Relationship of maxilla to cranial base in different facial types—a cephalometric evaluation

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ABSTRACT

Background: Many conflicting opinions have been put forth in the dental literature concerning the maxilla and its relationship to craniofacial complex. In view of this fact, this cephalometric study was conducted to determine the relationship of maxilla to cranial base in different facial types.

Materials and Methods: The sample consists of 120 pretreatment lateral cephalogram, which were categorized into three groups, normodivergent, hypodivergent, and hyperdivergent. Each group consists of 20 males and 20 females. Descriptive statistics for 11 variables were calculated.

Results and Conclusion: The result of this study implies that in hyperdivergent subjects' sagittal maxillary base size was smaller and upper posterior facial height (UPFH) was increased in comparison to hypodivergent and normodivergent subjects. Upper posterior facial height has positive correlation with anterior facial height. Posterior maxillary position in relation to cranial base increases with increase in cranial flexural angle in hypodivergent subjects and vice versa in hyperdivergent subjects. Upper posterior facial height decreases with increase in cranial flexural angle in hypodivergent subjects and vice versa in hyperdivergent subjects.

Keywords: Cranial base angle, hyperdivergent, hypodivergent, maxilla, normodivergent.

INTRODUCTION

Variations between craniofacial morphology are evident during development and growth.¹ Normal facial type can be attained and maintained in spite of the variations in the facial pattern seen as a result of the change in size, position, rotation of cranial base (CB), maxilla, and/or mandible or cumulative effect of any two or all three. In some individuals, a disturbed pattern of differential growth may lead to malformation of the teeth and jaws.

The relative size and anteroposterior position of the maxilla in relation to the rest of the craniofacial complex has been one of the major problems dealt by orthodontics. Many conflicting opinions have been put forth in the dental literature concerning the maxilla and its relationship. In view of this fact, this study was undertaken to determine, the constancy or variation in the relationship of maxilla to cranium in different facial types.

MATERIALS AND METHODS

This study was based on the lateral cephalograms of 120 subjects who visited our outpatient department for their orthodontic alignment of teeth. The pre-treatment lateral cephalograms were obtained in the natural head position. The cephalograms were analyzed for various linear and angular measurements and statistically evaluated. The lateral cephalograms of the subjects were categorized into three groups, differentiated using two variables: lower facial height angle (LFHA) through Rickett's Analysis² and Jarabak ratio. Each group comprised 20 male and 20 female subjects. The subjects were in the age group of 16–24 years, with the mean age of 18 years for females and 20 years for males.

Group A (Normodivergent facial type with normal mandibular plane angle, average anterior lower face height equal to the upper face height, with competent lips. Total anterior facial is slightly more than the posterior facial height

[PFH]³): Subjects having Angles Class I molar relationship with excellent occlusion, pleasant smile, straight profile, and no significant abnormalities in the vertical dimension of facial form, and showed LFHA between $47^\circ \pm 4^\circ$ and Jarabak ratio between 62% and 65% were included in this group.

Group B (Hypodivergent facial type with skeletal planes parallel to each other. Characterized by a low mandibular plane angle and short lower facial height, total posterior facial is nearly equal to the anterior facial height (AFH). The lower facial height is smaller than the upper facial height. The facial breadth equals the total facial height giving a squarish appearance. The ramus is long to equal the length of corpus, and the ramus broadened anteroposteriorly with a large coronoid process. The mandibular symphysis is short vertically and broad anteroposteriorly): Subjects with LFHA $<43^\circ$ and Jarabak ratio $>65\%$ were included in this group.

Group C (Hyperdivergent facial type with steep mandibular plane angle, long anterior lower face height, open bite tendency, and lip incompetence. Total anterior facial is more than the PFH. The lower facial height is larger than the upper facial height. The total facial length tends to be more than the facial breadth giving a long-face appearance. The mandibular symphysis is long vertically and small anteroposteriorly): Subjects with LFHA $>51^\circ$ and Jarabak ratio $<62\%$ were included in this group.

Reference planes namely Sella–Nasion Plane (SN), Frankfort Horizontal Plane (FHP), Palatal Plane (PP), ANS–posterior nasal spine (PNS), PP, Basion Horizontal Plane (Ba-H)⁴ at the level of the anterior border of the foramen magnum parallel to the constructed horizontal plane (cHP),⁵ cHP through Nasion 7° up from the SN plane were marked on acetate paper (Figure 1). Horizontal linear measurements (Figure 2) were made using posterior maxillary position {S' [S(- FH) on PP] – PNS} and maxillary base (MB) length {PNS – Pt. A (- PP)}. Vertical linear measurements (Figure 3) were calculated for the AFH (N–Me), PFH (S–Go), upper anterior facial height (UAFH) {N–Pt. A (- PP)}, and PNS vertical (Ba–H–PNS). Angular measurements (Figure 4) for the LFHA (ANS–Xi–PM) Xi—Geometrically determined centroid of the ramus² were evaluated.

Maxillary base length:CB length (Max:CB) and MB length:UAFH (Max:UAFH) were assessed to determine the relation of the MB size to the CB length and UAFH.

Posterior maxillary position (mm) in sagittal position, PNS vertical from Basion horizontal (mm) PNS–Ba–H, upper posterior facial height (UPFH) to the UAFH ratio (%) UPFH:UAFH, UPFH to the PFH (%) UPFH:PFH, UPFH to the AFH (%) UPFH:AFH were studied to determine the sagittal and vertical position relationship of the MB to the CB and the relationship of UPFH to PFH. Maxillary base

rotation angle (Ba–H–PP) was analyzed to determine the relation of the MB to the CB. Cranial base flexure angle (CBFA) (N–S–Ar) was also calculated to study the relation of CBFA on all other variables statistically by linear regression method.

RESULTS

Overall mean values of females from all three groups have been compared in Table 1 and of males in Table 2. Max:CB ratio showed significantly small maxilla in the anteroposterior dimension in relation to the anterior CB length in the

Figure 1 Reference planes used in the study.

S–N plane=Sella–Nasion plane; F–H plane=Frankfort–Horizontal plane; PP=palatal plane; Ba–H plane=Basion–Horizontal Plane; cHP=constructed horizontal plane.

Figure 2 Horizontal linear measurements used in the study.

hyperdivergent subjects when compared with normodivergent and hypodivergent subjects (Tables 1 and 2). Max to UAFH ratio was highly significant when hyperdivergent group was compared with hypodivergent or normodivergent group (Tables 1 and 2). Posterior maxillary position

Figure 3 Vertical linear measurements used in the study. AFH=anterior facial height; PFH=posterior facial height; PMH=posterior maxillary height; PNS=posterior nasal spine; UAFH=upper anterior facial height; UPFH=upper posterior facial height.

was found to be reduced in hyperdivergent group and increased in hypodivergent group (Tables 1 and 2).

Table 3 shows the linear regression of CBFA with other variables to show the effect of other variables on the CB flexure. Table 4 depicts the linear regression of CBFA with other variables to show the amount of relationship of the CB angle with the most effected variables.

Figure 4 Angular measurements used in the study. LAFH=lower anterior facial height angle; Max. Rot.=maxillary base rotation angle; CBF=cranial base flexure angle.

Table 1 Overall mean values (females)

Variable	Group A (n=20)		Group B (n=20)		Group C (n=20)		F	P
	Mean	SD	Mean	SD	Mean	SD		
Critical								
Lower facial height angle (°)	45.80	1.54	37.08	3.26	53.50	1.88	245.309	0.000
Jarabak ratio (%)	64.18	1.07	69.75	7.52	58.08	3.11	30.353	0.000
Size								
Maxilla to cranial base ratio (%)	71.75	2.18	72.92	3.23	69.33	4.52	5.617	0.006
Max base to UAFH ratio (%)	98.06	5.57	100.77	5.10	94.52	6.22	6.145	0.004
Position								
Posterior maxillary position (mm) (sagittal)	18.95	2.13	20.18	2.08	18.23	2.58	0.402	0.053
PNS vertical from Basion-Horizontal (mm) (vertical)	2.58	1.96	2.30	1.57	4.15	2.85	4.140	0.021
UPFH to UAFH ratio (%) (vertical)	82.07	3.31	81.04	6.23	81.69	6.68	0.172	0.842
UPFH to PFH ratio (%) (vertical)	56.48	2.90	52.94	4.42	59.72	4.36	14.688	0.000
UPFH to AFH	36.56	1.92	38.09	2.52	34.82	2.90	8.673	0.001
Rotation								
Maxillary base rotation angle (°)	−0.20	1.47	−0.53	2.65	−0.23	3.42	0.094	0.911
CBF angle (°)	124.20	4.43	127.40	5.00	121.03	5.24	8.459	0.001

AFH=anterior facial height; CBF=cranial base flexure; PFH=posterior facial height; PNS=posterior nasal spine; SD=standard deviation; UAFH=upper anterior facial height; UPFH=upper posterior facial height.

Table 2 Overall mean values (males)

Variable	Group A (n=20)		Group B (n=20)		Group C (n=20)		F	P
	Mean	SD	Mean	SD	Mean	SD		
Critical								
Lower facial height angle (°)	45.70	1.03	39.98	2.69	53.35	1.31	270.207	<0.001
Jarabak ratio (%)	64.29	0.89	71.95	3.73	59.34	2.00	129.472	<0.001
Size								
Maxilla to cranial base ratio (%)	73.04	3.95	72.44	3.04	69.18	5.85	4.391	0.017
Maxillary base to UAFH ratio (%)	98.70	7.16	99.72	5.74	91.89	6.70	8.423	0.001
Position								
Posterior maxillary position (mm) (sagittal)	19.90	1.75	21.13	2.65	19.23	2.77	3.134	0.051
Posterior nasal spine vertical from basion	2.73	2.92	1.88	1.38	6.00	2.27	18.260	<0.001
horizontal (mm) (vertical)								
UPFH to UAFH ratio (%) (vertical)	82.90	4.06	82.97	7.46	83.19	7.97	0.010	0.990
UPFH to PFH ratio (%) (vertical)	56.83	3.09	53.02	4.63	59.42	4.67	11.769	<0.001
UPFH to AFH	36.62	1.90	38.93	3.63	34.34	3.32	5.609	<0.001
Rotation								
Maxillary base rotation angle (°)	−0.15	2.08	−0.58	3.70	−0.18	3.96	0.101	0.904
CBF angle (°)	124.28	5.08	126.33	5.00	122.40	4.06	3.459	0.039

AFH=anterior facial height; CBF=cranial base flexure; PFH=posterior facial height; SD=standard deviation; UAFH=upper anterior facial height; UPFH=upper posterior facial height.

Table 3 Linear regression of cranial base flexure angle with other variables

	Unstandardized coefficients		Standardized coefficients beta	t	P
	B	SE			
(Constant) ^a	153.378	14.255		10.759	0.000
Max:CB	-0.010	0.134	-0.008	-0.075	0.940
Posterior maxillary position	-0.743	0.195	-0.355	3.813	0.000
UPFH_UAFH	-0.013	0.134	-0.015	-0.094	0.925
MBR	0.230	0.232	0.131	0.990	0.324
PNS_Base	0.195	0.189	0.098	1.030	0.305
UPFH_PFH	-0.390	0.127	-0.362	-3.076	0.003
MaxB_UAFH	0.099	0.099	0.129	1.006	0.317

^aDependent variable: CBF angle. CBF=cranial base flexure; Mx:CB=maxillary base length:CB length; MBR=maxillary base rotation; PFH=posterior facial height; PNS=posterior nasal spine; SE=standard error; UAFH=upper anterior facial height; UPFH=upper posterior facial height.

DISCUSSION

Many conflicting opinions have been put forth in the dental literature concerning the maxilla and its relationship to the craniofacial complex. In view of this fact, this cephalometric study was conducted to determine the relationship of maxilla to the CB in different facial types. The result of this study implies that in hyperdivergent subjects, sagittal MB size is smaller and the UPFH is increased in comparison with hypodivergent and normodivergent subjects. Anterior facial height increases with increase in the UPFH. Large cranial flexural angle has increased posterior maxillary position in relation

to the CB in hypodivergent subjects and vice versa in hyperdivergent subjects. Cranial flexural angle plays an important role in the AFH as if it increases, and leads to a decrease in the UPFH which in turn leads to a decrease in the anterior face height and vice versa in hyperdivergent subjects.

Max to UAFH ratio supports the fact that the maxilla is small in the anteroposterior dimension in hyperdivergent group. Significant hypoplasia in endochondral, mesodermal, and ectomesenchymal derived structures of the cranium and face has also been seen in subjects with Down syndrome.⁶ Increase in the posterior maxillary segment in hyperdivergent group as compared with normodivergent and

Table 4 Linear regression of cranial base flexure angle with other variables

	Unstandardized coefficients		Standardized coefficients <i>beta</i>	<i>t</i>	<i>P</i>
	<i>B</i>	<i>SE</i>			
(Constant)	155.573	5.950		26.147	0.000
Posterior maxillary position	-0.600	0.174	-0.287	3.452	0.001
UPFH_PFH	-0.349	0.089	-0.324	-3.906	0.000

PFH=posterior facial height; SE=standard error; UPFH=upper posterior facial height.

hypodivergent subjects elicits the inferior position of the PP in hyperdivergent subjects (Tables 1 and 2).

Upper posterior facial height to PFH ratio was found significantly increased in hyperdivergent subjects and significantly decreased in hypodivergent subjects (Tables 1 and 2). This was in accordance with the study done by Opdebeeck,⁷ 1978 on short-face syndrome.

However, other variables like UPFH to PFH ratio, PNS vertical-Ba-H demonstrated that the posterior segment of the maxilla was significantly increased in cases of hyperdivergent subjects. If the posterior segment was increased in hyperdivergent cases, the UPFH to UAFH ratio should increase. However, results show that UPFH to UAFH ratio was equivalent to other groups. This revealed that there was a proportional increase in UAFH with increase in UPFH. UPFH to AFH ratio was significantly decreased in hyperdivergent subjects and significantly increased in hypodivergent subjects (Tables 1 and 2).

Upper posterior facial height contributed more in PFH in hyperdivergent subjects. As UPFH increased in hyperdivergent subjects, it showed that the maxilla moved inferiorly resulting into downward and backward rotations of the mandible which further lead to increase in AFH.³

It was observed that UPFH played a significant role in increased or decreased lower anterior facial height.⁸ Long-face patterns were studied and it was found that patients with and without openbite demonstrated increased total AFH and specifically the lower face height. The increased facial height correlated with excess development of the maxilla in a vertical direction. No standardized pattern of the MB rotation was observed in any of the three groups.

Cranial base flexure angle findings obtained showed significant differences when normodivergent group was compared with hypodivergent and hyperdivergent groups (Tables 1 and 2). It was seen from the mean values of CBFA that it decreases in hyperdivergent subjects and increases in hypodivergent subjects. The relation of CBF to the posterior

maxillary position was obtained from linear regression statistical method and it revealed that CBFA has a direct proportional relation with the posterior maxillary position (Tables 3 and 4) which means that CBFA increases with the posterior maxillary position increase and decreases with the posterior maxillary position decrease. The similar pattern of relation between the CBFA and posterior maxillary position was observed in hyperdivergent and hypodivergent subjects (Tables 1 and 2).

Contrary to the findings of previous studies,^{9,10} CBFA had negative correlation to Sella-Nasion A (SNA). The probable explanation to this difference is that in this study, the posterior positioning of the maxilla in a sagittal dimension was considered in relation to the stable point in the CB, whereas in previous studies sagittal positioning of the maxilla was considered in angular measurement where SN were taken as the point of reference against variable point A. As evident from previous studies, Nasion keeps on growing. The cant of SN plane can contribute to increase or decrease in SNA angle thereby creating false positive results. Järvinen¹¹ supports this view against his own work done in 1980. He found that a part of the correlation between the NSAr and SNA angle anteroposterior relations of the maxilla to the CB had a topographical causation, the main cause of this topographical correlation probably being the rotation of the S-N plane, the SNA angle was regarded as an unreliable indicator for the anteroposterior maxillary positioning. One-way analysis of variance, used to determine the differences between the groups, showed that low-angle group had a larger cranial basis angle (N-S-Ar) and the high-angle group had a shorter maxilla.¹²

The above finding lead to the probable conclusion that the maxillary position was predetermined by genetic or epigenetic factors in which CBF does not affect the sagittal position of the maxilla. Only a space present between CBF and posterior border of the maxilla is affected by increase or decrease in CBFA. A very highly significant inverse proportional relationship was found between CBFA and UPFH to PFH ratio (Tables 3 and 4). This finding revealed that CBFA decreases with increase in UPFH to PFH ratio or increased UPFH and vice versa. The similar pattern of relation between the CBFA and UPFH was observed in hyperdivergent and hypodivergent subjects.

It again supports the finding obtained from hyperdivergent and hypodivergent subjects in which CBFA decreases and UPFH to PFH ratio increases in hyperdivergent subjects and CBFA increases and UPFH ratio decreases in hypodivergent subjects (Tables 1 and 2). From the above findings, it was found that CBFA has a significant important role in the vertical positioning of the maxilla as compared with sagittal maxillary positioning.

CONCLUSION

Smaller anteroposterior MB size is seen in hyperdivergent subjects. Upper posterior facial height is increased in hyperdivergent subjects and decreased in hypodivergent subjects. Upper posterior facial height has positive significant correlation with the AFH. Inferiorly placed PP was found in hyperdivergent subjects. Posterior maxillary position in relation to the CB increases with increase in CBFA in hypodivergent subjects and vice versa in hyperdivergent subjects. Upper posterior facial height decreases with increase in CBF angle in hypodivergent subjects and vice versa in hyperdivergent subjects. Proportional change of the UAFH occurs with change in the UPFH in both hyperdivergent and hypodivergent subjects.

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