that the radiographic cephalometric technique and discriminant function analysis is a useful technique to determine sex from skull and seems a promising, less expensive and readily available tool in forensic and anthropological investigations for sex identification from skull. From our study we also observed that Frontal Bone Prominence (G-Sg-M), Supraorbital Ridges (G-SgN) and GPI Index are highly reliable variables for sex identification.

References

1. Lou-Cai Y. Sex determination from pubis by discriminant function analysis. Forensic Sci Int. 1993;74:89-94.
2. Paiva LAS and Segre M. Sexing the human skull through the mastoid process. Rev Hosp Clín Fac Med Sao Paulo. 2003;58(1):15-20.
3. Hsiao TH, Chang HP, Liu KM. Sex determination by discriminant function analysis of lateral radiographic cephalometry. J Forensic Sci. 1996;41(5):792–5.
4. Patil KR, Modi RN. Determination of sex by discriminant function analysis and stature by regression analysis: a lateral cephalometric study. Forensic Sci Int. 2005;147(2-3):175–80.
5. Kranioti EF, Iscan MY, Michalodimitrakis M. Craniometric analysis of the modern Cretan population. Forensic Science International 2008;180:110.e1–e5.
6. Naikmasur VG, Shrivastava R, Mutalik S. Determination of sex in south Indian and immigrant Tibetans from cephalometric analysis and discriminant functions. Forensic Sci. Int. 2010;197:122.e1-122e6.
7. Ceballos JL. Roentgen diagnosis of sex based on adult skull characteristics. Radiology 1958;70:55-61.
8. Funayama M, Yasuhiro, Sagisaka K. Sex determination of the human based upon line drawing from roentgen cephalograms skull. Tohoku J. Exp. Med. 1986;149:407-16.
9. Giles Eugene. Sex determination by discriminant function analysis of crania. AJPA 1963;21:53-68.
10. John Poulsen and Aaron French. Discriminant Function Analysis (DA). www.sfsu.edu; 2003.
11. Packard RC, Zwemer TJ. Demographic Discrimination of American Indian and Alaskan Eskimo Groups by Use of Bjork Analysis. Journal of Dental Research 1971;50:364.
12. Inou M. Fourier analysis of the forehead shape of skull and sex determination by use of computer. Forensic Science International 1990;47:101-112.
13. Bibby RE. A Cephalometric study of sexual dimorphism. American Journal of Orthodontics 1979;76(3):256-59.