Original Article

Facial indices in lateral cephalogram for sex prediction in Chennai population – A semi-novel study

Mary Sheloni Missier,
Selwin Gabriel Samuel[1],
Ashwin Mathew George
Departments of Orthodontics and [1]Oral Pathology, Saveetha Dental College and Hospital, Saveetha Institute of Medical and Technical Sciences, Chennai, Tamil Nadu, India

Abstract

Background: Osteological examination is a very reliable tool to determine the sex of the individual as the consolidation of the dimorphic characteristics concludes the sex of the individual. This study was performed with lateral cephalograms, which is a vital diagnostic tool for patients undergoing orthodontic treatment. An index was formed, which could be considered as a reliable sex determinant in forensic applications. **Materials and Methods:** This pilot study was performed on samples of the Dravidian population. Two-fifty individuals, whose age ranged between 25 and 40 years, were taken (125 subjects were males and 125 subjects were females). A total of ninety-nine cephalometric variables were compared, subjected to statistical analysis and tested for significance using the *t*-test. **Results:** Out of a total of 99 variables tested only twenty-four variables showed statistical significance. So, these twenty-four variables were then subjected to discriminant function analysis to evaluate the effectiveness of each variable in predicting the sex of an individual Individually, Ramus length (Ramus ln), Condylion to Gnathion (Co-Gn) and ramus height showed the highest sex determining dependability of 78%. On the flipside, lower anterior facial height (LAFH), with 52%, showed the lowest consistency. **Conclusion:** From this study, it is clearly evident that cephalometric landmarks are reliable sex determinants to a good extent. All the statistically significant measurements, but one, showed acceptable percentages of reliability. This means the chosen variables can be used for the Dravidian population to robustly determine the sex of the individuals of interest.

Key words: Facial bones, lateral cephalogram, radiographic examination, sex determination

Address for correspondence:
*Dr. Selwin Gabriel Samuel,
43, Kasturiba Gandhi Nagar,
Vyasarpadi, Chennai - 600 039,
Tamil Nadu, India.
E-mail: iamdrselwin@gmail.com*

Introduction

Human beings (*Homo sapiens*) can be distinguished from other living organisms by their superior mental development, behavior, and speech.[1] Almost all species can be differentiated into males and females based on their sexual dimorphism. Over the years, humans have undergone a vast range of development from their stone age to this modern life.

Access this article online	
Website: www.jfds.org	**Quick Response Code**
DOI: 10.4103/jfo.jfds_81_18	

How to cite this article: Missier MS, Samuel SG, George AM. Facial indices in lateral cephalogram for sex prediction in Chennai population – A semi-novel study. J Forensic Dent Sci 2018;10:151-7.

Identity is a set of characteristics that define an individual. Universally, human identifications have been recorded for criminal and civil identification purposes. Such identifications include birthmarks (nevi), scars, and fingerprints.[2] These methods of identification cannot be used to identify the skeletal remains of humans. In forensic and medical sciences, innumerable researches are being done using skeletal remains. In mass disasters and sites of archaeological interests, the task of identification becomes inevitable. In such situations, deriving the possible inclusion and exclusion criteria such as age, sex, stature, and race aids in establishing the identity of an individual. In addition, skeletal tissues resist decomposition, unlike soft tissues, thereby facilitating the investigator to develop knowledge of the specimen under study, even after many decades of death.[3]

There are two methods of approaches for sex determination using the skeletal remains: morphological (nonmetric) and metric methods. When sex determination is done using the skeletal remains, pelvic bone is the most commonly used bone, and the second common bone used for sex determination is the skull.[4] The skull does not manifest definite sexual traits until after the full development of the secondary sexual characteristics that begin to appear during puberty. For example, in females, as they undergo development from puberty to adulthood, the skull portraits certain prepubertal characteristics such as smoothness and gracility. On the other hand, in male skulls, as the development progresses from puberty to adulthood, the skull portraits certain characteristics such as more robustness and large muscular attachment areas with more pronounced supraorbital ridges. Some other characteristics of the skull which also aid from the differentiation from male and female are the weaker developments of the frontal and occipital superstructures, but they are fairly reliable.[4]

Sex determination of an individual in question not only facilitates the ease of identification, but also helps to eliminate those in suspicion if they belong to the opposite sex. This is a very vital reason for identifying the sex of an individual in forensic scenarios. In the maxillofacial complex, frontal sinus and mandibular ramus are usually considered for sex determination.[5] Furthermore, maxillary sinus has also been studied as a dimorphic organ in quite a few studies.[6,7] On determining sex from the skull radiographs, it was found that they are accurate and prove to be a simpler method in predicting the sex by their linear and angular measurements. Various studies prove that the estimation of sex from the skull scores up to 80%–100% of accuracy.[8] Badam *et al*. in their study on 100 individuals found that it provided a greater degree of accuracy in determining the sex.[9] Devang Divakar *et al*. did a discriminate function analysis on a lateral cephalogram and found it as a reliable tool in determining the sex of an individual.[10]

Lateral cephalogram of the skull is taken to determine the sex as it gives a wide range of information from a single radiograph.[11] Therefore, many function analyses of lateral cephalogram have been used to determine the sex of an individual. In this study, we performed function analyses using a lateral cephalogram and focussed on the maximum number of parameters that can be considered in the facial bone and the mandible. The main goal of this study was, therefore, to check the reliability of using various parameters obtained from the lateral cephalogram to determine the sex of an individual.

Materials and Methods

This study was performed on samples of the Dravidian population. It was a cross-sectional study, done using the pretreatment lateral cephalograms of patients who came to our institution for orthodontic treatment. A total of 250 patients, out of which 125 were males and 125 were females, between 25 and 40 years of age, were chosen for the study. A written consent was obtained from all the patients whose radiographs were utilized for the study.

The inclusion criteria for the present study were as follows: patients willing for participating in the study, patients without any history of trauma to face, and patients without any previous history of orthodontic treatment or cosmetic surgery. Exclusion criteria for the present study were as follows: patients with the previous history of orthodontic treatment or surgery, patients not willing for participating in the study, medically compromised patients, pregnant patients (due to the risk of radiation exposure), patients with a history of trauma to the maxillofacial skeleton, and patients presenting radiographs of poor quality. A total of 99 cephalometric measurements, containing both linear and angular measurements, were taken for the study. The anatomic landmarks on the lateral cephalogram were marked and traced using Facad software [Figure 1]. This software

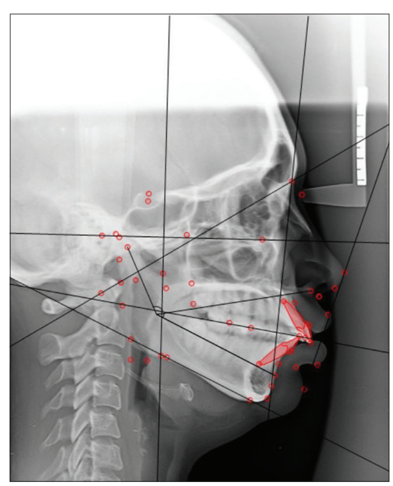

Figure 1: Cephalometric image of a patient traced by Facad software

automatically generates values for both linear and angular variables, thereby preventing human errors.

The cephalometric variables were subjected to statistical analysis. All the variables were initially tested for significance with the help of *t*-test. $P < 0.05$ was considered statistically significant.

Results

All the 99 variables, both linear and angular, were initially tested with "Individual *t*-test" for statistical significance. Out of them, only 24 variables showed statistical significance [Table 1]. These 24 variables were then subjected to discriminant function analysis to evaluate the effectiveness of each variable in predicting the sex of an individual in question.

For each variable that showed statistical significance, a discriminant model was created where separate formulas were used for males and females. Depending on the value obtained by substituting the numerical values into the designated formulas, the sex of the individual was determined. The formula that produced a higher value among the ones designated for every variable assumed the sex of the individual. Based on the accuracy, the predictability of the variables was calculated.

The predictability scores produced by all the variables, together, was 96%. Individually, Ramus length, Condylion to Gnathion, and ramus height showed the highest sex determining dependability of 78%. On the flipside, lower anterior facial height, with 52%, showed the lowest consistency. On an average, all other variables showed a reliability percentage of above 60% [Table 2].

Discussion

Forensic odontology needs a lot of research to prove its existence as a distinct specialty. At present, very little research has been carried out in this stream. Moreover, any anthropometric study performed on a geographical area cannot provide generalized information for populations of various ethnicity. This is because the skeletal growth patterns, influencing factors such as food habits and genetic makeup, and climate, may drastically vary from one location to another.

A study done by Indira *et al*. on Bengaluru population to determine the sex of an individual with the help of mandibular ramus had an overall reliability of 76%, based on five chosen parameters. However, a study done on a North Indian population by Saini *et al*. with the same parameters showed an overall accuracy of 80.2%, though both the studies observed all the parameters as significant sex predictors.[12,13] Hence, to create a database for identification on a categorical basis, region-specific research is mandatory.

Table 1: *T*-test of independent samples comparing the obtained values of males and females

Variables	Gender	*n*	Mean	SD	SEM	*P*
Age	Male	25	21.70	6.270	1.307	0.593
	Female	25	20.77	5.154	1.099	
Saddle angle	Male	25	120.8760	7.74555	1.54911	0.242
	Female	25	123.2680	6.46121	1.29224	
Articular angle	Male	25	142.1880	11.53030	2.30606	0.582
	Female	25	143.7880	8.65459	1.73092	
Gonial angle	Male	25	129.8520	6.49238	1.29848	0.344
	Female	25	128.0960	6.50746	1.30149	
Sum angle	Male	25	392.8960	5.72738	1.14548	0.141
	Female	25	395.1560	4.92350	0.98470	
S-N	Male	25	69.2920	6.91592	1.38318	0.010
	Female	25	64.9960	4.14673	0.82935	
S-Ar	Male	25	34.8080	6.04152	1.20830	0.131
	Female	25	32.5480	4.18540	0.83708	
Gonial upper angle	Male	25	54.4800	5.46512	1.09302	0.386
	Female	25	53.2640	4.28572	0.85714	
Gonial lower angle	Male	25	75.3680	5.47713	1.09543	0.702
	Female	25	74.8280	4.38544	0.87709	
Ramus ln	Male	25	46.0360	7.35866	1.47173	0.003
	Female	25	40.0600	5.83788	1.16758	
Mand ln	Male	25	67.6748	7.97745	1.59549	0.183
	Female	25	65.0960	5.25757	1.05151	
Mand ln: S-N	Male	25	97.8560	8.08389	1.61678	0.227
	Female	25	100.1320	4.53631	0.90726	
SNA	Male	25	83.3680	4.83018	0.96604	0.617
	Female	25	83.9920	3.87211	0.77442	
SNB	Male	25	80.1840	4.55189	0.91038	0.077
	Female	25	78.1040	3.52426	0.70485	
ANB	Male	25	3.1840	3.92712	0.78542	0.012
	Female	25	5.8840	3.33425	0.66685	
ML/NSL	Male	25	32.4156	6.29042	1.25808	0.441
	Female	25	33.7080	5.43346	1.08669	
Facial depth	Male	25	110.9920	10.78108	2.15622	0.022
	Female	25	104.6960	7.73329	1.54666	
Facial ln on Y-axis	Male	25	120.0280	13.84072	2.76814	0.009
	Female	25	110.9120	9.30736	1.86147	
Y-axis/NSL	Male	25	65.9640	3.87641	0.77528	0.108
	Female	25	67.7440	3.81849	0.76370	
PFH	Male	25	76.0880	9.74138	1.94828	0.003
	Female	25	68.7680	6.50178	1.30036	
AFH	Male	25	114.3000	12.21461	2.44292	0.038
	Female	25	107.8400	8.97436	1.79487	
P: A facial Hgh	Male	25	66.5400	4.36129	0.87226	0.022
	Female	25	63.8240	3.75935	0.75187	
SNPog	Male	25	80.5920	4.45879	0.89176	0.104
	Female	25	78.7200	3.47551	0.69510	
Convexity angle	Male	25	174.4280	8.28143	1.65629	0.021
	Female	25	169.2160	7.05282	1.41056	
OL/ML	Male	25	20.7680	5.45189	1.09038	0.796
	Female	25	20.3600	5.65685	1.13137	

Contd...

Table 1: Contd...

Variables	Gender	*n*	Mean	SD	SEM	*P*
InterIncisa	Male	25	108.0600	12.92578	2.58516	0.660
	Female	25	106.6160	9.96405	1.99281	
ILs/NSL	Male	25	118.8600	8.17241	1.63448	0.226
	Female	25	115.8800	9.00569	1.80114	
ILi/ML	Male	25	100.6680	8.70094	1.74019	0.163
	Female	25	103.8040	6.82871	1.36574	
Is to N-Pog	Male	25	12.6360	4.96319	0.99264	0.189
	Female	25	14.3000	3.79517	0.75903	
Ii to N-Pog	Male	25	7.0320	3.52038	0.70408	0.636
	Female	25	7.5000	3.42892	0.68578	
Ls-EL	Male	25	−0.6320	3.40009	0.68002	0.092
	Female	25	0.7240	1.99714	0.39943	
Li-EL	Male	25	3.3160	3.40131	0.68026	0.723
	Female	25	3.6400	3.01469	0.60294	
Saddle + articular	Male	25	263.0480	6.15752	1.23150	0.021
	Female	25	267.0640	5.76960	1.15392	
Nasolabial	Male	25	94.8520	13.52409	2.70482	0.744
	Female	25	96.1920	15.21942	3.04388	
Ls Cant	Male	25	12.8640	5.55869	1.11174	0.372
	Female	25	14.1120	4.11940	0.82388	
A-NP	Male	25	−3.5280	4.63551	0.92710	0.019
	Female	25	−0.5200	4.08044	0.81609	
Co-Gn	Male	25	113.5960	13.82008	2.76402	0.025
	Female	25	105.8440	9.53804	1.90761	
Co-A	Male	25	86.8400	10.80960	2.16192	0.346
	Female	25	84.3520	7.34921	1.46984	
Max-mand diff	Male	25	26.7560	8.19599	1.63920	0.007
	Female	25	21.4760	4.33900	0.86780	
LAFH	Male	25	66.9040	9.41251	1.88250	0.041
	Female	25	62.0760	6.55949	1.31190	
ML/FH	Male	25	30.0200	5.92621	1.18524	0.886
	Female	25	29.7720	6.25523	1.25105	
Facial axis	Male	25	91.9440	6.97789	1.39558	0.098
	Female	25	89.0960	4.73115	0.94623	
Pog-NP	Male	25	−12.0560	8.95666	1.79133	0.428
	Female	25	−10.2720	6.64176	1.32835	
Is-A	Male	25	7.3920	4.37149	0.87430	0.918
	Female	25	7.2760	3.45607	0.69121	
Ii to A-Pog	Male	25	5.3760	3.10970	0.62194	0.306
	Female	25	4.4680	3.10090	0.62018	
Convexity	Male	25	2.5840	3.74896	0.74979	0.027
	Female	25	4.8000	3.08180	0.61636	
LFH	Male	25	43.5600	5.24714	1.04943	0.964
	Female	25	43.5000	4.17243	0.83449	
Ms-PtV	Male	25	14.0360	7.78513	1.55703	0.322
	Female	25	11.7680	8.22935	1.64587	
ILi/A-Pog	Male	25	30.8600	7.31539	1.46308	0.945
	Female	25	30.7160	7.47750	1.49550	
Facial depth #2	Male	25	83.4760	4.88725	0.97745	0.600
	Female	25	84.1200	3.64120	0.72824	
Max depth	Male	25	86.2600	4.92172	0.98434	0.025
	Female	25	89.3760	4.57605	0.91521	

Contd...

Table 1: Contd...

Variables	Gender	*n*	Mean	SD	SEM	*P*
ML/FH #2	Male	25	30.0200	5.92621	1.18524	0.886
	Female	25	29.7720	6.25523	1.25105	
Mand arc	Male	25	36.4640	8.41872	1.68374	0.190
	Female	25	33.4960	7.31696	1.46339	
Xi-OL	Male	25	−2.3360	6.70217	1.34043	0.735
	Female	25	−2.9040	4.98217	0.99643	
Xi-PM/OL	Male	25	24.3760	5.83968	1.16794	0.514
	Female	25	25.4440	5.65295	1.13059	
Ramus Xi pos	Male	25	66.4000	7.62217	1.52443	0.440
	Female	25	64.8160	6.72785	1.34557	
OL/NSL	Male	25	11.6520	7.07691	1.41538	0.339
	Female	25	13.3440	5.13664	1.02733	
Is-NA	Male	24	7.4167	2.77342	0.56612	0.359
	Female	25	6.7120	2.54646	0.50929	
ILs/NA	Male	25	34.5040	8.98770	1.79754	0.312
	Female	25	31.8880	9.12512	1.82502	
Ii-NB	Male	25	9.7440	7.67616	1.53523	0.104
	Female	25	7.0560	2.29675	0.45935	
ILi/NB	Male	25	33.2520	8.03928	1.60786	0.283
	Female	25	35.6080	7.30194	1.46039	
Pog-NB	Male	25	0.7760	1.65108	0.33022	0.524
	Female	25	1.0640	1.51599	0.30320	
Ii-Pog//NB	Male	25	5.8320	3.10131	0.62026	0.855
	Female	25	5.9880	2.91752	0.58350	
Ls-SL	Male	25	0.9680	2.98799	0.59760	0.224
	Female	25	1.8720	2.12750	0.42550	
Li-SL	Male	25	4.1960	3.06601	0.61320	0.924
	Female	25	4.2800	3.13834	0.62767	
FMA (ML/FH)	Male	25	30.0200	5.92621	1.18524	0.886
	Female	25	29.7720	6.25523	1.25105	
IMPA (ILi/ML)	Male	25	100.1680	8.81862	1.76372	0.339
	Female	25	102.3040	6.67898	1.33580	
FMIA (ILi/FH)	Male	25	49.8120	8.74549	1.74910	0.423
	Female	25	47.8920	8.02548	1.60510	
Wits	Male	25	2.0560	6.27170	1.25434	0.150
	Female	25	4.3400	4.64399	0.92880	
OL/FH	Male	25	8.7600	7.10798	1.42160	0.668
	Female	25	7.9520	6.10253	1.22051	
Z	Male	25	58.3960	10.06104	2.01221	0.848
	Female	25	58.9440	10.08328	2.01666	
Facial angle	Male	25	85.4680	5.33368	1.06674	0.446
	Female	25	86.5040	4.13063	0.82613	
Ls curvature	Male	25	3.7640	1.62734	0.32547	0.537
	Female	25	4.0360	1.45742	0.29148	
A to N-Pog	Male	25	2.5840	3.74896	0.74979	0.027
	Female	25	4.8000	3.08180	0.61636	
HL angle	Male	25	18.3760	5.22385	1.04477	0.279
	Female	25	19.7840	3.73750	0.74750	
PRN-HL	Male	25	0.9840	5.31277	1.06255	0.091
	Female	25	−1.1400	3.11823	0.62365	
SLs-HL	Male	25	−7.3960	1.98420	0.39684	0.946
	Female	25	−7.3560	2.20077	0.44015	

Contd...

Table 1: Contd...

Variables	Gender	n	Mean	SD	SEM	P
A-SN	Male	25	15.4520	3.08439	0.61688	0.002
	Female	25	12.9720	2.15204	0.43041	
Ls strain	Male	25	11.8760	1.95006	0.39001	0.001
	Female	25	9.8840	2.18797	0.43759	
Strain factor	Male	25	3.5800	2.33880	0.46776	0.425
	Female	25	3.0960	1.89462	0.37892	
Li-HL	Male	25	3.6800	1.93261	0.38652	0.481
	Female	25	3.2120	2.67104	0.53421	
SLi-HL	Male	25	−3.5800	2.07023	0.41405	0.244
	Female	25	−2.8880	2.07873	0.41575	
Chin thickness	Male	25	10.2800	2.26863	0.45373	0.807
	Female	25	10.1240	2.22772	0.44554	
Ramus height	Male	25	46.0360	7.35866	1.47173	0.003
	Female	25	40.0600	5.83788	1.16758	
Ant cranial base Ln	Male	25	69.4880	6.49309	1.29862	0.007
	Female	25	65.1880	3.86634	0.77327	
Body length	Male	25	67.6720	7.97593	1.59519	0.184
	Female	25	65.0960	5.25757	1.05151	
Max In	Male	25	52.8960	6.57454	1.31491	0.032
	Female	25	49.4240	4.33804	0.86761	
Mand Ln #2	Male	25	70.8480	8.18663	1.63733	0.273
	Female	25	68.6440	5.62443	1.12489	
Max In #2	Male	25	49.0080	5.21016	1.04203	0.132
	Female	25	46.9248	4.35345	0.87069	
Ramus Ln #2	Male	25	54.7800	10.20102	2.04020	0.002
	Female	25	46.5360	7.23930	1.44786	
Sella angle	Male	25	120.8760	7.74555	1.54911	0.242
	Female	25	123.2680	6.46121	1.29224	
ML/NL	Male	25	25.3080	7.03805	1.40761	0.768
	Female	25	24.7000	7.46804	1.49361	
ILs/NL	Male	25	54.0320	7.86181	1.57236	0.643
	Female	25	55.1200	8.62854	1.72571	
ILi/ML #2	Male	25	100.1680	8.81862	1.76372	0.331
	Female	25	102.3440	6.70187	1.34037	
OL/NL	Male	25	4.5520	6.45743	1.29149	0.908
	Female	25	4.3560	5.44802	1.08960	
Inclination angle	Male	25	85.6240	5.58997	1.11799	0.266
	Female	25	83.8800	5.36167	1.07233	
Facial Hgh #2	Male	25	66.5400	4.36129	0.87226	0.022
	Female	25	63.8240	3.75935	0.75187	
Saddle + articular #2	Male	25	263.0480	6.15752	1.23150	0.021
	Female	25	267.0640	5.76960	1.15392	
Facial depth #3	Male	25	83.4760	4.88725	0.97745	0.600
	Female	25	84.1200	3.64120	0.72824	
ML/FH #3	Male	25	30.0200	5.92621	1.18524	0.886
	Female	25	29.7720	6.25523	1.25105	

SD: Standard deviation, SEM: Standard error of mean, LAFH: Lower anterior facial height, Ramus Ln: Ramus length, Co-Gn: Condylion to gnathion

That is why this study was performed in the Dravidian population to study the reliability of sex determination, though many studies have already been performed with lateral cephalograms, in other places of India.

Table 2: Accuracy of sex determination of variables that exhibited statistical significance, evaluated by discriminant functional analysis

Variables	Wilks' lambda	F	Predictability (%)
S-N	0.871	7.096	72
Ramus Ln	0.826	10.119	78
ANB	0.875	6.867	64
Facial depth	0.895	5.629	66
Facial In on Y-axis	0.865	7.468	74
PFH	0.831	9.766	76
AFH	0.914	4.541	66
P: A facial Hgh	0.896	5.562	66
Convexity angle	0.893	5.740	66
Saddle + articular	0.894	5.663	64
A-NP	0.890	5.931	62
Co-Gn	0.900	5.328	78
Max-mand diff	0.856	8.104	68
LAFH	0.916	4.427	52
Convexity	0.902	5.213	64
Max depth	0.899	5.375	62
A to N-Pog	0.902	5.213	64
A-SN	0.815	10.871	68
Ls strain	0.806	11.549	62
Ramus height	0.826	10.119	78
Ant cranial base Ln	0.856	8.094	72
Max In	0.908	4.857	68
Ramus Ln #2	0.816	10.859	74
Facial Hgh #2	0.896	5.562	66
Saddle + articular #2	0.894	5.663	64

*Collective predictability (%) - 96. LAFH: Lower anterior facial height, Ramus Ln: Ramus length, Co-Gn: Condylion to gnathion

The study was performed on live patients, on radiographs, that were already made for investigative purposes. Therefore, the patients were not unnecessarily exposed to radiation. All the cephalometric measurements were traced by a digital cephalometric software Facad. This is in the intention of not ruling out any variable which could prove itself a sole sex determinant. Among the variables, some of them were bilateral cephalometric measurements. Hence, there is a possibility to conclude the sex of the skull under study, even when one side of the face is missing or severed due to mass disasters or fatal violence. Another advantage of using lateral cephalogram is that it is a routine diagnostic aid in orthodontics, with the entire picture of the skull available for contemplation from both investigative and research purposes.

A study done with 143 computed tomography (CT) images of the skull, in Gujarati population, by Mehta *et al*., had an accuracy between 61.3% and 88.7% in sex prediction. This is comparatively lower than the overall reliability contributed by the 24 variables in the present study. Moreover, CT scans are relatively expensive and pose a higher radiation exposure on the patients.[14]

While there are ample options for selection of a statistical tool, discriminant function analysis seemed to be the most appropriate and ideal means of validating the obtained numerical, sex-based values on a statistical basis. As the output variables were dichotomous and categorical and the input variables were continuous, the authors surmised that it is prudence to employ discriminant function analysis to substantiate the study. Furthermore, there are quite a few studies that were performed on lateral cephalogram with the same statistical tool for sex determination.

Hsiao *et al*.[15] performed a study with 100 lateral cephalograms of Taiwanese adults and demonstrated 100% accuracy in sex determination with 18 cephalometric measurements that were subjected to discriminant function analysis. This study yet again proved the steadfastness of lateral cephalogram as a favorable means of sex determination.

Hsiao *et al*.[16] also performed a similar study on 100 Taiwanese children, where 13 linear, eight angular, and one proportional variable were employed. Out of the 22 variables, only nine variables were statistically significant. These nine variables when subjected to discriminant function analysis resulted 95% accuracy in gender prediction. However, this study was performed in children (between 14 and 17.5 years), which cannot be a long-term reliable tool for sex prediction, as many changes occur in the skeletal tissues during this period.

Patil and Mody[11] performed a study in the Central Indian population, on 150 individuals, to study the stature by regression analysis and sex by lateral cephalogram. With discriminant function, ten variables contributed to 99% reliability in sex determination. This is slightly more significant than the data found in this study. Nevertheless, this outcome cannot be applied to this study population without proper validation.

A large-scale study was recently done in Coorg, a hill station in India, among children and adolescents by Devang Divakar *et al*.[10] In this study, 616 lateral cephalograms were used and 24 variables were considered. Out of the 24 variables, only one variable proved to be a gender predictor with 100% accuracy.

It has been observed that no other study had considered 99 cephalometric variables for sex determination. This implies that all possible variables were given equal importance, and the study derived reliable and robust observations, giving no scope for incompleteness. This wholesome approach can be an ideal framework for prospective studies in other populations. Future studies on much larger sample sizes can prove its validity as a potential sex-determining tool.

On the other hand, this study has some minor limitations. The sample size is relatively small for assertively establishing conclusions of the objectives the study. The sample size should be greatly increased in future research work on this idea. Furthermore, the study cannot be applied in scenarios where the facial and cranial skeletons of the individuals are severely crushed, disfigured, or damaged beyond the scope of radiographic analysis. In such cases, employing other methods and techniques as corroborative evidence would seem ideal. However, wherever applicable, such as floods, earthquakes, tsunami, accidents, and homicides, the skulls of the bodies can be exposed to radiation and the obtained image can be subjected to the proposed technique and the sex can thereby be determined.

Conclusion

From this pilot study, it is evident that cephalometric landmarks are reliable sex determinants to a good extent. All the measurements, but one, showed acceptable percentages of reliability. This means, the chosen variables can be used for the Dravidian population to robustly determine the sex of the individuals of interest. It is also certain that the evidence can more easily be verified if the quantity of available information is more. Prospective studies embodying a bigger sample size needs to be performed to strengthen the observations of this pilot study. Similarly, the same study frame adopted for predicting the sex of the individuals of other populations may confirm the sex predictability of the indices used in this study in other geographical locations.

Financial support and sponsorship
Nil.

Conflicts of interest
There are no conflicts of interest.

References

1. Mattson MP. Superior pattern processing is the essence of the evolved human brain. Front Neurosci 2014;8:265.
2. Narayan Reddy KS. The Essentials of Forensic Medicine and Toxicology. 33rd ed. New Delhi: Jaypee Publishers; 2014.
3. Krishan K, Kanchan T, Garg AK. Dental evidence in forensic identification - an overview, methodology and present status. Open Dent J 2015;9:250-6.
4. Dubrul EL. Sicher and Dubrul's Oral Anatomy. 8th ed. St. Louis: Ishiyaku Euro America; 1988.
5. Samuel SG, Pandey A, Dahiya MS. A report on the current status of radiology in forensic odontology in the Indian scenario. Int J Forensic Odontol 2017;2:34-7.
6. Khaitan T, Kabiraj A, Ginjupally U, Jain R. Cephalometric analysis for gender determination using maxillary sinus index: A novel dimension in personal identification. Int J Dent 2017;2017:7026796.
7. Sidhu R, Chandra S, Devi P, Taneja N, Sah K, Kaur N. Forensic importance of maxillary sinus in gender determination: A morphometric analysis from Western Uttar Pradesh, India. Eur J Gen Dent 2014;3:53-6.

8. Naikmasur VG, Shrivastava R, Mutalik S. Determination of sex in South Indians and immigrant Tibetans from cephalometric analysis and discriminant functions. Forensic Sci Int 2010;197:122.e1-6.
9. Badam RK, Manjunath M, Rani MS. Determination of sex by discriminate function analysis of lateral radiographic cephalometry. J Indian Acad Oral Med Radiol 2011;23:179-83.
10. Devang Divakar D, John J, Al Kheraif AA, Mavinapalla S, Ramakrishnaiah R, Vellappally S, *et al.* Sex determination using discriminant function analysis in indigenous (Kurubas) children and adolescents of Coorg, Karnataka, India: A lateral cephalometric study. Saudi J Biol Sci 2016;23:782-8.
11. Patil KR, Mody RN. Determination of sex by discriminant function analysis and stature by regression analysis: A lateral cephalometric study. Forensic Sci Int 2005;147:175-80.
12. Indira AP, Markande A, David MP. Mandibular ramus: An indicator for sex determination – A digital radiographic study. J Forensic Dent Sci 2012;4:58-62.
13. Saini V, Srivastava R, Rai RK, Shamal SN, Singh TB, Tripathi SK, *et al.* Mandibular ramus: An indicator for sex in fragmentary mandible. J Forensic Sci 2011;56 Suppl 1:S13-6.
14. Mehta M, Saini V, Nath S, Menon SK. CT scan images for sex discrimination – A preliminary study on Gujarati population. J Forensic Radiol Imaging 2015;3:43-8.
15. Hsiao TH, Chang HP, Liu KM. Sex determination by discriminant function analysis of lateral radiographic cephalometry. J Forensic Sci 1996;41:792-5.
16. Hsiao TH, Tsai SM, Chou ST, Pan JY, Tseng YC, Chang HP, *et al.* Sex determination using discriminant function analysis in children and adolescents: A lateral cephalometric study. Int J Legal Med 2010;124:155-60.