ORIGINAL RESEARCH

Comparative Evaluation of Cranial Base Length and Flexure on Facial Parameters in Hypodivergent, Normodivergent and Hyperdivergent Patients: A Retrospective Cephalometric Study

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Abstract

Aim: The aim of the study was to assess the influence of cranial base length (CBL) and Flexure on facial parameters in Hypodivergent, Normodivergent, and Hyperdivergent patients.

Materials and methods: Around 60 standardized cephalograms were divided into Hypodivergent, Normodivergent, and Hyperdivergent groups (20 each) based on the FMA angle. The CBL, cranial flexure (CF), and various facial parameters were measured for each case. The results were analyzed for the correlation between Cranial and facial parameters in each of the three study groups.

Results: Comparison and Pairwise Comparison of variables between study groups were done using ANOVA and Tukey's *post hoc* Test. Cranial base length, mandibular body length, LAFH, N-Me-Go angle (*p-value* <0.001), and Jarabak's ratio were found to be significantly different between the groups. Pearson's Correlation showed that most of the facial parameters had a significant correlation with CBL in Hypodivergent groups.

Conclusion: The CBL is more closely related to facial parameters in vertical dysplasia individuals than CF. The CBL is positively correlated to facial variables, especially in Hypodivergent individuals. The N-Me-Go Angle introduced in the study was significantly different in all three vertical facial types studied; hence, it cannot be used as a valuable diagnostic tool.

Clinical significance: Changes in the length and flexure of the cranial base influence the anteroposterior position of jaw bases. The influence of the cranial base on the development of vertical dysplasias is not studied much, hence the present study aims at resolving this lacuna in literature.

Keywords: Cranial base length, Cranial flexure, FMA angle, N-Me-Go angle, Vertical dysplasia.

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Introduction

The craniofacial complex is composed of three main regions which are the cranial vault, the cranial base, and the facial cranium.[1] The cranial base attains 87% of adult size by the age of two years, 90% by 5 years, and 98% by 15 years.[2,3] Growth at the spheno-occipital synchondrosis is directly related to the length of the cranial base. The cranial base can be divided into its anterior and posterior parts. The anterior half is measured from Nasion (N) to the sella turcica (S), and the posterior half is measured from the sella turcica to the basion (Ba).[3] The cranial base serves as a template over which the face develops. Thus, what happens at the cranial base directly affects the structure, angles, size, and placement of the various components of the face.[2] Numerous orthodontists and anthropologists have long been interested in the relationship between different malocclusions and the configuration of the cranial base. The cranial base may have an impact on the connection between the maxilla and the mandible. Over the past few decades, numerous researchers have examined the cranial base morphology and orientation and addressed how it influences the facial prognathism leading to the appearance of different patterns of malocclusion.[4] Mandible is less impacted than the maxilla as it is farther from the cranial base. The articulation of the mandible and cranial base at the temporomandibular joint does, however, leave room for the idea that cranial base growth might also affect the position of the mandible.[5] The function of cranial flexure (CF) and its potential interaction with and contribution to the normal development of sagittal jaw connections are topics that are frequently addressed and have direct clinical applications in orthodontics and craniofacial biology.[6] Cranial base flexure changes can also predispose to a Class II or Class III tendency. Therefore, predicting a child's future skeletal pattern from the value

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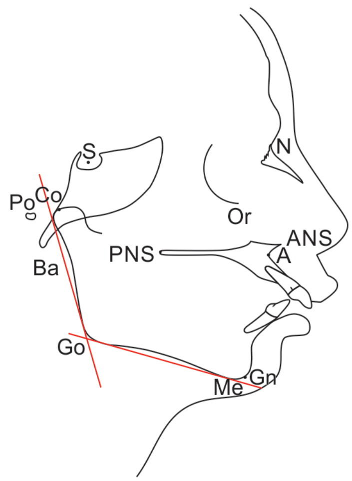

Fig. 1: Landmarks used in the study

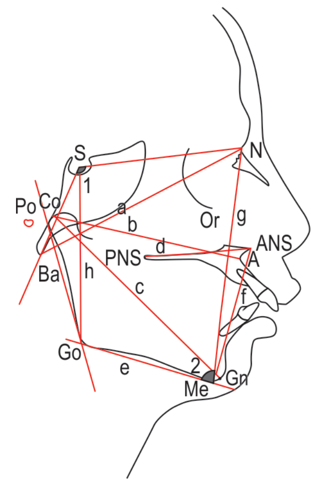

Fig. 2: Parameters measured in the study

Linear parameters: (a) CBL, Cranial base length, (g-e) FC, Facial circumference; (b) E. MAX.L (Effective Maxillary Length) Effective maxillary length; (c) E.MAN.L (Effective Mandibular Length), Effective mandibular length; (d) MAX.B.L, Maxillary body length; (e) MAN.B.L, Mandibular body length; (f) LAFH, Lower anterior facial height; (g) Anterior facial height; (h) Posterior facial height, Angular parameters: (1) Cranial base flexure; (2) N-Me-Go Angle

of the cranial base angle at a young age should be quite helpful for an orthodontist.[7] In orthodontics, absolute normal values are no longer accepted. Facial harmony is conveyed by a combination of floating norms of the angles and proportions. Everybody has a different facial structure. Therefore, studying any one factor by itself is insufficient to fully comprehend the traits of a certain facial type.[2] Geometrically, changes in cranial base length (CBL) and flexure can displace the jaw bases in the vertical direction also, thereby altering the vertical facial pattern.[2] The aim of the study was to evaluate the influence of CBL and flexure on facial parameters in hypodivergent, normodivergent, and hyperdivergent patients. An attempt was also made to examine the relevance of a new angle, the Nasion-Menton-Gonion (N-Me-Go) angle by studying its association with CBL and flexure. The possibility of correlating this facial parameter to the cranial base parameter in all facial types was explored.

The null hypothesis proposed was: The CBL and CF have no influence on the Vertical development of the face.

Materials and Methods

The present study was conducted at the Department of Orthodontics and Dentofacial Orthopaedics, CODS, Davangere in North Karnataka State of India. Patients in and around a radius of 60 km of the institution were selected from October 2020 to June 2021. Ethical clearance for the current study was obtained from the Institution (CODS/758/2018-19).

Pretreatment records of patients from October 2019 to October 2020 were screened for a good quality digital lateral cephalograms taken with Romexis Planmeca 2.3.1 version cephalostat. The lateral cephalometric radiographs taken using the same digital cephalostat in a standardized method and in a natural head position were selected to be a part of the study (Figs 1 and 2).

Sample Size Estimation

The sample size calculation was decided using the following formula with a confidence level of 95%:

$$n = \frac{z^2 pq}{e^2}$$

The sample size was estimated to be 20.16, thus estimated sample size was 20 for each group.

Sample Selection

The lateral cephalograms were initially screened according to the following criteria; Patients aged between 18 and 35 years, having a full complement of permanent dentition (excluding third molars) were included in the study. Those cases with previous orthodontic or/and orthognathic treatment and/or with craniofacial anomalies were excluded from the study.

Study Grouping

The lateral cephalograms obtained after initial screening were divided into three groups of 20 samples each, a total of 60 in number on the basis of FMA angle mentioned in the case record. Group A constituted Hypodivergent patients, with an FMA angle of less than 21°. Group B constituted Normodivergent patients, with an FMA angle of 21–29°. Group C constituted Hyperdivergent patients, with an FMA angle of greater than 29°.

The lateral cephalometric films were traced on the acetate matte tracing paper (0.003″ thick) with a 0.35 mm tracing pencil and all the landmarks were identified.

The landmarks used in the present study, as shown and explained in Figure 1 and Table 1 respectively. A total of 12 parameters were identified to generate 10 linear and 2 angular parameters as explained and shown in Table 2 and Figure 2 respectively.

Reliability analysis was performed before the start of the study by measuring 5 randomly selected X-rays from each group that was measured twice, two weeks apart by the same operator and once by another operator. The tracing of the cephalograms was done for 60 subjects by one of the investigators and cross-checked by a second investigator who is an orthodontist.

Statistical Analysis

The data were entered in Microsoft Excel 2020 version and analyzed using SPSS 22.0. Intergroup comparison and intragroup comparison were done using ANOVA followed by Tukey's *post Hoc* test. The correlation between CBL and CF with various facial parameters (linear and angular) mentioned in Tables 2 and 3 was evaluated using Pearson's Correlation Analysis.

Results

The mean age of the study population was 26.5 years irrespective of gender. In inter-group comparison between Normodivergent, Hypodivergent, and Hyperdivergent; CBL (p-value = 0.007), Mandibular body length (p-value = 0.006), Lower anterior facial height (p-value = <0.001), N-Me-Go angle (p-value = <0.001) and Jarabak's ratio (p-value = <0.001) were found to be significantly different are presented in Table 3. Whereas other variables were found to have no significant difference.

The correlation between CBL, flexure, and facial variables in each study group is presented in Table 4. As per the results, in the Hypodivergent group a significant positive correlation was found between CBL and all the facial parameters studied except LAFH whereas the CF showed a significant negative correlation only to effective mandibular length and LAFH. It implies that in low angle cases, an increase in CBL leads to a significant increase in facial circumference, maxillary and mandibular length, Jarabak's ratio, and the newly introduced N-Me-Go angle. However, as CF increases, the effective mandibular length and LAFH significantly reduce, while the other facial parameters, show an insignificant reduction. The N-Me-Go angle shows an insignificant positive correlation to CF change.

In the normodivergent group, the CBL showed a significant positive correlation with facial circumference, whereas, a significant negative correlation with Jarabak's ratio. The CF exhibited a significant negative correlation with Jarabak's ratio and N-Me-Go angle.

In the Hyperdivergent group, an increase in CBL projected a significant increase in maxillary and mandibular effective length and LAFH, whereas the CF had a significant positive influence only on the N-Me-Go angle.

The N-Me-Go angle was conceived as a facial parameter representative of vertical dysplasia independent of the cranial base. The correlation between N-Me-Go angle and Cranial and Facial variables in different facial types is presented in Table 5. In the Hypodivergent group, the N-Me-Go angle showed a significant positive correlation with Jarabak's ratio (p-value = 0.005, r value = 0.60) and CBL (p-value = 0.005, r value = 0.60). In the normodivergent group, a statistically significant negative correlation was found between the N-Me-Go angle to effective mandibular length (p-value = 0.04, r value = −0.45) and CF (p-value = 0.05, r value = −0.44). In the Hyperdivergent group, a statistically significant positive correlation of this angle with CF was derived (p-value = <0.001, r value = 0.71).

It implies that in low-angle cases, an increase in the N-Me-Go angle signifies an increase in the CBL and Jarabak's ratio whereas in average-angle cases, an increase in this angle signifies a decrease in CF and effective mandibular length. However, in high-angle cases, this angle shows a significant increase with an increase in CF and it has no effect on any of the facial variables.

Table 1: Landmarks used in the study and abbreviations

Sl. no.	*Landmarks*	*Abbreviations*
1	N	Nasion
2	S	Sella
3	Ba	Basion
4	Or	Orbitale
5	Po	Porion
6	ANS	Anterior nasal spine
7	PNS	Posterior nasal spine
8	A	Point A
9	Co	Condylion
10	Gn	Gnathion
11	Me	Menton
12	Go	Gonion

Table 2: Description of Linear and Angular parameters measured in the study

Sl. no.	*Variables*	*Description*
Linear parameters		
1	Cranial base length (CBL)	Line joining point N and Ba
2	Facial circumference (FC)	Linear measurement starting at the nasion point passing through Me, finally ending at the Go
3	Effective maxillary length (E.MAX.L)	Linear measurement from Co to point A
4	Effective mandibular length (E.MAN.L)	Linear measurement from Co to Gn
5	Maxillary body length (MAX.B.L)	Linear measurement from ANS to PNS
6	Mandibular body length (MAN.B.L)	Linear measurement from Me to Go
7	Lower anterior facial height (LAFH)	Linear measurement from ANS to Me
8	Anterior facial height	Linear measurement from N to Me
9	Posterior facial height	Linear measurement from point S to Go
10	Jarabak's ratio (JB ratio)	Ratio of posterior facial height to anterior facial height (S-Go/N-Me × 100)
Angular parameters		
1	Cranial base flexure (N-S-Ba angle) (1)	Angular measurement starting at point N passing through S, finally ending at Ba
2	N-Me-Go angle (2)	Angular measurement starting at the point N passing through Me, finally ending at the Go

Table 3: Comparison of variables between the study groups

						Anova	
Study groups	*N*	*Mean*	*SD*	*Min*	*Max*	*F*	*p-value*
CBL							
Hypo	20	110.03	5.00	101.00	120.00	5.47	0.007*
Normo	20	107.80	5.49	97.00	117.00		
Hyper	20	104.78	4.58	98.00	114.00		
MAN.B.L							
Hypo	20	74.50	5.96	64.00	85.50	5.64	0.006*
Normo	20	71.00	4.53	64.50	79.00		
Hyper	20	69.05	5.01	61.00	79.00		
LAFH							
Hypo	20	60.85	3.93	54.00	67.50	17.05	<0.001*
Normo	20	68.83	6.37	57.00	80.00		
Hyper	20	70.98	6.64	61.00	82.00		
N-Me-Go angle							
Hypo	20	80.95	4.33	70.00	90.00	61.74	<0.001*
Normo	20	72.48	3.14	69.00	78.00		
Hyper	20	68.23	3.49	62.00	76.00		
JB ratio (%)							
Hypo	20	76.05	3.88	69.50	84.50	211.66	<0.001*
Normo	20	64.02	1.49	61.70	66.30		
Hyper	20	60.32	1.37	56.60	61.80		

*$p < 0.05$, statistically significant; $p > 0.05$, non-significant (NS)

Table 4: Correlation between cranial base length, flexure and facial variables in each study group

	Hypo		*Normo*		*Hyper*	
	CBL	*CF*	*CBL*	*CF*	*CBL*	*CF*
CBL						
r		−0.08		0.58		0.25
p-value		0.72 (NS)		0.008*		0.29 (NS)
FC						
r	0.67	−0.30	0.62	0.20	0.41	0.01
p-value	0.001*	0.21 (NS)	0.004*	0.39 (NS)	0.07 (NS)	0.96 (NS)
E.MAX.L						
r	0.70	−0.24	0.37	0.15	0.56	0.3
p-value	0.001*	0.32 (NS)	0.11 (NS)	0.54 (NS)	0.01*	0.20 (NS)
E.MAN.L						
r	0.66	−0.55	0.40	0.10	0.47	−0.11
p-value	0.002*	0.01*	0.08 (NS)	0.66 (NS)	0.04*	0.65 (NS)
MAX.B.L						
r	0.55	−0.29	0.34	0.05	0.32	−0.02
p-value	0.01*	0.21 (NS)	0.14 (NS)	0.84 (NS)	0.17 (NS)	0.92 (NS)
MAN.B.L						
r	0.67	−0.28	0.34	0.14	0.12	−0.10
p-value	0.001*	0.23 (NS)	0.15 (NS)	0.55 (NS)	0.63 (NS)	0.67 (NS)
LAFH						
r	0.42	−0.45	0.39	−0.03	0.47	0.15
p-value	0.07 (NS)	0.04*	0.09 (NS)	0.91 (NS)	0.04*	0.54 (NS)
N-Me-Go angle						
r	0.46	0.29	−0.02	−0.44	0.25	0.71
p-value	0.04*	0.21 (NS)	0.93 (NS)	0.05*	0.29 (NS)	<0.001*
JB ratio (%)						
r	0.72	−0.16	−0.51	−0.51	0.11	−0.11
p-value	<0.001*	0.51 (NS)	0.02*	0.02*	0.63 (NS)	0.65 (NS)

Pearson's correlation test, *$p < 0.05$, statistically significant; $p > 0.05$, non-significant (NS)

Table 5: Correlation between N-Me-Go angle and cranial and facial variables in each study group

	N-Me-Go angle		
	Hypo	*Normo*	*Hyper*
CBL			
r	0.46	–0.02	0.25
p-value	0.04*	0.93 (NS)	0.29 (NS)
CF			
r	0.29	–0.44	0.71
p-value	0.21 (NS)	0.05*	<0.001*
FC			
r	–0.02	–0.31	–0.25
p-value	0.93 (NS)	0.19 (NS)	0.29 (NS)
E.MAX.L			
r	0.29	–0.23	0.04
p-value	0.22 (NS)	0.34 (NS)	0.88 (NS)
E.MAN.L			
r	–0.14	–0.45	–0.39
p-value	0.56 (NS)	0.04*	0.09 (NS)
MAX.B.L			
r	0.19	–0.20	0.15
p-value	0.44 (NS)	0.40 (NS)	0.53 (NS)
MAN.B.L			
r	–0.03	–0.27	–0.18
p-value	0.90 (NS)	0.26 (NS)	0.46 (NS)
LAFH			
r	–0.04	–0.28	–0.15
p-value	0.86 (NS)	0.23 (NS)	0.52 (NS)
JB ratio (%)			
r	0.60	0.44	0.34
p-value	0.005*	0.05 (NS)	0.14 (NS)

Pearson's correlation test, $*p < 0.05$, statistically significant; $p > 0.05$, non-significant (NS)

Discussion

The cranial base angle at birth is approximately 142° but then reduces to 130° at 5 years of age. Architecturally, the base of the cranium offers a platform for the development of the face and the brain.[8]

Thiesen G et al. observed that the mandible project backward when the cranial base angle is open, and forward when it is closed. As a result, the deflection angle and the size of the cranial base have been speculated as possible causes of skeletal class II malocclusions, while an increase in the anterior cranial base would cause the maxilla to move forward and a greater mandibular retrusion would be linked with an increased cranial base angle.[2]

In subjects with class III, Guyer et al. discovered a shorter posterior cranial base, but no discernible change in the angle of the cranial base.[8] On the other hand, according to Marquez, class III individuals have a smaller anterior section and deflection angle of the cranial base.[9]

Sanborn observed a lower S-N value in the class III group and the SNB angle was sharper in class III malocclusion.[10] Hopkin et al. described a linear relation between prognathism and the cranial base angle, with the angle gradually decreasing from class II, via class I, to class III individuals.[11]

Kerr and Hirst, found the cranial base angle to be the greatest marker for differentiating between angle's class I and class II cases. Additionally, they claimed that in roughly 73% of patients, the cranial base angle at the age of five was a precise predictor of the patient's ultimate occlusal type at the age of 15.[12]

Literature on the effects of cranial base parameters on the vertical aspects of malocclusion is lacking in spite of the fact that these are the most difficult to control in the growing individual and their etiology too is often unclear.

The facial parameters included in the current study are of direct interest to the Orthodontist and knowledge of how the cranial base affects the final vertical and sagittal position of the maxilla and the mandible in the face can influence diagnosis and treatment planning.

An overall assessment of the results of the current study highlights the following points:

- The CBL has a larger influence on facial development compared to CF.
- The effect of the CBL on facial development was most pronounced in hypodivergent cases.
- The null hypothesis is thus partially rejected as the CBL was shown to have an influence on the development of the vertical facial type, but the CF was not found to have any influence on the development of the vertical facial type.

The study of Awad et al. is in agreement with the present study results. They found a weak correlation between all angular cranial base variables and all vertical jaw base variables. However, the linear cranial base variables showed a much stronger correlation with vertical jaw base variables. In their study the total CBL showed a substantial positive correlation with total facial height variables, indicating that facial height increases as CBL increases.[4]

The study of Kasai et al. is in agreement with the present study results. They found that CBL was highly correlated with mandibular body length, facial height, facial length, and LAFH. But the cranial base angle was negatively correlated with both mandibular and maxillary prognathism. In their study variation in CF was not associated with corresponding variation in divergence of the face.[13]

The N-Me-Go angle was conceived as a facial parameter representative of vertical dysplasia independent of the cranial base. But as per the present study, the angle failed to show any consistent correlation with either CBL or CF in any of the groups. So, it cannot be considered to be of any diagnostic value on the basis of this study. A more extensive study with a larger sample size may be able to evaluate the validity of this angle.

Xiao et al. found a significant difference in cranial base angle between the vertical facial patterns, whereas the CF did not show any difference between the facial patterns in their study.[14]

Subtelny and Sakuda in the study found a significant LAFH in normal occlusion and open bite malocclusion whereas a non-significant cranial base angle, mandibular body length in both groups which is in agreement with the present study.[15]

As Hopkin et al.,[11] Kerr and Hirst[12] and Dhopatkar et al.[16] reported, the cranial parameters at age five could give a fair indication of the future growth of the face, the role of cranial base parameters in the extreme divergence of the face can be of immense value in the diagnosis and management of vertical dysplasias. However, a more extensive study with a larger sample must be undertaken to formulate a definitive causal effect of cranial parameters on facial growth.

In the current study evaluation of various parameters was done using a two dimensional digital lateral cephalogram which can be considered as a limitation. Although the sample size was considered to be adequate, future studies should include a broader range of malocclusions and evaluation of parameters to be done.

Conclusion

From current study it can be concluded that, CBL is more closely related to facial parameters in vertical dysplasia individuals than CF and positively correlated to facial variables especially in hypodivergent individuals. Also, it can be noted that there is no consistent relation between CF and facial parameters. The N-Me-Go Angle introduced in the current study had no significant correlation with either cranial or facial parameters in all three facial type that was observed; hence, it cannot be used as a valuable diagnostic tool on the basis of the present study.

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