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Relationship of Angular And Linear Measurements Between Cranial Base And Jaw Base in Subjects With Skeletal Class-I, Class-Ii And Class-Iii Malocclusion – A Cephalometric Study

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Abstract: *The cranial base area of the craniofacial complex has long been of interest to orthodontists and craniofacial anthropologists. The cranial base provides support for the brain and adaptation during growth between the developing neurocranium and viscerocranium. The aims of this investigation was to assess if there is any evidence that the cranial base angle predisposes the jaw base relationship in a Dravidian population, and to gain data specific for this population with particular reference to the angular and linear cranial base morphology.*
Materials And Methods: *The study involved 105 subjects (male:52 ; female:53 : age: 18± 5 SD years) from Chennai who were classified into 3 sagittal discrepancy group on the basis of their ANB angle.A cephalometric analysis of the angular and linear measurements of the cranial and jaw bases was carried out. The morphological characteristics of the cranial and jaw bases in the three groups were compared and assessments were made as to whether a relationship existed between the cranial base and the jaw base discrepancy.*
Results:Significant differences were found in the cranial base angles in Class II and Class III groups. Increase in cranial base angle inskeletal Class II group resulted in the decrease of SNB by 25%, while in skeletal Class III groupshowed a marked reduction of SNA by 26%. In the linear measurement, skeletal Class III cases presented with increaseof anterior cranial base lengthwith a distinct increase of SNB.Also increase in the posterior cranial baseresulted in increase in mandibular length by 57% in Class III group.
Conclusion: *Cranial base angle and jaw base were positively correlated in both class II and class III malocclusions, whereas cranial base length and mandibular length had positive correlation in class III malocclusion only.*
Keywords: *Cranial base, Jaw Base, Cephalometry*

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I. Introduction

The cranial base area of the craniofacial complex has long been of interest to orthodontists and craniofacial anthropologists [1]. The cranial base provides support for the brain and adaptation during growth between the developing neurocranium and viscerocranium[2,3]. It separates the delicate tissues of the brain from the rest of the face and has a major influence on growth. Young[4], 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[5] and few others[6,7,8,9] 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 main postnatal growth site is the spheno-occipital synchondrosis, which lengthens the base of the skull. The positioning of the maxilla anterior to the synchondrosis and the mandible, which articulates posteriorly gives the synchondrosis the potential to influence growth of both cranium and face and to be a factor in facial disharmony and consequently malocclusion[10].

Renfroe[11], Bjork[12], and Hopkin[13] and few others[14,15] 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-II tendency, while the reduction in the flexion of the cranial base would increase Class-III tendency. Depending on the fact that the maxilla is connected with the anterior part of the cranial base and the rotation of the mandible is influenced by the maxilla, a relationship can be found between the cranial base variations and sagittal malpositions of the jaws[16]. Difference in cranial base and jaws are seen in different race and ethinicity. Craniofacial variation between different races has been well documented, with Africans typically having a more dolicocephalic shape and the Mongoloids a more brachycephalic shape than Caucasians[17]. A Finnish study related historical skulls to present-day populations, and showed the differences in inter-racial craniofacial differences[18] .The prevalence of Class III malocclusion in a Chinese population is higher than Caucasian population (3-4%), which has been noted to be around 13% and has even been as high as 23% [19,20,21].

As the majority of studies have been carried out in Caucasian populations, it is unclear how much influence the cranial base has on the jaw base relationship in an Indian population. The importance of acquiring data relevant to a particular subgroup cannot be underestimated.

The aims of this investigation was to assess if there is any evidence that the cranial base angle predisposes the jaw base relationship in a Dravidian population, and to gain data specific for this population with particular reference to the angular and linear cranial base morphology.

II. Materials And Methods

Samples :-

The samples for this retrospective study which was ethically approved were obtained from patients attending the Department of orthodontics at our University during the period of 2014–2016 in a consecutive series. Their consent to use their clinical records for research purposes was obtained. All of the subjects were Chennai residents, of southern Dravidian origin, and healthy with no evidence or history of medical complications, craniofacial malformation, or syndromes. Any subject with a previous history of orthodontic treatment was excluded from the study. Subjects with severe crowding were also excluded. Based on a pilot study that we conducted, variance within groups (skeletal Classes I, II, and III) in cranial baseangle (NSBa) was 4.9 degrees. Each group required 35patients to yield a 95% power for identifying a significantdifference in a one-way ANOVA at a 5% level ofsignificance (alpha = 0.05). The power analysis wasundertaken by G*Power 3.1.7 (a program developed byAxel Buchner, Edgar Erdfelder, and Franz Faul; http://www.psycho.uni-duesseldorf.de/abteilungen/aap/gpower3).

The final sample was comprised of 105 patients (male: 52;female: 53; age: 18 ± 5 SD years).

Cephalometric Analysis:

Lateral cephalometric radiographs were taken in centricrelation as part of a routine orthodontic diagnosticprocess using a PLANMECA (PROMAX Oy 00880 Finland) machine with subjects in a natural headposture position. It was estimated that the magnificationfor a mid-sagittal structure would be close to the value of8.8%. Subjects were then allocated into three definedgroups of Class I, Class II, and Class III on the basis of theirANB angulations with the Indian norm as the reference. The pretreatment digital cephalograms of 105 patients were calibrated to 50mm to avoid calibration error, after which landmarks were identified. A composite cephalometric analysis including eight linear measurements and six angular measurements were compiled using the Ilexis FACAD AB-2014 Version 3.8.0.0 software. Randomly 50 radiographs were hand traced and measured by the same investigator and each measurement was repeated after 2 weeks to reduce intra - observer error. No statistically significant variations were found between these readings; hence the first trial values were used for the statistical analysis. The cephalometric variables analyzed in this study are shown in Figure 1.

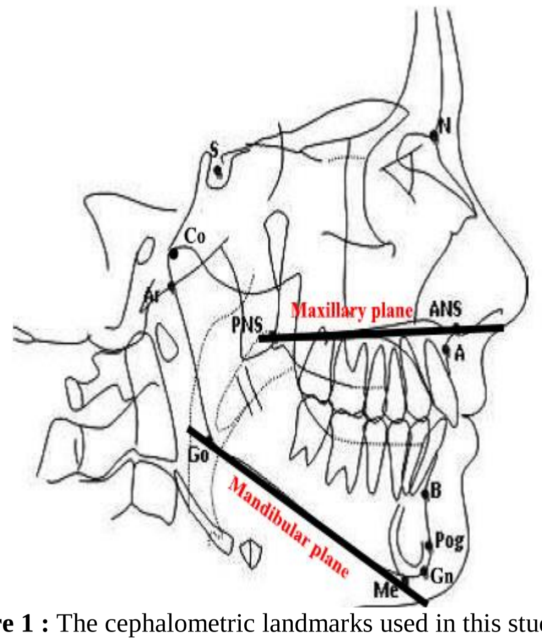
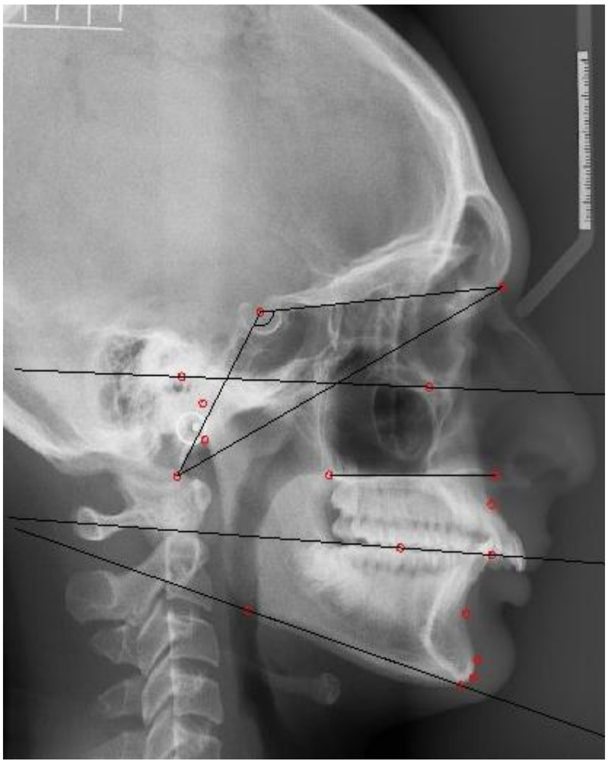


Figure 1 : The cephalometric landmarks used in this study.

Reference point: cranial base: N (Nasion), S (Sella), Ba (Basion); jaw base: Co (Condylion), Go (Gonion), Me (Menton), A(Supramentale), B (Supramentale), Pog (Pogonion). Reference plane: ANS-PNS (Maxillary plane) Go-Me (Mandibular plane).



Ceph name	Original	Norm	Unit
SNA	81.3	80-84	°
SNB	77.6	78-82	°
ANB	3.7	1-5	°
Wits	5.4	0-4	mm
SN	72.9		mm
SBa	52.2		mm
NBa	110.9		mm
Co ANS	89.9		mm
Co Pog	109.1		mm
ANS PNS	49.8		mm
GoMe	67.1		mm
NSBa Angle	-124.0		°
NSAr	-120.6		°
GoGn-SN	21.2		°

Figure 2 :-Using Facad Version 3.8 To Trace And analyse landmarks

III. Statistical Analysis

For each of the three morphological subtypes, the means and standard deviations were calculated for each cephalometric variable in each group. A One-way Analysis of Variance (ANOVA) was carried out to compare the characteristics of cranial bases and jaw bases between the three groups. A Pearson Correlation Coefficient was calculated between each cephalometric variable with particular emphasis on the relationships between the cranial base angle and the sagittal jaw discrepancy markers for the whole sample and the three groups. Significance for the tests was noted at three levels, $P < 0.05$ (*), $P < 0.01$ (**), and $P < 0.001$ (***). The correlation was regarded as meaningful when r > =0.5 in addition to the significance revealed by P < 0.05, whereas the correlation was regarded as weak when r < 0.5, even if there was some statistical significance (P < 0.05). All of the statistical analyses were performed using Statistical Package for Social Sciences software package (SPSS for Windows, Version 15.0, Chicago, IL, USA).

IV. Results

Cephalometric profile of the cranial base and jaw base of Dravidian sample:

There were 35 subjects in the Class I group (18 ± 5 years old), 35 in the Class II group (18 ± 5 years old), and 35 in the Class III group (18 ± 5 years old). No significant difference was shown in the ages of the three groups (P > 0.05). The cephalometric values for the whole sample and for each subgroup are presented in Table 1. For the cranial base, the angular measurement showed that there was a significant difference in the NSBa angle between the three groups (P < 0.01): the Class II group had a larger cranial base angle (NSBa) (128.53 ± 5.49), whereas the Class III cases had a smaller NSBa (124.06 ± 6.34). For the jaw base relationship, the differences in the sagittal discrepancies among the three groups can be seen by the variation in SNB, ANB, Wits, maxillary length, and the mandibular length, all of which showed significance at P < 0.01.

Table: 1.Cephalometric profile of the cranial base and jaw base of Dravidian sample

		MEASUREMENT	GROUP I (N = 35)		GROUP II (N = 35)		GROUP III (N = 35)		P VALUE (ANOVA)
			MEAN	SD	MEAN	SD	MEAN	SD	
Cranial Base	Angular Measurement	NSAr	123.93	5.69	123.76	6.56	117.25	5.88	0.000**
		NSBa	128.49	5.64	128.53	5.49	124.06	6.34	0.002**
	Linear Measurement	SN	65.67	3.97	65.80	3.04	64.91	4.00	0.559
		SBa	43.74	2.90	44.26	3.29	44.01	3.77	0.804
		NBa	98.84	4.13	96.56	17.32	96.51	5.36	0.585
Jaw Base	Angular Measurement	SNA	83.28	3.81	85.73	3.69	85.06	4.04	0.026*
		SNB	80.51	3.76	76.47	3.26	87.49	4.42	0.000**
		ANB	2.78	1.37	9.25	1.28	-2.44	3.06	0.000**
		GoGnSN	26.40	5.99	28.86	7.57	26.31	7.46	0.234
	Linear Measurement	CoANS	84.76	4.76	86.75	5.50	82.52	5.82	0.006**
		CoPog	130.72	7.04	99.30	5.04	110.64	9.81	0.000**
		ANS-PNS	47.73	2.81	48.27	2.83	45.27	4.20	0.001**
		GoMe	65.68	4.98	63.61	3.88	69.08	4.93	0.000**
		Wits appraisal	0.82	2.18	8.80	1.76	-6.48	5.00	0.000**

*P < 0.05; ** P < 0.01

Correlation between the cranial base measurements

The correlation between the angular measurement (i.e., NSBa) and linear measurement (i.e., SBa) existed in skeletal Class I cases (r = −0.475, P < 0.01) and in skeletal Class III cases (r = -0.473, P < 0.01) but not in Class II cases(TABLE 2). Among the linear variables, it was found that NBa was correlated with both SBa (r = 0.294, P < 0.01) and SN (r = 0.325, P < 0.01). Strong correlation was also observed between SBa and SN (r = 0.465, P < 0.01).

Table 2: Correlation (R) Between The Cranial Base Measurements In A South Indian Sample

	Class – I (n=35)	Class – II (n=35)	Class – III (n=35)	Total (n=105)
NSBa-NBa	-0.123*	-0.192	0.040	-0.081
NSBa-SBa	-0.475**	0.093	-0.473**	-0.279**
NSBa-SN	-0.454**	0.050	-0.259	-0.193*
NBa-SBa	0.579**	0.209	0.676**	0.294**
NBa-SN	0.799**	0.143	0.837**	0.325**
SBa-SN	0.271	0.301	0.465**	0.353**

*P < 0.05; ** P < 0.01

Correlation between the cranial base and jaw base

The analysis of the cranial base angle for the whole sample showed a noticeable correlation in the sagittal jaw base between NSBa and SNA (r = -0.558, P < 0.01) also between NSBa and SNB (r = -0.566, P<0.01) indicating that the SNA angle and SNB angle decreases as the cranial base angle increases (Table 3). The correlation of NSBa with ANB was weak (r < 0.224, P < 0.05). However, NSBa had a strong positive correlation with MMPA (r = 0.378, P < 0.01).

Table: 3 Correlation test (r value) between the cranial base angle and jaw base measurements:

	Class – I (n=35)	Class – II (n=35)	Class – III (n=35)	Total (n=105)
NSBa-SNA	-0.723**	-0.547**	-0.517**	-0.558**
NSBa-SNB	-0.725**	-0.504**	-0.407*	-0.566**
NSBa-ANB	-0.024	-0.275	-0.096	0.224*
NSBa-wits	0.100	-0.405*	-0.288	0.171
NSBa-MMPA	0.679**	0.056	0.442**	0.378**
NSBa-Max length	-0.488**	0.182	-0.073	0.022
NSBa-Mand length	-0.252	0.194	0.050	-0.156

*P < 0.05; ** P < 0.01

For the cranial base length to jaw base relationship (Table 4), none of the linear variables of the cranial base correlated strongly with the sagittal jaw base relationship except for a positive correlation between SBa and SNA in skeletal Class III cases ($r = 0.444$, $P < 0.01$). SBa had the same correlated tendency to SNB ($r = 0.388$, $P < 0.05$), but not to ANB ($P > 0.05$) in skeletal Class III cases.

Table: 4 correlation test (r value) between the cranial base length and jaw base measurements:

	Class I (n=35)	Class II (n=35)	Class III (n=35)	Total (n=105)
NBa-SNA	-0.101	0.299	0.121	0.130
NBa-SNB	-0.014	0.248	0.250	0.088
NBa-ANB	-0.246	0.216	-0.204	-0.004
NBa-wits	0.151	0.115	-0.008	0.019
SBa-SNA	0.345*	0.315	0.444**	0.376**
SBa-SNB	0.356*	0.405*	0.388*	0.227*
SBa-ANB	-0.013	-0.131	0.023	0.025
SBa-Wits	0.051	0.001	0.162	0.076
SN-SNA	0.122	0.147	0.192	0.145
SN-SNB	0.208	0.224	0.349*	0.092
SN-ANB	-0.236	-0.147	-0.253	0.004
SN-Wits	0.086	0.050	0.042	0.109

*P < 0.05; ** P < 0.01

There was a significant correlation between MMPA with NSBa ($r = 0.378$, $P < 0.01$), with SBa ($r = -0.381$, $P < 0.01$) and SN ($r = -0.406$, $P < 0.01$) (Table 5).

Table 5: Correlation test (r value) between the cranial base and mandibular plane angle:

	Class I (n=35)	Class II (n=35)	Class III (n=35)	Total (n=105)
NSBa-MMPA	0.679**	0.056	0.442**	0.378**
NBa-MMPA	-0.096	-0.120	-0.317	-0.141
SBa-MMPA	-0.342*	-0.471**	-0.367*	-0.381**
SN-MMPA	-0.322	-0.508**	-0.466**	-0.406**

*P < 0.05; ** P < 0.01

In the relationship between cranial base length and jaw base length (Table 6),NBa was related to mandibular length in the whole sample ($r = 0.317$, $P < 0.01$), but low correlation was seen with maxillary length ($r = 0.217$, $P < 0.05$), which means that the shorter NBa is, the shorter the mandibular length. Similarly, SN was found to be correlated with both maxillary length for the whole sample ($r = 0.595$, $P < 0.01$) and mandibular length ($r = 0.506$, $P < 0.01$). Also SBa showed a correlation with both maxillary length ($r = 0368$, $P < 0.01$) and mandibular length ($r = 0.444$, $P < 0.01$) in the whole sample.

Table 6: Correlation test (r value) between the cranial base length and jaw length:

	Class–I (n=35)	Class–II (n=35)	Class–III (n=35)	Total (n=105)
NBa-Max length	0.430*	0.071	0.071	0.217*
NBa-Mand length	0.713**	0.323	0.323	0.317**
SBa-Max length	0.355*	0.425*	0.425*	0.368**
SBa-Mand length	0.411*	0.757**	0.757**	0.444**
SN-Max length	0.556**	0.533**	0.533**	0.595**
SN-Mand length	0.669**	0.603**	0.603**	0.506**

*P < 0.05; ** P < 0.01

V. Discussion

The growth of the cranial base in the very early years follows a neural pattern, with the most rapid rate of growth in the first 3 years[9]. The cranial base angle is reasonably stable after the age of five [22,23]. Changes in angular and linear parameters during the observation period occurred mostly between the ages of 10 and 12 years[24]. The synchondrosis influences growth in the region until shortly after puberty when it fuses[25]. After puberty, the angle appears to remain stable[26]. In this study, we chose a sample comprising young adults (mean age: 18 ± 5 years old) to exclude the interference from unknown growth.

Patients with vertical facial morphology, when identified earlier could be controlled by the use of head gears to redirect the growth. Therefore early identification and intervention can change the treatment protocol. Nobuyuki Ishii[27] did a study on Class II division 1 malocclusions, and found that the Japanese population had an increased mandibular plane leading to excessive vertical growth pattern, when compared to Caucasians. Differences in morphological and craniofacial structures were seen. It is found that from the past study not much of correlation was done between the cranial base and the jaw base in different type of malocclusion.

The significance of cranial base flexure as an early factor in the etiology of malocclusion remains controversial. Varrela[28,29] investigated characteristics of a sample of Class II patients between 3 and 7 years of age and did not find the cranial base to be different in these patients compared with a Class I control group.

The relationship between the cranial base and the maxilla was first noted by Jarvinen who published the link between SNA and the cranial base: an increased cranial base angle would lead to a decreased SNA[30,] and this link was later explained with a detailed statistical analysis [31]. Further studies have shown that the correlation between the two values was probably high due to topographical factors, most likely the rotation of the SN plane [32,33]; thus the SN value was deemed an unreliable indicator. As a result, it has been suggested that the position of the maxilla is likely to be determined more by genetic or epigenetic factors rather than directly by the cranial base [34].

Cranial base in relation to jaw base angle

In the choice of cranial base landmarks, debate has arisen over the use of the Articulare instead of the Basion (Ba) [35], suggesting that it is easier to identify. However, since 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 [36]. Therefore, based on these results both Ar and Ba were chosen as the landmark points in this study.

In our study correlation tests between NSBa – SNA and NSBa – SNB in all three groups showed negative correlation that was highly significant. Hence any increase in any one of these values will show a corresponding decrease in the other. However the level of correlation varied across the groups for both the values. For the Class II group , the level of correlation between NSBa and SNA showed a mild range (r^2 = 30%) indicating that NSBa increase showed 30% reduction in the SNA value while in Class III group an increase of NSBa showed only 26% reduction in SNA value. This is in agreement with the studies by Hopkinet al.,[37]Varjanne and Koski,[38] Järvinen,[39] Moyers,[40]Profitt and Fields,[41] Kasai et al.[42] From this it can be inferred that Class II cases show a tendency for compensating the changes in the cranial base, while in Class III this tendency in compensation is reduced hence giving a more noticeable skeletal discrepancy.

Comparing the NSBa and SNB values in Class II cases the level of negative correlation was low (r^2 = 25%) indicating that an increase in NSBa resulted in a reduction of SNB value by 25%. Class III group also showed negative correlation (r^2=16%) which was significant but only to a level of 16%. This inverse correlation between the cranial base angle NSBa and the jaw base variable SNB (table 10) shows that an increased NSBa was accompanied by a reduced SNB, leading to a more Class II profile, and vice versa. This result would seem logical, as the mandible would be positioned more posteriorly on the posterior cranial base leg, coinciding with the previous studies. The low level of correlation in Class III cases further indicates reduced compensation which leads to more obvious skeletal discrepancy.

The linear variable SBa had a stronger positive correlation with SNA ($r = 0.044$, $P < 0.01$) in skeletal Class III samples (Table 11), possibly because with the decrease in SBa and a decrease in SNA will lead to the forward position of the mandible resulting in a skeletal Class III tendency. But the level of correlation (r^2 = 19%) for this parameter in this study was at 19% which is considered to be mild. This indicated that when there is a decrease in SBa, there was a 19% decrease in SNA. Correlating SBa – SNB all three groups showed a positive correlation with mild statistical significance. Whereas a mild significance with positive correlation was seen when correlating SN – SNB in the Class III group.

Vertical discrepancies can affect the sagittal position due to a downward and backward rotation of the mandible. Jarvinen looked at the cranial base angle in relation to the vertical facial pattern, and found that the low angle group had a larger cranial base angle, and the high angle group had a shorter cranial base [43]. In this study, when correlating the mandibular plane angle with the NSBa, NBa, SBa and SN, the highest significance was seen for Class I and Class III groups for MMPA to NSBa , with higher positive correlation levels noted in the Class I group (r2 = 46%) than Class III (r2 = 19%). However Class II group did not show any statistical significance. This reveals that many Class I cases show a greater level of compensation thereby bringing them to a normal state. But Class III cases again indicate low compensating tendency leaving their skeletal discrepancy intact.

SBa to MMPA was highly significant only for Class II group with the low level of correlation (r2 = 22%). SN – MMPA was highly significant for Class II and Class III group with the level of correlation at 25% and 21% respectively. These results indicate that changes in SBa will not effect the mandibular plane angle to a level which would be of clinical significance.

Cranial base in relation to jaw base length

Length of the posterior cranial base in particular has a significant role to play in the sagittal presentations. Previous studies have suggested that a longer posterior cranial base can exacerbate a sagittal Class II situation and a shorter base may increase the chance of a Class III relationship [44,37,45,20]. In contrast, other studies have not been able to confirm such findings regarding cranial base length, but still report some significant differences in angle [46].

In this study, when correlating SBa to mandibular length, SN to Maxillary length and SN to mandibular length, Class II and Class III groups showed a positive correlations with high statistical significance. On examination of level of correlation (r^2 = 57%) between SBa and Mandibular length both Class II and Class III groups showed higher value at 57%.

However for SN to maxillary length and SN to Mandibular length the levels of correlation were low at 28% and 38% respectively in both Class II and Class III groups.This revealed that Class II cases showed high compensating tendency which in turn corrected their skeletal discrepancy. But Class III cases again indicate low compensating tendency leaving their skeletal discrepancy intact.

The present study was designed as cross sectional evaluation of cranial and jaw bases of specific age groups only. One of the main limitations was we could not perform longitudinal evaluation over a period of time. Also larger sample size should be taken in order to obtain more stable and statistically significant results. Future studies have to be conducted with further subdividing malocclusion based on skeletal discrepancies along with different mandibular divergence patterns to obtain appropriate results. Besides, 3-dimensional cone beam computer tomography (CBCT) is more viable than two dimensional cephalometric radiographs and can also solve the problem of image overlapping. Further population based investigation should be conducted in future to evaluate the relationship between cranial base and jaw base three dimensionally.

VI. Conclusion

The cranial base sets the boundaries of the cranial and facial skeleton. Therefore, the shape of the cranial base is an important factor in establishing the position of the maxilla and mandible. From this study following conclusions can be drawn:

In Class II group, the increased cranial base angle contributed to the backward positioning of the maxilla by about 30% as a result of compensatory effect which might be clinically beneficial. However this also resulted in backward positioning of the mandible by about 25% which worsened the clinical convex profile.

Whereas in Class III group, the increased cranial base angle contributed to the backward positioning of the maxilla by about 26% which worsened the midface exaggerating the clinical concave profile.

3) It is observed that increased anterior cranial base length can be correlated with forward positioning of the mandible and increased posterior cranial base length attributed to increased mandibular length by about 57% in Class III group.

5) In Class II group, increase in posterior cranial base length contrarily resulted in increased mandibular length which might be due to the result of natural compensation that would have occurred to mask the severity of the skeletal discrepancy.

Overall the increased linear and angular measurements discerned in the Class II group of the present population studied might be due the result of compensation that has contributed, which is population specific and should not be generalized. Hence these conclusions can be utilized for diagnostic purpose and should be applied appropriately.

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[47]. Competing interests
[48]. The authors declare that they have no conflict of interests.

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