Original Article

Correlation of the Cranial Base Angle and Its Components with Other Dental/Skeletal Variables and Treatment Time

Louis M. Andria, DDS, MS, FICD[a]; Luis P. Leite, DDS, MS[b]; Tracie M. Prevatte, BS[c]; Lydia B. King, MPH[d]

Abstract: Many authors have studied the correlation of cranial base flexure and the degree of mandibular prognathism and classification of malocclusion. This indicates that the cranial base flexure may or may not have an effect on the degree of mandibular prognathism and classification of malocclusion. This study evaluates the correlation of the pretreatment cranial base angle and its component parts to other dental and skeletal cephalometric variables as well as treatment time. The sample consisted of 99 Angle Class II and Class I malocclusions treated in the mixed dentition with cervical headgear and incisor bite plane. Thirty of the patients required full appliance treatment. Treatment duration averaged 4.3 years (SD, 1.5 years). Only the starting cephalograms were used to acquire linear, proportional, and angular cranial base dimensions using Ba-S-N (total cranial base), Ba-S/FH (posterior cranial base), and SN/FH (anterior cranial base). Pearson product moment correlation coefficients were computed and used to assess the association of the following skeletal and dental variables: N-Pg/FH, MP/FH, Y-axis/FH, U1/L1, L1/MP, A-NPg mm, A-Perp, B-Perp, and treatment time with the cranial base measurements. Significance was determined only when the confidence level was $P < .05$. Although there was no significant correlation of BaSN or SN/FH with NPg, the angular BaS/FH, linear BaS mm, and proportional length of BaS %BaN were all statistically negatively correlated to the facial angle. This indicates that the posterior cranial base leg is the controlling factor in relating the cranial base to mandibular prognathism. (*Angle Orthod* 2004;74:361–366.)

Key Words: Cranial base; Mandibular protrusion; Correlation coefficients; Posterior cranial base leg; Treatment time

INTRODUCTION

There is an abundance of contradictory literature relating the cranial base flexure to the classification of malocclusion and the degree of mandibular prognathism. One group contends that the cranial base flexure has no effect on the class of malocclusion or mandibular prognathism,[1–11] whereas others contend that the cranial base flexure is a factor.[12–28] The cranial base consists of two legs. For cephalometric measurement purposes, the maxilla is attached to the anterior leg that extends from the sella turcica (S) to the frontal-nasal suture (N). The mandible is attached to the posterior leg extending from the sella turcica (S) to the anterior border of the foramen magnum, defined as basion (Ba). Therefore, geometric logic would dictate that any change in flexure could affect the relationships of the maxilla and mandible and influence the type of malocclusion.

This investigation tests several null hypotheses on the effect of the cranial base angle on skeletal profile and dental relationship.

- The cranial base angle (BaSN) and its component parts (BaS/FH and SN/FH) will have no effect on the maxilla and mandible positions in the profile.
- The cranial base angle and its component parts will have no influence on the alveolar positions in the profile.
- The cranial base angle and its component parts will have an effect on incisor relationships.
- The cranial base angle and its component parts will have no relationship to the length of treatment time.

MATERIALS AND METHODS

Pretreatment cephalometric records of 99 Angle Class II and Class I male and female patients were selected at ran-

[a] Adjunct Associate Professor, Pediatric Dentistry/Orthodontics, Medical University of South Carolina, Charleston, SC.
[b] Associate Professor, Pediatric Dentistry/Orthodontics, Medical University of South Carolina, Charleston, SC.
[c] Dental Student, College of Dentistry, Medical University of South Carolina, Charleston, SC.
[d] Graduate Resident, College of Medicine Biometry and Epidemiology, Medical University of South Carolina, Charleston, SC.
Corresponding author: Louis M. Andria, DDS, MS, FICD, Pediatric Dentistry/Orthodontics, Medical University of South Carolina, 25 Bee Street, PO Box 250126, Charleston, SC 29425
(e-mail: louandria@nuvox.net).

Accepted: July 2003. Submitted: June 2003.

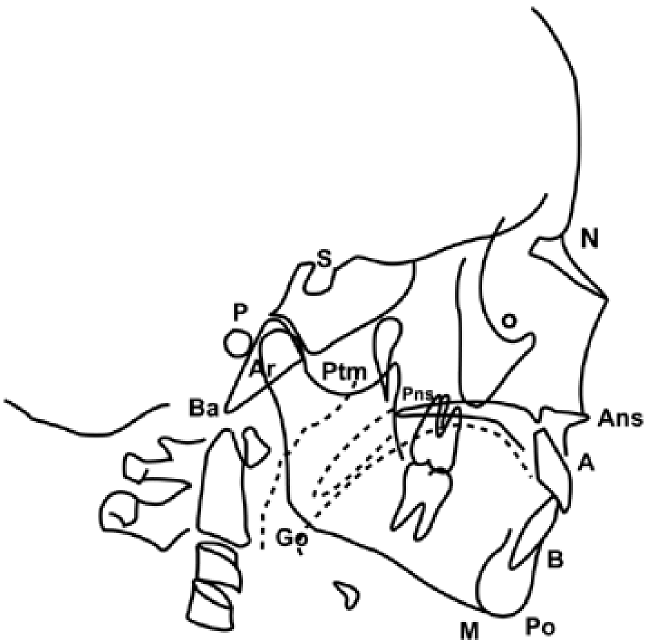

FIGURE 1. Cephalometric landmarks.

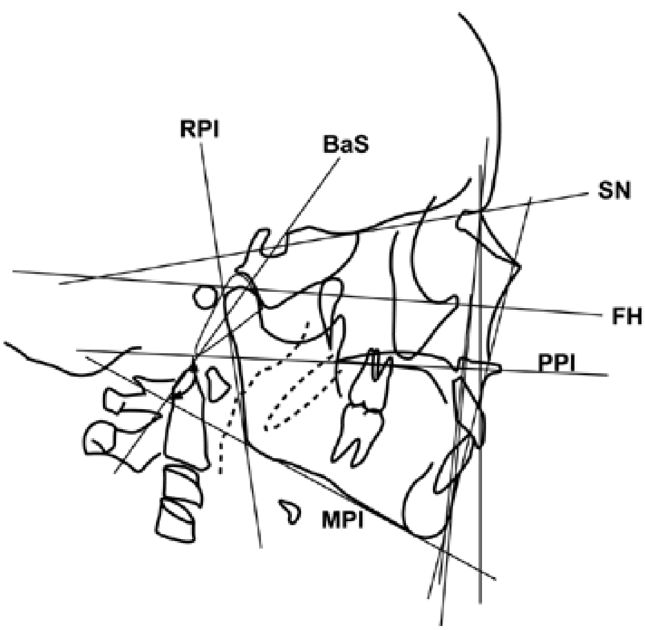

FIGURE 2. Cephalometric planes.

dom from the files from one of the author's private practice and donated to the Pediatric Dentistry/Orthodontic Department at the Medical University of South Carolina. There were 34 males and 65 females, and the mean age of the patients was 9.7 years with a standard deviation of two years. All patients were treated in the mixed dentition, with 30 requiring fixed-appliance therapy. The criteria used in selection were as follows: (1) lateral cephalometric head films were of excellent quality with clearly visible cephalometric landmarks; (2) no patients had congenital anomalies, significant facial asymmetries, or congenitally missing teeth; and (3) records for each patient included dental casts, facial photographs, full mouth, or panoramic radiographs and lateral cephalometric head films. Pretreatment starting records were selected for the study. Each starting cephalometric head film was traced, and both midline and bilateral images were traced. All bilateral images were bisected and thereafter treated as midline structures inasmuch as the cranial base is a midline structure. Linear measurements were read to the nearest 0.05 mm, and all angular measurements were read with a standard protractor to the nearest 0.05°. A right-angle coordinate system, as described by Coben,[29] was used to determine proportions relative to total cranial base length. The presence of clinical treatment folders enabled the inclusion of treatment time. The mean treatment time was 4.3 years with a standard deviation 1.5 years.

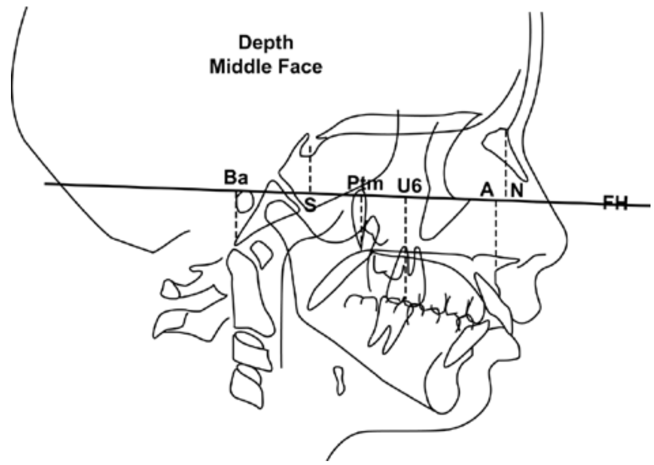

FIGURE 3. Cranial base and middle-face depth.

Pearson product moment correlation coefficients and *P* values were computed for each of the cranial base measurements Ba-S-N (total cranial base), Ba-S/FH (posterior cranial base), and SN/FH (anterior cranial base) with the following variables: N-Pg, MP/FH, Y-axis/FH, U1/L1, L1/MP, A-NPg mm, A-Perp, B-Perp, BaS %BaN, and treatment time. Significance was determined only when the confidence level was $P < .05$.

Cephalometric landmarks and measurements

The landmarks and planes used are presented in Figures 1 and 2. Linear measurements were acquired by projecting cranial landmarks at right angles to Frankfort horizontal (Figure 3). A right-angle coordinate system was used to determine proportional data.[29] The position of the alveolar bases were determined by relating A to the facial plane and points A and B as perpendicular to Frankfort horizontal and recording the linear distance from the facial plane (A and B perpendicular). The legs of the cranial base angle and

TABLE 1. Correlation of Cranial Base Angle with Other Cephalometric Variables

Variable	Correlation Coefficient	*P*
BaSN with BaS/FH	.917715	<.0001*
BaSN with SN/FH	.643815	<.0001*
BaSN with facial angle	−.166264	>.05
BaSN with mandibular plane	.016222	>.05
BaSN with Y-axis	−.017093	>.05
BaSN with interincisal angle	−.087958	>.05
BaSN with lower incisor to MP	.114729	>.05
BaSN with A-NPg	.032453	>.05
BaSN with A-Perp	−.073202	>.05
BaSN with B-Perp	−.169722	>.05
BaSN with BaS %BaN	.799225	<.0001*
BaSN with treatment time	−.181916	>.05

* Statistically significant.

TABLE 2. Correlation of Posterior Cranial Base Angle with Other Cephalometric Variables

Variable	Correlation Coefficient	*P*
BaS/FH with facial angle	−.30349	.0023*
BaS/FH with mandibular plane	.073017	>.05
BaS/FH with Y-axis	.122036	>.05
BaS/FH with interincisal angle	−.132781	>.05
BaS/FH with lower incisor to MP	.169976	>.05
BaS/FH with A-NPg	.095684	>.05
BaS/FH with A-Perp	−.13402	>.05
BaS/FH with B-Perp	−.263645	.0084*
BaS/FH with BaS %BaN	.867678	<.0001*
BaS/FH with treatment time	−.175447	>.05

* Statistically significant.

facial and mandibular plane angles were related to the Frankfort horizontal.

RESULTS

Table 1 indicates that the only significant correlation found with the cranial base angle was the positive correlation with its two legs and with the proportional length of the posterior cranial base. In contrast, Table 2 illustrates that the posterior leg had a significant negative correlation with the facial angle and B perpendicular and of course a positive correlation with its proportional linear length to total cranial base length. Table 3 indicates that the anterior leg only has a significant negative correlation to the Y-axis and a significant positive correlation to the linear proportional length of the posterior leg to the total cranial base length.

The linear length of the posterior leg of the cranial base had a significant positive correlation with cranial base angle; the posterior cranial base angle to Frankfort horizontal, the anterior cranial base angle to Frankfort horizontal, and the facial angle are given in Table 4. Although there was no correlation to the maxilla's position in the profile or in the interincisal angle, a significant negative correlation was indicated by the lower incisor angulation to the mandibular plane and to the mandibular alveolar position in the profile as well as to the treatment time.

Table 5 shows whether a difference existed between the proportional lengths of the posterior leg compared with the actual linear lengths. A striking contrast existed, with a positive correlation of the proportional length of BaS to the

TABLE 3. Correlation of Anterior Cranial Base Angle with Other Cephalometric Variables

Variable	Correlation Coefficient	*P*
SN/FH with facial angle	.181484	>.05
SN/FH with mandibular plane	−.090229	>.05
SN/FH with Y-axis	−.27219	.0064*
SN/FH with interincisal angle	.047725	.05
SN/FH with lower incisor to MP	−.063338	>.05
SN/FH with A-NPg	−.101069	>.05
SN/FH with A-Perp	.082349	>.05
SN/FH with B-Perp	.095109	>.05
SN/FH with BaS %BaN	.251986	.02552*
SN/FH with treatment time	−.103519	>.05

* Statistically significant.

TABLE 4. Correlation of Posterior Cranial Base Linear Length with Other Cephalometric Variables

Variable	Correlation Coefficient	*P*
BaS mm with BaSN	.748958	<.0001*
BaS mm with BaS/FH	.827113	<.0001*
BaS mm with SN/FH	.206977	.0039*
BaS mm with facial angle	−.28054	.0052*
BaS mm with MP/FH	.105706	>.05
BaS mm with Y-axis	.173118	>.05
BaS mm with U1/L1	−.19377	>.05
BaS mm with lower incisor to MP	−.241258	.0172*
BaS mm with A-NPg	.162245	>.05
BaS mm with A-Perp	−.11799	>.05
BaS mm with B-Perp	−.23399	.019*
BaS mm with treatment time	−.25442	.011*

* Statistically significant.

TABLE 5. Correlation of Proportional Cranial Base Length with Other Cephalometric Variables

Variable	Correlation Coefficient	*P*
BaS %BaN with facial angle	−.23095	.0192*
BaS %BaN with mandibular plane	.108482	>.05
BaS %BaN with Y-axis	.167436	>.05
BaS %BaN with interincisal angle	−.26593	.0078*
BaS %BaN with lower incisor to MP	.254832	.0109*
BaS %BaN with A-NPg	.147829	>.05
BaS %BaN with A-Perp	−.03689	>.05
BaS %BaN with B-Perp	−.20278	.0441*
BaS %BaN with BaS/FH	.867678	<.0001*
BaS %BaN with SN/FH	.251986	.0255*
BaS %BaN with treatment time	−.22796	.0297*

* Statistically significant.

lower incisor inclination, indicative of an increase in the incisor angles. An apparent clashing existed with the negative correlation of the lower incisor inclination on the mandibular plane to the linear length of BaS, showing a decrease in the angle. A larger proportional length may be the result of a longer posterior cranial base to a shorter total cranial base length as demonstrated by the significant positive correlation of BaSN to SN/FH. A positive correlation would reduce the length of both the anterior and total cranial base lengths and thereby proportionally increase the posterior cranial base length. Both the linear and proportional lengths had the same statistically significant negative correlation to the facial angle, B perpendicular, and treatment time. Both had similar positive significant correlations to BaS/FH, SN/FH, and BaSN.

DISCUSSION

Frankfort horizontal was selected as the reference plane in describing the anterior and posterior cranial bases because of the close physiologic relation between the ear and the eye as represented by the cephalometric landmarks porion and orbital.[30] The variation of the Frankfort plane has been shown to vary around zero degrees and represents a horizontal to the earth's surface.[31] The semicircular canals in the ear and the orbital size change little at an early age with the downward movement of the maxilla compensated by deposition on the orbital floor.[32] The sense of balance is intimately related to sight. One only has to observe any individual attempting to maintain their equilibrium with their eyes closed. Any change in this relationship during growth would have adverse effects.

It is wrong to equate the variation of the cranial base angle only to Basion because two legs are present and three points of reference (any of which can vary horizontally or vertically) are necessary in the formation of an angle (Figure 4). The back leg (BaS) of the cranial base angle (BaSN) may be tipped anteriorly or posteriorly, whereas the front leg (SN) may also be tipped up or down anteriorly by a variation in either S or N vertically. Furthermore, variable lengths may compensate for any cranial deflection, eg, an acute posterior leg that places the mandible forward can have this action negated by a long posterior leg that places both Basion and the mandible posteriorly and vice versa.

Initial evaluation of the cranial base angle may be in agreement with previous studies that indicated that the degree of flexure has no effect on the class of malocclusion.[1–11] In contrast the statistically significant negative correlation of the posterior cranial base angle to both the facial angle and B perpendicular would imply that as the angle increased, both the skeletal and alveolar components of the mandible would be located more posteriorly in the face, as seen in the typical Class II division 1 patient. This may explain the contrasting findings of the studies indicating the

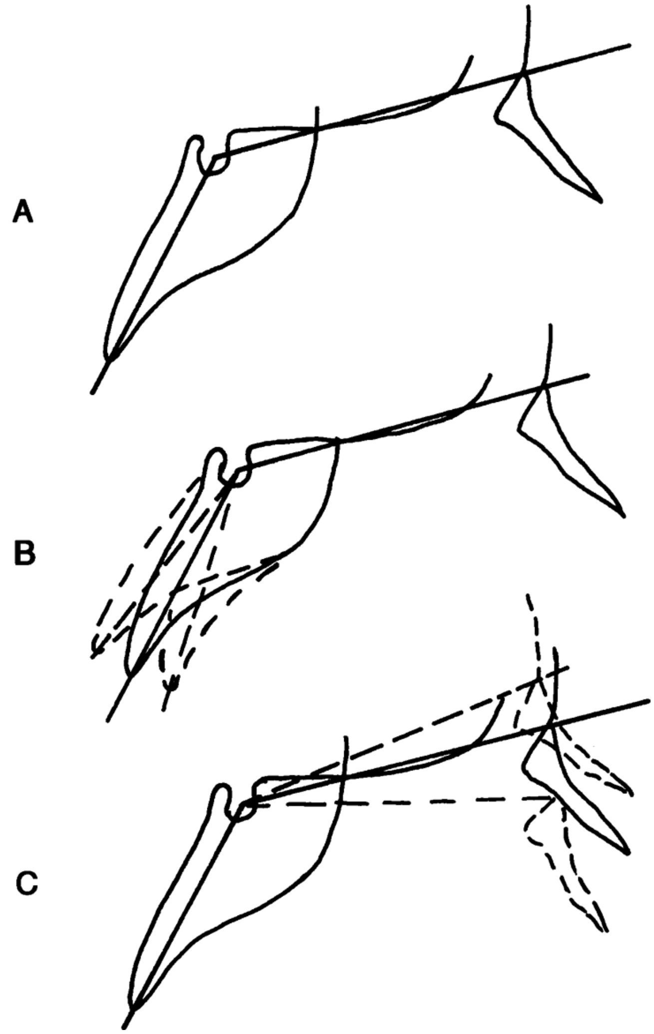

FIGURE 4. (A) Cranial base angle. (B) Cranial base angle can be altered by posterior flexion. (C) Cranial base angle can be altered by changes in anterior height. Each variation can affect the mandibular relation to other facial structures.

opposite,[12–28] where only the total cranial base angle was evaluated.

The statistically negative correlation of SN/FH to the Y-axis implies that a larger anterior cranial base angle would produce a more acute Y-axis. The Y-axis has been used as an indicator of both horizontal and vertical mandibular development. Yet, no statistical significance is seen when SN/FH is related to either the facial angle or the mandibular plane (Table 3). An additional factor that cannot be ignored is the position of sella turcica. A lower sella would increase the anterior cranial base angle and simultaneously reduce the Y-axis. Once again finding an answer appears to produce another question. The answer may be the statistically significant positive correlation of SN/FH to the proportional length of the posterior cranial base. This corroborates the suggestion of a lower position of sella. A lower sella would produce a larger cranial base angle, and Table 1 demonstrates a statistically positive correlation of BaSN to the proportional length of BaS, whereas a higher nasion would have no effect on the effective length of BaS.

The additional factor of linear and proportional lengths of the posterior cranial base may compensate for angular variations. Both the total cranial base and posterior cranial base angles may well be within a one standard deviation range, but the linear and proportional dimensions may vary. Because the glenoid fossa is located in the posterior cranial base, an elongated cranial base would bring the glenoid fossa back[12,22] and the mandible with it. Tables 2 and 4 have almost identical negative significant correlations relating both the angular and linear posterior cranial base values to the facial angle and the B perpendicular.

The significant negative correlations to treatment time and insignificance with the angular values found in both the linear and proportional posterior cranial base lengths could be indicative that the linear factors are more influential than the angular in predicting the length of treatment time. Apparently treatment time will be reduced when the linear and proportional lengths of the posterior leg are longer. An obtuse posterior cranial base angle may, on occasion, have a short linear or proportional length, thereby reducing the significance level of the angular variable. A shorter posterior length in an obtuse posterior cranial base angle would place the glenoid fossa and the condyle at a higher level, possibly increasing the mandibular plane angle. This would be accompanied by a greater vertical component to mandibular growth and a lesser horizontal component, thereby increasing the treatment time for Class II correction.

Future studies will include any changes that may have occurred at the conclusion of treatment and a minimum of two years after removal of all retainers. A possible increase in the sample size may enable an evaluation of the constancy of the saddle angle,[33] sex differences,[34] sex differences during pubescence,[35,36] and cranial variation after treatment and after retention.

CONCLUSIONS

The cranial base or saddle angle by itself does not appear to have any statistical significance to the position of the chin in the profile, the incisor relationships, the alveolar points A and B, or the length of treatment time. The anterior cranial base does not appear to have any statistically significant relationship to the position of the chin in the profile, the mandibular alveolar component, the incisor relationships, or the length of treatment time.

In contrast, the posterior cranial base angle has a statistically significant negative correlation to both the skeletal facial angle and the alveolar point reflecting a more posterior skeletal and alveolar position of the mandible. The linear length of BaS demonstrated statistically negative correlations to the facial angle, the alveolar point B, the lower incisors angulation on the mandibular plane, and the treatment time. The proportional length differed from the linear only with an additional negative correlation of the interincisal angle and a positive correlation of the lower incisors angle on the mandibular plane. As the proportional length increased, the interincisal angle decreased, whereas the lower incisor became more upright to the mandibular plane.

REFERENCES

1. Wilhelm BM, Beck MF, Lidral AC, Vig KWL. A comparison of cranial base growth in Class I and Class II skeletal patterns. *Am J Orthod Dentofacial Orthop.* 2001;119:401–405.
2. Rothstein T, Phan XL. Dental and facial characteristics and growth of females and males with Class II Division 1 malocclusion between the ages of 10 and 14 (revisted). Part II. Anteroposterior and vertical circumpubertal growth. *Am J Orthod Dentofacial Orthop.* 2001;120:542–555.
3. Sandham A, Cheng L. Cranial base and Cleft lip and palate. *Angle Orthod.* 1988;58:163–168.
4. Renfroe EW. A study of the facial patterns associated with Class I, Class II division 1 and Angle Class I, Class II division 2 malocclusions. *Angle Orthod.* 1948;18:12–15.
5. Guyer EC, Ellis EE, McNamara JA, Behrents RG. Components of class III malocclusion in juveniles and adolescents. *Angle Orthod.* 1986;56:7–30.
6. Battagel JM. The aetiology of Class III malocclusion examined by tensor analysis. *Br J Orthod.* 1993;20:283–296.
7. Varella J. Longitudinal assessment of Class II occlusal and skeletal development in the deciduous dentition. *Eur J Orthod.* 1993; 15:345.
8. Varella J. Early development traits in Class II malocclusion. *Acta Odontol Scand.* 1998;56:375–377.
9. Dhopatkar A, Bhatia S, Rock P. An investigation into the relationship between the cranial base angle and malocclusion. *Angle Orthod.* 2002;72:456–463.
10. Klocke A, Nanda RS, Kahl-Nieke B. Role of cranial base flexure in developing sagittal jaw discrepancies. *Am J Orthod Dentofacial Orthop.* 2002;122:386–391.
11. Lewis AB, Roche AF, Wagner B. Pubertal spurts in cranial base and mandible: comparisons between individuals. *Angle Orthod.* 1985;55:17–30.
12. Bjork A. Cranial base development. *Am J Orthod.* 1955;41:198–225.
13. Hopkin GB, Houston WJB, James GA. The cranial base as an etiologic factor in malocclusion. *Angle Orthod.* 1968;38:250–255.
14. Kerr WJS, Hirst D. Craniofacial characteristics of subjects with normal and post normal occlusions—a longitudinal study. *Am J Orthod Dentofacial Orthop.* 1987;92:207–212.
15. Kerr WJS, Adams CP. Cranial base and jaw relationships. *Am J Anthrop.* 1988;77:213–220.
16. Bacon W, Eiller V, Hildwein M, Dubois G. The cranial base in subjects with dental and skeletal class II. *Eur J Orthod.* 1992;14: 224–228.
17. Dibetts JMH. Morphological association between the Angle classes. *Eur J Orthod.* 1996;18:111–118.
18. Bacetti T, Antonini A. Glenoid fossa position in different facial types; a cephalometric study. *Br J Orthod.* 1997;24:55–59.
19. Singh GD, McNamara JA, Lozanoff S. Finite element analysis of the cranial base in subjects with class III malocclusion. *Br J Orthod.* 1997;24:103–112.
20. Anderson D, Popovich F. Lower cranial base height versus cranial facial dimensions in Angle Class II malocclusions. *Angle Orthod.* 1983;53:253–260.
21. Anderson D, Popovich F. Relation of cranial base flexure to cra-

nial form and mandibular position. *Am J Phys Anthrop.* 1983;61: 181–187.
22. Scott JH. *Dento-Facial Development and Growth.* Oxford: Pergamon Press; 1967.
23. Rickets RM. Facial and dental changes during orthodontic treatment as analyzed from the temporomandibular joint. *Am J Orthod.* 1955;41:407–434.
24. Moss ML. Correlation of cranial base angulation with cephalic malformations and growth disharmonies of dental interest. *N Y State Dent J.* 1955;24:452–454.
25. James GA. Cephalometric analysis of 100 Class II div 1 malocclusions with special reference to the cranial base. *Dent Pract.* 1963;14:35–46.
26. Houston WJB. A cephalometric analysis of Angle Class II div 2 malocclusion in mixed dentition. *Dent Pract.* 1967;17:372–376.
27. Kerr WJS, Hirst D. Craniofacial characteristics of subjects with normal and postnormal occlusions—a longitudinal study. *Am J Orthod Dentofacial Orthop.* 1987;92:207–212.
28. Bjork A. The nature of facial prognathism and its relation to normal occlusion of the teeth. *Am J Orthod.* 1951;37:106–124.
29. Coben SE. The integration of facial skeletal variants. *Am J Orthod.* 1955;41:407–434.
30. Ricketts RM, Schullof RJ, Bahga L. Orientation-sella-nasion or Frankfort horizontal. *Am J Orthod.* 1976;69:648–654.
31. Downs WB. Variations in facial relationships: their significance in treatment and prognosis. *Am J Orthod.* 1948;34:812–840.
32. Enlow HE. *Handbook of Facial Growth.* Philadelphia, Pa: WB Saunders Co; 1975.
33. Lewis AB, Roche AF. Saddle angle: constancy or change? *Angle Orthod.* 1977;47:46–53.
34. Roche AF, Lewis AB. Sex differences in the elongation of the cranial base during pubescence. *Angle Orthod.* 1974;44:279–294.
35. Lewis AB, Roche AF. Cranial base elongation in boys during pubescence. *Angle Orthod.* 1974;44:83–93.
36. Lewis AB, Roche AF. Cranial base elongation in girls during pubescence. *Angle Orthod.* 1972;42:358–367.