Original Article

To cite:

Amit Tripathi, Rajesh Kishnani, Abhilasha Manker, Ashish Garg, Piyush Manker, Katya Pandey

Three-Dimensional Cephalometric norms, correlation and sexual dimorphism in Central Indian population -A Cone Beam Computed Tomographic Study.

J Contemp Orthod 2021;5(1): 43-51

Received on: 12-01-2021

Accepted on: 23-03-2021

Source of Support: Nil

Conflict of Interest: None

Three-Dimensional Cephalometric norms, correlation and sexual dimorphism in Central Indian population -A Cone Beam Computed Tomographic Study.

[1]Amit Tripathi, [2]Rajesh Kishnani, [3]Abhilasha Manker, [4]Ashish Garg, [5]Piyush Manker, [6]Katya Pandey

[1]BDS, MDS, Assistant Professor, Department of Orthodontics and Dentofacial Orthopaedics, Sri Aurobindo College of Dentistry, SAIMS, Indore, India.

[2]BDS, MDS, Professor and Ex-Head Of Department, Department Of Orthodontics & Dentofacial Orthopedics, Sri Aurobindo College Of Dentistry, Indore, Madhya Pradesh, India.

[3]BDS, MDS, Assistant Professor, Department of Pedodontics and Preventive Dentistry, Sri Aurobindo College of Dentistry, SAIMS, Indore, India.

[4]BDS, MDS, Professor and Head Of Department, Department Of Orthodontics & Dentofacial Orthopedics, Sri Aurobindo College Of Dentistry, Indore, Madhya Pradesh, India.

[5]BDS, MDS, Assistant Professor, Department of Prosthetic Dentistry, College of Dental Science and Hospital, Rau (M.P.), India.

[6]BDS, MDS, Assistant Professor, Department of Conservative Dentistry and Endodontics, College of Dental Science and Hospital, Rau (M.P.), India.

ABSTRACT

Background: Cephalometric norms are important in assessing optimal treatment alternatives in different population. Universal norms are based on cephalometric data from Caucasian population and based on one size fits all ideology. Aim of the study was to create a database of normative type and determine gender dimporphism on three dimensional cephalometric analysis for Central Indian population. The secondary aim was to observe correlation between different skeletal and dentoalveolar variables.

Materials: Craniofacial CBCT scans of 60 adult subjects (30 females and 30 males; age group of 21 years and above) having skeletal class I relation and normal occlusion were included in the study. Landmark identification and measurements of skeletal and dentoalveolar variables were done on three dimensional life size model and compared for facial symmetry, gender dimorphism, correlation between skeletal and dentoalveolar variables and condylar and ramal variables.

Results: Cephalometric norm of central Indian population showed a tendency towards class II skeletal relationship and convex profile. Antero-posterior, vertical and transverse facial variables differed significantly for males and females suggesting gender dimorphism. Greater body length, facial height, facial width and basal curve length of maxilla and mandible were observed in males ($p \leq 0.05$). Pearson correlation showed significant correlations among various skeletal variables, skeletal and dento-alveolar variables and condylar and ramal variables in the population.

Conclusion: Baseline values play important part in determining abnormalities and post-treatment objectives for the population. A strategic approach is important based on racial and gender differences while planning orthodontic treatment.

Keywords: Three dimensional cephalometric analysis, Central Indian population, facial symmetry, correlation between cephalometric variables, condylar and ramal variables.

Conflict of interests: The authors declare that they have no conflict of interest.

INTRODUCTION

Since its introduction by Broadbent[1] and Hofrath,[2] cephalometric study has been an essential diagnostic aid in treatment planning, growth assessment and quantification of treatment outcomes in dento-facial orthopedics and orthognathic surgeries.[3,4,5] Anthropologists have acknowledged remarkable variations in craniofacial features amongst human races (Roomi et al., 2011). These variations ascended from diversity in geographic location, environment, nutrition, genetics and ancestry. Thus, remarkable differences in facial characteristics in various populations are apparent.[6,7]

Cephalometric norms are dentofacial patterns that assess cranio-facial features, growth patterns and abnormalities. They streamline the selection of optimal treatment alternatives and

Table (1): Comparison of three-dimensional measurements between male and female subjects

Variable	Total (SD)	Female (n=30)	Male (n=30)	p – value
Antero-posterior measurements				
SNA (°)	82.22±1.82	81.02±2.83	83.43±0.82	<0.0001**
SNB (°)	78.83±1.96	77.87±2.14	79.79±1.78	<0.0001**
SNPg angle (°)	79.4±1.72	78.21±1.68	80.59±1.77	<0.0001**
NPg-FH (°)	89.26±2.24	87.78±2.91	90.75±1.57	<0.0001**
A to N-Pg (mm)	3.61±1.35	4.32±1.68	2.90±1.03	<0.0001**
Pg to NB (mm)	1.30±1.33	1.65±1.45	0.95±1.22	0.048*
Facial convexity (°)	7.18±3.01	8.61±4.37	5.75±1.65	0.001**
Mx length (mm)	53.59±3.41	50.39±1.48	56.79±5.35	<0.0001**
Mn body length (Me-Go) (mm)	73.14±3.14	72.14±3.20	74.14±3.08	0.017*
Co-Go to FH (°)	78.41±3.54	78.05±3.64	78.78±3.44	0.429
Cond AP inclination (°)	69.01±4.37	66.97±3.89	71.05±4.85	0.001**
Vertical facial measurements				
Facial height (mm)	110.96±3.08	109.20±3.59	112.73±2.57	<0.0001**
Upper anterior facial height (mm)	52.27±2.54	52.26±2.51	52.29±2.58	0.967
Lower anterior facial height (mm)	58.75±2.30	57.10±2.53	60.41±2.07	<0.0001**
Mx height (mm)	45.32±1.80	44.80±1.63	45.85±1.97	0.028*
Ramal length (mm)	55.70±2.74	52.56±2.80	58.85±2.69	<0.0001**
Cond height (mm)	19.07±2.09	16.09±1.63	22.06±2.55	<0.0001**
Y-Axis (°)	58.29±4.33	57.35±1.95	59.23±2.38	0.001**
Me-Go-Co angle (°)	120.58±9.41	121.37±2.93	119.80±6.48	0.230
Transverse facial measurements				
Upper facial width (mm)	94.69±2.54	92.30±2.42	97.08±2.66	<0.0001**
Ant Mx basal arch width (mm)	31.71±1.59	30.32±1.67	33.11±1.51	<0.0001*
Post Mx basal arch width (mm)	70.25±2.22	67.50±1.34	73.01±3.06	<0.0001**
Go-Me-Go angle (°)	70.30±2.12	67.42±1.79	73.18±2.45	<0.0001**
Me deviation (°)	14.67±2.91	16.53±3.66	12.81±2.17	<0.0001**
Me to MS (mm)	13.26±5.87	13.14±3.66	13.38±2.21	0.762
Ramal ML inclination (°)	83.43±2.77	83.59±3.08	83.28±2.46	0.673
Go to MS (mm)	44.21±1.46	42.52±2.02	45.90±0.90	<0.0001**
Cond to MS (mm)	50.25±2.89	47.36±3.17	52.69±2.61	<0.0001**
Cond ML dimension (mm)	15.63±1.59	15.39±1.20	15.95±1.98	0.191
MxT-point A-CE (mm)	51.73±5.19	51.06±4.17	52.41±6.22	0.327
Other measurements				
Go-MBC-Me-MBC-Go (mm)	77.43±3.94	76.33±3.54	78.53±4.35	0.036*
Me-MBC-Go angle (°)	141.09±4.33	142.02±5.61	140.18±3.06	0.122
Ant Mn basal length (mm)	25.04±2.76	24.73±2.58	25.36±2.95	0.381
Post Mn basal length (mm)	51.66±3.44	50.57±4.54	52.75±2.35	0.023*

evaluation of treatment outcomes. At present, the cephalometric norms are widely based on 2-dimensional (2D) cephalometric database from Caucasian population, indicating the 'one size fits all' approach. These however, do not justify the diversity in prominent cranio-facial features, body structure and growth pattern amongst different racial and ethnic groups.[7,8]

Three-dimensional (3D) imaging techniques such as Cone Beam Computed Tomography (CBCT) have revolutionized orthodontic diagnosis and treatment planning. While the conventional radiography was swayed by x-ray beam geometry, structural noise and image magnification; CBCT enabled the practitioner to reorient the head position, eliminate magnification factor and identify transverse asymmetry.[1,3,9] CBCT thus, unveils the possibility of gauging anatomical landmarks and new parameters that are otherwise indistinct on 2-dimensional cephalogram, providing valuable insight on growth and development of craniofacial complex.[3,10,11]

India is an ethnological museum, a melting pot of races, owing to invasions, relocations and mass deportation. The normal facial features vary in different regions of the country based on the origin and ancestry. Thus various studies reporting 3 D cephalometric databases from different Indian population groups have been carried out to establish normative cephalometric values for the population.[12,13] However, no studies reporting an elaborated data on cephalometric norms in Central Indian population have been carried out to the best of our knowledge. Therefore, the aim of this study was to generate a database of normative type for Central Indian adult population

with normal cranio-facial balance using 3D cephalometric measurements. Also presence of facial asymmetry, gender dimorphism, correlation between dentoalveolar and skeletal variables, and correlation between condylar and ramal variables was determined.

Table (2): Correlation (r) between facial height variables and antero-posterior, transverse facial, and other three dimensional variables

Variable	Facial height (n=60) r (p value)	Upper Facial height (n=60) r (p value)	Lower Facial height (n=60) r (p value)
Antero-posterior measurements			
SNA (°) (n = 60)	-0.089(0.498)	-0.205(0.116)	0.091(0.490)
SNB (°) (n = 60)	-0.093(0.481)	-0.215(.099)	0.081(0.540)
Mx length (n = 60)	0.318(0.013)	0.118(0.371)	0.281(0.030**)
Mn body length (Me-Go) (n = 120)	0.105(0.425)	0.048(0.716)	0.100(0.448)
Transverse facial measurements			
Upper facial width (n = 60)	0.400(0.002**)	0.139(0.289)	0.342(0.007**)
Ant Mx basal arch width (n = 60)	0.323(0.012**)	0.075(0.568)	0.318(0.013**)
Post Mx basal arch width (n = 60)	0.384(0.002**)	0.165(0.207)	0.329(0.010**)
Go to MS (n = 120)	0.448(0.000**)	0.087(0.506)	0.452(0.000**)
Cond to MS (n = 120)	0.336(0.009**)	0.135(0.305)	0.292(0.024**)
Other measurements			
Mx T-Point A-CE (n = 120)	0.019(0.886)	0.013(0.924)	0.011(0.934)
Go-MBC-Me-MBC-Go (n = 120)	-0.028(0.830)	-0.013(0.924)	0.006(0.962)
Ant Mn basal length (n = 120)	0.158(0.229)	0.391(0.002**)	-0.162(0.216)
Post Mn basal length (n = 120)	-0.124(0.346)	-0.334(0.009**)	0.182(0.164)

MATERIAL AND METHODOLOGY

This study was carried out in the department of Orthodontics and Dentofacial Orthopedics, Ethical clearance was obtained from Institutional ethical committee (IEC), before commencement of the study. Subjects belonging to Central Indian ethnicity and those intended for CBCT scans of craniofacial complex due to reasons other than orthodontic treatment were approached for the study. The subjects were then examined for inclusion and exclusion criteria. Patients normal balanced facial appearance, having Skeletal Class- I relation, Angle's Class- I molar relation and class I canine relationship, permanent dentition, less than 3-mm arch length discrepancy in each jaw, normal curve of Spee of 0 to 1.5 mm, absence of rotation of teeth, co-incident facial and dental midlines and no acute or previous temporomandibular disorder were included in the study.

Patients with a history of previous facial surgeries, orthodontic treatment, facial trauma, congenital anomalies, gross facial asymmetry, multiple missing teeth, pregnant females and those below the age of 21 years were excluded from the study. Out of the 87 participants enrolled, 60 patients fulfilling the inclusion and exclusion criteria were selected for the study and a written informed consent was obtained. The subjects were divided in two groups on the basis of gender- group I: males (n=30), group II: females (n=30).

Participants were subjected to CBCT scans using standardized CBCT machine (KODAK CS-9300, Carestream). The configuration settings of 80kV, 5 mA, field of view - 200 x 179 mm; exposure time- 17s and voxel size 0.39 mm were set for all the scans. All the images were stored in DICOM format and thereafter transferred and processed in third party software, OnDemand 3 D (CyberMed Inc., Seoul, Korea). The software was used to reconstruct 3 D life-sized models of cranio-facial structures from DICOM images.

The reconstructed images were then assessed for identification of landmarks by a single calibrated operator who received training and guidance under orthodontist post-graduate teacher. The training was carried out on different set of similar samples till a high level of agreement between operator and the guide was achieved (0.90). The Cohen kappa statistic was found to be 0.8.

In the 3D model reorientation of the head was done for each scan, followed by selection of point N (Nasion) at the intersection of a transverse X plane passing through Frankfort horizontal (FH) plane, midsagittal Y plane passing through N and anterior nasal spine (ANS), and a vertical Z plane running perpendicular to the X and Y plane at the level of orbitales. (**FIG. 1**). All the cephalometric points as well as linear and angular measurements were defined and derived on 3D reconstruction model to produce individual analysis. Identification of landmarks and measurements on each image were done at two different instances and a mean of the two observations for each landmark was considered as standard referenced data for calculating the 3D measurements (**FIG.2**).[14]

Mandibular basal curve length

To calculate the mandibular basal curve (MBC) length, the best fitting curve passing through: menton (Me), left and right gonion (Go), MBC points bilaterally, and approximating the curvature of mandibular body was generated using 4th degree polynomial equation *f(x)* (**FIG. 3**).[13,14]

$$f(x) = p_1x^4 + p_2x^3 + p_3x^2 + p_4x + ps$$

Maxillary basal curve length

Maxillary basal curve length was determined using 4th degree polynomial equation *f(x)* to generate best fitting curve through: point A to maxillary tuberosity passing through canine eminence (CE) (**FIG. 4**)

STATISTICAL ANALYSIS

Statistical analysis was done using Statistical Package of Social Science (SPSS Version 20; Chicago Inc., USA). Data comparison was done by applying specific statistical tests to find out the statistical significance of the comparisons. Quantitative variables were compared using mean values and qualitative variables using proportions. Significance level was fixed at $p \leq 0.05$.

Mean and standard deviation were calculated for all the data values obtained from the sample. Comparison of dento-alveolar and skeletal variables bilaterally and difference of angular and linear measurements between the groups was done by independent sample t-test. The correlation between different variables was determined using Pearson correlation analysis. Significance level was fixed at $p \leq 0.05$.

RESULTS

Evaluation of facial symmetry and sexual dimorphism of cephalometric norms

Table (3): Correlation between Condylar and Ramal variables

Variable	Me-Go-Me angle	Cond to MS	Ramal length	Ramal ML inclination	Co-Go to FH	Cond AP inclination
Cond AP inclination	-0.637 (0.000*)	0.357 (0.005*)	0.575 (0.000*)	0.062 (0.638)	0.828 (0.000*)	1.000 (0.000*)
Cond height	-0.421 (0.001*)	0.430 (0.001*)	0.622 (0.000*)	0.299 (0.020*)	0.347 (0.007*)	0.495 (0.000*)
Cond ML dimension	0.417 (0.001*)	0.037 (0.778)	-0.232 (0.074)	0.271 (0.036*)	-0.267 (0.039*)	-0.256 (0.048*)

The differences in cephalometric measurements on either side were statistically insignificant, suggesting good facial symmetry in all the participants. Therefore, mean of the two values were calculated and used for future comparisons and analysis. Comparison of 3D cephalometric data in male and female subjects showed significant differences in antero-posterior plane (Co-Go to FH), except for Ramal inclination to FH plane (Table 1).

The mean SNA, SNB, SNPg, NPg-FH, Mx length, Mn body length and Cond antero-posterior inclination showed significantly larger values in males as compared to females ($p \leq 0.05$). On the contrary, A to N – Pg, Pg to NB and facial convexity were significantly larger in females as compared to males ($p \leq 0.05$). The vertical variables and transverse variables showed statistically significant difference in facial height and facial width, and Y-axis with significantly larger values in males ($p \leq 0.05$). While no significant difference was noted on comparing the Me-Go-Co angle for both the groups. Also, Me deviation angle was larger in females as compared to males with high significance ($p < 0.0001$). The Mn basal curve length (Go-MBC-Me-MBC-Go) and post Mn basal length (Mx T- point A-CE) showed significantly larger values in males as compared to females ($p \leq 0.05$) (table 3).

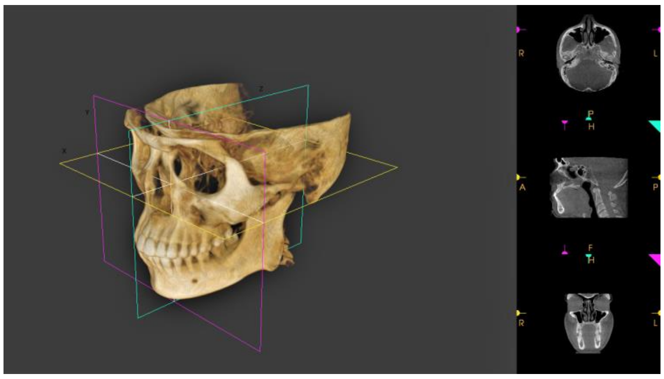

Figure (1): The transverse (X), mid-sagittal (Y), and vertical (Z) planes at the level of Nasion

Correlation between facial height variables and antero-posterior, vertical facial, transverse facial, and other three dimensional variables

Correlation between facial height variables with other variables in different planes showed that, the anterior and lower facial heights had strong to moderate correlations with Maxillary length, upper facial width, maxillary basal width, Gonion to midsaggital and Condyle to midsaggital, ($p<0.05$) (Table 4). Also, the upper facial height showed moderate to weak correlation with Mx height and Ant Mn basal length.

Correlation between Condylar and Ramal variables

The condylar and ramal variables showed a moderate to weak negative correlation between the condylar antero-posterior inclination, and condylar height with the gonial angle ($p \leq 0.001$) (Table 3). Cond anteroposterior inclination had moderate to strong positive with Cond to midsagittal, ramal length and ramal anteroposterior inclination. The Cond height showed moderate to weak positive correlation with the ramal variables except with Me-Go-Me angle ($p<0.001$). The Cond width had a moderate to weak positive correlation with Gonial angle ($p=0.001$) and ramal medio-lateral inclination. Also the correlation between condylar and ramal variables was weak negative between condylar width and ramal antero-posterior inclination and condylar antero-posterior inclination.

DISCUSSION

India has been conquered, invaded and infiltrated by intruders for many years, resulting in a heterogeneous population. This has made the racial distribution very complex. Indian population had been classified into seven racial types by Herbert Risley based in facial features. These are: 1) the Turk-Iranian, 2) Indo-Aryan, 3)Scytho- Dravidian 4) Aryo-Dravidian 5) the Mongol-Draviadian 6) the Mongoloid 7) the Dravidian.[6] The facial characteristics of different races have been taken as an indication for identifying races. The cephalometric norms thereby, also vary amongst these racial groups. Besides subjects with malocclusion, significant anatomical variations also occur in subjects with apparently normal occlusion.[15] Thus, a tailored treatment plan on the basis of individual skeletal type and treatment needs should be encouraged.[16] Central Indian population has a combination of Scytho-Dravidian and Dravidian race, possessing medium to broad or dolichocephalic head and broad nose. Also, variation in soft tissue traits showing mild convexity of face, and a tendency towards Angles class-II in females is acceptable esthetically.[17]

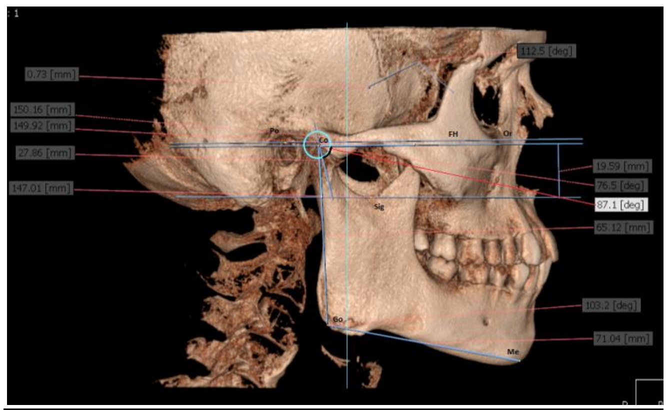

Figure (2): Lateral view showing Condylar anteroposterior inclination angle(a), Condylar height (b), Gonial angle (c)

Figure (3): Caudocranial view showing: curve passing through, Gonion (Go), Mandibular Body Curve (MBC) and Menton (Me) bilaterally

Previous studies have emphasized on determining cephalometric data of normative type for different racial groups for orthodontic evaluation. This can assist in attaining facial features that are considered as the norm of aesthetics and balanced face within the limits of characteristics for the population.[18] Current study provides reference frame for cephalometric norms in Central Indian population and presents the scope to further understand individual growth patterns. Mohammad et al.[19] found that

Malaysian Malay population showed bimaxillary dental protrusion, less prominent chin and higher cant of the occlusion and mandibular plane when compared with the Caucasian cephalometric values. They suggested that a single standard of facial esthetics should not be applied to all racial and ethnic groups.[19]

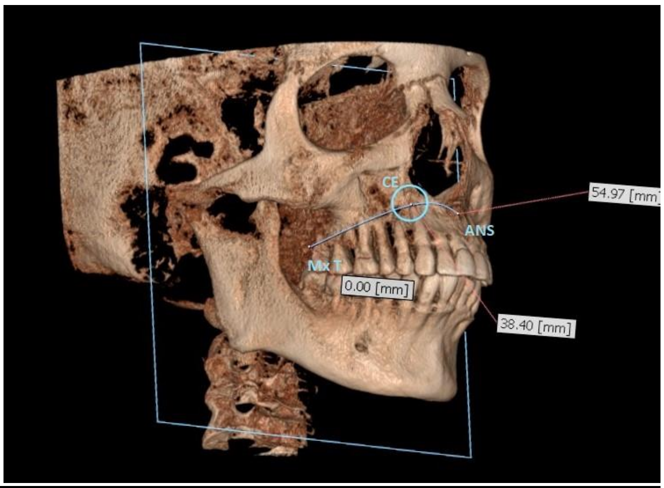

Figure (4): Maxillary Basal curve passing from Maxillary tuberosity(MxT) to Anterior Nasal Spine(ANS) through Canine Eminence(CE)

Therefore, the present study directed towards creating and comparing cephalometric normative database for adult males and females of central India using CBCT. Also comparison of individual cephalometric variables on left and right side, correlation between various skeletal variables and their correlation with dentoalveolar variables and correlation between condylar and ramal variables was determined.

Evaluation of facial symmetry and sexual dimorphism of cephalometric norms

Facial asymmetry can result in functional and esthetic concerns, thus, evaluation of cephalometric parameters, that influence facial symmetry is crucial while planning for an orthodontic treatment.[20] In the current study, comparison of cephalometric variables on either side of face showed no significant differences, suggesting good facial symmetry in the given sample population. The findings were similar to that of Bayome et al [14] and Devanna[13]. On the contrary, previous studies have reported larger dimensions on one side in population with normal occlusion.[21-23]

Statistical significant difference in antero-posterior variables was noted between male and female groups. Greater values of SNA and SNB suggested presence of protrusive maxilla and mandible in males. Also the maxillary length, mandibular body length and condylar AP inclination were significantly greater in males. A significant increase in A to N-Pg and Pg to NB, suggested retrognathic maxilla and a prominent bony chin in females. On the other hand, angular measurements like NPg-FH (facial angle) and SNPg were significantly greater in males indicating forwardly placed mandible relative to the cranial base. The facial convexity was also greater in females, indicating a more convex profile in females. Our findings were in agreement with those of Bayome et al.[14], Devanna[13] and Thilander et al.[24] suggesting linear measurements were greater in males as compared to females. The findings suggest that the dimensions of the face played a key role in demarcating gender dimorphism in the current population.[25]

Cephalometric variations and deviations in the vertical plane are important for identifying facial type of an individual. It is the interplay of various configurations that results in different facial types.[26] In the current study several vertical and transverse variables were significantly greater in males as compared to females suggesting longer and wider face in males. These findings were in acceptance with those of Devanna in North Karnataka population and Bayome et al. in Korean population.[13,14] The mean values in current study for anterior facial height, lower facial height, Mx height and ramal length were less than that observed by Bayome et al. in Korean population suggesting a shorter facial length in current population.[14] Also condylar height, Y-axis, Go-Me-Go angle (menton angle), menton to mid-sagittal and cond to mid-sagittal were significantly greater in males in contrast to the observation of Bayome et al. suggesting broader face in Central Indian male population.[14]

Lee et al. proposed a new landmark ‘MBC point’, as the most convex point on the curve between menton and gonion and reported a significant difference in posterior mandibular body length among the asymmetric and normal occlusion groups.[27] The difference was not significant on direct measurement because the previous idea of the mandibular body length (Me–Go) failed to meet the actual mandibular length. Mandibular body curve length in the current study was determined as suggested by Bayome et al and using the 4^{th} degree polynomial equation of the best fitting curve from Me to Go, passing through MBC for mandible; and from point A, to tuberosity passing through CE for maxilla.[14] The mandibular basal curve length and posterior mandibular basal length were however significantly larger in males as compared to females in our study.

Correlation among facial height variables and antero-posterior, transverse facial and other 3D variables

Association between different cephalometric variables has been advocated by previous studies to comprehend the relationship between various cranio-facial structures.[14,28] In the present study it was observed that facial height variables showed no significant correlation with the sagittal skeletal variables. Only a weak positive correlation was seen between lower facial height and

Maxillary length (0.28, p=0.030).

Transverse measurements were significantly correlated to anterior and lower facial height with weak to moderate correlation, suggesting dependence between facial dimensions and skeletal variables in normal occlusion population. The findings were in contrast to the conclusions of Yemitan et al. who found no significant correlation between facial height and skeletal variables.[29] The observations were in agreement with that of Devanna[13] and Bayome et al.[14].

The facial balance is dependent on harmony between various structures aligned in different planes three dimensionally. CBCT has the advantage of accurately assessing the volume, shape and asymmetries of facial structures such as condyle. Huntjens et al. had suggested that condylar asymmetries do not correlate well with facial asymmetry.[30] This was attributed to the compensation of such minor asymmetries in dento-facial setup during the growth and development of face. In the current study, a correlation between the condylar and mandibular variables was found; suggesting adaptive ability of mandibular condyle, as proposed by Enlow and Hans.[31]

In Table 3, the negative correlation between the variables tends to preserve the ratio between vertical height of mandible and its sagittal configuration. Recent studies showed that difference in the length of ramus on one side to the other was typical of both mandibular retrusion and prognathism group.[32-34] Also, we found correlation between condylar width and condylar anteroposterior inclination to be weak negative. This negative correlation was also reported by Bayome et al., although the correlation was not significant.[14]

CONCLUSION

The given population showed Class II growth pattern and this was observed to be more in case of females. A gender dimorphism was observed with respect to vertical components and transverse variables such as facial width, maxillary basal width, menton angle, Go and Cond to mid-sagittal in males, suggesting longer and broader facial dimensions in males as compared to females in our study.

The values obtained in the present study and the conclusions drawn on the basis of the findings were different from those of similar studies carried out in Indian population and other ethnic groups. [12,13,25,35,36] In addition, the methods employed for digitization of CBCT images in this study, may possibly be technique sensitive and require additional improvements. Further studies are hence recommended to assess the operator learning curve, the reliability of the measurements, the predictors of the correlated variables, and the normative database for different racial and ethnic groups.

FUNDING AND COMPETING INTERESTS

The authors have no financial and non-financial competing interests to declare.

ACKNOWLEDGEMENT

Our sincere gratitude to Dr. Tushar Phulambrikar, for constant support throughout the study.

REFERENCES

1. Broadbent BH. A new X-ray technique and its application to orthodontia: the introduction of cephalometric radiography. The Angle Orthodontist 1981;51(2):93-114.

2. Hofrath H. Die Bedeutung der Röntgenfern- und Abstandsaufnahme für die Diagnostik der Kieferanomalien. Fortschritte der Orthodontik 1931;1(2):232-58.

3. Cevidanes L, Heymann G, Cornelis M, DeClerck H, Tulloch J. Superimposition of 3-dimensional cone-beam computed tomography models of growing patients. American Journal of Orthodontics and Dentofacial Orthopedics 2009;136(1):94-99.

4. Cevidanes L, Oliveira A, Grauer D, Styner M, Proffit W. Clinical Application of 3D Imaging for Assessment of Treatment Outcomes. Semin Orthod 2011;17(1):72-80.

5. Tai K, Hotokezaka H, Park J et al. Preliminary cone-beam computed tomography study evaluating dental and skeletal changes after treatment with a mandibular Schwarz appliance. American Journal of Orthodontics and Dentofacial Orthopedics 2010;138(3):262.e1-262.e11.

6. Malhotra K, Vasulu T. Development of typological classification and its relationship to microdifferentiation in ethnic India. Journal of Biosciences. 2019;44(3).

7. Cheung L, Chan Y, Jayaratne Y, Lo J. Three-dimensional cephalometric norms of Chinese adults in Hong Kong with balanced facial profile. Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology, and Endodontology 2011; 112(2):e56-e73.

8. Ludlow J, Davies-Ludlow L, Brooks S. Dosimetry of two extraoral direct digital imaging devices: NewTom cone beam CT and Orthophos Plus DS panoramic unit. Dentomaxillofacial Radiology 2003;32(4):229-234.

9. Smith BR, Park JH, Cederberg RA. An evaluation of cone-beam computed tomography use in postgraduate orthodontic programs in the United States and Canada. Journal of dental education 2011; 75(1): 98-106.

10. Dado D, Rosenstein S, Alder M, Kernahan D. Long-Term Assessment of Early Alveolar Bone Grafts Using Three-Dimensional Computer-Assisted Tomography: A Pilot Study. Plast Reconstr Surg 1997;99(7):1840-1845.

11. Ericson S, Kurol J. Incisor root resorptions due to ectopic maxillary canines imaged by computerized tomography: a comparative study in extracted teeth. The Angle Orthodontist. 2000;70(4): 276-283.

12. Atit M, Darda M, Deshmukh S, Naik C, Rahalkar J, Subramanian V. Mean values of Steiner, Tweed, Ricketts and McNamara analysis in Maratha ethnic population: A cephalometric study. APOS Trends in Orthodontics 2013;3(5):137.

13. Devanna R. Two-dimensional to three-dimensional: A new three-dimensional cone-beam computed tomography cephalometric analysis. Journal of Orthodontic Research 2015;3(1):30.

14. Bayome M, Park J, Kook Y. New three-dimensional cephalometric analyses among adults with a skeletal Class I pattern and normal occlusion. The Korean Journal of Orthodontics 2013;43(2):62.

15. Kim JY, Lee SJ, Kim TW, Nahm DS, Chang YI. Classification of the skeletal variation in normal occlusion. The Angle Orthodontist 2005;75(3): 311-319.

16. Karaca Bozdag Z, Kurkcuoglu A, Ustdal Guney A, Cam Y, Oguz O. An Assessment of Gender Difference in Visual Cephalometric Analysis Applied to Class I Individuals: In Turkish Adults A Preliminary Study. Eastern Journal Of Medicine 2019;24(1):1-7.

17. Raghav S, Baheti K, Hansraj V, Rishad M, Kanungo H, Bejoy PU. Soft tissue cephalometric norms for Central India (Malwa) female population. Journal of International Oral Health 2014;6(5):51-9.

18. Hixon E. The norm concept and cephalometrics. Am J Orthod 1956;42(12):898-906.

19. Mohammad HA, Abu Hassan MI, Hussain SF. Cephalometric evaluation for Malaysian Malay by Steiner analysis. Sci Res Essays 2011;6(3): 627-34.

20. Nalçaci R, Öztürk F, Sökücü O. A comparison of two-dimensional radiography and three-dimensional computed tomography in angular cephalometric measurements. Dentomaxillofacial Radiology 2010;39(2):100-106.

21. Scanavini P, Paranhos L, Torres F, Vasconcelos M, Jóias R, Scanavini M. Evaluation of the dental arch asymmetry in natural normal occlusion and Class II malocclusion individuals. Dental Press J Orthod 2012;17(1):125-137.

22. Kim Y, Kang S, Sun H. Cephalometric Angular Measurements of the Mandible Using Three-Dimensional Computed Tomography Scans in Koreans. Arch Plast Surg 2016;43(1):32-37.

23. de Moraes M, Hollender L, Chen C, Moraes L, Balducci I. Evaluating craniofacial asymmetry with digital cephalometric images and cone-beam computed tomography. American Journal of Orthodontics and Dentofacial Orthopedics. 2011;139(6):e523-e531.

24. Thilander B, Persson M, Adolfsson U. Roentgen–cephalometric standards for a Swedish population. A longitudinal study between the ages of 5 and 31 years. Eur J Orthod 2005;27(4):370-389.

25. Sachan A, Srivastav A, Chaturvedi T. Soft-tissue cephalometric norms in a north Indian ethnic population. J Orthod Sci 2012;1(4):92.

26. Schudy F. Vertical growth versus anteroposterior growth as related to function and treatment. The Angle Orthodontist 1964;34(2): 75-93.

27. Lee H, Bayome M, Kim S, Kim K, Behrents R, Kook Y. Mandibular dimensions of subjects with asymmetric skeletal Class III malocclusion and normal occlusion compared with cone-beam computed tomography. Am J Orthod and Dentofacial Orthop 2012;142(2):179-185.

28. Wang R, Ho C, Lin H, Lo L. Three-dimensional cephalometry for orthognathic planning: Normative data and analyses. Journal of the Formosan Medical Association 2020;119(1):191-203.

29. Yemitan TA, Oludare YS, Ogunbanjo BO. Vertical Facial Height and its Correlation with Skeletal Pattern Among Young Nigerian Orthodontic Patients. International Journal of Dentistry and Oral Science 2018:661-666.

30. Huntjens E, Kiss G, Wouters C, Carels C. Condylar asymmetry in children with juvenile idiopathic arthritis assessed by cone-beam computed tomography. The European Journal of Orthodontics 2008;30(6):545-551.

31. Enlow D, Hans M. Essentials of facial growth. [Albuquerque, NM]: Distributed by TMData Resources; 2008.

32. Kim E, Palomo J, Kim S, Lim H, Lee K, Hwang H. Maxillofacial characteristics affecting chin deviation between mandibular retrusion and prognathism patients. Angle Orthod 2011;81(6):988-993.

33. You K, Lee K, Lee S, Baik H. Three-dimensional computed tomography analysis of mandibular morphology in patients with facial asymmetry and mandibular prognathism. Am J Orthod Dentofacial Orthop 2010;138(5):540.e1-540.e8.

34. You K, Kim K, Lee K, Baik H. Three-dimensional computed tomography analysis of mandibular morphology in patients with facial asymmetry and mandibular retrognathism. American Journal of Orthodontics and Dentofacial Orthopedics 2018;153(5):685-691.

35. Yadav A, Walia C, Borle R, Chaoji K, Rajan R, Datarkar A. Cephalometric norms for Central Indian population using Burstone and Legan analysis. Indian Journal of Dental Research. 2011;22(1):28.

36. Chhajed S, Kodumuru S, Singh G, Arun A, Cholleti S, Kothari S. Facial Soft Tissue Cephalometric Norms in a Central Indian Ethnic Population. The Journal of Indian Orthodontic Society. 2014;48:7-13.