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Original Article

Cephalometric norms for orthognathic surgery in North Indian population using Nemoceph software

Tripti Tikku [a,*], Rohit Khanna [b], Rana Pratap Maurya [c], Sneh Lata Verma [c], Kamna Srivastava [d], Mangesh Kadu [e]

[a] Professor & Head, Department of Orthodontics, BBDCODS, Lucknow, Uttar Pradesh, India
[b] Professor, Department of Orthodontics, BBDCODS, Lucknow, Uttar Pradesh, India
[c] Reader, Department of Orthodontics, BBDCODS, Lucknow, Uttar Pradesh, India
[d] Senior Lecturer, Department of Orthodontics, BBDCODS, Lucknow, Uttar Pradesh, India
[e] Department of Orthodontics, BBDCODS, Lucknow, Uttar Pradesh, India

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ABSTRACT

Background: Cephalometric norms, useful in providing guidance to orthodontist during diagnosis and treatment planning are subjected to variability in morphologic characteristics in different ethnic and racial groups, hence norms established for one population group are not applicable for all.

Aims and objectives: To compare and correlate the established hard tissue cephalometric norms for orthognathic surgery (COGS analysis) given by Legan and Burstone with norms obtained for North Indian population.

Methods: Pre-treatment digital lateral cephalograms of 100 orthodontically untreated subjects having pleasing profile and normal occlusion in the age range of 18–25 yrs (mean age of 21 ± 2.62 years) were selected. 16 linear and 6 angular hard tissue parameters of COGS analysis were analyzed using nemoceph software for the males and females separately. The data obtained were compared with previously established norms for Orthognathic Surgery using SPSS Version 15.0.

Results: North Indian males and females had smaller anterior cranial base length with prognathic maxilla and mandible, protrusive chin with poor chin form, decreased facial height, decreased posterior maxillary height with anticlockwise rotation of mandible, increased anterior and posterior maxillary dental heights, decreased ramal and corpus length, clockwise rotation of occlusal plane, presence of sagittal discrepancy between maxillary and mandibular denture bases in comparison to Caucasian males and females respectively. North Indian females had more proclination of mandibular incisors than Caucasian females. Sexual dimorphism was also evident in the present study with males exhibiting significantly larger cranial base length, greater middle third facial height and posterior maxillary height, counterclockwise rotation of mandibular plane, greater anterior and posterior mandibular dental heights and longer ramal and corpus length in comparison to females.

* *Corresponding author.*
E-mail address: triptitiku@yahoo.com (T. Tikku).
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Conclusion: North Indian population showed significant differences in facial morphology as compared to Caucasians population. Sexual dimorphism was also evident in North Indian populations. Thus the need to develop separate Orthognathic Surgical norms for better treatment planning of North Indian population is justified.

1. Introduction

Roentgenographic cephalometry was first introduced to the orthodontic specialty by Broadbent in America and Hofrath[1] in Germany in 1931, mainly as a tool to study craniofacial growth and development, to assess treatment progress, prognosis and growth prediction for the individual patient. Various cephalometric analysis to assess hard tissue structures had been in practice for more than half a century.[2–5]

As in the current perspective facial esthetics is a major concern for the patient, and sometimes orthodontic treatment alone might not be sufficient to achieve this. In those cases, to achieve harmonious dental, skeletal as well as soft tissue relationships a combination of fixed orthodontic therapy and orthognathic surgery is required. In such cases commonly used cephalometric analysis may not provide accurate information concerning the facial form and proportions of the patient, and in many instances, it may actually be misleading. Hence for the successful treatment of orthosurgical patients, a specialized cephalometric appraisal system, called Cephalometrics for orthognathic surgery (COGS),[5,6] was developed at Indiana University. The COGS system describes the horizontal and vertical position of facial bones by use of a constant coordinate system that includes various linear and angular measurements which are measured either parallel or perpendicular to true horizontal plane (HP). This HP can correct arbitrary nature of reference planes (SN and FH) used in other analysis that also vary just as the landmarks in maxilla and mandible that are related to them. Another advantage offered by this analysis is that it is based on the landmarks that can be altered by various surgical procedures. Various rectilinear measurements describe the discrepancy in critical skeletal components that can be readily transferred to acetate overlay and study casts for detailed planning of treatment and post surgical evaluation.

Most of the cephalometric norms are based on data derived from Caucasian samples. As there are structural differences between different racial populations, hence the norms derived for Caucasians may not be applicable for other population groups. Considering thus, many authors established cephalometric norms for their respective populations.[7–16] Previous studies have established the COGS norms for Rajasthan,[17] Eastern UP,[18] Central india,[19] Karnataka[20] and south India[21] but not for North India. As all North Indians are descendents of Indo Aryans community, hence there is a need for developing norms for this population that can be used uniformly. Considering the validity of COGS analysis in accurate diagnosis of orthosurgical cases, it was decided to establish COGS norms for North Indian population.

2. Materials and method

The study was conducted on pre-treatment digital lateral Cephalograms of 100 orthodontically untreated subjects in the age range of 18–25 yrs with mean age of 21 ± 2.62 years. The sample was divided in Group I with 50 males and Group II with 50 females having normal occlusion and pleasing facial profile. All these subjects who were the natives of North India were screened from 354 students of Babu Banarasi Das University on the basis of rating of their frontal and profile photographs. Informed consent from the patients and approval from the Ethical Committee of Babu Banarasi Das College of Dental Sciences, Lucknow, India were taken.

3. Criteria for selection of subjects for taking photographs

All subjects were natives of North India (at least two ancestoral generations of the subjects selected belong to various states of North India i.e. U.P., Uttarakhand, Delhi, Punjab, Haryana, Rajasthan and Bihar), All the subjects had a pleasing profile, Class I molar relationship and all permanent teeth except 3rd molars, Subjects were in the age group of 18–25 years to ensure complete growth, No significant medical history or history of any trauma and No previous history of orthodontic/prosthodontic or surgical treatment.

4. Method of taking and rating facial photographs

Frontal and right profile photographs of 354 subjects (150 males and 154 females) were taken with digital camera (Canon Powershot SX30IS with image stabilizer, 41.1 mega pixels and 35X optical zoom). Photographs were edited using Adobe Photoshop 7.0, developed in size of 5 × 3.5 inch and then numbered in the album as per the profile rating chart.

All photographs were evaluated by a panel of judges (2 orthodontists, 2 plastic surgeons and 2 beauticians) without the knowledge of subject's identity. Each member of the panel was requested to judge on the basis of the balance of the facial parts and not on the quality of parts like beautiful eyes, skin texture and color. The panel members rated the photographs on a Profile Rating Chart on the basis of a five point scale with 1 = poor, 2 = fair, 3 = good, 4 = very good and 5 = excellent. Subjects who scored 3 or more than 3 were selected for taking lateral cephalogram.

5. Method to take lateral cephalogram

Planmeca proline XC cephalostat (Finland), was used to take the digital lateral cephalograms of the subjects with functional head positioner, patients standing in natural head position, the teeth in maximum intercuspation i.e. centric occlusion and lips relaxed.

All lateral cephalograms were transferred to a computer loaded with Planmeca software, saved in bitmap files and taken in a CD ROM for tracing and analysis on Nemotech digital imaging software (Version 6.0). 16 linear and 6 angular hard tissue parameters given by Legan and Burstone were measured in the present study after identification of appropriate landmarks (Fig. 1).

Reference planes used in the study (Fig. 2) [Burstone CJ, James RB, Legan HL-1978][5] were S-N Plane, Horizontal Plane (HP), TVL, Palatal Plane/Nasal floor (NF), Mandibular Plane (Go-Gn) and Occlusal Plane (OP).

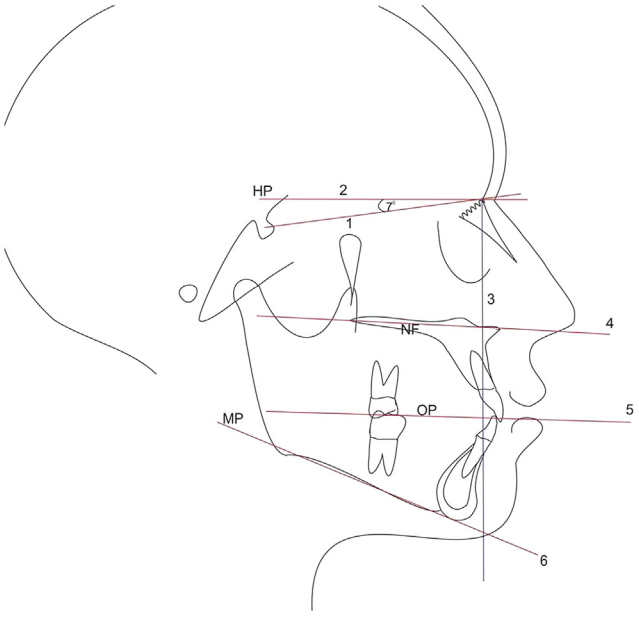

Fig. 2 – Reference planes: 1. SN-Plane, 2. Horizontal Plane (HP), 3.True Vertical Line (TVL), 4. Nasal Floor Plane, 5. Occlusal Plane, 6. Mandibular Plane.

6. Parameters used in the study

6.1. *Skeletal measurements*

(A) Cranial base: (Fig. 3)

1. *Ar to Ptm through horizontal plane (Posterior cranial base)*: Measured parallel to HP from Articulare to Ptm.

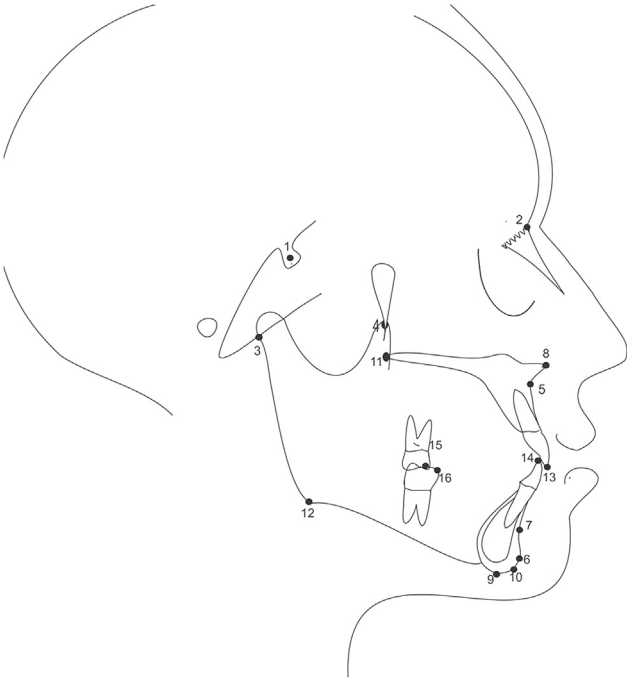

Fig. 1 – Hard tissue landmarks: 1. Sella (S), 2. Nasion (N), 3. Articulare (Ar), 4. Pterigomaxillary Fissure (Ptm), 5. Subspinale (A), 6. Pogonion (Pg), 7. Supramentale (B), 8. Anterior Nasal Spine (ANS), 9. Menton (Me), 10. Gnathion (Gn), 11. Posterior Nasal Spine (PNS), 12. Gonion (Go), 13. U1, 14. L1, 15. A6, 16. B6.

2. *Ptm to N through horizontal plane (Anterior cranial base)*: Measured parallel to HP from Ptm to Nasion.

(B) Horizontal (Skeletal measurements): (Fig. 4)

1. *N-A-Pg angle (Angle of facial convexity)*: It is an angle formed by the line N-A and a line A to Pg.
2. *N to A through horizontal plane (Apical base of maxilla)*: Linear measurement from Nasion to point A parallel to HP.
3. *N to B through horizontal plane (Apical base of mandible)*: Linear measurement from Nasion to Point B parallel to HP.
4. *N to Pg through horizontal plane (Chin prominence)*: Linear measurement from Nasion to Pogonion (Pg).

(C) Vertical (Skeletal, Dental) measurements:

a) Skeletal components (Fig. 3)

i. Skeletal Anterior Component:

1. *N to ANS through TVL (Middle third facial height)*: Measured perpendicular to HP from N to ANS.
2. *ANS to Gn through TVL (Lower third facial height)*: Measured perpendicular to HP from ANS to Gn.

ii. Skeletal Posterior Component:

3. *N to PNS through TVL (posterior vertical height)*: Measured perpendicular to HP from PNS to Nasion.
4. *MP-HP angle (Posterior facial divergence)*: It is an angle formed between mandibular plane (Go-Gn) to HP.

b) Dental Components: (Fig. 3)

5. *U1 to NF/Palatal plane (anterior maxillary dental height)*: Measured from a perpendicular line

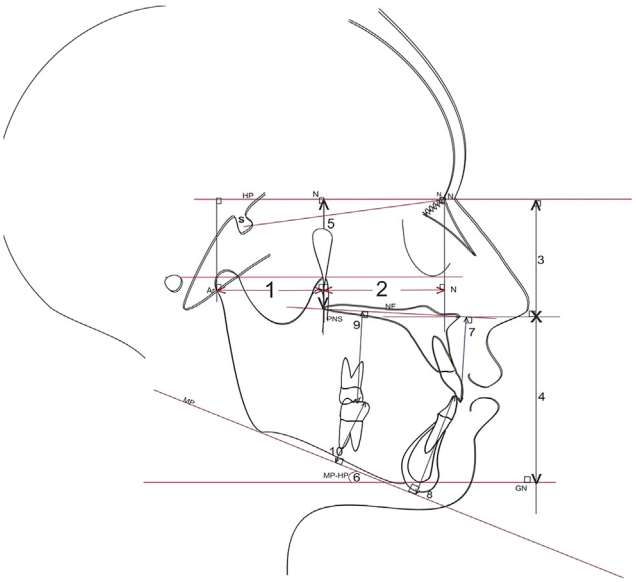

Fig. 3 – Cranial base and vertical skeletal and dental Measurements: 1. Ar to Ptm through horizontal plane, 2. Ptm to N through horizontal plane, 3. N to ANS through TVL (Middle third facial height), 4. ANS to Gn through TVL (Lower third facial height), 5. Pns-n through TVL (Posterior vertical height), 6. MP-HP (Angle) Posterior facial divergance, 7. U1 to palatal plane (Ant. maxillary dental height), 8. A6 to palatal palne (Ant. mandibular dental height), 9. L1 to mandibular plane (Posterior maxillary dental height), 10. B6 to mandibular plane (Posterior mandibular dental height).

dropped from the incisal edge of upper central incisor to the nasal floor/Palatal plane.

6. *A6 to NF/Palatal plane (posterior maxillary dental height)*: Measured from the mesiobuccal cusp tip of the maxillary first molar to the nasal floor/Palatal plane.

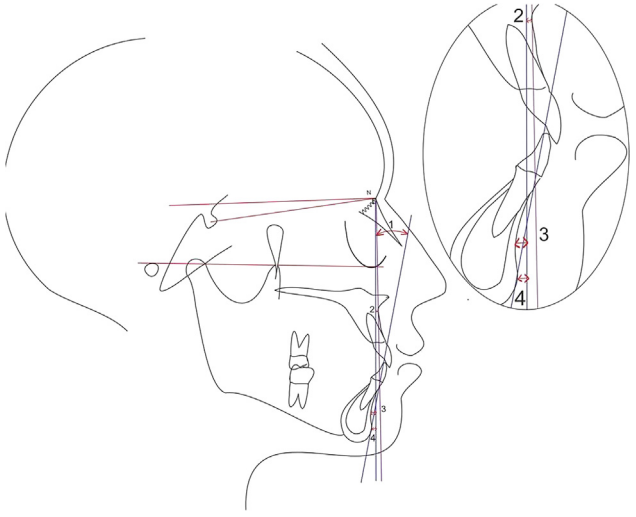

Fig. 4 – Skeletal horizontal measurements: 1. N-A-Pg angle (Degree of skeletal convexity), 2. N to A through horizontal plane, 3. N to B through horizontal plane, 4. N to Pg through horizontal plane.

7. *L1 to MP (anterior mandibular dental height)*: Measured from incisal edge of mandibular central incisor to the mandibular plane.
8. *B6 to Mandibular plane (posterior mandibular height)*: Measured from the mesiobuccal cusp tip of mandibular first molar to the mandibular plane.

(D) Maxilla and Mandible: (Fig. 5)

1. *Ramus height (Ar-Go)*: Measured from articulare to Gonion.
2. *Corpus length (Go-Pg)*: Measured from gonion to Pogonion.
3. *Symphysis dimension (chin position)*: Measured from point B to Pogonion.
4. *Gonial angle*: Angle formed between Articulare, Gonion and Gnathion.
5. *Effective length of maxilla (ANS-PNS)*: Distance between ANS to PNS.

(E) Dental: (Fig. 5)

1. *Occlusal plane to horizontal plane angle (Canting of occlusal plane)*: Angle formed between OP and HP.
2. *AB through occlusal plane (Relation of maxilla and mandible to OP)*: Linear measurement from the distance Point A to Point B dropped perpendicularly to OP.
3. *U1 to palatal plane angle (Angulation of maxillary incisors)*: Determined by measuring the angle formed

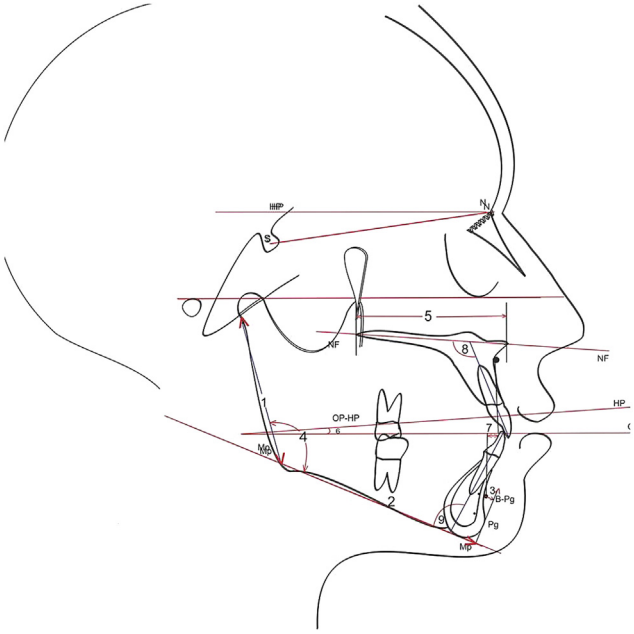

Fig. 5 – Measurements of dental relationship and length of maxilla and mandible: 1. Ramus height (Ar-Go), 2. Corpus length (Go-Pg), 3. Symphysis dimension (Chin position), 4. Gonial angle, 5. Effective length of maxilla (ANS – PNS), 6. Occusal plane to horizontal plane (Angular – Canting of occlusal plane), 7. A-B through occlusal plane (Relationship of the maxillary and mandibular apical base), 8. U1 to paltal plane (Angulation of maxillary central incisor to palatal plane) 9. L1 to mandibular plane (Angulation of mandibular central incisor to mandible).

between the nasal floor and the long axis of upper central incisor.

4. *L1 to mandibular plane angle (Angulation of mandibular central incisors)*: Determined by the angle formed between mandibular plane and the long axis of the lower central incisor.

7. Statistical analysis

The statistical analysis was done using SPSS (Statistical Package for Social Sciences) Version 15.0 statistical Analysis Software. The Mean and standard deviation (SD) was calculated for all the values. Student's *t*-test was done to evaluate statistical significance between the values obtained and norms established by Legan and Burstone for Caucasians. Error of measurement was tested by doing double determination of ten cephalograms randomly selected at fifteen days interval from the collected sample by the same operator. The comparison was drawn between first and second determination by student's 't' test. Statistically, no significant differences between first and second measurements were seen (Table 1).

8. Results

Mean and SD values of various hard tissue parameters of COGS analysis for Group I and Group II of North Indian population are shown in Table 2 and norms established by Legan and Burstone for Caucasian population are shown in Table 3. On comparison of Group I with Caucasian males, statistically significant difference was noted for all parameters except for Ar-Ptm, N-A-Pg, Ar-Go-Gn, U1-NF and L1-MP (Table 4). On comparison of Group II with Caucasian females, statistically significant difference was noted for all parameters except Ar-Ptm, N-A-Pg, MP-HP, Ar-Go-Gn and U1-NF (Table 5). When Group I and Group II were compared (Table 6) Ar-Ptm, Ptm-N, N-ANS, PNS-N, L1-MP, B6-MP, Ar-Go and Go-Pg were significantly higher for Group I whereas MP-HP was significantly higher for Group II and other parameters showed statistically insignificant difference.

9. Discussion

To obtain harmonious dental, skeletal as well as soft tissue relationships a combination of fixed orthodontic therapy and orthognathic surgery is required. Thus a specialized cephalometric appraisal system, Cephalometric for orthognathic surgery (COGS)[5] that describes horizontal and vertical position of facial bones by various linear and angular parameters was developed. As most of the cephalometric norms are based on the Caucasian population and cannot be always applied to the other population groups, hence separate norms had been developed for various racial and ethnic groups. Considering the evidence of sexual dimorphism in previous studies,[13–18] separate norms of COGS analysis for males and females of North Indian population were established.

The subjects were above 18 years of age in order to ensure that complete growth had taken place so that variability, because of growth could be avoided as also suggested in the studies by Anderson et al,[22] Bergman and C.J. Burstone.[23] For accurate assessment of facial morphology and for standardization of the method, the lateral

Table 1 – Reliability analysis.

Parameters	Variables	I Observation $n = 10$		II Observation $n = 10$		*t* Value	*P* Value	Level
		Mean	SD	Mean	SD	0.355	0.731	NS
Cranial base	Ar-Ptm (mm)	37.1	2.8	36.7	2.2	0.567	0.585	NS
	Ptm-N (mm)	52.8	4.1	50.9	3.7	0.128	0.909	NS
Skeletal horizontal	N-A-Pg (°)	3.9	6.4	3	6	0.229	0.824	NS
	N-A (mm)	0	3.7	0.3	3.7	0.188	0.855	NS
	N-B (mm)	−5.3	6.7	−5.9	7	0.833	0.217	NS
	N-Pg (mm)	−4.3	8.5	−4	8.1	0.734	0.351	NS
Skeletal vertical	N-ANS (mm)	54.7	3.2	54	2.4	0.023.	0.982	NS
	ANS-Gn (mm)	68.6	3.8	68.6	3.3	0.1	0.922	NS
	PNS-N (mm)	53.9	1.7	53	2.2	0.933	0.375	NS
	MP-HP (°)	23	5.9	24.2	5	0.591	0.569	NS
Dental vertical	U1-PP (mm)	30.5	2.1	29.1	1.7	0.468	0.651	NS
	A6-PP (mm)	26.2	2	27	1.6	0.023	0.982	NS
	L1-MP (mm)	45	2.1	44.1	1.8	0.168	0.87	NS
	B6-MP (mm)	35.8	2.6	34.5	1.9	0.016	0.987	NS
Maxilla-mandible	Ar to Go (mm)	52	4.2	51.1	3.1	0.894	0.394	NS
	Go to Pg (mm)	83.7	4.6	81.9	4.9	0.231	0.823	NS
	B-Pg (mm)	8.9	1.7	7.2	1.9	0.053	0.959	NS
	Ar-Go-Gn (°)	119.1	6.5	121	6.9	0.425	0.681	NS
Dental	OP-HP (°)	6.2	2.2	7.1	2.5	0.728	0.485	NS
	A-B (mm)	−1.1	2	−1.19	2.5	0.606	0.56	NS
	U1-NF (°)	111	4.7	111.91	5.3	0.077	0.94	NS
	L1-MP (°)	95.9	5.2	95.9	5.7	0.678	0.515	NS

Table 2 – Mean and SD values of hard tissue parameters of Group I and Group II.

Parameters	Variables	Group I (N = 50)		Group II (N = 50)	
		Mean	SD	Mean	SD
Cranial base	Ar-Ptm (mm)	36.11	2.38	33.55	2.93
	Ptm-N (mm)	46.53	3.45	45.13	2.96
Skeletal horizontal	N-A-Pg (°)	3.73	5.52	3.88	4.81
	N-A (mm)	2.72	3.12	1.74	2.92
	N-B (mm)	−0.61	4.44	−1.79	4.03
	N-Pg (mm)	1.93	4.95	0.18	4.37
Skeletal vertical	N-ANS (mm)	47.76	3.98	45.89	2.99
	ANS-Gn (mm)	58.18	7.13	57.10	3.38
	PNS-N (mm)	50.06	4.38	48.09	3.88
	MP-HP (°)	17.15	5.35	20.74	8.78
Dental vertical	U1-PP (mm)	26.42	4.30	25.43	2.17
	A6-PP (mm)	22.19	1.79	21.62	1.74
	L1-MP (mm)	39.33	2.66	36.86	2.55
	B6-MP (mm)	32.39	2.75	29.90	1.76
Maxilla-mandible	Ar to Go (mm)	48.60	5.69	43.94	3.30
	Go to Pg (mm)	73.06	4.50	71.25	3.92
	B-Pg (mm)	6.19	1.33	5.96	1.69
	Ar-Go-Gn (°)	119.02	5.78	119.81	5.52
Dental	OP-HP (°)	15.15	3.33	14.03	3.95
	A-B (mm)	5.99	3.01	4.91	3.37
	U1-NF (°)	111.69	7.71	113.14	7.08
	L1-MP (°)	99.99	7.30	101.49	7.94

cephalograms were taken in relaxed lip position as relaxed lips demonstrate the relationship of soft tissues relative to hard tissues without muscular compensation for dentoskeletal abnormalities as also suggested by Hwang et al,[11] Bergman and Arnett,[24]Connor and Moshiri,[25] and Burstone.[6]

For convenience the hard tissue cephalometric parameters would be discussed under 5 groups, cranial base, Horizontal skeletal relationship, Vertical skeletal and dental relationship, maxilla and mandible and dental relationship.

9.1. *Cranial base*

It is divided into posterior cranial base length and anterior cranial base length. *Posterior cranial base (Ar-Ptm)*: Though Ar-Ptm distance was shorter in North Indian population as compared to Caucasians but the difference

Table 3 – Overall mean and SD values of hard tissue parameters of Caucasian male and female as established by Legan and Burstone.

Parameters	Variables	Caucasian males N = 14		Caucasian females N = 16	
		Mean	SD	Mean	SD
Cranial base	Ar-Ptm (mm)	37.1	2.8	32.8	1.9
	Ptm-N (mm)	52.8	4.1	50.9	3.0
Skeletal horizontal	N-A-Pg (°)	3.9	6.4	2.6	5.1
	N-A (mm)	0.0	3.7	−2.0	3.7
	N-B (mm)	−5.3	6.7	−6.9	4.3
	N-Pg (mm)	−4.3	8.5	−6.5	5.1
Skeletal vertical	N-ANS (mm)	54.7	3.2	50.0	2.4
	ANS-Gn (mm)	68.6	3.8	61.3	3.3
	PNS-N (mm)	53.9	1.7	50.6	2.2
	MP-HP (°)	23.0	5.9	24.2	5.0
Dental vertical	U1-PP (mm)	30.5	2.1	27.5	1.7
	A6-PP (mm)	26.2	2.0	23.0	1.3
	L1-MP (mm)	45.0	2.1	40.8	1.8
	B6-MP (mm)	35.8	2.6	32.1	1.9
Maxilla-mandible	Ar to Go (mm)	52.0	4.2	46.8	2.5
	Go to Pg (mm)	83.7	4.6	74.3	5.8
	B-Pg (mm)	8.9	1.7	7.2	1.9
	Ar-Go-Gn (°)	119.1	6.5	122.0	6.9
Dental	OP-HP (°)	6.2	5.1	7.1	2.5
	A-B (mm)	−1.1	2.0	−0.4	2.5
	U1-NF (°)	111.0	4.7	112.5	5.3
	L1-MP (°)	95.9	5.2	95.9	5.7

Table 4 – Comparison of hard tissue parameters of Group I with Caucasian males.

Parameters	Variables	Group I ($n = 50$)		Caucasian males		Caucasian males	'P' value	Level of significance
		Mean	SD	Mean	SD			
Cranial base	Ar-Ptm (mm)	36.11	2.38	37.1	2.8	1.32	0.191	NS
	Ptm-N (mm)	46.53	3.45	52.8	4.1	5.77	<0.001	***
Skeletal horizontal	N-A-Pg (°)	3.73	5.52	3.9	6.4	0.10	0.922	NS
	N-A (mm)	2.72	3.12	0.0	3.7	2.77	0.007	**
	N-B (mm)	−0.61	4.44	−5.3	6.7	3.10	0.003	**
	N-Pg (mm)	1.93	4.95	−4.3	8.5	3.51	0.001	***
Skeletal vertical	N-ANS (mm)	47.76	3.98	54.7	3.2	5.99	<0.001	***
	ANS-Gn (mm)	58.18	7.13	68.6	3.8	5.24	<0.001	***
	PNS-N (mm)	50.06	4.38	53.9	1.7	3.20	0.002	**
	MP-HP (°)	17.15	5.35	23.0	5.9	3.54	0.001	***
Dental vertical	U1-PP (mm)	26.42	4.30	30.5	2.1	3.42	0.001	***
	A6-PP (mm)	22.19	1.79	26.2	2.0	7.22	<0.001	***
	L1-MP (mm)	39.33	2.66	45.0	2.1	7.35	<0.001	***
	B6-MP (mm)	32.39	2.75	35.8	2.6	4.15	<0.001	***
Maxilla-mandible	Ar to Go (mm)	48.60	5.69	52.0	4.2	2.08	0.042	*
	Go to Pg (mm)	73.06	4.50	83.7	4.6	7.78	<0.001	***
	B-Pg (mm)	6.19	1.33	8.9	1.7	6.33	<0.001	***
	Ar-Go-Gn (°)	119.02	5.78	119.1	6.5	0.04	0.965	NS
Dental	OP-HP (°)	15.15	3.33	6.2	5.1	7.85	<0.001	***
	A-B (mm)	5.99	3.01	−1.1	2.0	8.29	<0.001	***
	U1-NF (°)	111.69	7.71	111.0	4.7	0.32	0.752	NS
	L1-MP (°)	99.99	7.30	95.9	5.2	1.96	0.055	NS

was statistically insignificant. This suggested that Mandible was found proportionally posterior to maxilla in both the populations. Similar findings were observed for males of Rajasthani,[17] Central India,[19] Karnataka[20] and population. On the contrary, females of Rajasthani[17] and Karnataka[20] population had longer poster cranial base than Caucasians. *Anterior Cranial base Length (Ptm-N)*: This finding suggested that North Indians had a smaller anterior cranial base length and the distance between posterior most position of maxilla and nasion is lesser in North Indian population.

9.2. *Horizontal skeletal parameters*

Angle of convexity (N-A-Pg angle): North Indian and Caucasian[5] population had similar skeletal profile. Same results were

Table 5 – Comparison of Hard tissue parameters of Group II with Caucasian females.

Parameters	Variables	Group II ($n = 50$)		Caucasian females		't' Value (DF = 64)	'P' value	Level of significance
		Mean	SD	Mean	SD			
Cranial base	Ar-Ptm (mm)	33.55	2.93	32.8	1.9	0.96	0.341	NS
	Ptm-N (mm)	45.13	2.96	50.9	3.0	6.77	<0.001	***
Skeletal horizontal	N-A-Pg (°)	3.88	4.81	2.6	5.1	0.91	0.365	NS
	N-A (mm)	1.74	2.92	−2.0	3.7	4.17	<0.001	***
	N-B (mm)	−1.79	4.03	−6.9	4.3	4.35	<0.001	***
	N-Pg (mm)	0.18	4.37	−6.5	5.1	5.11	<0.001	***
Skeletal vertical	N-ANS (mm)	45.89	2.99	50.0	2.4	5.00	<0.001	***
	ANS-Gn (mm)	57.10	3.38	61.3	3.3	4.35	<0.001	***
	PNS-N (mm)	48.09	3.88	50.6	2.2	2.46	0.017	*
	MP-HP (°)	20.74	8.78	24.2	5.0	1.50	0.140	NS
Dental vertical	U1-PP (mm)	25.43	2.17	27.5	1.7	3.48	0.001	***
	A6-PP (mm)	21.62	1.74	23.0	1.3	2.92	0.005	**
	L1-MP (mm)	36.86	2.55	40.8	1.8	5.73	<0.001	***
	B6-MP (mm)	29.90	1.76	32.1	1.9	4.27	<0.001	***
Maxilla-mandible	Ar to Go (mm)	43.94	3.30	46.8	2.5	3.18	0.002	**
	Go to Pg (mm)	71.25	3.92	74.3	5.8	2.40	0.020	*
	B-Pg (mm)	5.96	1.69	7.2	1.9	2.48	0.016	*
	Ar-Go-Gn (°)	119.81	5.52	122.0	6.9	1.30	0.199	NS
Dental	OP-HP (°)	14.03	3.95	7.1	2.5	6.59	<0.001	***
	A-B (mm)	4.91	3.37	−0.4	2.5	5.80	<0.001	***
	U1-NF (°)	113.14	7.08	112.5	5.3	0.33	0.741	NS
	L1-MP (°)	101.49	7.94	95.9	5.7	2.60	0.012	*

Table 6 – Comparison of Hard tissue parameters between Group I and Group II.

Parameters	Variables	Group I males ($n = 50$)		Group II Females ($n = 50$)		't' Value (DF = 98)	'P' value	Level of significance
		Mean	SD	Mean	SD			
Cranial base	Ar-Ptm (mm)	36.11	2.38	33.55	2.8	4.80	<0.001	***
	Ptm-N (mm)	46.53	3.45	45.13	4.1	2.17	0.032	*
Skeletal horizontal	N-A-Pg (°)	3.73	5.52	3.88	6.4	0.14	0.890	NS
	N-A (mm)	2.72	3.12	1.74	3.7	1.63	0.107	NS
	N-B (mm)	−0.61	4.44	−1.79	6.7	1.39	0.167	NS
	N-Pg (mm)	1.93	4.95	0.18	8.5	1.87	0.064	NS
Skeletal vertical	N-ANS (mm)	47.76	3.98	45.89	3.2	2.66	0.009	**
	ANS-Gn (mm)	58.18	7.13	57.10	3.8	0.97	0.336	NS
	PNS-N (mm)	50.06	4.38	48.09	1.7	2.38	0.019	*
	MP-HP (°)	17.15	5.35	20.74	5.9	2.47	0.015	*
Dental vertical	U1-PP (mm)	26.42	4.30	25.43	2.1	1.45	0.151	NS
	A6-PP (mm)	22.19	1.79	21.62	2.0	1.61	0.110	NS
	L1-MP (mm)	39.33	2.66	36.86	2.1	4.75	<0.001	***
	B6-MP (mm)	32.39	2.75	29.90	2.6	5.38	<0.001	***
Maxilla-mandible	Ar to Go (mm)	48.60	5.69	43.94	4.2	5.00	<0.001	***
	Go to Pg (mm)	73.06	4.50	71.25	4.6	2.14	0.035	*
	B-Pg (mm)	6.19	1.33	5.96	1.7	0.74	0.458	NS
	Ar-Go-Gn (°)	119.02	5.78	119.81	6.5	0.70	0.486	NS
Dental	OP-HP (°)	15.15	3.33	14.03	5.1	1.54	0.127	NS
	A-B (mm)	5.99	3.01	4.91	2.0	1.69	0.095	NS
	U1-NF (°)	111.69	7.71	113.14	4.7	0.98	0.329	NS
	L1-MP (°)	99.99	7.30	101.49	5.2	0.98	0.328	NS

obtained for Rajasthani[17] and Central Indian[19] males, where as Karnataka[20] males had significantly straighter profile. For females non significant difference was noted between Rajasthani,[17] Karnataka[20] and Central India[19] with Caucasian[5] population.

Apical base of maxilla (N-A) was placed significantly anterior in North Indians than Caucasians[5] suggestive of prognathic maxilla in our population. Similar finding was observed for Rajasthani[17] and Karnataka[20] population and central Indian[19] females. In contrast central Indian[19] males did not show significant difference.

Apical base of Mandible (N-B) was placed significantly posteriorly in Caucasians suggestive of more retrognathic mandibular position in Caucasians in comparison to North Indian population. Similar result was obtained only for males of Karnataka[20] population whereas non significant difference was seen for females of Karnataka[20] population. The findings of Rajasthani population[17] were contrary to the finding of the present study.

Chin position (N-Pg): Chin was more anteriorly placed in North Indians than Caucasians.[9] Similar results were seen for Central India[19] and Rajasthani[17] females while insignificant difference was noted for Central Indian[19] and Rajasthani[17] males and Karnataka population.[20]

Sexual dimorphism was not observed for any of the horizontal skeletal parameters, similar findings were seen for the Rajasthani population.

9.3. *Vertical skeletal parameters*

Middle third facial height of North Indians was significantly decreased in both the sexes as compared to the Caucasians.[5] In contrast, males of Rajasthan,[17] Central India[19] and Karnataka[20] did not show significant difference with Caucasian[5] males whereas females of these populations had significantly greater middle third facial height than Caucasian[5] females.

Lower third facial height of North Indian population was significantly reduced when compared to the Caucasians,[5] whereas Central India,[19] Karnataka[20] population, and Rajasthani[17] males showed non significant difference. In contrast, Rajasthani[17] females had larger lower third facial height than Caucasian females.

Posterior maxillary height was significantly lesser in North Indians males and females as compared to the Caucasian.[5] In contrast, males of Karnataka,[20] Central India[19] and Rajasthani[17] population and Karnataka[20] females showed non significant difference with their corresponding counterparts whereas Central Indian[19] and Rajasthani[17] females had greater posterior maxillary height than the Caucasian[5] females.

Posterior facial divergence (MP-HP angle) was significantly lesser in both the sexes of our population as compared to Caucasians,[5] suggestive of counterclockwise rotation of mandible in North Indian population. Similarly findings were seen for Karnataka[20] population and females of Rajasthani population.[17] In contrast Central Indian[19] population and Rajasthani[17] males had non significant difference on comparison with Caucasians.

Anterior maxillary dental height was significantly reduced in both the sexes of North Indian population when compared with Caucasians. Central Indian,[19] Rajasthani[17] and Karnataka[20] population showed statistically non significant difference in comparison to Caucasians.[5]

Posterior maxillary dental height was decreased significantly in both the sexes of North Indian population in comparison to

Caucasians.[5] In contrast Central Indian,[19] Karnataka[20] and Rajasthani males[17] showed statistically non significant difference with Caucasian counterparts. While Rajasthani[17] females showed significant difference.

Anterior mandibular dental height was significantly lesser in our population as compared to Caucasian[5] population. Similar result was observed for Rajasthani[17] population and males of Karnataka[20] population, whereas Central Indian[19] population and Karnataka females[20] showed statistically non significant difference on comparison with Caucasians.[5]

Posterior mandibular dental height was significantly decreased in both the sexes of North Indian population in comparison to Caucasians.[5] In contrast Central Indian[19] and Karnataka[20] population showed statistically non significant difference for both the sexes while Rajasthani[17] population had significant difference for males.

Length of the mandibular ramus was significantly lesser in both the sexes of present study in comparison to Caucasian. In contrast Central Indian[19] population, Rajasthani females[17] and Karnataka females[20] had significantly greater ramal length, whereas Rajasthani[17] and Karnataka[20] males showed no significant difference on comparison with Caucasian.[5]

Length of the mandibular body: Corpus length was significantly lesser in our population as compared to Burstone's[5] study. Similar results were seen for Rajasthani[17] males whereas Central Indian[19] and Karnataka[20] females has significantly greater mandibular body length than Caucasian[5] females and their males demonstrated non significant difference with Caucasian males.

Chin prominence was less in North Indian population as compared to the Caucasians. The results were supported by the studies on Central Indian[19] and Rajasthani population.[17] In contrast Karnataka population[20] showed non significant difference with Caucasians.

Gonial angle did not showed any significant difference for North Indian population as compared to Caucasians. Similar results were seen for Central Indian,[19] Karnataka[20] population and Rajasthani females.[17] While Rajasthani males[17] had greater gonial angle than Caucasian males suggestive of more vertical growth pattern in Rajasthani males.

Sexual dimorphism was evident for few vertical skeletal parameters with males exhibiting greater middle facial height, posterior maxillary height, counterclockwise rotation of mandible, anterior and posterior mandibular height, ramal and corpal length than females. Similar results were obtained for Rajasthani population[17] except for lower facial height, posterior maxillary height, ramal and corpal length that did not show evidence of sexual dimorphism in Rajasthani population.[17]

9.4. *Dental*

Occlusal plane angle (OP-HP): Occlusal plane was steeper in North Indian population when compared with Caucasians.[5] In contrast Central Indian[19] and Rajasthani[17] population, Karnataka females showed statistically non significant difference than Caucasian counterparts, while it was significantly less steeper in Karnataka[20] males.

Antero-posterior position of maxilla and mandible (A-B ll OP) tells us about dysplasia in sagittal plane with greater apical base discrepancy in North Indian individuals than Caucasian. In contrast Central Indian,[19] Rajasthani[17] and Karnataka[20] population showed statistically non significant difference on comparison with Caucasians.[5]

Maxillary central incisor angulation did not show any significant difference between males and females of our population with Caucasian[5] population. It was significantly higher in Central Indian[19] males, Rajasthani[17] and Karnataka[20] population whereas Central Indian[19] females showed non significant difference with Caucasian[5] females.

Mandibular central incisor angulation was non significant in North Indian males as compared to Caucasian[5] males whereas North Indian females had more proclined incisors than Caucasian[5] females. Similarly males and females of Central Indian,[19] Karnataka[20] and Rajasthani[17] population had significantly more proclined incisors than their Caucasian[5] counterparts.

Sexual dimorphism was not evident for any dental parameters. In contrast, Rajasthani males had less steep occlusal plane, proclined maxillary and mandibular incisors than Rajasthani females.

10. Conclusions

Following conclusions were drawn from this study:

1. Both North Indian males and females had smaller anterior cranial base length with prognathic maxilla and mandible, protrusive chin with poor chin form, decreased facial height, decreased posterior maxillary height with mandible being rotated anticlockwise, overall increased anterior and posterior maxillary dental heights, decreased ramal and corpus length, clockwise rotation of occlusal plane, presence of more sagittal discrepancy between maxillary and mandibular denture bases in comparison to Caucasian males and females respectively. Whereas North Indian females had more proclination of mandibular incisors than Caucasian females.
2. Sexual dimorphism was also evident in the present study where Males exhibited significantly larger cranial base length, greater middle third facial height and posterior maxillary height, counterclockwise rotation of mandibular plane, greater anterior and posterior mandibular dental heights and longer ramal and corpus length in comparison to females.

This study was an attempt to provide better knowledge of facial morphology in the North Indians hence a comprehensive treatment planning can be done based on the norms derived for the correction of skeletal discrepancies.

Conflicts of interest

All authors have none to declare.

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