Cranial Base Angle and Nasopharyngeal Depth

LAWRENCE T. ENGMAN, D.D.S., M.S.
D. C. SPRIESTERSBACH, Ph.D.
KENNETH L. MOLL, Ph.D.
Iowa City, Iowa

It has been suggested by Wildman (*13*) that there is a relationship between the angle of the cranial base and nasopharyngeal depth. According to this interpretation, the more obtuse the cranial base angle, the greater the nasopharyngeal depth. And further, the greater the nasopharyngeal depth, the greater are the demands placed upon the velopharyngeal mechanism for proper functioning. On the basis of data on noncleft subjects with 'cleft palate type speech', Ricketts (*9*, *10*, *11*) suggested that cleft individuals may exhibit cranial base abnormalities. However, no such differences in cranial base angle or nasopharyngeal depth have been found between individuals with operated cleft palates, unoperated cleft palates, and normals (*2*, *7*, *8*). The relationship between these two parameters (cranial base angle and nasopharyngeal depth) has not been investigated. The etiological and diagnostic implications of such a relationship, if it exists, in the cleft palate population makes such an investigation timely.

Procedure

Subjects. The subjects for this study consisted of 49 Caucasian males ranging in age from 12 to 16 years. Twenty-four of the subjects had clefts of the palate, with or without clefts of the lip. Of these 24 subjects, 13 had unilateral and 10 had bilateral clefts of the lip and palate. One subject had a palatal cleft only. This sample was drawn from patients seen in the Department of Otolaryngology and Maxillofacial Surgery, University of Iowa. No restrictions were made concerning the nature of the physical management, if any, used to achieve palatal closure.

The remaining 25 subjects, all noncleft individuals, were drawn from patients seen in the Orthodontic Clinic of the University of Iowa College

---

Dr. Engman is in practice in Englewood, Colorado. Dr. Spriestersbach and Dr. Moll are Professor and Research Associate Professor, respectively, of Speech Pathology, Department of Otolaryngology and Maxillofacial Surgery and Department of Speech Pathology and Audiology, University of Iowa. This report is based on research which was supported in part at the University of Iowa by Research Grant D-853, National Institute of Dental Research, United States Public Health Service.

of Dentistry. Subjects in this group did not have any debilitating diseases which would have obviously affected growth.

Stramrud (*12*), in a longitudinal study concerned with changes in the cranial base angle with age, concluded that, on the average, the angle remains unchanged from three years to adulthood. This finding was substantiated by Bjork (*1*). King (*6*) found essentially no change in nasopharyngeal depth after 12 years of age. Therefore, it was felt that the measurements of cranial base angle and nasopharyngeal depth used in this study would be relatively stable for the age range selected.

X-RAY PROCEDURE. Lateral cephalic roentgenograms were taken of each subject. The roentgenographic equipment has been described earlier (*5*). It includes a generator with a line compensator capable of delivering 130 kv, an electric timer, a rotating anode with a one-millimeter focal spot, and a Potter-Bucky diaphragm with a 12:1 grid. Stability of the equipment is achieved by heavy mountings to the floor. The distance of the focal spot to the film is fixed at 182.88 cm. A modification of the self-centering Higley head positioner (*4*) is mounted independently of a modified dental chair.

A preliminary study was performed before beginning this investigation. The preliminary study dealt with variations in the position of the atlas as a function of the position of the head in relation to the long axis of the trunk. Two films were taken on each of three subjects. One film was taken with the subject's head oriented in the Frankfort plane and in an upright position in relation to the long axis of the trunk. The second film was taken with the subject's head still oriented in the Frankfort plane, but protruding forward in relation to the long axis of the trunk. As much as five millimeters difference between the two films was observed in the anteroposterior position of the atlas in relation to any palatal or dental structures. It thus appears that when measurements dependent on the position of the arch of the atlas are being used, the head should be positioned not only in the Frankfort plane but also in a consistent position relative to the long axis of the trunk.

In this study, all subjects were positioned with the head in an upright position in relation to the long axis of the trunk. The head was oriented in the Frankfort plane. The subject was instructed to occlude his teeth and not to swallow while the film was being taken.

FILM ANALYSIS. Various landmarks were marked by puncturing each film with a sharp pointed instrument. Reference lines were drawn directly on the films with the same instrument. For angular measurements a protractor with a movable arm was employed. A Boley gauge and a steel tape graduated in millimeters were used for linear measurements. Measurements were made to the nearest one-tenth of a millimeter or to the nearest one-half degree. Linear measurements were corrected for roentgenographic enlargement.

LANDMARKS. To aid in landmark identification, a series of radiographs were taken of cleared skull specimens on which the landmarks used in this study were marked with metal pins. On each roentgenogram obtained in this study, the following landmarks were identified (Figure 1).

a. Nasion (N): a point representing the junction of the frontal and nasal bones.
b. Sella (S): a point representing the center of the bony crypt forming the sella turcica.
c. The most anterior point on the occipital condyles (APOC). If the condyles had developed symmetrically and the subject was correctly oriented, this landmark was, in the present study, defined as being the point of junction of the left occipital condyle with the precondylar portion of the occipital bone. This was true since the

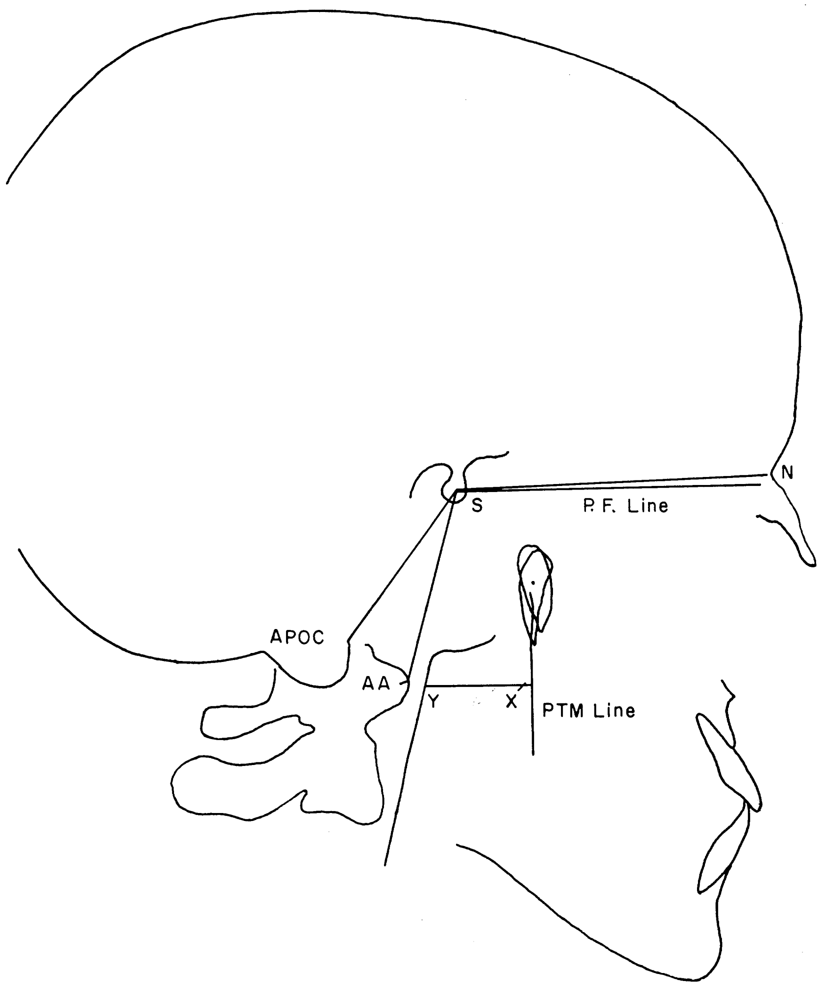

FIGURE 1. Diagram of landmarks utilized in this investigation (see text for full explanation).

subject's left side was closer to the target source than his right side and therefore subject to slightly more roentgenographic enlargement.

d. Anterior arch of the atlas (A): the most anterior point on the first cervical vertebra.

e. Pterygomaxillary line (PTM Line). The pterygomaxillary fissure is usually designated as that point where the anterior margin of the pterygoid process meets the dorsal contour of the maxilla. It was found that such a 'point' could not be reliably located on the films. Therefore, an anterior limit for the nasopharyngeal depth measurement in this study was located in the following manner: the shadow of the pterygomaxillary fissure was divided into the upper, middle, and lower thirds. In the middle third, a point half-way between the anterior and posterior limits of the shadow was identified. From this point, a line (PTM Line) was drawn perpendicular to the Frankfort plane.

f. A line drawn from sella, parallel to the Frankfort plane (PF Line). The Frankfort plane was established as a perpendicular to the vertical post of the ear rod.

g. The point of intersection of the PTM Line with a line parallel to the Frankfort plane and originating at AA (Point X).

h. The point where a line from AA, parallel to the Frankfort plane, intersects the posterior pharyngeal wall (Point Y).

MEASUREMENTS. One of the most frequently used measures of cranial base angulation has been that of nasion-sella-basion. That measure, however, could not be reliably located on the films used in this study and four other measures of cranial base angulation were selected which were based on landmarks that could be reliably located. They were defined in the following way (Figure 1).

a. N-S-APOC: the inferior angle formed by the line connecting nasion, sella, and the most anterior point of the occipital condyle.

b. N-S-AA: the inferior angle formed by the lines connecting nasion, sella, and the most anterior point on the atlas.

c. PF-S-APOC: the inferior angle formed by the intersection of a line drawn from sella, parallel to the Frankfort plane, with a line from sella to the most anterior point on the occipital condyle.

d. PF-S-AA: the inferior angle formed by the intersection of a line drawn from sella, parallel to the Frankfort plane, with a line from sella to the most anterior point on the atlas.

In addition, nasopharyngeal depth was defined as the linear distance between Point X and Point Y.

RELIABILITY. Errors in subject positioning were investigated by comparison of two films taken on each of 15 subjects. Each of the subjects was removed from the x-ray positioning apparatus after the first film was taken. He was then repositioned and a second film was taken. Errors regarding landmarks identification and measurement were investigated either by comparison of observations made by the experimenter and one other observer or by repeated observations made by the experimenter. The specific procedures used and the extent of the errors of measurement are described by Engman (*3*). In general, the magnitude of the errors was consistent with those of similar studies and was considered to be acceptably small.

CRITERION VALUES. For each film, three independently-obtained values were obtained for each of the five dimensions. For the purpose of data analysis, all three values were considered. If two values for a dimension coincided and the third differed by no more than one-half degree or one-tenth of a millimeter, the duplicated value was used. If none of the three values agreed and no more than one degree or two-tenths of a millimeter separated any two, the mean of the three was utilized. In all instances, differences between values fell between these limits.

Results and Discussion

INTERRELATIONSHIPS OF CRANIAL BASE ANGLES. The interrelationships of the four measures of cranial base angulation were evaluated for the combined subject groups by computing correlation coefficients between each possible measurement pair. The correlation values are presented in Table 1. Substantial relationships were demonstrated for only two of the six comparisons. These two correlations involved measures based on the same anterior landmark. The results indicate that the four cranial base angles measured in this study do not represent a common dimension and so each of the four measures were considered in the data analysis.

CRANIAL BASE ANGLES AND NASOPHARYNGEAL DEPTH. Nasopharyngeal depth was correlated with each of the four cranial base angles for the normal and cleft groups separately (see Table 2). Only one of the obtained correlation coefficients, that between N-S-APOC was nasopharyngeal depth for the normal group, was significantly different from zero. This value, −.41, does not suggest a high degree of correlation between the two dimensions. It can also be noted that five of the eight correlation coefficients were negative. On the basis of these results,

TABLE 1. Correlation coefficients between each possible pair of measures of cranial base angle for the normal and cleft palate groups combined. Values of correlation coefficients required for significance at the 5% and 1% levels of confidence are .28 and .37 respectively.

Measure	*N-S-AA*	*PF-S-APOC*	*PF-S-AA*
N-S-APOC	.85	.67	.11
N-S-AA		.45	.16
PF-S-APOC			.83

TABLE 2. Correlation coefficients between nasopharyngeal depth and four measures of cranial base angle in the cleft palate group and in the normal group. For the cleft palate group, coefficients of .40 and higher are required for significance at the 5% level of confidence. For the normal group, coefficients of .39 and higher are required for significance at the 5% level of confidence.

Measures of Cranial Base Angle	*Cleft Palate Group*	*Normal Group*
1. N-S-APOC	.01	−.41
2. N-S-AA	−.09	−.26
3. PF-S-APOC	.22	−.28
4. PF-S-AA	.09	.07

it does not appear that Wildman's hypothesis that there is a positive relationship between cranial base angle and nasopharyngeal depth is justified.

INTERGROUP COMPARISONS. The means, ranges, and standard deviations of each of the five measures made in this study are presented for the cleft palate and normal groups in Table 3. It can be noted that these data are very similar for both groups. The results of *t* tests comparing group means revealed no statistically significant differences on any of the five dimensions. These results are in agreement with those of Brader (*2*).

TABLE 3. Means, ranges, and standard deviations for four measures of cranial base angle and nasopharyngeal depth in the cleft palate and normal groups. Nasopharyngeal depth is reported in millimeters. The other four dimensions are reported in degrees. None of the *t*s are significant.

Measure	*Cleft Palate Group*	*Normal Group*	*t*
1. N-S-APOC			
Mean	128.4	128.6	.15
Range	121.5–140	120–137	
SD	4.48	4.78	
2. N-S-AA			
Mean	112.2	112.4	.69
Range	107–122.5	106–122	
SD	3.64	2.56	
3. PF-S-APOC			
Mean	125.9	125	.65
Range	112–134	116.5–134	
SD	4.48	4.99	
4. PF-S-AA			
Mean	109.7	108.8	.79
Range	100–116	102–115.5	
SD	3.59	4.24	
5. Nasopharyngeal Depth			
Mean	23.53	23.77	.24
Range	13.3–29.1	16.4–30.1	
SD	3.65	3.34	

TABLE 4. Means, ranges, and standard deviations for measures of four cranial base angles and nasopharyngeal depth in the unilateral and bilateral cleft lip and palate sub-groups. Nasopharyngeal depth is reported in millimeters. The other four dimensions are reported in degrees. None of the *t*s are significant.

Measure	*Unilateral*	*Bilateral*	*t*
1. N-S-APOC			
Mean	128.5	128.2	.21
Range	123.5–137	121.5–140	
SD	2.26	4.03	
2. N-S-AA			
Mean	112.3	112.2	.06
Range	107–119	107–122.5	
SD	3.56	4.23	
3. PF-S-APOC			
Mean	126.5	124.8	1.27
Range	121–130	112–134	
SD	3.06	4.8	
4. PF-S-AA			
Mean	110.4	108.7	1.13
Range	107–115	100–116	
SD	2.09	4.55	
5. Nasopharyngeal Depth			
Mean	23.58	23.79	.13
Range	13.3–28.7	20.9–29.1	
SD	4.12	2.88	

The differences between the means of the five dimensions for 13 unilateral and 10 bilateral cleft lip and palate cases were also evaluated (see Table 4). Although these intergroup differences were generally somewhat greater than those found between the normal and cleft palate groups, none of the *t* values were significant at the 5% level.

Summary and Conclusions

The subjects for this study consisted of 24 males with cleft palates and 25 males without clefts. All subjects were Caucasian and ranged in age from 12 to 16 years. Lateral cephalic roentgenograms were taken on all subjects. Four measures of cranial base angulation and one measure of nasopharyngeal depth were taken from each radiograph. The relationships between the various cranial base measurements and the depth of the pharynx were evaluated by correlation techniques. Comparisons on each of the five measurements between the normal and cleft groups and between the unilateral and bilateral cleft groups were made.

From results of this study the following conclusions seem warranted:

1. There is little, if any, relationship between cranial base angulation and nasophyaryngeal depth in either normal or cleft palate individuals. Only the correlation coefficient of −.41 between the angle of nasion-sella-occipital condyle and nasopharyngeal depth in the normal group was

statistically significant. The hypothesis that there is a *positive* relationship between these two dimensions is not supported by these data.

2. There are no differences between normal and cleft palate individuals or between individuals with unilateral clefts and those with bilateral clefts on any of the dimensions studied.

3. The conclusion of Ricketts (*10*) that abnormal pharyngeal depth may be one of the bases of velopharyngeal inadequacy in individuals with clefts is not supported by the results of the present study.

3600 South Logan Street
Englewood, Colorado

References

1. Bjork, A., Cranial base development. *Amer. J. Orthod., 41,* 198–225, 1955.
2. Brader, A. C., A cephalometric x-ray appraisal of morphological variations in cranial base and associated pharyngeal structures: implications in cleft palate therapy. *Angle Orthod., 27,* 179–195, 1957.
3. Engman, L. T., Cranial base angle and nasopharyngeal depth in individuals with cleft palates and individuals without cleft palates. M.S. thesis, Univ. Iowa, 1962.
4. Higley, L. B., A head positioner for scientific radiographic and photographic purposes. *Internat. J. orthod. oral Surg., 22,* 699–704, 1936.
5. Hixon, E. H., Cephalometrics and longitudinal research. *Amer. J. Orthod., 46,* 36–42, 1960.
6. King, E. W., A roentgenographic study of pharyngeal growth. *Angle Orthod., 22,* 23–37, 1952.
7. Mestre, J., and Subtelny, J. D., A comparative cephalometric analysis of untreated cleft palate adults and normal adults. *Cleft Palate Bull., 10,* 7–8, 1960.
8. Ortiz-Monasterio, F., Rebeil, A. S., Vanderrama, M., and Cruz, R., Cephalometric measurements on adult patients with non-operated cleft palates. *Plastic reconstr. Surg., 24,* 53–61, 1959.
9. Ricketts, R. M., Present status of knowledge concerning the cleft palate child. *Angle Orthod., 26,* 10–21, 1956.
10. Ricketts, R. M., The cranial base and soft structures in cleft palate speech and breathing. *Plastic reconstr. Surg., 14,* 47–61, 1954.
11. Ricketts, R. M., The significance of variation in the cranial base and soft structures. *Amer. Assoc. Cleft Palate Rehab. Newsletter, 2,* 4–6, 1952.
12. Stramrud, L., External and internal cranial base. *Acta odont. Scand., 17,* 239–266, 1959.
13. Wildman, A. J., Analysis of tongue, soft palate and pharyngeal wall movement. *Amer. J. Orthod., 47,* 439–461, 1961.