Extreme Variation in Vertical Facial Growth and Associated Variation in Skeletal and Dental Relations

John R. Isaacson, D.D.S., M.S.D.
Robert J. Isaacson, D.D.S., Ph.D.
T. Michael Speidel, D.D.S., M.S.D.
Frank W. Worms, D.D.S., M.S.D.

Facial growth and development have been frequently studied using cephalometric roentgenography. Most of these studies have concluded that facial growth relative to a cranial base line proceeds along a vector composed of variable amounts of horizontal forward growth and vertical downward growth. The relative proportions of forward growth and downward growth have been characterized as relatively constant for a given individual producing a relatively constant vectorial direction of facial growth.

The sites of the greatest amounts of facial growth have been documented by many methods. Good evidence has been presented that major sites of bony additions include the facial sutures and maxillary alveolar processes and the mandibular condyle and alveolar processes.[4]

Since the mandible possesses an articulation with the skull, it is necessary that vertical growth increases in the anterior face exactly equal vertical growth increases in the posterior face in amount and timing or the mandible will rotate at its articulation. If vertical increases at the facial sutures and/or the alveolar process should exceed the vertical increases at the mandibular condyle, the mandible would rotate backward. Conversely, if vertical growth at the condyle should exceed the sum of the vertical growth components at the facial sutures and alveolar processes, the mandible would rotate forward. Either one of these changes would alter the downward and forward constant vectorial direction of facial growth.

In a series of excellent reports Björk[1-3] has clearly demonstrated that such rotations of the mandible do take place in at least some examples of normal growth. Metallic implants were placed in the maxilla and mandible to permit a description of absolute growth changes of the jaws themselves. He noted that such rotations of the mandible are not discernible using conventional cephalometric landmarks and methods due to extensive remodeling of the mandible and its lower border. Thus, a given individual does demonstrate an apparent linear consistency of growth pattern and direction. This consistency is not necessarily a result of regular equal increments of growth. It may be achieved by very unequal amounts of growth at the major growth sites accompanied by mandibular rotation and remodeling. These remodeling changes tend to reshape the mandible to recreate former spatial relationships. Thus, the consistency of pattern and resultant growth direction is maintained, but the mechanism of manifestation is perhaps more complex than usually suspected.

Presented by Dr. Robert Isaacson as the fourth Wendell L. Wylie Memorial Lecture at the University of California, November 1970.

Mandibular rotations can logically be expected to alter facial heights. A number of workers have investigated vertical facial growth changes, but only a few have considered the possibility of mandibular rotations.[1-3,5-9,11-13,15,16] In order to examine the relationships between vertical parameters and mandibular rotation, this study was designed to examine extreme variations in facial growth. It was hypothesized that mandibles that are rotating either backward or forward would manifest higher or lower mandibular plane - sella nasion angles, respectively. Remodeling could be expected to be continually masking the changes, but the growth pattern of one extreme should manifest substantial morphological differences from the opposite extreme of growth pattern.

Methods and Materials

The data in this study were collected from pretreatment cephalometric radiographs and study models of patients present in the active files of the Division of Orthodontics, School of Dentistry, University of Minnesota. The files were screened for all patients with a recorded mandibular plane - sella nasion angle greater than 38 degrees or less than 26 degrees. These values represent one standard deviation from Riedel's[10] mean plus an allowance for measurement error.

This search yielded 183 patients with recorded angles greater than 38 degrees and 60 patients with recorded angles less than 26 degrees (approximately 30 per cent of the total case load). From each of these two groups 20 records were randomly selected. A third group of 20 patients whose mandibular plane angles were recorded at 32 degrees, Riedel's mean, was similarly selected. The mean age of these three groups of patients was in years: low MP-SN 13.34 ±2.09, average MP-SN 13.26±1.69 and high MP-SN 14.20±3.16.

New tracings were constructed of all sixty lateral head films. Landmarks were identified by conventional definition except where noted otherwise, and lines constructed. Measurements were grouped according to the following: (Fig. 1)

1. Vectorial resultants of anteroposterior and vertical relations
   - MP to SN - mandibular plane - sella nasion angle
   - OP to SN - occlusal plane - sella nasion angle
   - OP to MP - occlusal plane - mandibular plane angle
2. Anteroposterior relations
   - A. Bone to bone
     - SNA - sella nasion - A point angle
     - SNB - sella nasion - B point angle
     - ANB - A point nasion - B point angle
   - B. Tooth to bone
     - S to 6 - linear distance of the mesiobuccal cusp tip of the maxillary first molar from sella along SN
3. Vertical relations
   - A. Bone to bone
     - TFH - linear total facial height (menton - nasion) measured along a perpendicular to SN
     - UFH - linear upper facial height (anterior nasal spine - nasion) measured along a perpendicular to SN
     - LFH - linear lower facial height (anterior nasal spine - menton) measured along a perpendicular to SN
     - Ramus height - linear height of the ramus (summit of condyle taken as top of ear rod to gonion) measured perpendicular to SN

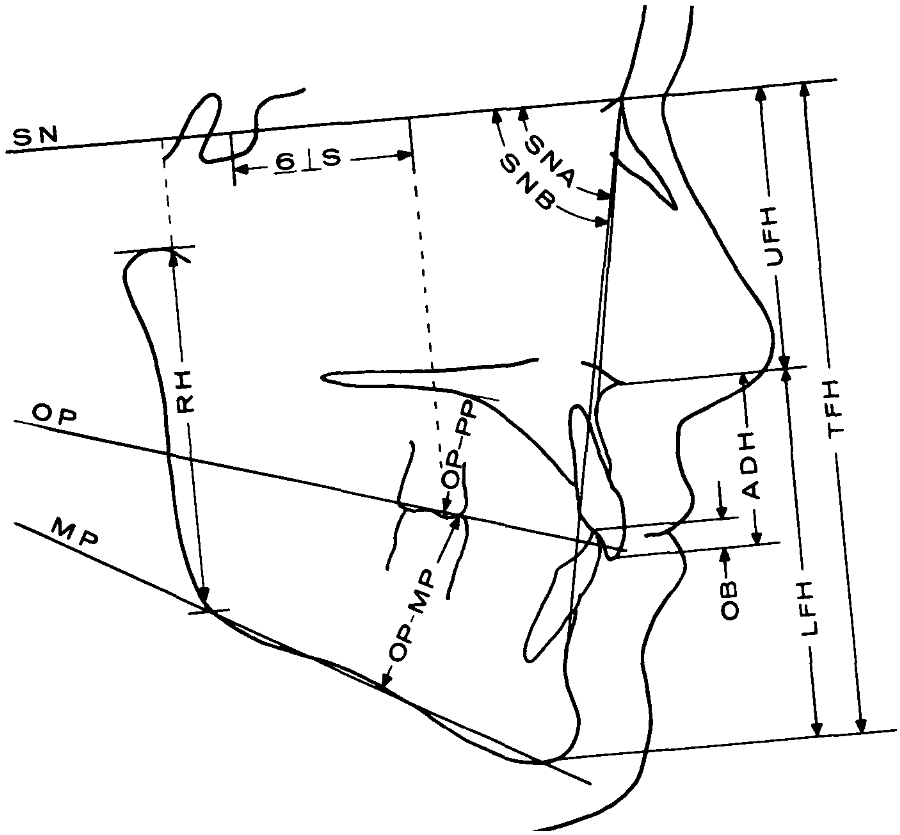

Fig. 1 Parameters of facial growth measured in this study. See methods and materials section of text for definition of lines used.

B. Tooth to bone

OP-PP - height of maxillary first molar measured as a perpendicular to occlusal plane through the mesiobuccal cusp to inferior cortex of palate

OP-MP - height of mandibular molar measured as a perpendicular to the mandibular plane through the mesiobuccal cusp to the occlusal plane

Anterior dental height - linear distance from ANS to the incisal edge of the maxillary central incisor along a perpendicular to SN

C. Tooth to tooth

Overbite - linear distance between the incisal edges of the maxillary and mandibular central incisors along a perpendicular to SN

Study models were utilized to measure palatal width. This was recorded as the distance between the mesiolingual cusp tips of the maxillary first molars.

Results

The vectorial parameters, MP-SN, OP-SN and OP-MP, for the three groups of patients are shown in Table I. The mean mandibular plane angle decreased from the high group (42.80) to the average group (31.75) to the low

TABLE I

Vectorial Resultants of Anteroposterior and Vertical Relations

	HIGH MP-SN		AVERAGE MP-SN		LOW MP-SN	
Angle	Mean	S.D.	Mean	S.D.	Mean	S.D.
MP-SN	42.80	3.64	31.75	1.36	22.53	2.21
OP-SN	20.25	3.16	15.70	2.33	12.93	2.94
OP-MP	22.20	3.68	16.05	2.48	9.43	3.02

group (22.53). As the mandibular plane angle decreased so did the component angles. The OP-MP angle decreased from a mean of 22.20 for the high group, to 16.05 for the average group, to 9.43 for the low group. The mean OP-SN angle also decreased, but more slowly. The sum of OP-SN and OP-MP approximately totalled the MP-SN angle.

Table II shows that, as the MP-SN angle decreased, the mean values for SNA and SNB increased. The mean SNA went from 78.88 for the high angle group, to 81.18 for the average group, and 83.75 for the low angle group. The mean SNB showed similar changes going from 75.05 in the high group, to 77.98 in the average group, to 80.35 in the low group. The mean ANB for each group remained nearly constant.

TABLE II

Bone to Bone and Tooth to Tooth

	HIGH MP-SN		AVERAGE MP-SN		LOW MP-SN	
Angle	Mean	S.D.	Mean	S.D.	Mean	S.D.
SNA	78.88	4.05	81.18	2.35	83.75	3.32
SNB	75.05	4.17	77.98	2.12	80.35	3.50
ANB	3.82	5.17	3.20	3.32	3.42	2.32
Sella 6*	28.25	6.10	32.50	3.91	35.25	4.98

* measured in millimeters

The linear distance from a perpendicular to SN through sella to the upper first molar describes the horizontal placement of the maxillary denture. These mean measurements also increased as the MP-SN angle decreased going from 28.25 mm in the high group, to 32.50 mm in the average group, to 35.25 mm in the low group. Table II shows, therefore, that not only the skeletal components increased in the horizontal dimension as the MP-SN angle decreased, but also the dental components became more anteriorly situated.

Table III shows that total face height increased appreciably when the MP-SN angle increased. The means of total facial height were 122.7 mm for the high angle group, 115.3 for the average group and 110.2 for the low group. Most of these increases were in

TABLE III

Vertical Relations — Bone to Bone

	HIGH MP-SN		AVERAGE MP-SN		LOW MP-SN	
Angle	Mean	S.D.	Mean	S.D.	Mean	S.D.
TFH	122.70	8.87	115.30	5.39	110.20	6.84
UFH	53.45	3.29	53.25	2.60	53.02	2.95
LFH	69.13	6.93	62.05	3.72	57.18	5.43
Ramus Ht	52.35	3.86	56.30	3.92	58.75	3.31

TABLE IV

Vertical Relations — Tooth to Bone and Tooth to Tooth
with Palatal Width Dimensions taken from Study Models

with Palatal Width Dimensions taken from Study Models

	HIGH MP-SN		AVERAGE MP-SN		LOW MP-SN	
Linear Distance (mm)	Mean	S.D.	Mean	S.D.	Mean	S.D.
Pal Ht, OP-PP	22.50	3.05	19.63	1.73	17.13	1.77
Mand Ht, OP-MP	31.20	2.70	28.20	2.26	28.30	2.52
Ant Dent Ht	31.30	1.80	28.70	1.87	26.30	2.89
Overbite	–0.65	3.47	3.38	2.09	5.25	2.28
Pal Width	35.60	3.37	38.12	2.14	40.57	3.47

the lower face height. The mean upper face height remained constant at approximately 53 mm. The mean lower facial height for the high angle cases was 69.13 mm, the average group 62.05 and the low angle group 57.18.

The mean height of the ramus was inversely related to the MP-SN angle. In other words, the ramus was shortest (52.35 mm) in the high angle group and longest in the low angle group (58.75). The average group had a mean ramal length of 56.3 mm.

Table IV shows the summations of the dental measurements. The amount of posterior alveolar development in the upper arch was measured from the cephalometric x-ray as the perpendicular distance from the occlusal plane (OP) to the inferior edge of the palate (PP) through the mesiobuccal cusp of the first molar. The mean of this measurement decreased as the MP-SN angle decreased. In the high angle cases the mean distance was 22.50 mm. This distance decreased to means of 19.6 mm for the average group and 17.1 for the low angle group.

The posterior alveolar mandibular development similarly decreased with decreases in the MP-SN angle but much less dramatically than the maxilla did. The mandibular height showed a mean SN angle decreased. The mean anterior dental height for the high group was 31.3 mm. The same parameter in the average group was 28.7 mm and the low group 26.3 mm.

Overbite became deeper when the MP-SN angle decreased. In the high angle group there was open bite instead of overbite. The mean amount of open bite in the high group was —0.65 mm, but this group also had a larger standard deviation. Actual values ranged from an open bite of 9.5 mm to a closed bite of 4.0 mm. The mean overbite for the average group was 3.38 mm and for the low group 5.25.

The width of the palate through the molar areas increased as the MP-SN decreased. The mean width for the high angle group was 35.6 mm. This increased to a mean of 38.12 mm for the average group and 40.57 for the low angle group.

Table V shows the results of percentage contributions instead of absolute values. The percentage of LFH decreased from 56.17 in the high angle group, to 53.77 for the average group, to 51.85 in the low angle group. The complementary upper facial height percentages were 43.83 (high), 46.23 (average) and 46.64 (low), even though the absolute measurements re-

become frank open bites as their occlusal curves are leveled. Therefore, forward rotaters should have all teeth banded including second molars and reverse curves utilized in the archwires. Backward rotaters should have only the necessary teeth banded, preferably not the second molars, with sufficient occlusal curve present in the archwires to maintain the vertical occlusal curve present.

Intermaxillary elastics will produce posterior extrusion and help deep-bite, forward rotaters and hurt backward rotaters with open-bite tendencies. Extractions will harm deep-bite, forward rotaters to the extent that anchorage is lost and the molars come forward and/or the incisors upright their inclinations. The reverse, of course, applies to backward rotaters where extractions are desirable because molars can come forward and incisors can be uprighted to increase overbite. Note, however, that the anchorage loss can reduce overbite by mandibular rotation, but incisor uprighting is only a dental correction and does not improve facial height esthetics.

The maxillary posterior alveolar process was found to be much more important than the posterior mandibular alveolar process in contributing to vertical development. Data in Table IV show that in both low and average mandibular plane angle groups the mean mandibular height in the first molar area was essentially the same. In the high angle cases, the mean mandibular molar height was increased by three millimeters over the other groups. Although mandibular height does contribute to the increased vertical development of the high angle case, it is relatively less important as shown in Table VI.

Theoretically, growth changes in any one of several areas can increase or decrease vertical facial dimensions. This study has examined only three of these areas, ramus height, posterior maxillary alveolar height and posterior mandibular alveolar height. An area which was not examined is the position of the glenoid fossa. If this fossa can become situated in a more superior position, it gives the same effect as shortening the ramus. Conversely, lowering of the fossa affects mandibular position just as a long ramus would. Also, vertical downward movement of the maxilla at its sutures would act like alveolar increases.

Substantial evidence exists today that the simplicity or complexity of the force system is not the deciding factor in producing the best treatment. In average skeletal patterns much leeway exists and the undesirable side effects of inappropriate mechanotherapy will not be so obvious. Severe skeletal pattern discrepancies, however, represent at least one third of a typical practice and are the major source of problem cases. These must be managed carefully and appropriately with full knowledge of what has happened and what can happen in extreme variations in facial growth.

School of Dentistry
University of Minnesota
Minneapolis, Minnesota 55455

BIBLIOGRAPHY

1. Björk, A.: Facial growth in bilateral hypoplasia of the mandibular condyle: a radiographic, cephalometric study of a case, using metallic implants, *Vistas in Orthodontics*, Lea & Febiger, p. 347-358, 1962.
2. ———: Variations in the growth pattern of the human mandible: longitudinal radiographic study by the implant method, *J. D. Res.*, 42: 400-411, 1963.
3. ———: Prediction of mandibular growth rotation, *Am. J. Orthodont.*, 55:585-599, 1969.
4. Brodie, A. G.: On the growth pattern of the human head from the third month to the eighth year of life, *Am. J. Anat.*, 68:209-262, 1941.
5. Creekmore, T. D.: Inhibition or stimulation of the vertical growth of the facial complex, its significance to treatment, *Angle Orthodont.*, 37:285-297, 1967.

6. Johnson, E. L.: The Frankfort-mandibular plane angle and the facial pattern, *Am. J. Orthodont.*, 36:516-533, 1950.
7. Meredith, H. V., Knott, V. B., and Hixon, E. H.: Relation of the nasal and subnasal components of facial height in childhood, *Am. J. Orthodont.*, 43:285-294, 1958.
8. Poulton, D. R.: The influence of extraoral traction, *Am. J. Orthodont.*, 53:8-18, 1967.
9. Richardson, A.: A cephalometric investigation of skeletal factors in anterior open bite and/or deep bite, *Trans. Europ. Ortho. Soc.*, pp. 159-171, 1967.
10. Riedel, R. A.: Relation of maxillary structures to cranium in malocclusion and normal occlusion, *Angle Orthodont.*, 22:142-145, 1965.
11. Sassouni, V. and Nanda, S.: Analysis of dentofacial vertical proportions, *Am. J. Orthodont.*, 50:801-823, 1964.
12. Schudy, F. F.: The rotations of the mandible resulting from growth: its implications in orthodontic treatment, *Angle Orthodont.*, 35:36-53, 1965.
13. ————: The control of vertical overbite in clinical orthodontics, *Angle Orthodont.*, 38:19-39, 1968.
14. Thompson, J. R. and Brodie, A. G.: Factors in the position of the mandible, *J.A.D.A.*, 29:925, 1942.
15. Wylie, W. L.: The relationship between ramus height, dental height and overbite, *Am. J. Orthodont. and Oral Surg.*, 32:57-67, 1946.
16. Wylie, W. L. and Johnson, E. L.: Rapid evaluation of facial hypoplasia in the vertical plane, *Angle Orthodont.*, 22:165-182, 1952.