Original Article

Relationship of the Cranial Base and Jaw Base in Different Skeletal Patterns in Orthodontic Patients Visiting Dental Teaching Hospital

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ABSTRACT

Introduction: The cranial base plays an important part in determining how the mandible and maxilla relate to each other and variations in the cranial base angle, the anterior, posterior and total cranial lengths can potentially be a cause of imbalances in facial growth, and occlusion. We aimed to determine the relationship between cranial base & jaw base in different sagittal skeletal patterns among patients visiting Dental Teaching Hospital.

Materials and Methods: One hundred two pre-treatment lateral cephalograms of different sagittal skeletal patterns of age >18 years (34 radiographs for each type of malocclusion with equal male and female) were obtained from the records of patients seeking orthodontic treatment in Dental Teaching Hospital, Maharajgunj Medical Campus, Institute of Medicine. A group of measurements were measured and compared among all study groups to assess the existence of any relationship between the cranial base and both jaw bases discrepancies. Mean and standard deviations were calculated.

Results: The anterior cranial base length, posterior cranial base length and total cranial base length were increased in subjects with Class II sagittal skeletal patterns and decreased in Class III skeletal patterns with mean values of 66.324±2.218 and 64.632±2.193, 34.09±1.698 and 86.62±3.160 and 31.32±0.976 and 84.29±1.643 mm respectively. The cranial base angle increased in Class II and decreased in Class III with mean values of 128.12°±3.160° and 122.68°±4.650° respectively. Maxillary jaw base was increased in Class II skeletal patterns and decreased in Class III with mean values of 88.06±4.539 and 84.53±3.413 mm respectively. Mandibular jaw base and maxillo-mandibular difference increased in Class III and decreased in Class II with mean value 110.62±4.300 and 117.65±5.325 and 22.47±2.339 and 33.09±2.999 mm respectively.

Conclusion: Cranial base and jaw base parameters showed significant relationship with Class I, II and III sagittal skeletal patterns. Cranial base and jaw base parameters except posterior cranial base and cranial base angle showed significant sexual dimorphism.

Keywords: Cephalometric analysis, Cranial base, Jaw bases, Sagittal Skeletal Pattern

INTRODUCTION

Many anthropologists and orthodontists have long been interested in the connection between the appearance of various malocclusion kinds and the cranial base structure. After studying dried skulls, Huxley[1] came to the conclusion that the cranial base can influence the relationship between the maxilla and the mandible. Young and Bryce[2] discovered in their research that

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jaw prognathism and cranial base morphology may be related. Björk[3] found a connection between the jaw base relationship and the cranial base morphology using cephalometric radiographs.

Numerous scholars have examined the cranial base's morphology and orientation over the past few decades, discussing how it influences facial prognathism and gives rise to various malocclusion patterns. Class III malocclusion patterns had shorter anterior cranial base measurements than Class I patterns, according to Jacobson et al.[4]

While there was no change in mandibular measurements across the three malocclusion classes, Dibbets observed a progressive decline in cranial base linear measurements (S-N) and (S-Ba) as well as the cranial base angle (NSBa) between Classes II, I, and III, respectively.[5] According to Proff et al., skeletal Class III participants had lower cranial base length and cranial base flexure than subjects with other malocclusion patterns.[6] According to Chin et al., when the cranial base angle rose, the SNB angle fell.[7]

Other researchers, meantime, offered evidence that contradicted the earlier conclusions, showing that the cranial base had no effect on how certain bone patterns occur. Subjects with Class I and Class III malocclusion did not differ in their cranial base morphology, according to Battagel.[8] Class I and Class II samples of Japanese crania did not differ significantly in their cranial base morphology, according to Kasai et al.[9] According to the variable ANB, Dhopatkar et al. did not discover any connection between the cranial base angle and the skeletal base pattern.[10] In a similar vein, Polat and Kaya discovered that there were no appreciable variations in cranial base angular or linear measurements across all malocclusion group types.[11]

It seems that despite all of these divergent opinions, there is still debate over the role of cranial base shape in the aetiology of malocclusion. Based on the hypothesis that the cranial base would significantly affect both jaw bases and the appearance of various skeletal morphological patterns, this study was conducted to evaluate the establishing the relationship between the cranial base angle and cranial base length.

MATERIALS AND METHODS

This study was cross sectional performed on a sample of 102 pre-treatment lateral cephalograms of Nepalese orthodontic patients of both sexes (51 males, 51 females) and of different skeletal malocclusion patterns seeking treatment at the Orthodontic Department of Tribhuvan University Dental Teaching Hospital, Maharajgunj Medical Campus, Institute of Medicine, Kathmandu, Nepal. The patients were included if there was normal growth pattern (FMA= 25° ± 3°, SnGoGn= 32° ± 5 °), complete diagnostic records including lateral cephalograms, good quality cephalometric radiographs, full complement of permanent teeth upto 2nd molar, and age more than 18 years. The patients with previous orthodontic treatment, congenital anomalies/ syndromes and marked asymmetries, and previous history of trauma to face and neck region were excluded from the study. The study was done for one year from May 2020 to May 2021.

The primary outcome measure used to calculate the sample size was taken as cranial base angulation and sagittal skeletal patterns. In a similar study mean obtained in two groups were 132.68°(X1) and 127.65°(X2) and standard deviation were 5.14°(SD1) and 5.23°(SD2) respectively[12]. With probability of significance of 95% and power of 95% and adding 20% for non-response, the required sample size in each group is 34.

$Z\alpha = 1.96$; $Z\beta = 1.64$

SD = SD1 + SD2 / 2

$N = 2\,(Z\alpha + Z\beta)^2\,(S)^2 / (X1 - X2)^2$

$= 2(1.96 + 1.64)^2\,(5.14+5.23/2)^2 / (132.68-127.65)^2$

$= 27.49$

Now adding 20% for non-response, Sample in each group is 34.

Overall, 102 lateral cephalograms meeting inclusion criteria were taken and divided into 3 equal groups:

- Group I: Class I sagittal skeletal pattern = 34
- Group II: Class II sagittal skeletal pattern = 34
- Group III: Class III sagittal skeletal pattern = 34

Lateral cephalograms were previously taken from cephalometric set up following the standard radiographic protocol for lateral cephalometry with the subjects positioned with ear rods of cephalostat exerting moderate pressure on the external auditory meatus and Frankfort horizontal plane parallel to the floor and in centric occlusion. All radiographs were taken from a single source using the cephalostat from PLANMECA Promax Panoramic Systems. The exposure data of the X-ray source was 66 kV and 10 mA for 10.5 seconds.

Armamentarium (Fig. 1) used were Matte acetate tracing paper of 0.003 inch thick, 3HB pencil of 0.5 mm thickness, metal scale and Protractor from Natraj Geometry Box, tracing view box using trans-illuminated light, and Cephalometric protractor (Ormocepha; Ormco Corporation, 13K27, 760- 0000).

Fig.1: Armamentarium used

The healthy patients (age >18 years) with normal growth pattern pattern (FMA = 25° ± 3°, SnGoGn = 32° ± 5°) were taken. The healthy patients were defined as patient without congenital craniofacial anomalies and no history of facial trauma. Total samples were divided into 3 groups on the basis of Steiner's analysis, Skeletal class I, ANB= 2°±2°; Skeletal class II, ANB= > 4° and Skeletal class III, ANB= < 0°.

This study was conducted after obtaining ethical clearance from the Institutional Review Committee of Institute of Medicine [Ref: 01(6-11) E2/076/077]. Written informed consent was obtained from all the patients. Lateral Cephalograms that were taken for the routine orthodontic treatment purpose were collected from patients visiting to the Department of Orthodontics in this research. Cephalograms of patient meeting the inclusion criteria was traced using 0.3 mm thick 3HB pencil on 0.003" thick and 8"×10" size acetate paper under the view box.

For the assessment of the intra-observer reliability, 25% (9 samples from each sagittal skeletal pattern) of the samples were randomly selected after 2 weeks of initial evaluation of samples. The selected samples were retraced to determine errors associated with tracing and measurements. Kappa value of intraobserver agreement was used to assess the intraobserver reliability.

Collected data were entered in Microsoft Excel, 2016. Then, obtained data were transferred into Statistical Package for Social Science (SPSS version 26.0) for statistical analysis. The means, minimum, maximum values, range, and standard deviations of the cranial base and jaw base parameters were calculated. ANOVA was used to calculate difference between sagittal skeletal patterns groups and within groups for all measurements. Differences in cranial base and jaw base variables between male and female were tested using independent t- tests. Pearson correlation coefficient was calculated to determine correlation between cranial base and jaw base parameters. Kappa value was used to assess the intraobserver reliability. Shapiro-Wilk test was done to determine the normality of the data.

RESULTS

The lateral cephalograms of 102 patients (Female=51 and Male=51) were included and divided into three groups. The sample comprised an equal number of males and females in each of the 3 sagittal skeletal patterns (17 males and 17 females). The mean age of the sample was 22.11± 2.52, ranging from 18 to 31 years.

The Kappa value of intraobserver agreement for Anterior cranial base (ACB), Posterior cranial base (PCB), Total cranial base (TCB), Cranial base angle (CBA), Effective maxillary length (Mx) and Effective mandibular length (Md) were 0.91, 0.93, 0.93, 0.92, 0.90 and 0.93, respectively. This shows almost perfect intraobserver agreement for all measurements. The Shapiro-Wilk and Kolmogorov-Smirnov tests were done to test the normal data distribution. Values for all of them were above 0.05, so our data were considered to be normally distributed. The mean and standard deviation of all measurements were calculated. Table 1 shows the means and standard deviations of linear variables for all subjects.

Table 1: Mean and standard deviation of cranial base and jaw base parameters in different sagittal skeletal patterns

Skeletal pattern	Anterior cranial base (ACB) (mm)	Posterior cranial base (PCB) (mm)	Total cranial base (TCB) (mm)	Cranial base angle (CBA) (degrees)	Maxillary base (Mx) (mm)	Mandibular base (Md) (mm)	Mx-Md (mm)
I	66.26±1.89	32.32±1.83	85.74±4.32	124.74±3.31	85.76±4.43	113.00±5.67	27.24±2.62
II	66.32±2.21	34.09±1.69	86.62±3.65	128.12±3.16	88.06±4.53	110.62±4.30	22.47±2.33
III	64.63±2.19	31.32±0.97	84.29±1.64	122.68±4.65	84.53±3.41	117.65±5.32	33.09±2.99

The overall sample showed anterior cranial base length was increased in subjects with Class II sagittal skeletal patterns and decreased in Class III skeletal patterns, with mean values 66.324±2.218 and 64.632±2.193 mm respectively. The cranial base angulation was found to be increased in Class II skeletal patterns and decreased in Class III skeletal patterns. The mean values being 124.74°±3.315°, 128.12°±3.160°, 122.68°±4.650° in Class I, Class II and Class III respectively. The mean cranial base according to gender distribution is shown in Table 2.

Table 2: Mean and standard deviation of cranial base and jaw base parameters in Male and Female

	Sex	Mean	SD
Anterior Cranial base (ACB) (mm)	Male	66.54	2.16
	Female	64.93	2.00
Posterior cranial base(PCB) (mm)	Male	32.75	2.06
	Female	32.41	1.75
Total cranial base (TCB) (mm)	Male	86.69	3.59
	Female	84.41	3.03
Cranial base angle (CBA) (degrees)	Male	124.71	4.38
	Female	125.65	4.32
Maxillary base (Mx) (mm)	Male	87.69	4.29
	Female	84.55	3.89
Mandibular base (Md) (mm)	Male	116.00	6.09
	Female	111.51	4.69
Md-Mx (mm)	Male	28.25	5.35
	Female	26.94	4.80

ANOVA test was applied to compare anterior cranial base among skeletal groups. The result showed that it increased in subjects with Class II sagittal skeletal pattern and decreased in Class III skeletal patterns with mean values 66.324±2.218 and 64.632±2.193 mm respectively and was statistically significant. The effective maxillary jaw length was found to be increased in Class II skeletal pattern and decreased in Class III skeletal pattern. While the effective mandibular jaw length was found to be increased in Class III patterns and decreased in Class II pattern respectively. The maxillo-mandibular jaw base difference (Mx-Md) was found to be increased in Class III patterns and decreased in Class II patterns respectively. All these differences were statistically significant (Table 3).

Table 3: ANOVA test to compare anterior cranial base among skeletal groups

	Mean Square	F	Sig.
Anterior cranial base	31.326	7.069	0.001
Posterior Cranial Base	66.627	27.759	0.001
Total cranial base	46.775	4.042	
Cranial base angle	256.618	18.074	<0.001
Maxillary base (Mx)	109.059	6.305	0.003
Mandibular base (Md)	434.539	16.496	<0.001
Maxillo-Mandibular Difference (Mx-Md)	961.598	134.971	<0.001

The Pearson correlation coefficient was used to assess the association between cranial base and jaw base variables. The anterior cranial base showed a weak positive correlation with posterior cranial base and mandibular base (r=0.350 and r=0.217) respectively, a moderate positive correlation with total cranial base and maxillary base (r=0.540 and r=0.575) respectively and a weak negative correlation with maxilla-mandibular difference (r= - 0.249). The posterior cranial base showed a weak positive correlation with anterior cranial base (r=0.350), a moderate positive correlation with total cranial base and maxillary base (r=0.468 and r=0.506) respectively and a moderate negative correlation with maxilla-mandibular difference (r= -0.458). Maxillo-mandibular difference showed a weak negative correlation with anterior cranial base (r= -0.249 and r= -0.242) respectively, a moderate negative correlation with posterior cranial base and cranial base angle (r= -0.458 and r= -0.488) respectively and a strong positive correlation with mandibular jaw base (r= 0.689) (Table 4).

Table 4: Correlation between cranial base and jaw base variables

		Anterior Cranial base (ACB)	Posterior cranial base(PCB)	Total cranial base (TCB)	Cranial base angle (CBA)	Maxillary base (Mx)	Mandibul ar base (Md)	Md- Mx
Anterior Cranial base (ACB)	Pearson Correlation	1	.350**	.540**	-.047	.575**	.217*	-.249*
	Sig. (2-tailed)		<0.001	<0.001	.637	<0.001	.029	.012
Posterior cranial base(PCB)	Pearson Correlation	.350**	1	.468**	.190	.506**	-.022	-.458**
	Sig. (2-tailed)	<0.001		<0.001	.055	.000	.822	<0.001
Total cranial base (TCB)	Pearson Correlation	.540**	.468**	1	.260**	.520**	.242*	-.166
	Sig. (2-tailed)	<0.001	<0.001		.008	<0.001	.014	.094
Cranial base angle (CBA)	Pearson Correlation	-.047	.190	.260**	1	.049	-.384**	-.488**
	Sig. (2-tailed)	.637	.055	.008		.626	<0.001	<0.001
Maxillary base (Mx)	Pearson Correlation	.575**	.506**	.520**	.049	1	.535**	-.242*
	Sig. (2-tailed)	<0.001	<0.001	<0.001	.626		<0.001	.014
Mandibular base (Md)	Pearson Correlation	.217*	-.022	.242*	-.384**	.535**	1	.689**
	Sig. (2-tailed)	.029	.822	.014	<0.001	<0.001		<0.001
Md-Mx	Pearson Correlation	-.249*	-.458**	-.166	-.488**	-.242*	.689**	1
	Sig. (2-tailed)	.012	<0.001	.094	<0.001	.014	<0.001	

***. Correlation is significant at the 0.01 level (2-tailed).*

**. Correlation is significant at the 0.05 level (2-tailed).*

DISCUSSION

The cranial base plays a pivotal role in directing the craniofacial growth pattern, both topographically and functionally, thus helping to integrate the skull, including the brain, the orbital cavity, and the pharynx. Therefore, it would be logical to presume that the basicranium influences the position and the orientation of both the maxilla and the mandible, and how both the jaws are related to each other in both antero-posterior and vertical directions, hence affecting the whole facial skeletal pattern and appearance. Therefore, our study aimed to investigate the relationship between the cranial base morphology and the jaw base measurements in different sagittal skeletal patterns and compare them between males and females.

Ford reported that the growth pattern of the anterior cranial base is intermediate between the nerve and general types, but individual bones forming the anterior cranial base follow the growth pattern of the nerve or general type without the intermediate type. It is considered that the growth and development of the skull base are closely related to the growth and development of the maxilla and mandible.

The antero-posterior diameter of the skull base increases through cartilage growth in spheno-ethmoidal synchondrosis, inter-sphenoidal synchondrosis, and spheno-occipital synchondrosis. Growth of inter-sphenoidal synchondrosis stops at birth and growth of spheno-ethmoidal synchondrosis completes at about 7 years old. Growth of spheno-occipital synchondrosis is important and ossification in the cartilage continues until near 18 years old.[12] The amount of growth in this region is the largest, being the centre of skull base growth. Growth of cranial base is said to reach 98% by 15 years of age.[13,14] Hence to avoid the differences due to growth, the patients above 18 years of age were included in our study.

The vertical discrepancies can affect the sagittal position due to rotation of the mandible, so it affects the true sagittal skeletal pattern as well as maxillo-mandibular lengths.[15] So, in our study, only patients with normal growth patterns were taken. To better understand the cephalometric aspects, the skull base was divided into anterior and posterior lengths, the former extending anteriorly from sella turcica (S) to fronto-nasal suture (N), and the latter extending from sella turcica to the intersection of the dorsal contour of the mandibular condyles and the lateral portions of the middle cranial fossa on the temporal bone, defined as articulare.[16] There is a consensus that the length of the anterior skull base corresponds to the linear N-S distance, but the same cannot be said about the posterior region, which corresponds to either S-Ba or S-Ar linear distances.[17] In our study posterior cranial base was represented by S-Ar, as suggested by Bjork.[3] Basion is difficult to determine on radiographs, whereas Ar point is easily viewed on the lateral cephalometric. However, it can be argued that the Ba is closer to the cranial base and is more likely to be valid. Previous studies have shown that the correlation between the two points is high and the choice between them is unlikely to affect a study's results.[18] The previous researcher used N-S-Ba, N-S-Art as well as S-Ba and S-Ar, and found similar measurements.[19]

The ANOVA suggested an increased anterior cranial base length in Class II samples and decreased length in Class III samples, which was statistically significant. The post hoc Tukey test suggested that there was a significant difference between Class I and Class II, and Class II and Class III groups. These results were similar to earlier studies.[20-24] A study showed decreased anterior cranial base length in Class III skeletal pattern, and a similar finding was found in Nepali subjects.[25,26]

The posterior cranial base appears to play a more important role in Class III morphogenesis by virtue of its proximity to the mandibular complex. Articulation at the glenoid fossa does provide potential for influence from the cranial base. A previous study showed marked shortening of posterior cranial base length.[33] Morphometric study indicates that the morphogenetic basis for anterior displacement of the mandible lies within the posterior cranial base, presumably coinciding with early cessation of growth activity within the petro-occipital complex.[27] A study provided support for the belief that developmental mechanisms in the petro-occipital complex account for such anterior mandibular displacement.[28] It is conceivable that insufficient proliferation within the posterior cranial-base cartilage could lead to the changes in form that are constituents of the Class III condition.

In our study, we found cranial base angle increased in Class II and decreased in Class III. Among the groups, the result of post hoc Tukey showed significant difference of cranial base angle between Class I and Class II and Class II and Class III. Similar findings were obtained in other studies that found significantly smaller cranial base angle in Skeletal Class III. Similarly, large cranial base angle in skeletal Class II malocclusion was seen in a study and this cranial base angle seems to establish before 5 years.[29] Some researchers used Basion as the posterior limit of the cranial base and found similar findings.[30, 31]

Concerning jaw base lengths, effective maxillary and mandibular lengths showed significant differences among the skeletal malocclusion groups. Effective mandibular length was largest in skeletal class III group followed by skeletal class II and least in skeletal class I group. Hence, these results suggest a link between jaw base lengths and facial prognathism, especially in different skeletal malocclusion subjects, where their increase is associated with the change in the facial skeleton and appearance, conforming to previous findings. An increase of the sagittal mandibular length in association with a normally sized or shortened maxilla has been reported to be invariable trait in Class III anomalies across subjects of white and Asian descent of various ages.

One aspect of craniofacial growth that has received limited attention is sexual dimorphism. In our study, all the cranial base and jaw base parameters, except cranial base angle, were more in males than in females. According to Broadbent and co-workers, "sexual dimorphism is in the main an expression of secondary sexual characteristics that occur after puberty and adolescent years".[32] On average craniofacial complex is between 5% and 9% larger in males than in females, depending upon the measurement taken. The distinctly different patterns of sexual dimorphism of anterior cranial base length and posterior cranial base were reported.[33] One possible explanation is that this region is associated with both neural and somatic growth patterns that are different.[34] Also, anterior limit of cranial base is part of frontal bone and this bone increases in thickness by surface deposition during life, accompanied by increasing pneumatization of frontal sinus particularly during adolescent.[35] In-addition the region of frontal sinus, as pointed out by Broadbent and co-workers is larger in males than in females.[32] These-factor could influence the position of Nasion differently in male and female. Significant size differences between males and females also has been reported from the measurement of dry skulls and adult patient.[36] In our study posterior cranial base is more in male than female but not significant with ρ value > 0.05 which is similar to study done by Cossio et al.[37]

This study was conducted in an Orthodontic Unit with one hundred and two samples. A larger sample size would have been better. Many studies have shown that the growth of cranial base is different among various races. This study did not include ethnic variation found in the Nepali population, which could be a major limitation of our study. Furthermore, this is a two-dimensional study based on lateral cephalograms.

CONCLUSION

Anterior, posterior and total cranial base lengths showed significant relationship with Class I, II, and III sagittal skeletal patterns. Cranial base angle showed significant relationship with Class I, II, and III sagittal skeletal patterns. Cranial base and jaw base parameters, except posterior cranial base and cranial base angle, showed significant sexual dimorphism.

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