Evaluation of relationship between cranial base angle and maxillofacial morphology in Indian population: A cephalometric study

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ABSTRACT

Objective: To investigate the role played by the cranial base flexure in influencing the sagittal and vertical position of the jaws in Indian population.

Materials and Methods: Lateral cephalograms of 108 subjects were divided into three categories (Group A: NSAr > 125˚, Group B: NSAr-120˚-125˚, Group C: NSAr < 120˚) according to value of NSAr. Measurement of eight angular (SNA, SNB, NPg-FH, ANB, NAPg, SN-GoGn, Y-Axis, ArGo-SN) and seven linear (N-S, S-Ar, Ar-N, Ar–Pt A, Ar–Gn, Wits appraisal, N- Pt A) variables were taken.

Results: Pearson correlation coefficient test was used to individually correlate angular and linear variables with NSAr for the whole sample as well as in individual group. Unpaired *t*-test was used to analyze the difference in the means of all the variables between the three groups. Significance was determined only when the confidence level was *P* < 0.05. Several parameters (SNB, NAPg, ANB, Y-Axis, GoGn-SN) showed significant positive correlation while others showed negative correlation (SNA, NPg-FH, N-S) with NSAr.

Conclusions: This study show cranial base angle has a determinant role in influencing the mandibular position and it also affects both the mandibular plane angle and y-axis. Flattening of the cranial base angle caused a clockwise rotation of the mandible. The jaw relation tends to change from class III to class II, with progressive flattening of the cranial base and vice-versa.

Key words: Cranial base angle, lateral cephalogram, maxilla-mandibular relationship, skeletal pattern, treatment planning

INTRODUCTION

The cranial base area of the craniofacial complex has long been of interest to orthodontists and craniofacial anthropologists. Young,[1] as early as 1916, recognized relationship between cranial base morphology and prognathism of the jaws. After the birth of a child, cranial base angle has a tendency to reduce with age. In their study Moss and Greenberg,[2] Scott,[3] Stramrud,[4] Melson,[5] Ohtsukhi *et al*.[6] they have found that the measure of cranial base angle stabilizes between 5 and 7 years and there after any change is hardly noticed in its value. The maxilla appears to be attached to the anterior segment and the mandible to the posterior segment of the cranial base. The

consensus of different authors such as Renfroe,[7] Bjork,[8] Coben,[9] Moss,[10] and Hopkin[11] proved that the cranial base morphology has considerable influence upon the position of maxilla and mandible, thus determining the skeletal pattern of an individual. The increase in the flexion of the cranial base would increase Class-III tendency, while the reduction in the flexion of the cranial base would increase Class-II tendency. Thus, it should be of great help for an orthodontist to predict the future skeletal pattern of a child from the value of cranial base angle at an early age.

However, it is noticed that most of the workers had collected and grouped their samples according to the skeletal jaw relationship

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and then had tried to assess and compare the values of cranial base angle of each skeletal group. Very few studies are carried out to assess the skeletal jaw pattern of individuals having different values for their saddle angle.

Thus in view of above facts, a cephalometric study is conducted with following aims and objectives to explore the relationship between the cranial base angle and the maxillofacial morphology.

1. To estimate the values of different craniofacial skeletal parameters for individuals having varied range of cranial base angle
2. To compare and correlate the value of cranial base angle with eight angular and seven linear parameters in different groups
3. To compare and correlate the value of cranial base angle with eight angular and seven linear parameters for overall data
4. To find the difference in the values of all the parameters between groups having varied range of cranial base angle.

MATERIALS AND METHODS

Materials
For this study, sample consisting of 108 lateral cephalograms are collected from the records of the patients reported at the Department of Orthodontics, Government Dental College and Hospital, Ahmedabad, on the basis of following criteria:
1. None of the subjects had undergone orthodontic treatment in the past
2. The age range of the subject was between 12 and 16 years
3. There was no facial disharmony whatsoever due to any systemic problem or any major accident in the past affecting the bones of the facial skeleton.

Methods
Once the lateral cephalograms are collected, estimation of the values of cranial base angle is done for each case. On the basis of their values, the total sample is divided into three categories:
• Group A: NSAr > 125° (*n* = 33)
• Group B: NSAr-120°–125° (*n* = 30)
• Group C: NSAr < 120° (*n* = 45)

In this study, for the purpose of estimating the degree of flexure of the cranial base angle (NSAr), point "Articulare" rather than "Basion" has been used to represent the posterior extent of the cranial base. It is proved by Bhatia and Leighton[12] that the growth patterns studied by use of Basion or Articulare, are very similar.

Further cephalometric points [Table 1] are plotted, lines [Table 2] and angles [Table 3] are drawn. Eight angular (SNA, SNB, NPg-FH, ANB, NAPg, SN-GoGn, Y-axis, ArGo-SN) and seven linear (N-S, S-Ar, Ar-N, Ar-Pt A, Ar-Gn, Wits appraisal,

N-Pt A) parameters are recorded for carrying out necessary statistical analysis. The above measurements are selected primarily to investigate the role played by the cranial base flexure in influencing the sagittal and vertical position of the jaws.

Table 1: Points

Points	Location
Sella (S)	The centre of the shadow of the pituitary fossa (sella turcica)
Nasion (N)	The deepest point of the frontonasal suture
Articulare (Ar)	It is the point of intersection of the images of the posterior border of the mandible and the inferior border of the basilar part of occipital bone
Gonion (Go)	The point formed by the intersection of the mandibular plane and the posterior border of the ascending ramus of the mandible. It is a constructed point
Gnathion (Gn)	A point formed by the intersection of the mandibular plane with the facial plane. It is a constructed point
Subspinale or Point A	The deepest midline point on the pre maxilla between anterior nasal spine and the crest of the maxillary alveolar process
Supramentale or Point B	The deepest midline point on the mandible between the pogonion and the crest of the mandibular alveolar process
Pogonion (Pg)	The most anterior point on the bony chin in the median plane
Porion (Po)	The superior point of the external acoustic meatus
ANS	Anterior nasal spine; this is the tip of the bony anterior nasal spine
PNS	Posterior nasal spine; the intersection of a continuation of the anterior wall of the pterygopoalatine fossa and the floor of the nose marking the dorsal limit of the maxilla
Menton (Me)	The most inferior midline point on the mandibular symphysis (unilateral)
Orbitale (Or)	The lowest point on the inferior margin of the orbit

Table 2: Lines

Planes	Connecting points
S-N plane	Line formed by connecting point S and point N. This represents the anterior cranial base
S-Ar line	Line formed by connecting sella and articulare. This represents posterior cranial base length
Ar-N line	Line formed by joining point articulare and nasion. This represents the total cranial base length
Ar-Go lINE	Line formed by joining point articulare with the constructed point gonion. It represents the length of the vertical ramus of the mandible
Mandibular plane	Plane formed by connecting gonion with gnathion
Facial plane	Plane formed by connecting nasion with pogonion
S-Gn line	Line formed by connecting sell with constructed point gnathion
Frankfort horizontal plane	Line formed by joining porion and orbitale
N-A line	Line joining nasion with point A
A-Pg line	Line joining point A with pogonion
N-B line	Line joining nasion with point B

Statistical Analysis

We performed statistical analysis using the Microsoft Office Excel 2007 and IBM SPSS version 22 software. Various angular and linear variables were measured and their mean and standard deviations were calculated in all the three groups as shown in Table 4.

All the variables were then individually correlated with NSAr for the whole sample as well as in individual group using Pearson correlation co-efficient test. Unpaired *t*-test was then used to analyze the difference in the means of all the variables between the three groups.

Table 3: Angles and measurements

Angles	Connecting points
NSAr angle (saddle angle)	Is the angle formed between nasion, sella and articulare. It represents the crania base flexure
SNA	Angle formed between the lines SN and NA
SNB	Angle formed between the lines SN and NB
ANB	Angle formed between the lines NA and NB
NA Pg	Angle formed between the lines NA and APg
NPg-FH	Angle formed between the facial plane NPg and FH plane
SN-GoGn	Angle between the SN plane and the mandibular plane, represents the mandibular plane angle
Y-axis	Angle formed between the S Gn line and FH plane
ArGo-SN	Angle formed between Ar-Go and SN plane
N-S	Linear distance between nasion and sella
S-Ar	Linear distance between sella and articulare
Ar-N	Linear distance between articulare and nasion
Ar-Pt A	Linear distance between articulare and point A
Ar-Gn	Linear distance between articulare and gnathion
Wits	Linear distance between points A and B reflected on to the occlusal plane
N-Pt A	Linear distance of point A from a perpendicular to the FH plane dropped from nasion

Table 4: Mean and SD of all parameters in three groups

Type of variable	Variables	Group A Mean	SD	Group B Mean	SD	Group C Mean	SD
Angular (°)	NSAr	130.9	4.56	122.73	1.95	116.63	3.1
	SNA	80.18	4.24	81	3.56	82.73	4.73
	SNB	75.02	4.33	77.5	3.47	82.43	4.2
	ANB	5.16	2.08	3.17	1.93	0.3	3.82
	N-A-Pg	8.16	4.2	5.03	3.6	−0.67	7.38
	FH– NPg	87.52	3.72	88.4	3.86	90.43	2.82
	SN-GoGn	30.67	6.32	28.73	6.97	29.4	5.47
	Y-axis	59.2	5.08	57.33	4.29	56.53	3.08
	SN-ArGo	87.64	4.68	88.13	4.52	85.7	4.81
Linear (mm)	Wits	2.69	1.78	1.68	2.95	-5	4.68
	N-S	71.15	2.76	72.63	3.87	72.6	3.93
	S-Ar	36.38	3.59	37.03	4.69	36.27	4.93
	Ar-N	98.33	4.1	97.5	5.37	94.83	6.03
	Ar-PtA	89.48	5.05	87.67	4.74	85.6	6.45
	Ar-Gn	106.82	6.9	107.5	5.24	109.63	10.74
	N-PtA	1.83	3.32	1.63	3.54	0.67	3.84

SD – Standard deviation

RESULTS

Table 5 shows the frequency of observations for each values of angle NSAr in the total sample and corresponding mean values of angle SNA. The co-efficient correlation value for their comparison reveals a highly significant negative correlation between the two angles ($r = -0.3667/P < 0.001$). When similar comparison is carried out group wise, as shown in Table 6, a negative correlation is seen in all the groups, however it is statistically significant for Groups A ($r = -0.2907/P = 0.023$) and C ($r = -0.5590/P = 0.001$), but not for Group B ($r = -0.1641/P = 0.386$). Table 5 shows co-efficient correlation value for comparison between angles SNB and angle NSAr in the overall data. It shows a highly significant negative correlation between the two angles ($r = -0.6483/P < 0.001$). The cranial base angle seemed to influence the mandible more than the maxilla as revealed by a stronger negative correlation between angle SNB and NSAr than with angle SNA in the overall sample. Table 6 which is showing comparison between the two angles in individual groups, show a significant negative correlation in Groups A ($r = -0.3803/P = 0.003$) and C ($r = -0.4196/P = 0.022$) but not in Group B ($r = -0.1903/P = 0.314$), which might be due to the small range of angle NSAr for this group. A correlation of greater significance level, between the two angles, is seen in Group A. Table 6 suggests significant negative correlation between NPg-FH and NSAr in the overall data ($r = -0.308/P = 0.001$). However, comparison between the individual groups revealed a nonsignificant negative correlation between the two angles as shown in Table 6. From Table 5, (correlating angle ANB with angle NSAr), Table 5 (correlating angle NAPg with angle NSAr) and Table 5 (correlating Wits appraisal with angle NSAr); each reveals highly significant positive correlation of each of these parameters when compared with angle NSAr for the overall sample ($r = -0.308/P = 0.001$), ($r = 0.5059/P < 0.001$), ($r = 0.5430/P < 0.001$). From Table 6 one can assess the behavior of individual parameters within the different groups when compared to angle NSAr. It shows significant positive correlation between angle NSAr and these three parameters, suggesting sagittal positioning of the jaws in Group B only ($r = 0.4785/P = 0.006$), ($r = 0.3885/P = 0.011$), ($r = 0.4574/P = 0.002$). In this study as shown in Table 5, the mandibular plane angle as well as Y-axis angle shows a positive correlation with angle NSAr in the overall sample ($r = 0.1863/P = 0.041$), ($r = 0.2713/P = 0.003$), however the level of significance of correlation is much higher for Y-axis angle than for GoGn-SN angle. The same relationship when assessed in between the groups, as shown from Table 6, no significant correlation is found at any level. However when values of Y-axis angle and GoGn-SN angle were compared for different groups by *t*-test, no differences are found when Group B is compared with Groups A and C, but when compared to Group A, Group C differs significantly for Y-axis only. The anterior cranial base (N-S) shows a negative nonsignificant correlation with angle NSAr in the

Table 5: Reltionship between NSAr and other parameters in total sample

NSAr	Frequency of observations	SNA	SNB	NPg FH	ANB	NAPg	WITTS	SN-GoGn	Y-axis	N-S	S-Ar	Ar-N	Ar-Pt A	NPtA	Ar Gn	ArGn SN
110	4	89	85.5	91.3	3.5	6	−2.5	26	56.3	74.8	37	93.7	89.5	4.5	111	85.3
115	3	83	87.6	92	−4.6	−8.33	−10.3	30.3	55	72	33.3	90.6	82.3	0	112	81
116	3	84	83	90.3	1.33	1.33	−3.6	31.7	57.3	74.6	37.3	96.6	86.7	−1	112	86.3
117	4	83	82.5	91.3	1.25	−1	−3.7	24	54.3	70.8	36.5	93.2	84.3	3	106	86.5
118	7	81	80	89	1	0.85	−4	32	58.1	73.3	36.7	96.7	86.3	0.14	110	87.1
120	12	80.6	80	89.1	0.41	−1.41	−4	29.8	58.3	72.8	38.2	97.5	85.9	0.5	109	86.1
121	6	81.67	78.3	88.5	3.33	4.5	2	30	57.3	72.5	35.2	95	86.5	1.16	108	87.8
122	6	83.33	80	90	3.33	6	2.16	29.3	57.5	71	39.2	98	89.2	3.5	109	87
124	6	79.83	76.2	87.7	3.66	6.66	1.08	25.3	56.3	74.5	36.5	99	89	1.83	106	88
125	12	80.67	77.2	89.5	3.54	4.81	2.63	28.8	55.7	72	35	96	87.1	1.9	114	88.6
126	6	83.66	77.8	88.5	5.83	8.33	2.5	32.2	58.7	70.5	38.6	96.1	89	2.66	107	86.8
127	5	82.4	76.2	87.4	6.2	6.2	3.2	26.4	58.8	71	39.4	100	89.8	0.8	107	85
128	6	79.6	75.2	87.5	4.5	8.33	1	28.8	56.8	72.6	33.3	95	87.2	0.66	104	85
129	4	76.5	72.5	85.8	4	5.5	3	34	59.3	71.5	37	99	86.5	−2.5	104	88.5
130	4	81.5	77	88.8	4.5	6.25	4.5	27.5	57.3	72.3	37.5	100	92	2.75	111	92.5
131	9	85	75.1	86.9	4.55	9	1.7	29.1	62.3	71.6	37	100	89.4	1.27	107	84.6
132	3	83.6	76.6	87	5.33	10	2.3	26.7	57	70.7	37	98.6	94.7	6	111	87
133	4	77.5	71.8	88	4.75	6.75	2.5	31.8	61.8	68.8	35.3	96.5	87.3	2	110	93.3
134	4	82.55	72.5	86.7	5.75	8.5	3.25	36.3	57	72.3	34.3	98.5	89.3	2.75	106	90
Co-efficient corelation (*r*)		−0.37	−0.65	−0.31	0.53	0.51	0.54	0.19	0.27	−0.23	−0.1	0.27	0.29	0.07	0.15	0.17
P value		<0.001*	<0.001*	0.001*	<0.001*	<0.001*	<0.001*	0.04	0.003*	0.11	0.29	0.003*	0.002*	0.46	0.09	0.06

*Significant at *P*<0.05

overall sample as well as when compared in individual group [Tables 5 and 6]. Similar are the finding for the posterior cranial base (S-Ar) [Tables 5 and 6]. Furthermore, differences in the values of the above parameters between groups are not significant as per *t*-test [Table 7]. However as shown from, Table 5, the total cranial base length (Ar-N) have significant positive correlation with angle NSAr in the overall sample (*r* = 0.268/*P* = 0.003). Furthermore, Table 6 shows significant positive correlation between the two parameters in Group A, (*r* = 0.3749/*P* = 0.004). When mean values for length Ar-N is compared by *t*-test, [Table 7], significant difference is found between Groups A and C. As shown in Table 5, Maxillary length showed a significant positive correlation with cranial base angle in the overall sample (*r* = 0.2853/*P* = 0.002). The maxillary length progressively increases with an increase in the cranial base angle [Table 4] thus compensating for increase in its value. This increase in the maxillary length was significant between the Groups A and C, [Table 7]. Now when the maxillary position is evaluated by the method suggested by McNamara (measuring the linear distance of point A, from a perpendicular dropped from nasion to FH plane) and is correlated with NSAr, then no significant correlation is established [Tables 5 and 6]. Thus changes in NSAr do not affect N-pt A in this study. When mandibular length (Ar-Gn) is correlated with NSAr angle [Tables 5 and 6], an insignificant negative correlation is seen both in the overall data and in the individual groups. The inclination of the posterior border of the ramus (ArGo-SN) is correlated with angle NSAr [Tables 5 and 6] where no significant correlation is found.

DISCUSSION

In this study, lateral cephalograms of 108 subjects were divided into three categories according to the values of angle NSAr of each subject as studies, which have found the skeletal pattern based on the cranial base angle are few.[13-16] This study shows that as the cranial base angle reduces, the maxilla tends to protrude and angle SNA increases [Tables 4-6]. This is in agreement with the studies by Hopkin *et al.*,[13] Varjanne and Koski,[14] Järvinen,[15] Moyers,[17] Enlow,[18] Profitt and Fields,[19] Kasai *et al.*[16] However, from Table 7, when differences in the values of angle SNA were compared between Groups A, B and C; significant differences were not seen at any level. This concludes that though a significant negative correlation exists between these two angles, the sagittal position of maxillary apical base as described by point A is not highly affected.

It is clear as the cranial base angle reduces, the mandible tends to protrude, and angle SNB increases [Tables 4-6]. Moreover, as the cranial base angle reduces, the chin tends to protrude [Tables 4-6]. Further, differences in the values of angle SNB and NPg-FH when compared between the Groups A, B and C [Table 7], shows that significant differences exist in the measure of these angles between the groups with extreme ranges of the cranial base angle (Groups A and C). It can be concluded that mandibular position is affected to a great extent by the changes in the cranial base angle.

The above correlation suggests a relationship between the magnitude of the cranial base flexure and mandibular position.

Table 6: Relationship between angle NSAr and various parameters in individual groups

	SNA	SNB	NPg-FH	ANB	NAPg	Witts	SN-GoGn	Y-axis	N-S	S-Ar	Ar-N	Ar-Pt A	N-Pt A	Ar-Gn	Ar-GoSN
Group A	r=−0.2781 (P=0.036)*	r=−0.3680 (P=0.005)*	r=−0.147 (P=0.275)	r=0.2040 (P=0.128)	r=00.2333 (P=0.081)	r=0.1370 (P=0.309)	r=0.2475 (P=0.063)	r=0.2102 (P=0.117)	r=−0.0855 (P=0.527)	r=−0.2844 (P=0.032)	r=0.3749 (P=0.004)*	r=0.1856 (P=0.167)	r=0.1263 (P=0.349)	r=−0.0447 (P=0.741)	r=0.1235 (P=0.360)
Group B	r=−0.0308 (P=0.847)	r=−0.1903 (P=0.314)	r=−0.0068 (P=0.966)	r=0.0398 (P=0.835)	r=00.3885 (P=0.011)*	r=0.4574 (P=0.002)*	r=0.1686 (P=0.286)	r=0.2549 (P=0.103)	r=0.0016 (P=0.992)	r=−0.2125 (P=0.177)	r=0.0152 (P=0.924)	r=0.1807 (P=0.254)	r=0.1286 (P=0.417)	r=−0.1969 (P=0.211)	r=0.2118 (P=0.178)
Group C	r=−0.5936 (P=0.004)*	r=−0.4913 (P=0.020)*	r=−0.276 (P=0.214)	r=−0.2161 (P=0.334)	r=−0.2404 (P=0.281)	r=−0.1559 (P=0.488)	r=0.2783 (P=0.210)	r=0.1115 (P=0.621)	r=−0.3488 (P=0.112)	r=−0.0912 (P=0.687)	r=0.0166 (P=0.942)	r=−0.3386 (P=0.123)	r=−0.3699 (P=0.090)	r=−0.2197 (P=0.326)	r=0.0416 (P=0.854)

*Significant at *P*<0.05

Table 7: *t*-test to find significance of difference in the values of all the variables in the three groups

Variable	Between Groups A and B	Between Groups A and C	Between Groups B and C
NSAr	0.001*	0.003*	0.381
SNA	0.49	0.345	0.101
SNB	0.693	0.004*	0.639
ANB	0.201	<0.001*	0.016
N-A-Pg	0.326	0.003*	0.063
FH-NPg	<0.001*	<0.001*	0.837
SN-GoGn	0.892	0.024*	0.495
Y-axis	0.593	0.782	0.857
SN-ArGo	0.095	0.034*	0.677
Wits	0.699	0.498	0.709
N-S	0.098	0.054	0.529
S-Ar	0.279	0.103	0.551
Ar-N	0.324	0.004*	0.717
Ar-PtA	0.234	0.024*	0.102
Ar-Gn	0.962	0.046	0.078
N-PtA	0.673	0.291	0.238

*Significant at *P*<0.05

The smaller the cranial base angle, the more forward the mandibular position which increases the tendency to a Class-III jaw relationship and larger the cranial base angle, the more backward the position of the mandible, which increases the tendency to a Class-II jaw relationship. Also in contrast to maxilla, the mandible is affected more by changes in the cranial base angle. The above findings are in agreement with those of Kasai *et al.*[16] and Bjork,[20] who demonstrated the relationship between the cranial base angle and mandibular position and Baccetti *et al.*,[21] who showed that the temporomandibular joint position was more posterior in skeletal Class-II than skeletal Class-III.

In order to assess the influence of saddle angle on maxillo-mandibular relationship, three parameters were studied, the ANB angle, Wits appraisal and angle of convexity (N-A-Pg). The observed correlation between the cranial base angle and the above parameters suggest that the opening of the cranial base flexure can result in a skeletal Class-II jaw relation and the closing of the cranial base flexure can result in a skeletal Class-III jaw relation. In this study the mean values of angle ANB, wits and angle N-A-Pg in the three groups support the above contention [Table 4]. When the values of ANB angle, wits, NAPg angle were compared in individual groups using the *t*-test, significant differences were seen between Groups A and C. The above findings support the work of Kerr and Hirst[22] who suggested that the cranial base angle at 5 years of age determines the fundamental jaw relationship and is an accurate predictor of ultimate facial type at 15 years of age. Anderson and Popovich[23] found more Class-II occlusions in large cranial base angle subjects. Kerr and Adams[24] concluded that the size and shape of the cranial base influences mandibular position by determining the anterioposterior position of the condyles relative to the facial profile. Enlow,[18] Harris *et al.*,[25] Bacon *et al.*[26] have reported that the cranial base angle to be larger in Class-II subjects. However, according to Varrela,[27] early

characteristics of a sample of Class-II occlusion patients found no cranial base etiology in the Class-II group. Kerr *et al.*[28] compared the cranial base in Class-I and Class-II skeletal patterns and found no significant differences between the skeletal classes for any of the cranial base measurements.

In this study subjects with most closed cranial base angle had a skeletal Class-III jaw relationship [Table 4]. This supports the findings of Enlow[18] but contradicts the findings of Anderson and Popovich[23] According to Anderson and Popovich[23] Class-III occlusion in subjects do not have the most closed cranial base angles.

To study the influence of cranial base angle on the rotation of the mandible, angle NSAr was correlated with Y-axis and mandibular plane angle (SN-GoGn). Correlation suggest that increase in the cranial base flexure can cause a clockwise rotation of the mandible [Tables 5 and 6]. The above findings are in agreement with those of Klocke *et al.*[29]

In this study, it is found that changes in the cranial base angle are independent of anterior as well as posterior cranial base length [Tables 5-7]. However, increase in the cranial base angle has high association with increase in the overall cranial base length and this tendency is greater near the upper extremities of cranial base angle [Tables 5-7]. Weidenreich[30] stated that the deflection of the cranial base shortened the nasion-basion line (overall cranial base), this correlates well with the present study in which the total cranial base length decreased significantly with a decrease in the cranial base angle [Tables 5 and 6].

An interesting association is seen between the cranial base angle and maxillary length. The maxillary length progressively increases with an increase in the cranial base angle [Table 4], thus compensating for increase in its value. This increase in the maxillary length was significant between the Groups A and C [Table 7]. Now when the maxillary position is evaluated by the method suggested by McNamara (measuring the linear distance of point A, from a perpendicular dropped from nasion to FH plane) and is correlated with NSAr, then no significant correlation is established [Table 7]. Thus changes in NSAr do not affect N-pt A in this study.

When mandibular length (Ar-Gn) was correlated with NSAr angle [Tables 5 and 6], an insignificant negative correlation is seen both in the overall data and in the individual groups. This suggest that the increase in the value of saddle angle, which has the tendency to cause retrusion of mandible is not being compensated by the mandibular length and this is the cause that the values of angle SNB and angle NPg-FH is influenced to a greater extent as compared to the values of angle SNA and N-PtA.

No significant correlation was found between inclination of the posterior border of the ramus (ArGo-SN) and NSAr, [Table 5].

This suggests that with increase in cranial base angle, which tends to position the head of the condyle more posteriorly, there is no compensation from the slope of the ascending ramus to bring the angle of mandible, or body, or chin forward.

CONCLUSION

It has been known for a long time that the cranial base angle influences the craniofacial morphology. Based on this study, following conclusions are drawn:
- The cranial base has definite influence on the maxilla. As the cranial base angle reduces, the maxilla tends to protrude and angle SNA increases.
- The mandibular position is influenced to a greater extent by the cranial base angle than maxillary position. Cranial base angle has a determinant role in influencing the mandibular position.
- The flattening of the cranial base angle causes a clockwise rotation of the mandible.
- The jaw relation tends to change from Class-III to Class-II, with progressive flattening of the cranial base and vice-versa.

REFERENCES

1. Young M. A contribution to the study of Scottish skull. Trans R Soc Edin 1916;51:347-453.
2. Moss M, Greenberg SN. Post natal growth of the human skull base. Angle Orthod 1955;25:77-84.
3. Scott JH. The cranial base. Am J Phys Anthropol 1958;16:319-48.
4. Stramrud L. The pattern of craniofacial associations. Acta Odontol Scand 1959 ;24 Suppl 46:1-174.
5. Melson B. The cranial base. The postnatal development of the cranial base studied histologically on human autopsy material. Acta Odontol Scand 1974;32 Suppl 62:1-126.
6. Ohtsukhi F, Mukherjee D, Lewis AB, Roche AF. Growth of the cranial base and vault dimensions in children. J Anthropol Soc Nippon 1982;90:239-58.
7. Renfroe E. Study of facial pattern associated with class I, class II div I and class II div II malocclusions. Angle Orthod 1948;18:12-5.
8. Bjork A. Some biological aspects of prognathism and occlusion of the teeth. Acta Odontol Scand 1950;9:1-40.
9. Coben SE. The integration of facial skeletal variants. Am J Orthod 1955;41:407-34.
10. Moss ML. Correlation of cranial base angulation with cephalic malformations and growth disharmonies of dental interest. NY State Dent J 1955;24:452-4.
11. Hopkin GD. The growth factor in the prognosis of treated case of angle class III malocclusion. Trans Eur Orthod Soc 1965;41:353-65.
12. Bhatia SN, Leighton BC. A Manual of Facial Growth. Oxford: Oxford University Press; 1993.
13. Hopkin GB, Houston WJ, James GA. The cranial base as an aetiological factor in malocclusion. Angle Orthod 1968;38:250-5.
14. Varjanne I, Koski K. Cranial base, sagittal jaw relationship and occlusion. A radiological-craniometric appraisal. Proc Finn Dent Soc 1982;78:179-83.
15. Järvinen S. Saddle angle and maxillary prognathism: A radiological analysis of the association between the NSAr and SNA angles. Br J Orthod 1984;11:209-13.
16. Kasai K, Moro T, Kanazawa E, Iwasawa T. Relationship between cranial base and maxillofacial morphology. Eur J Orthod 1995;17:403-10.
17. Moyers RE. Hand Book of Orthodontics. IVth ed. London: Mosby Publishers; 1988.
18. Enlow DH. Facial Growth. 3rd ed. Philedelphia: W.B Saunders; 1990.

19. Profitt W, Fields HW. Contemporary Orthodontics. 2nd ed. St Louis: Mosby Year Book; 1993.
20. Bjork A. Cranial base development. Am J Orthod 1955;41:198-225.
21. Baccetti T, Antonini A, Franchi L, Tonti M, Tollaro I. Glenoid fossa position in different facial types: A cephalometric study. Br J Orthod 1997;24:55-9.
22. Kerr WJ, Hirst D. Craniofacial characteristics of subjects with normal and postnormal occlusions – A longitudinal study. Am J Orthod Dentofacial Orthop 1987;92:207-12.
23. Anderson D, Popovich F. Relation of cranial base flexure to cranial form and mandibular position. Am J Phys Anthropol 1983;61:181-7.
24. Kerr WJ, Adams CP. Cranial base and jaw relationship. Am J Phys Anthropol 1988;77:213-20.
25. Harris JE, Kowalski CJ, Walker SJ. Dentofacial differences between "normal" sibs of Class II and Class III patients. Angle Orthod 1975;45:103-7.
26. Bacon W, Eiller V, Hildwein M, Dubois G. The cranial base in subjects with dental and skeletal Class II. Eur J Orthod 1992;14:224-8.
27. Varrela J. Early developmental traits in class II malocclusion. Acta Odontol Scand 1998;56:375-7.
28. Kerr WJ, Miller S, Ayme B, Wilhelm N. Mandibular form and position in 10-year-old boys. Am J Orthod Dentofacial Orthop 1994;106:115-20.
29. Klocke A, Nanda RS, Kahl-Nieke B. Role of cranial base flexure in developing sagittal jaw discrepancies. Am J Orthod Dentofacial Orthop 2002;122:386-91.
30. Weidenreich F. Some particulars of skull and brain of early hominids and their bearing on the problem of the relationship between man and anthropoids. Am J Phys Anthropol 1947;5:387-427.

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