ANALYSIS OF SKELETAL OPEN BITE AND DEEP BITE UTILIZING THE COUNTERPART ANALYSIS

by

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Abstract

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The counterpart analysis (Enlow, 1971) is utilized to analyze three groups: (1) normal untreated cases (Class I individuals with good occlusion and ANB value of 0-4.5°); (2) open bite cases before treatment, at debanding and post-retention which were divided into Class I (ANB value of 0-4.5°) and Class II (ANB value 4.5°); and (3) deep bite cases before treatment, at debanding, and post-treatment which were divided into Class I (ANB value of 0-4.5°) and Class II (ANB value 4.5°). Measurements were performed and statistically analyzed in order to determine the combination of skeletal characteristics of the craniofacial complex that are associated with skeletal open bite. The anatomic effects of treatment of the open bite and deep bite cases were evaluated and reported.

In the open bite group, as compared with the control and deep bite groups, it was found that the anatomic basis for the open bite related to a combination of open gonial angle, downward aligned mandibular plane, greater downward aligned occlusal place, negative Curve of Spee, greater palatal depth, lesser ANB angle, slight

maxillary protrusive tendency for the aggregate cranial floor/maxilla and ramus/corpus at A and B points and SPr and IPr, more posteriorly aligned ramus, neutral molar position, excess vertical PM dimension, occlusal plane rotated downward less than the backward rotation of the ramus, and a palatal plane that was below the deepest surface of the occipital fossa indicating a counterclockwise rotation during vertical development of the nasomaxillary complex.

Conversely, in the deep bite group, the anatomic basis related to a combination of closed gonial angle, upward aligned mandibular plane, lesser downward aligned occlusal plane, deep Curve of Spee, lesser palatal depth, greater ANB angle, greater maxillary protrusive tendency for the aggregate cranial floor/maxilla and ramus/corpus at A and B points and SPr and IPr, lesser posteriorly aligned ramus, maxillary protrusive tendency of maxillary molars, decreased vertical PM dimension, upward corpus-occlusal rotation in relation to the ramus rotation, and a palatal plane that was above the deepest surface of the occipital fossa indicating a clockwise rotation during vertical development of the nasomaxillary complex.

The most discriminating combination of variables between open and deep bite was the palatal plane alignment, Curve of Spee, ANS-PNS depth, aggregate cranial floor/maxilla and ramus/corpus dimensions at A and B points, and the ramus/MCF horizontal dimensions (skeletal). One hundred percent of the cases were correctly classified by this combination.

It is a combination of several or all of the above factors, not any one by itself, that is associated with the development of both open bite and deep bite.

At debanding, following, treatment, changes in some of the above listed variables contributed to an improvement in occlusion, but others actually contradicted the treatment effort. At post-retention, many, but not all, of these variables were observed to rebound toward their pre-treatment positions.

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DEDICATED

to my parents,
whose love and encouragement
helped me achieve my educational goals

and to my wife,
for her devotion and support

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INTRODUCTION

The cause, development and the anatomic and functional relationships of open as well as deep bite have been the subjects of research for many years. Many approaches have been utilized, including visual observation, the use of stress guages attached to the teeth, and the analysis of lateral cephalographs. Numerous theories have been proposed.

Visual observation and the utilization of stress guages have not led to decisive conclusions concerning the causative basis for open bite. Various methods of analysis of lateral cephalographs have been based on population "norms" or "means". Linear and angular measurements of a cephalogram were compared to those of a "sample" population to which the individual may not have any relation. Most conventional methods of analysis are intended to determine "what" a particular craniofacial growth pattern is as compared with population standards. The various planes and angles used do not usually have any specific relation to actual fields and sites of growth and remodeling.

The counterpart analysis is a method by which craniofacial parts are compared to each other to determine their nature of fit. This analysis explains "how" a growth pattern has occurred in a specific individual, and it accounts for the regional developmental activities among the various growth fields.

The individual's skeletal relationships are determined and evaluated according to his own anatomic norms rather than population averages. Cephalometric planes and angles are designed to coincide spefically with the key fields and sites of growth and remodeling (thus making the procedure appropriate for an anatomic analysis). This permits a meaningful evaluation of overall craniofacial form and pattern without need for population comparisons, and is the basis of the counterpart concept.

The counterpart analysis shows where imbalances exist, to what extent, and what the anatomic effect of the imbalances are. When a specific anatomic part enlarges, its counterpart(s) must enlarge or become displaced in the same direction if the same morphologic pattern and balance are to continue. Otherwise, there is a disproportionate protrusion or retrusion of the part(s) involved.

The anterior cranial fossa, the maxilla, and the mandibular corpus are mutual horizontal counterparts. The middle cranial fossa, the pharyngeal space, and the ramus are also horizontal counterparts to one another. The ramus-middle cranial fossa composite is a vertical counterpart to the nasomaxillary complex.

LITERATURE REVIEW

Hellman (1931) reported the results of his examination of forty-four male skulls of American Blacks. All of the skulls had the full complement of teeth in normal occlusion, except three which had the incisors and canines in infraocclusion. His first impression was that there was a lack of development in the alveolar process in the incisor region of the open bite cases. He performed several facial measurements and later concluded that, in open bite cases, there is an absolutely or relatively short ramus and body of the mandible, and not a lack of development in the incisor region. The facial height was within the range of variability of the normal or even greater than normal. When favorable growth changes occur, an increase in size of the short ramus and mandible could result in the closing of open bite. He also analyzed the results of 126 questionnaires he had sent out and found that 50% of treated open bite cases were successful and 50% had relapse of the open bite after treatment.

Swinehart (1942) examined 115 cases of open bite. He concluded that open bite can occur in all types of malocclusion, and that the mesial-distal relationship of the arches influence the tendency, location and extent of open bite. He found the tendency to be greatest in Class II, less in Class III, and least in Class I. In Class I and II, the location is in the incisor region and in Class

III the location is in the buccal segments. Swinehart also concluded that there is an infraocclusion of the maxillary teeth in the open bite region, an obtuse mandibular angle, a short ramus, and a downward bending of the mandible. He felt that a posterior supraocclusion is not, by itself, a cause for open bite.

Muller (1963) performed 20 measures on the cephalograms of 541 persons. He constructed polygons from several cephalometric points and compared the results. He concluded when open bite occurs the nasal floor lies relatively deep and backward toward the occipital base, moving in that direction during development. This decreases room for the tongue, which becomes situated between the dentition, and an open bite thereby results.

Hapek (1964) examined lateral cephalograms of fifty-two children having open bite. Applying Downs' Analysis to each case, he concluded that open bite can occur in a variety of skeletal patterns. There was no difference in upper face height. As the Frankfort mandibular angle increased, the lower face height, total face height, and mandibular incisor alveolar height also increased.

Subtelny (1964) examined 25 open bite cases and 30 normal cases (without open bite). Three features were considered to be etiologic factors in open bite. They are: (1) growth deficiencies, (2) disproportionate muscle growth and aberrant muscle function, and (3) thumb or finger-sucking habits. He compared linear and angular skeletal-dental relationships of normal and open bite cases using appropriate cephalometric landmarks. He reached several conclusions, as follows. The posterior cranial base was shorter.

No difference was found in the angulation of the cranial base, and the dimension of the anterior cranial base was normal. The premaxilla had a tendency to tip toward the cranial base, but no difference was found in the vertical or antero-posterior dimension of the maxilla. Also, no difference was found in the length, angulation, or distance of the palate to the cranial base. The SNA was smaller in open bite, and a greater eruption of maxillary molars and incisors occurred. There was not an inadequacy of dentoalveolar development but actually the opposite. Excessively steep mandibular planes occurred, and there was a tendency for shorter height of the ramus and greater gonial angle. Excessive eruption of mandibular molars did not occur, and the vertical dimension of the skeletal face (nasion to lower border of symphysis of the mandible) was greater in open bite but was confined to the lower region of the face. No difference was reported in the length of the mandible, but it was more retruded in relation to the cranial base. Excessive vertical dimension did occur from the nasal floor to the symphysis of the mandible, but not in the posterior area of the face or the molar region. It could not be determined if the tongue was or was not a causative factor in open bite.

Neff (1966) conducted an experiment with 30 persons utilizing lateral cephalograms and strain guages to record swallowing, tooth contact and tongue force. He concluded the presence of the tongue between the teeth alone is not enough to cause an open bite, but there must also be another active force around the passive tongue. The source of this force appears to be the muscles

of mastication when used during swallowing.

Richardson (1967) examined cephalograms of 110 cases of anterior open bite and 110 cases of deep overbite. Polygons (nasion-sella-articulare-gonion-menton) were constructed and the resulting linear measurements and angles recorded. He concluded that the mean lower facial height (ANS-menton) was much greater in open bite than in deep overbite. There was a tendency towards an increase in the articulare-gonion-menton and sella-articulare-gonion angles. The difference between deep overbite and open bite cases appeared not to be linear values but rather jaw and joint angles (shape rather than size). However, he felt that these angles are not the only variables which determine lower facial height.

Nahoum (1971) investigated the role of the palatal plane in determining facial proportions. Lateral cephalograms of 52 open bite cases and 166 Class I normal occlusion cases were traced and compared using sella, nasion, anterior nasal spine, posterior nasal spine, gnathion and menton. He measured upper, lower, and total facial height along a line from nasion to menton. Anterior nasal spine was the dividing point along nasion-menton. Also measured were the angles sella nasion-to-mandibular plane, sella nasion-to-palatal plane, and palatal plane-to-mandibular plane. Total facial height was greater in open bite cases. However, the upper facial height to the lower facial height ratio was less in open bite. The upward cant of the anterior portion of the palatal plane decreases the upper face height and increases the lower face height.

Worms and co-workers (1971), made visual examinations of 1,048 Navajo children for occlusal discrepancies. He concluded that simple anterior open bite (from canine to canine) corrected itself 80% of the time due to a developmental factor in the mixed dentition period. Compound open bite (from premolar to premolar), however, was more frequent in Class II malocclusions, girls, and older age groups. He thus felt that age and sex have an effect on open bite cases.

Moss (1971) examined lateral cephalograms of two groups of individuals. Group I had 7 open bite and 9 deep bite cases. Group II had 10 normal swallowers, 10 tongue thrusters, 5 Class II, division 1 cases, and 5 open bite cases. The locations of foramen ovale, mandibular foramen, and the mental foramen were drawn on each film tracing. He found that the nerve foramina fit on a logarithmic spiral. In open bite, foramen ovale was located further down the spiral than the normal occlusion subjects, but with growth the foramen moved down the spiral to the same extent as in the other groups and maintained a lower position on the logarithmic spiral. The average position of the mandibular foramen and mental foramen, however, was further down the spiral in open bite. The distance between foramen ovale and the mandibular foramen was shorter in open bite than in normal cases.

Loufty (1973) utilized the Downs' and Steiner analyses to analyze 72 open bite cases and 40 deep overbite cases of Kuwait school children. The length of the mandible was not significantly different in either of the groups. Total facial height was greater

in open bite, but the area of dysplasia appeared to be in lower face height. Increased height was related to jaw angles rather than linear measurements. No difference in the anterior-posterior relationship of the upper to the lower jaw was observed.

Nahoum (1975), in later research on open bite, evaluated cephalograms of 92 males with good occlusions, 18 persons with Class II open bite, and 18 persons with Class III open bite. Open bite subjects had shorter posterior face height and a longer anterior face height. A smaller 6 to mandibular plane distance and a shorter $\underline{1}$ to sella nasion distance was noted. A larger gonial angle with a steep, notched mandibular plane, upward-canted maxillary occlusal plane, downward canted mandibular plane, and a smaller upper face height/lower face height ratio occurred in open bite cases. Total face height was greater in Class III than in Class II or control subjects. The lower occlusal plane-sella nasion angle was larger in open bite cases. He reported that all persons with open bite had a tongue thrusting habit to create an oral seal when swallowing.

Schendel (1976) examined cephalograms of 31 patients with vertical maxillary excess (long face syndrome). Fifteen of these persons had open bite. Twenty-two anatomic points were labeled and measurements performed. In the open bite group, they found that the mandibular plane was steeper, as was the occlusal plane angle. Ramus height was normal but it was longer in the non-open bite group. The mandible was displaced posteriorly.

STATEMENT OF THESIS

The objective of this investigation is to determine the particular combinations of skeletal characteristics in the craniofacial complex, utilizing the counterpart analysis, that relate specifically to skeletal open bite and deep bite. A secondary purpose is to evaluate the anatomic effects of the treatment on these cases at deband and post-treatment stages.

METHODS AND MATERIALS

Source

The lateral cephalograms of deep bite and open bite cases utilized in this study were obtained from the files of the Orthodontic Clinic at Case Western Reserve University and also from private practitioners. The control (Class I) cases were made available from the Broadbent-Bolton collections housed at the Case Western Reserve University.

Sample

Group I (control)

A sample of 15 control subjects exhibiting Class I occlusion was selected according to the following requirements.

1. ANB value of 0-4.5°
2. no orthodontic or surgical treatment prior to the age studied
3. normal overbite (approximately 2 mm)
4. normal overjet.

The average age for the subjects in this group was 175 months (14 years, 6 months), and the range was 158-191 months (13 years, 2 months-15 years, 11 months). There were eleven males and four females in this group.

Group II (Class I open bite)

A second sample of 15 treated cases of Class I open bite was used. These cases were selected according to the following requirements:

1. ANB value of 0-4.5°
2. initial, deband, and post treatment cephalograms available
3. skeletal anterior open bite present (the mandibular central incisal edge would not contact the maxillary central incisal edge if opposed)

In this group, the average age at the time of the initial cephalogram was 155 months (12 years, 11 months), and the range was 102-221 months (8 years, 6 months-18 years, 5 months). The average age at debanding was 188 months (15 years, 2 months), and the range was 158-250 months (13 years, 2 months-20 years, 10 months). The average post-retention age was 221 months (18 years, 5 months), and the range was 186-273 months (15 years, 6 months-22 years, 9 months). There were eleven males and four females in this group.

Group III (Class II open bite)

A third sample of 15 treated cases of Class II open bite was utilized. These cases were selected according to the following requirements:

1. ANB value greater than 4.5°
2. initial, deband and post treatment cephalograms available
3. skeletal anterior open bite present (the mandibular central incisal edge would not contact the maxillary central incisal edge if opposed).

The average age in this group at the time of the initial cephalogram was 144 months (12 years), and the range was 79-186 months (6 years, 7 months-15 years, 6 months). The average age

at debanding was 182 months (15 years, 2 months), and the range was 157-210 months (13 years, 1 month-17 years, 6 months). The average post-retention age was 206 months (17 years, 2 months), and the range was 169-276 months (14 years, 1 month-22 years, 10 months). There were nine males and six females in this group.

Group IV (Class I deep bite)

A fourth sample of 15 treated cases of Class I deep bite was selected. These cases were selected according to the following requirements:

1. ANB value of 0-4.5°
2. initial, deband and post retention cephalograms available
3. skeletal deep bite (mandibular central incisal edge contacting or above maxillary central incisor cingulum and an overlap of 80% or greater).

The average age in this group at the time of initial cephalograms was 156 months (13 years), and the range was 126-175 months (10 years, 6 months-14 years, 7 months). The average age at debanding was 184 months (15 years, 4 months), and the range was 149-200 months (12 years, 5 months-16 years, 8 months). The average post-retention age was 210 months (17 years, 6 months), and the range was 185-223 months (15 years, 5 months-18 years, 7 months). There were seven males and eight females in this group.

Group V (Class II deep bite)

A fifth sample of 15 treated cases of Class II deep bite was obtained. These cases were selected according to the following

requirements:

1. ANB value greater than 4.5°
2. initial, deband and post retention cephalograms available
3. skeletal deep bite (mandibular central incisal edge contacting or above maxillary central incisor cingulum and an overlap of 80% or greater).

The average age in this group at the time of the initial cephalogram was 155 months (12 years, 11 months), and the range was 87-194 months (7 years, 3 months-16 years, 2 months). The average age at debanding was 187 months (15 years, 7 months), and the range was 164-221 months (13 years, 8 months-18 years, 5 months). The average post-retention age was 215 months (17 years, 11 months), and the range was 181-250 months (15 years, 1 month-20 years, 10 months). There were nine males and six females in this group.

Technical Details

The deep bite and open bite cephalograms used in this study were taken with a Broadbent, Moss or Wehmer cephalometer. The control cases were all taken in the Bolton-Brush Study Center with a Broadbent cephalometer.

Tracings were done on 0.003" acetate using an England Eagle Turquoise 10 pencil with 1 H drawing leads. A Baum protractor (Unitex Corporation, Monrovia, California) was used to make angular and linear measurements.

Morphologic Rationale for the Cephalometric Variables to be Measured and Compared

Fourteen measurements were performed. The variables (measurements), their symbol and their effect on the occlusion are as follows:

G_D gonial angle deviation of individual's gonial angle from the norm gonial angle ($G_D = G_n - G_i$). A (-) effect ($G_i > G_n$) is an open bite tendency. A (+) effect ($G_n > G_i$) is a deep bite tendency

G_n norm gonial angle as determined by the Michigan Standards (Riolo, et al., 1975).

G_i gonial angle of an individual.

A_1 mandibular plane alignment. A (-) effect (individual's mandibular plane below the neutral mandibular plane) is an open bite tendency. A (+) effect (individual's mandibular plane above the neutral mandibular plane) is a deep bite tendency.

A_2 occlusal plane alignment. A (+) effect (individual's occlusal plane above neutral occlusal plane) is a deep bite tendency. A (-) effect (individual's occlusal plane below neutral occlusal plane) is an open bite tendency.

A_3 Curve of Spee. When the incisal edge of the mandibular central incisor is above the functional occlusal plane, a (+) effect is recorded. This is a deep bite tendency. When the incisal edge is below the functional occlusal plane, a (-) effect is recorded. This is an open bite tendency.

A_4 ANS-PNS depth. A (-) effect (center of maxilla below the ANS-PNS line) is an open bite tendency. A (+) effect (center of maxilla above ANS-PNS line) is a deep bite tendency.

A_7 ANB. This measurement was used to determine the skeletal classification of the individual.

B_1 Aggregate cranial floor/maxilla and ramus/corpus dimensions at A and B points. A (+) effect, A point anterior to B point, is a deep bite tendency. A (-) effect, B point anterior to A point, is an open bite tendency.

B_2 Aggregate cranial floor/maxilla and ramus/corpus dimensions at SPr and IPr. A (+) effect, SPr anterior to IPr, is a deep bite tendency. A (-) effect, IPr anterior to SPr, is an open bite tendency.

B_3 Cranial floor (MCF) and posterior maxillary (PM) relative alignments. A (+) effect (forward alignment of MCF/PM) is a deep bite tendency. A (-) effect (backward alignment of MCF/PM) is an open bite tendency.

B_4 Ramus alignment. A (-) effect (ramus aligned posterior to neutral ramus) is an open bite tendency. A (+) effect (ramus anterior to neutral ramus) is a deep bite tendency.

B_7 Molar positions (composite).

B_8 PM as compared with ramus/MCF vertical dimensions. A (-) effect (an increased vertical PM dimension) is an open bite tendency. A (+) effect (a decreased vertical PM dimension) is a deep bite tendency.

B_9 Corpus-occlusal alignment. A (-) effect (a greater downward corpus/occlusal rotation relative to ramus rotation) is an open bite tendency. A (+) effect (a greater upward corpus/ occlusal rotation relative to ramus rotation or a backward ramus rotation greater than downward corpus/ occlusal rotation) is a deep bite tendency.

B_{11} Palatal plane. A (-) effect (the line connecting ANS-PNS extending posteriorly is below the deepest surface of the occipital fossa) is an open bite tendency. A (+) effect (the line connecting ANS-PNS extending posteriorly is above the deepest surface of the occipital fossa) is a deep bite tendency.

Statistical Methods

All measurements were recorded on IBM keypunch cards. Data was analyzed utilizing an SPSS (Statistical Package for the Social Sciences) program. A Univac 1108 computer (Chi Corporation, Division of Ectran, Cleveland, Ohio) was utilized for statistical analysis. Descriptive analyses provided the means, standard deviations, and variances for each variable. Analyses of variance determined which variables showed statistically significant differences in bite (normal, open, deep) and Class (I, II). Discriminant analyses (testing all variables and groups of selected variables) determined linear combinations of variables which most significantly distinguished among/between groups (normal bite [Bolton], vs. open bite vs. deep bite; and open bite vs. deep bite only).

TABLE I

DEFINITIONS OF ANATOMIC LANDMARKS

Points	Definition
A	A point, the most posterior point on the premaxilla between anterior nasal spine and superior prosthion.
ANS	Anterior nasal spine, the forward-most tip.
Ar	Articulare, the point at which the inferior surface of the cranial base intersects the posterior surface of the condylar process.
ARa	Anterior ramus, the point at which the functional occlusal plane intersects the anterior surface of the ramus.
B	B point, the most posterior point on the anterior surface of the mandibular alveolar process.
IPr	Inferior prosthion, the point of contact of the alveolar process between the mandibular central incisors.
Go	Gonion, the intersection of the mandibular plane and a line tangent to the posterior border of the ramus.
M	Menton, the most inferior point of the symphysis of the mandible.
N	Nasion, the most posterior surface of the nasofrontal suture.
PNS	Posterior nasal spine, the posterior-most tip of the posterior spine of the palatine bone.
PRa	Posterior ramus, the point at which the functional occlusal plane intersects the posterior surface of the ramus.
S	The midpoint of sella turcica.

TABLE I continued

SE	Sphenoethmoidal junction, the point at which the floor of the anterior cranial fossa intersects the averaged image of the great wings of the sphenoid bone.
SPr	Superior prosthion, the point of contact of the alveolar process between the maxillary central incisors.

TABLE II

DEFINITION OF CEPHALOMETRIC PLANES

Line	Description
Ar to Go	The alignment of the ramus is demonstrated by the line connecting articulare with gonion.
ARa	Anterior ramus plane, a line from the intersection of the anterior border of the ramus with FOP, up to the reference line that is parallel to PRa.
FOP	Functional occlusal plane, a line from the maxillary-mandibular first bicuspid occlusal contact to the most posterior occlusal contact of the maxillary and mandibular first molars.
MCF	Middle cranial fossa, a line from Ar to SE.
NOA	Neutral occlusal axis, a line perpendicular to PM through the most posterior occlusal contact of the maxillary and mandibular first molars.
NRa	Neutral ramus, a line from Ar to a point midway between Ar and PM neutral at the level of gonion.
PM	Vertical PM, a line from SE through the averaged inferior-most point of the ptergomaxillary fissure.
PRa	Posterior ramus plane, a line from Ar to the intersection of the posterior border of the ramus with FOP.
REF	Reference line, a line parallel to FOP from Ar anteriorly.

Figure 1. This diagram demonstrates all of the points and planes used in the counterpart analysis, including additions to the original procedure presented by Enlow (1971). Dashed lines indicate neutral dimensions while the solid lines represent the individual's relationship.

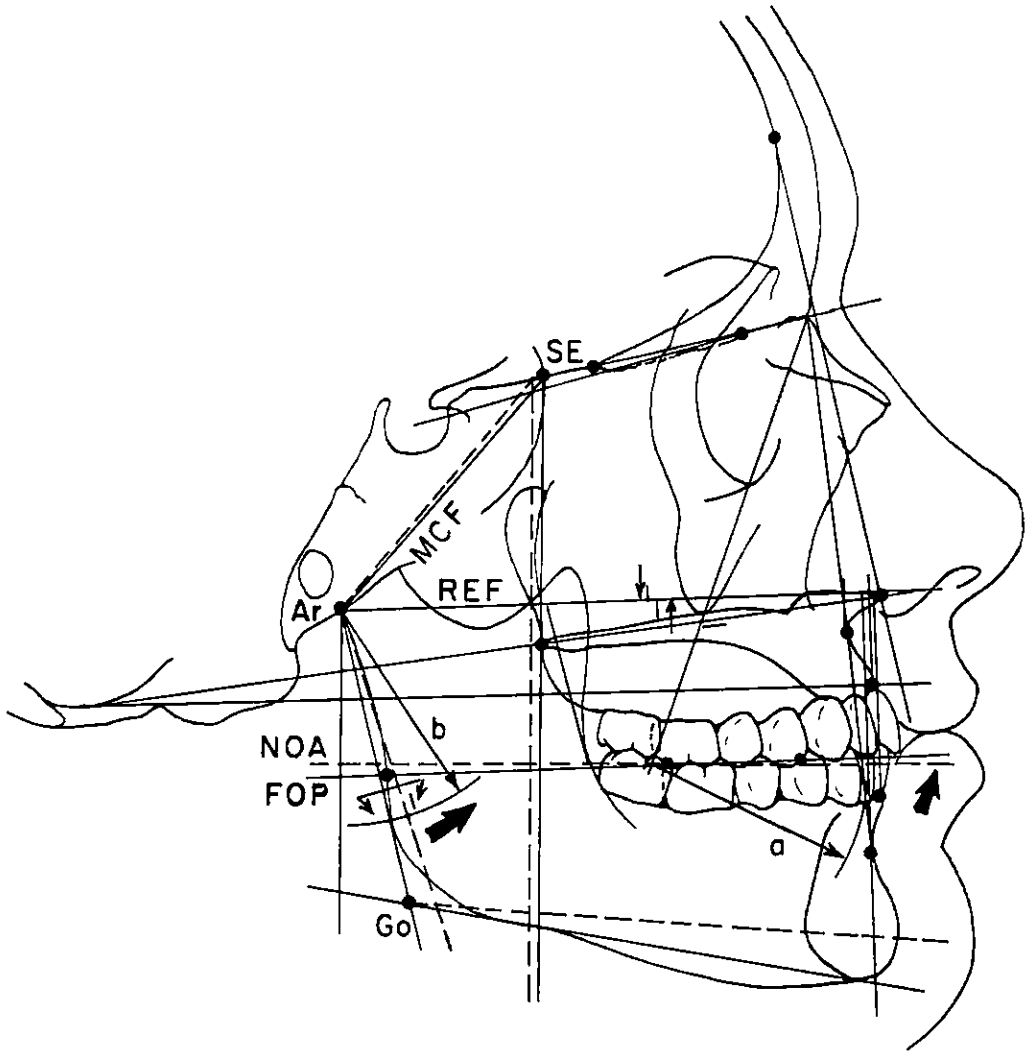


Figure 1

Figure 2. Aggregate cranial floor/maxilla and ramus/corpus horizontal dimensions at A and B points. This diagram demonstrates the comparison of lengths from Ar to A point and Ar to B point. The measurement is made along REF or FOP. When A point is ahead of B point, a maxillary protrusive (+) effect occurs. If A point is behind B point, a mandibular protrusive (-) effect occurs. If both points coincide, no difference (0) results.

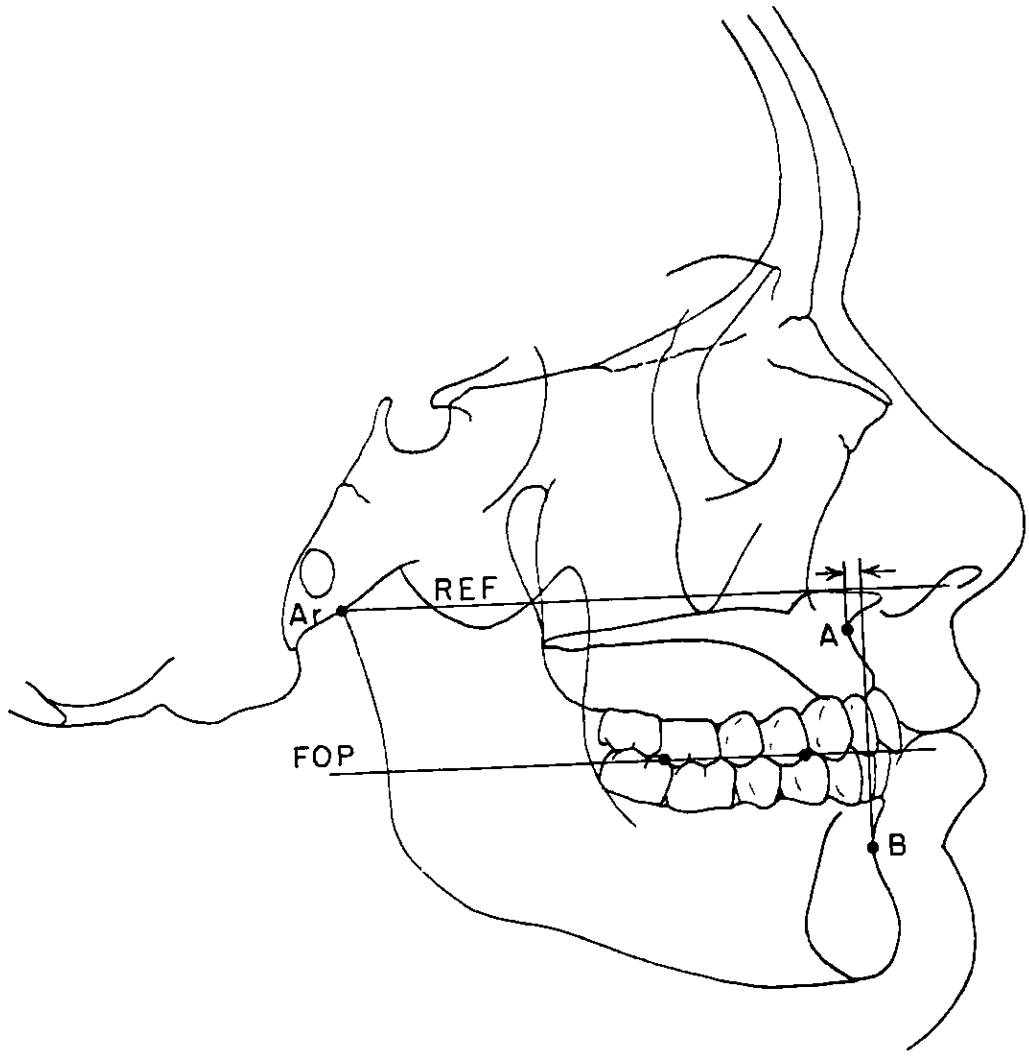


Figure 2

Figure 3. Aggregate cranial floor/maxilla and ramus/corpus horizontal dimensions at SPr and IPr. This measurement is similar to Figure 2 but using SPr and IPr.

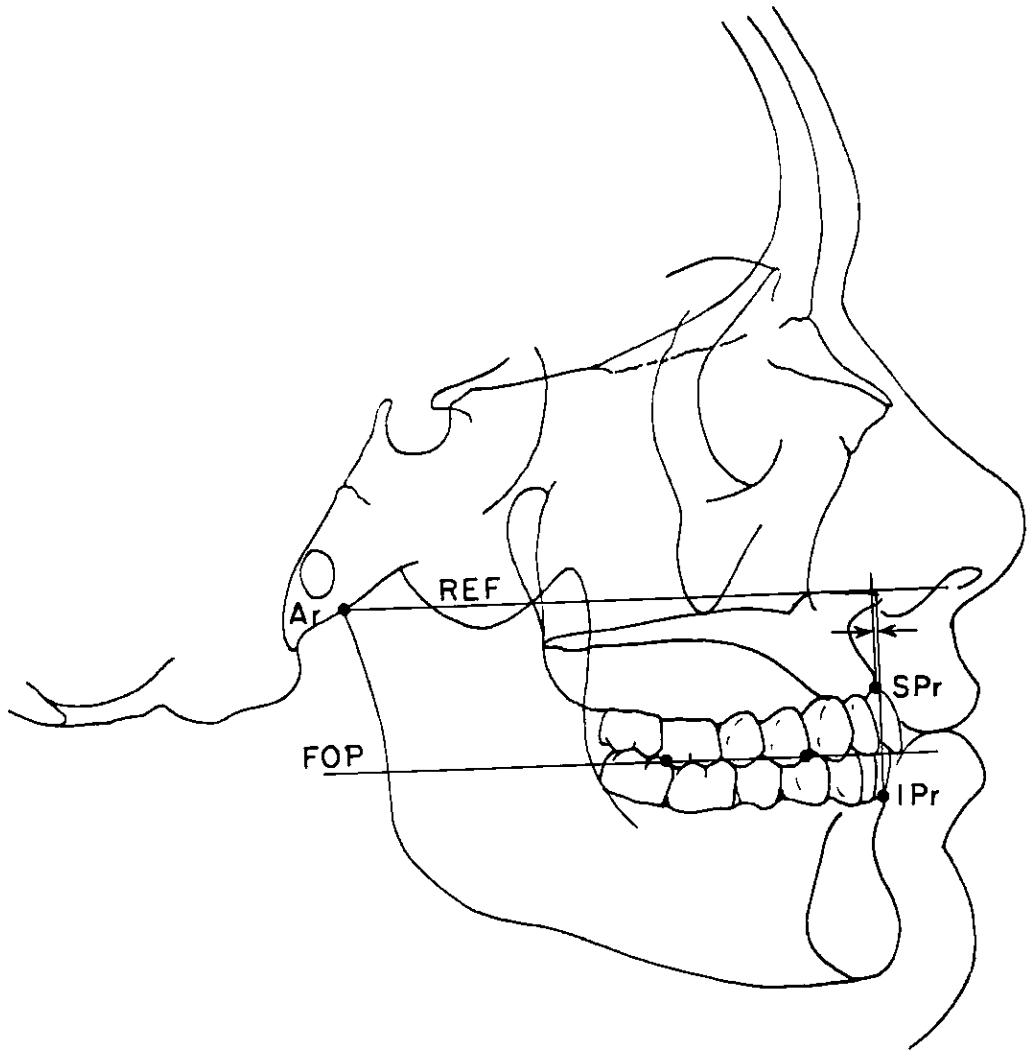


Figure 3

Figure 4. Middle cranial fossa (MCF) and posterior maxillary (PM) relative alignment. This diagram demonstrates a neutral MCF/PM alignment, which has an internal angle of 40.3°. This is drawn using a preconstructed template. The template is constructed by (1) measuring the length of MCF (such as by using the Baum protractor), and (2) transferring this length to the corresponding line on the template, thus keeping the length of MCF neutral and neutral MCF the same. (3) A second line is drawn indicating neutral PM at 40.3° to neutral MCF. (4) Place the tracing over the template with PM and PM neutral parallel. (5) Draw the neutral MCF/PM alignment with a dashed line on the tracing. When the solid line is forward of the dashed line, a (+) results. If behind, a (-) results. If both coincide, no protrusive effect (0).

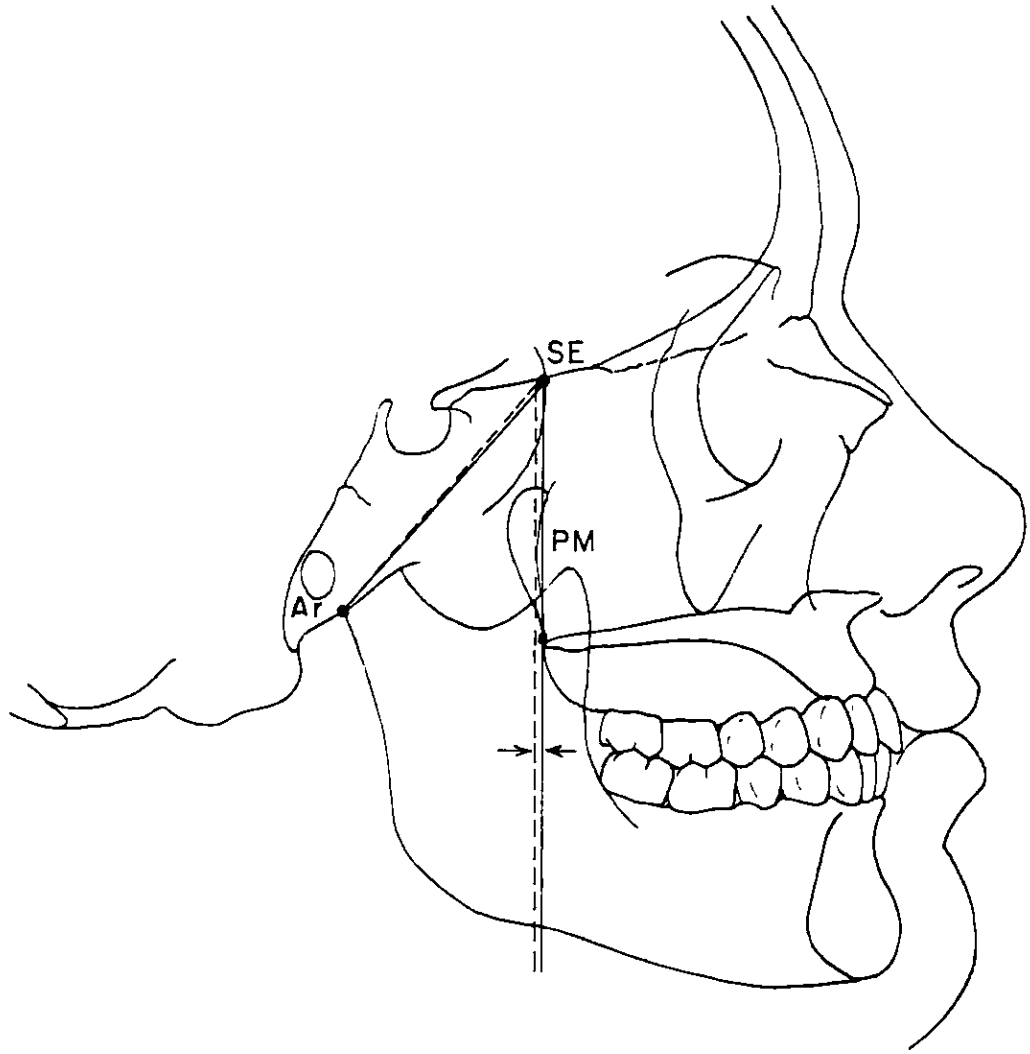


Figure 4

Figure 5. Ramus alignment. This diagram demonstrates the (+), (-) or (0) alignment of the ramus. A line from Ar to Go indicates the individual's ramus plane. Neutral ramus plane is constructed by a line from Ar to the midpoint from Ar to PM neutral at the level of Go. The alignment comparison is made at the level of FOP. A (-) effect occurs when the individual's ramus plane is behind the neutral ramus plane. If ahead, a (+) effect results. If they coincide, a (0) effect occurs.

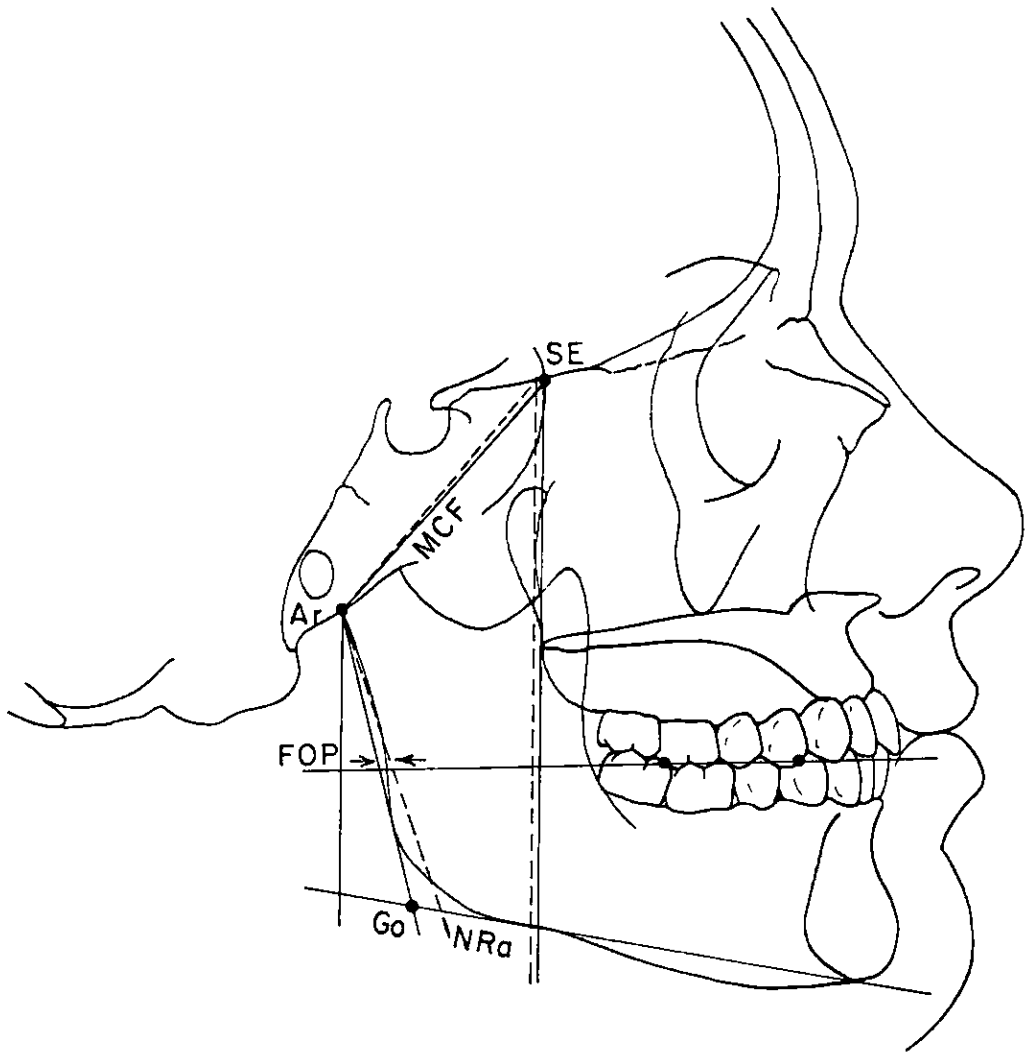


Figure 5

Figure 6. Ramus/MCF horizontal dimensions (skeletal). This diagram indicates the comparison of the posterior cranial floor (Ar to PM neutral) to the width of the ramus (Ar to ARa). The measurement is made at the level of REF. PRa is indicated by a line from Ar to where the posterior border of ramus crosses FOP. A parallel to ARa from where the anterior border of the ramus crosses FOP to REF demonstrates ARa. A (-) effect occurs when the ramus width is greater than Ar to PM neutral, and (+) effect when less. When the distances are the same, no effect (0) results.

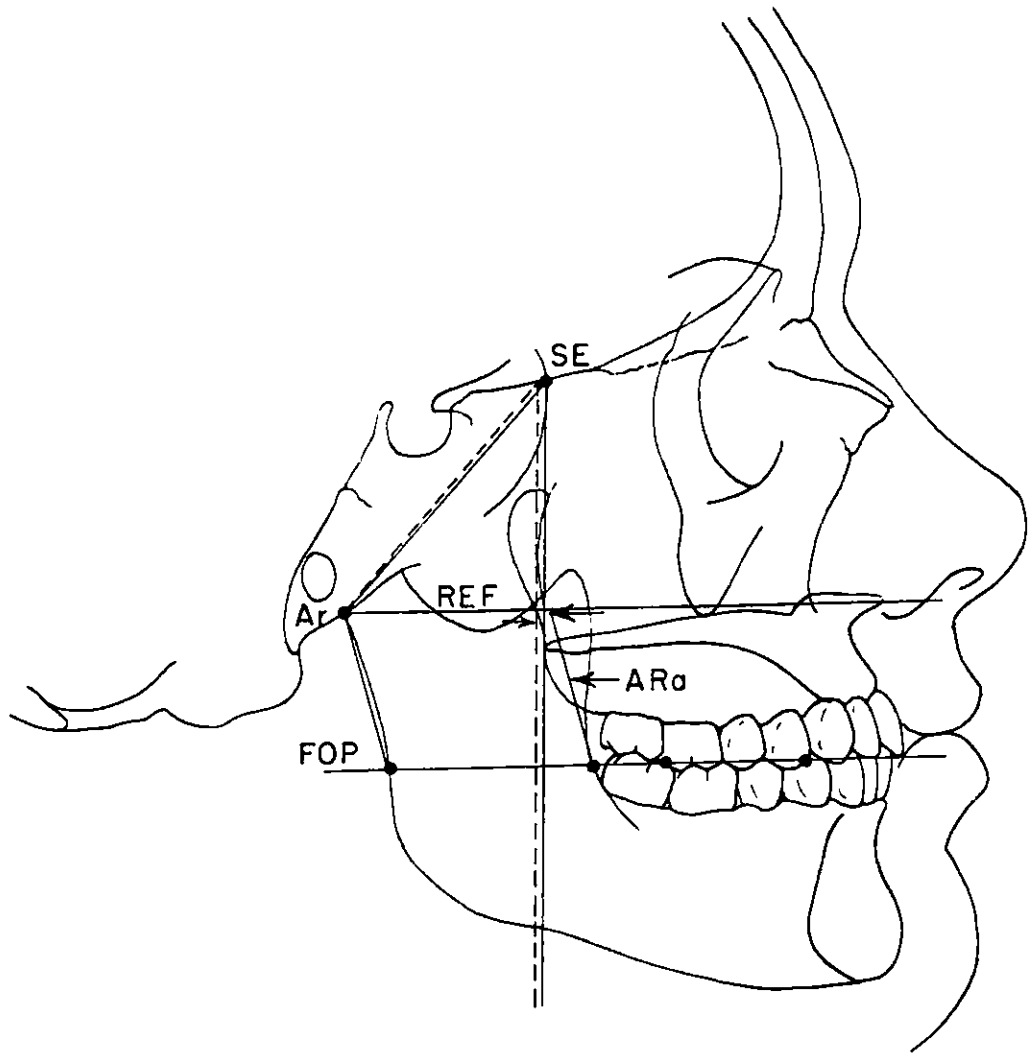


Figure 6

Figure 7. Ramus/MCF horizontal dimensions (dental). The neutral positions of the molars are demonstrated with this measurement. The distal surface of the maxillary and mandibular molars is indicated on REF by short vertical lines. The maxillary molar is corrected to it's neutral position by adding or subtracting the distance of PM to neutral PM. When the MCF-PM rotation is forward, the correction is toward Ar. The mandibular molar is corrected to neutral by adding or subtracting the distance from NRa to PRa along the FOP. If PRa is behind NRa, the correction is away from Ar along REF. In Class I individuals, there is a slight mandibular protrusive effect considered normal, and is recorded as a (0) effect. The arrows demonstrate the neutral positions.

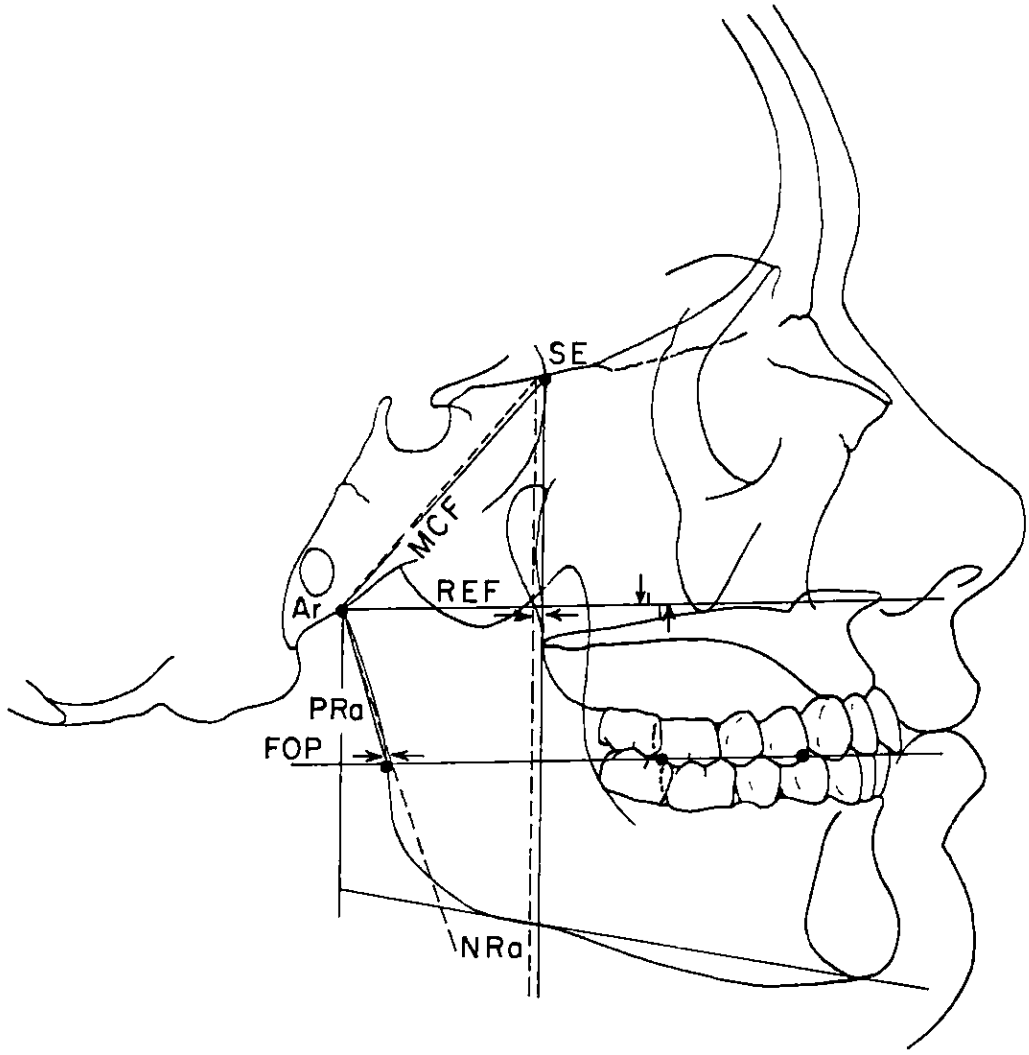


Figure 7

Figure 8. Molar positions (composite). Short vertical lines along REF indicate the distal surfaces of the maxillary and mandibular first molars. The measurement is made along REF from Ar to the vertical lines. A slight mandibular protrusive effect is normal, and as in Figure 7 is recorded as a (0) effect.

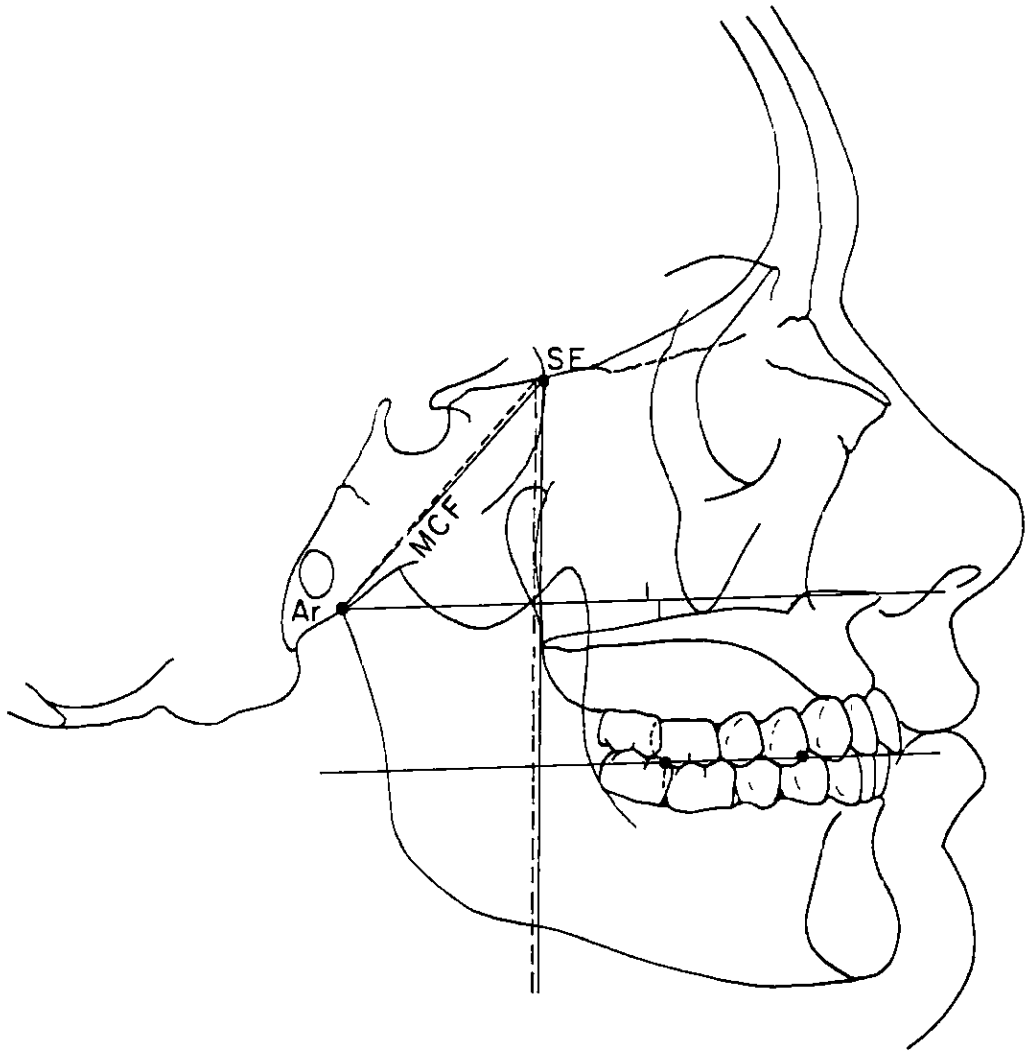


Figure 8

Figure 9. PM as compared with ramus/MCF vertical dimensions. The vertical PM dimension is determined for the individual by this measurement. When MCF rotates forward or backward, and the ramus rotates the same amount in the same direction, no change (0) in vertical PM dimension has occurred. If the ramus rotates more in the same direction, a "long" PM results. A "short" PM occurs when the ramus rotates less than PCF. Ethnic variation and population tendencies were not considered in the present study. A "long" PM has a (-) effect while a "short" PM has a (+) effect.

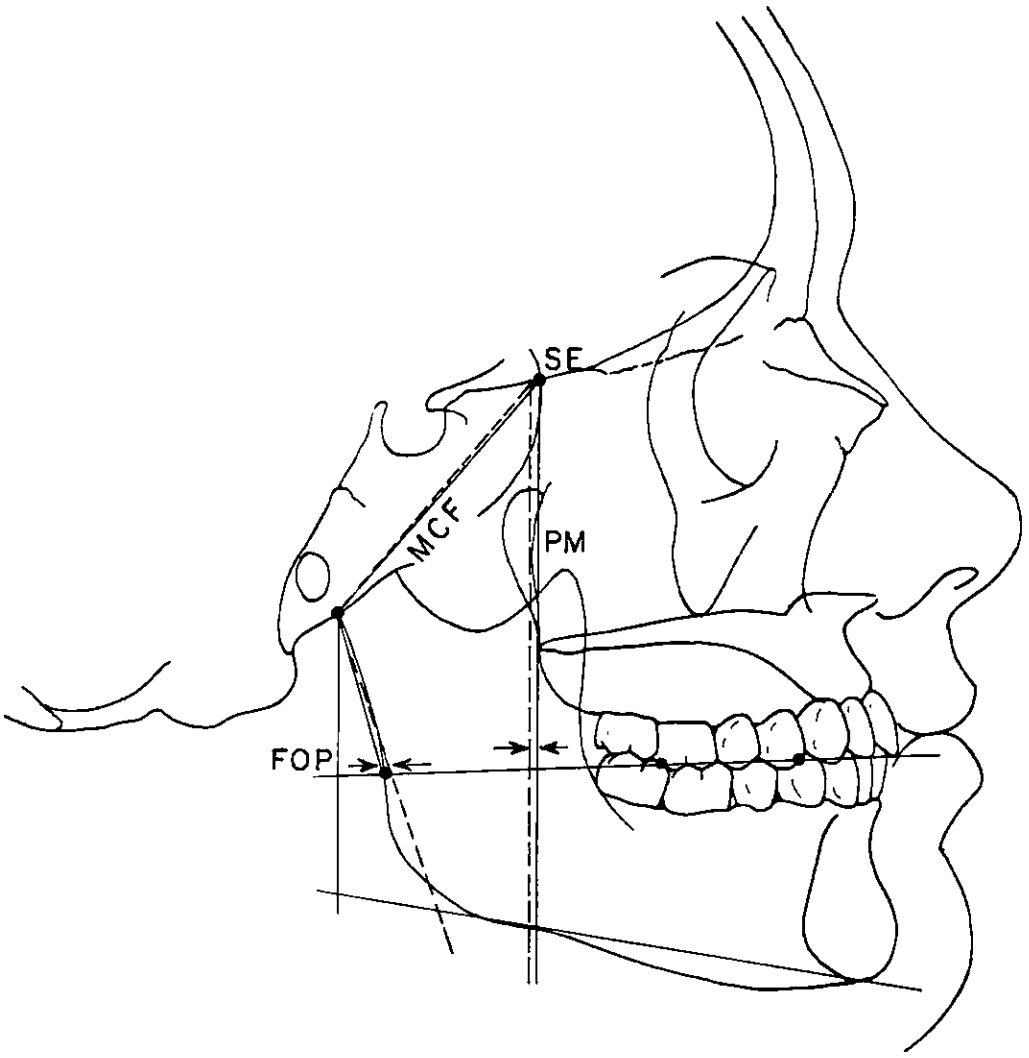


Figure 9

Figure 10. Corpus-occlusal alignment. Occlusal rotation is compared to ramus rotation. A neutral occlusal axis (NOA) is drawn by a line perpendicular to PM and passing through the most posterior occlusal molar contact point. Next a line from nasion through the most inferior point of the zygoma is drawn to FOP. An arc is drawn from this point to where a perpendicular from B point crosses FOP (line a). Line a and the arc are transferred to Ar to determine ramus rotation (line b). The distance and direction of rotation of FOP from NOA is noted, and transferred at the point where arc intersects AG-Go and NRa and is marked off in the same direction of rotation relative to NRa (beginning at NRa) as FOP is related to NOA. When the rotations are equal (in amount and direction), the lines (a short dash and Ag-Go) will coincide, with a (0) effect. A (-) effect results from a greater downward corpus/occlusal rotation relative to ramus rotation. A (+) effect occurs if a greater upward corpus/occlusal rotation relative to ramus rotation or if the backward ramus rotation is greater than the downward corpus/occlusal rotation.

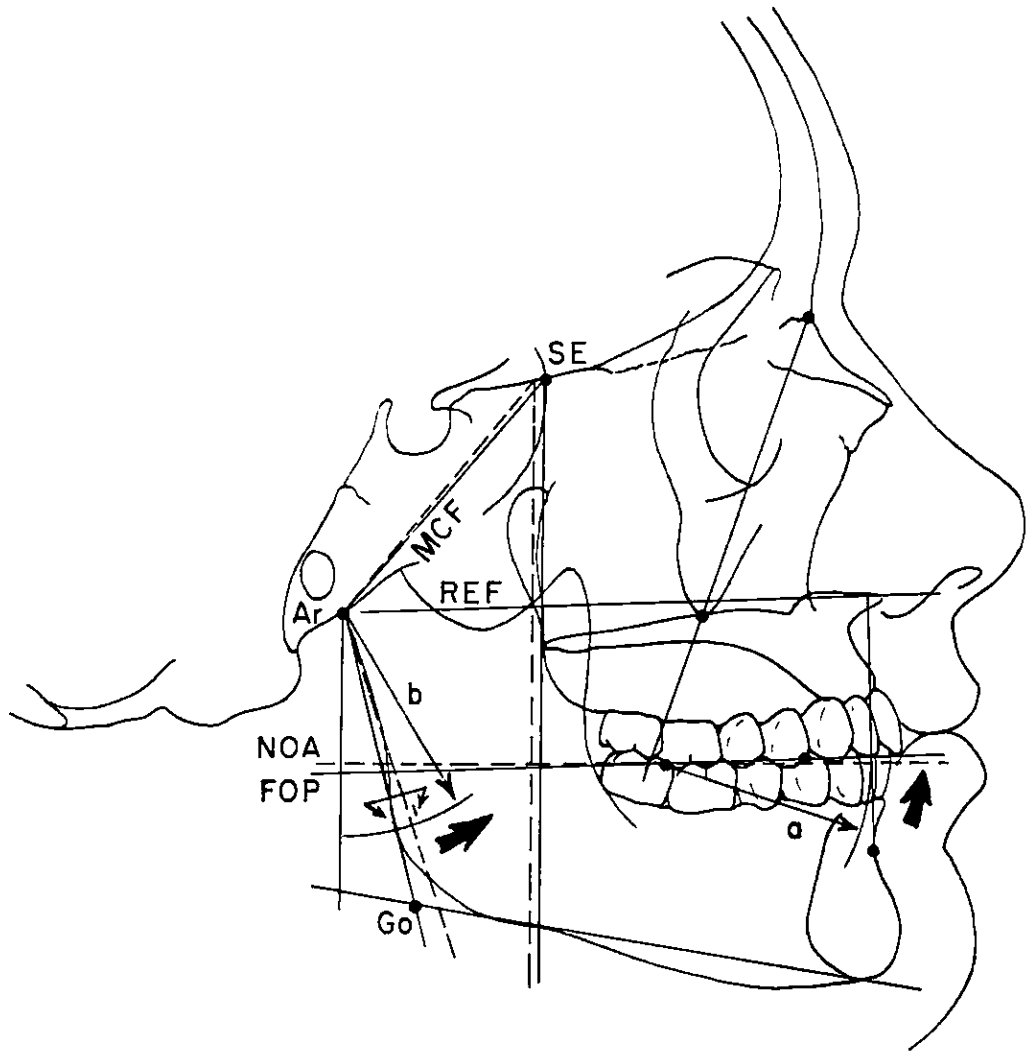


Figure 10

Figure 11. Vertical anterior maxillary plane. This diagram demonstrates the anterior boundary of growth of the nasomaxillary complex. In a mature individual SPr should be on a line from the most anterior point of the frontal lobe of the brain perpendicular to a line from the posterior boundary of the cribiform plate to the anterior point of the cribiform plate. In a growing person, SPr will be behind this line (Enlow, 1975).

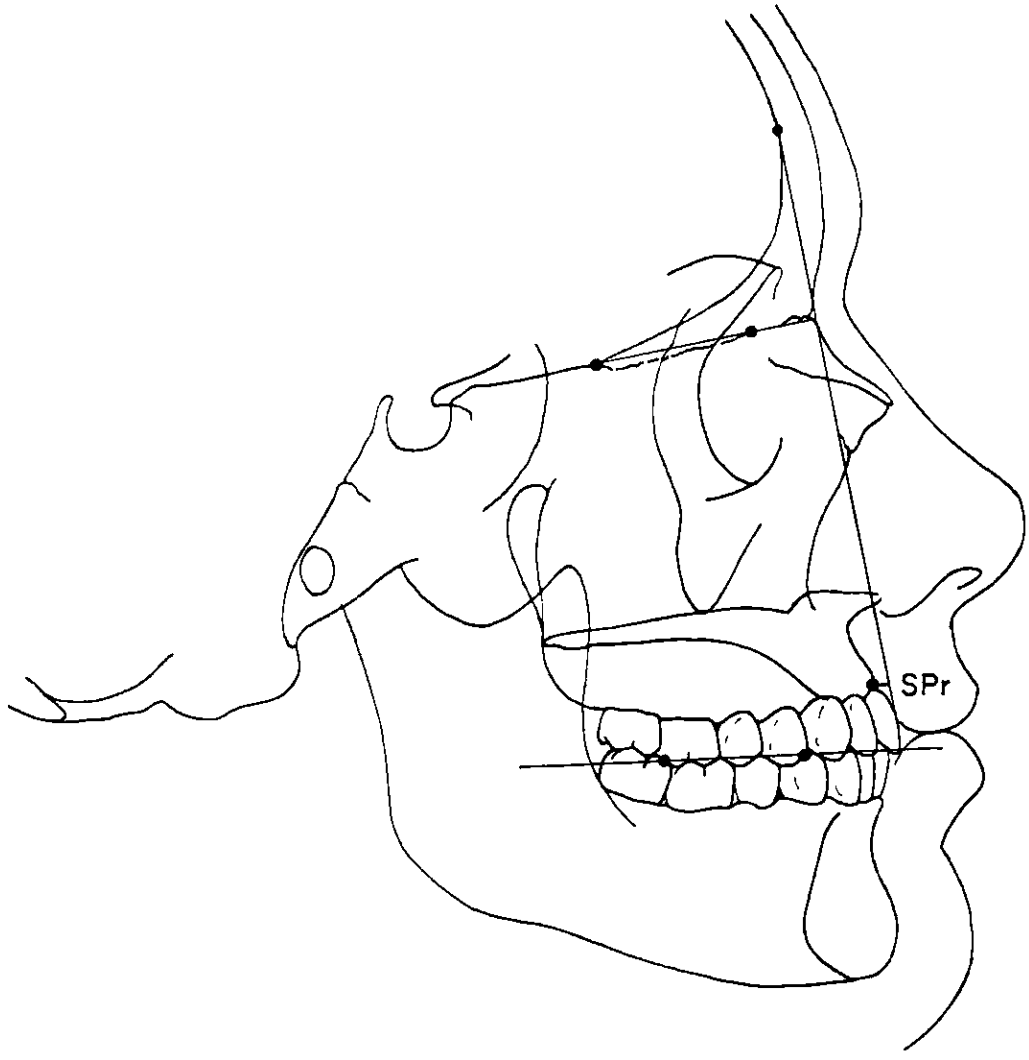


Figure 11

Figure 12. Mandibular plane alignment. The mean gonial angle as determined from the Michigan Standards (Riolo, et al., 1975) is used as a neutral value, as indicated by the dashed line. The measurement for alignment is made on a line that registers on B point and is perpendicular to FOP. If the individual's mandibular plane (indicated by the line Go to Me) is below the dashed line, a (-) effect results. When above, a (+) effect occurs. If they coincide, a (0) effect results.

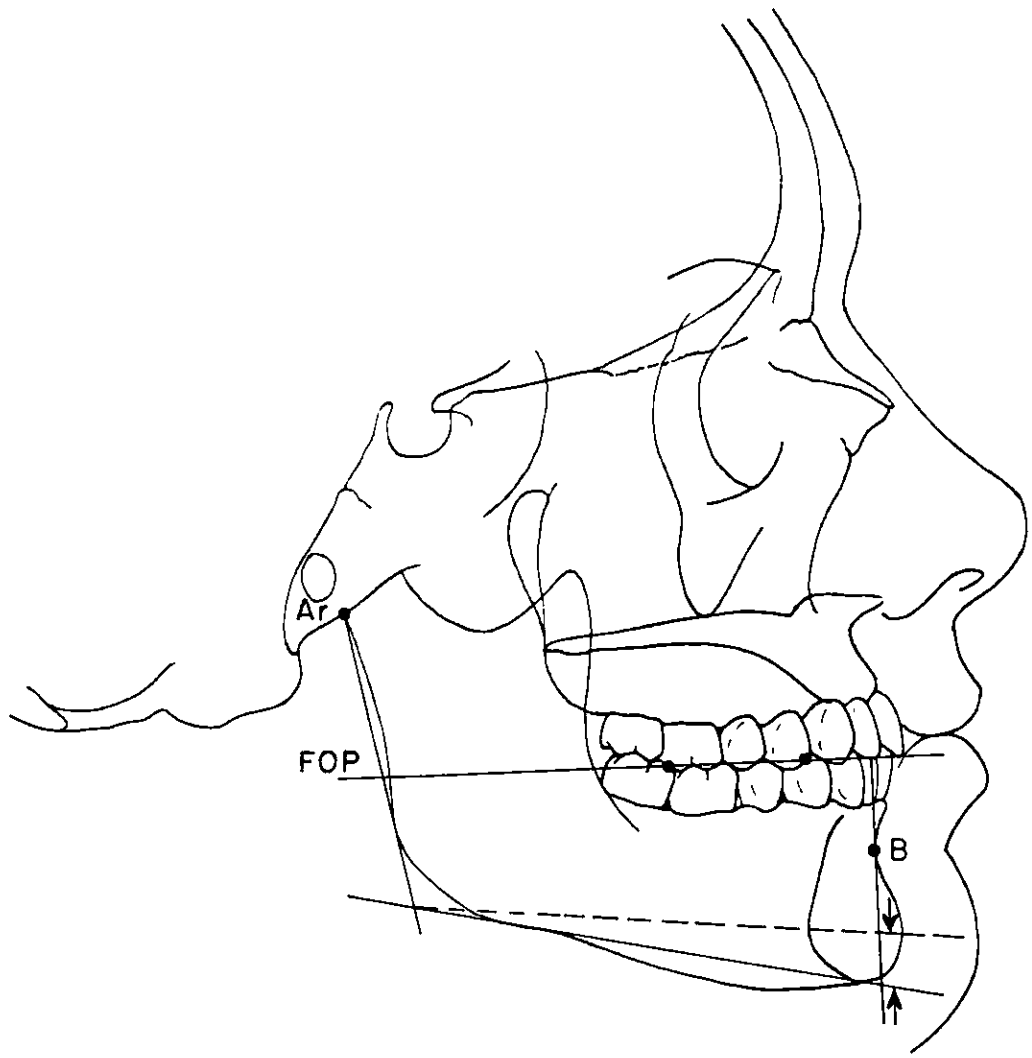


Figure 12

Figure 13. Gonial Angle alignment. This relationship is similar to that demonstrated by Figure 12. The measurement is made in degrees for comparison.

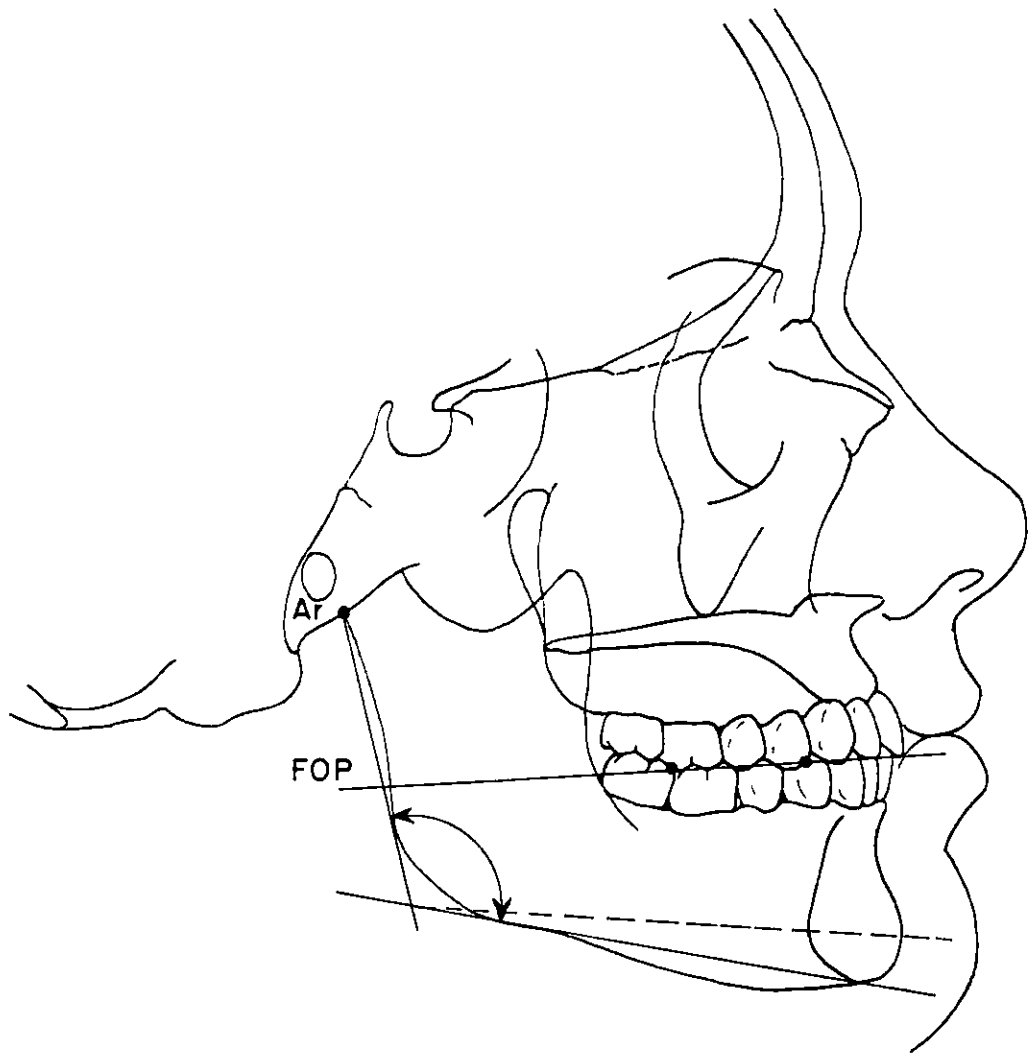


Figure 13

Figure 14. Occlusal plane alignment. The amount of occlusal plane rotation is indicated. The measurement between NOA and FOP is made where a perpendicular from SPr crosses FOP. If FOP is below NOA, a (-) effect results. A (+) occurs when FOP is above NOA. When the lines coincide, a (0) effect results.

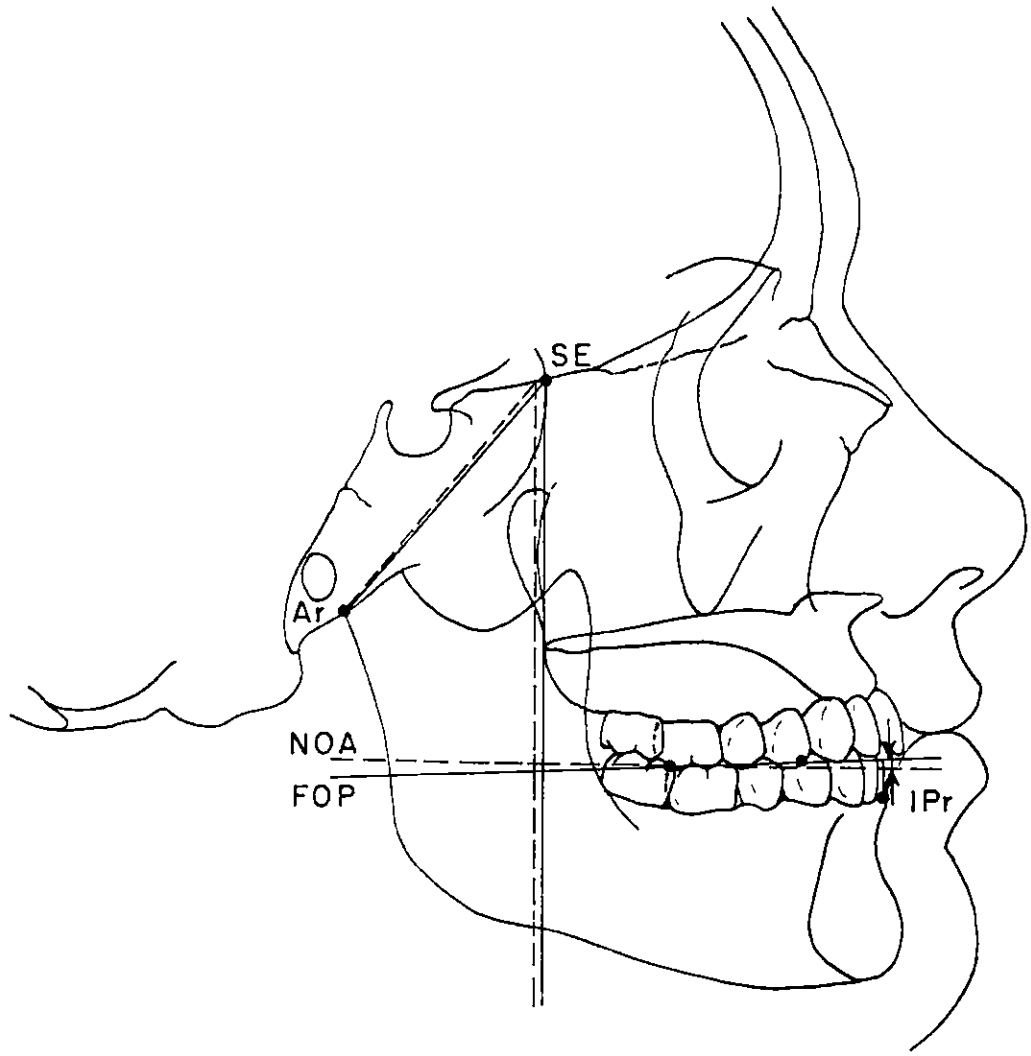


Figure 14

Figure 15. Curve of Spee. The shortest distance between the incisal edge of the mandibular central incisor and FOP was measured and recorded. If the incisal edge is above FOP, the measurement is (+). If below, the measurement is (-). When the incisal edge is on the FOP, a (0) is noted.

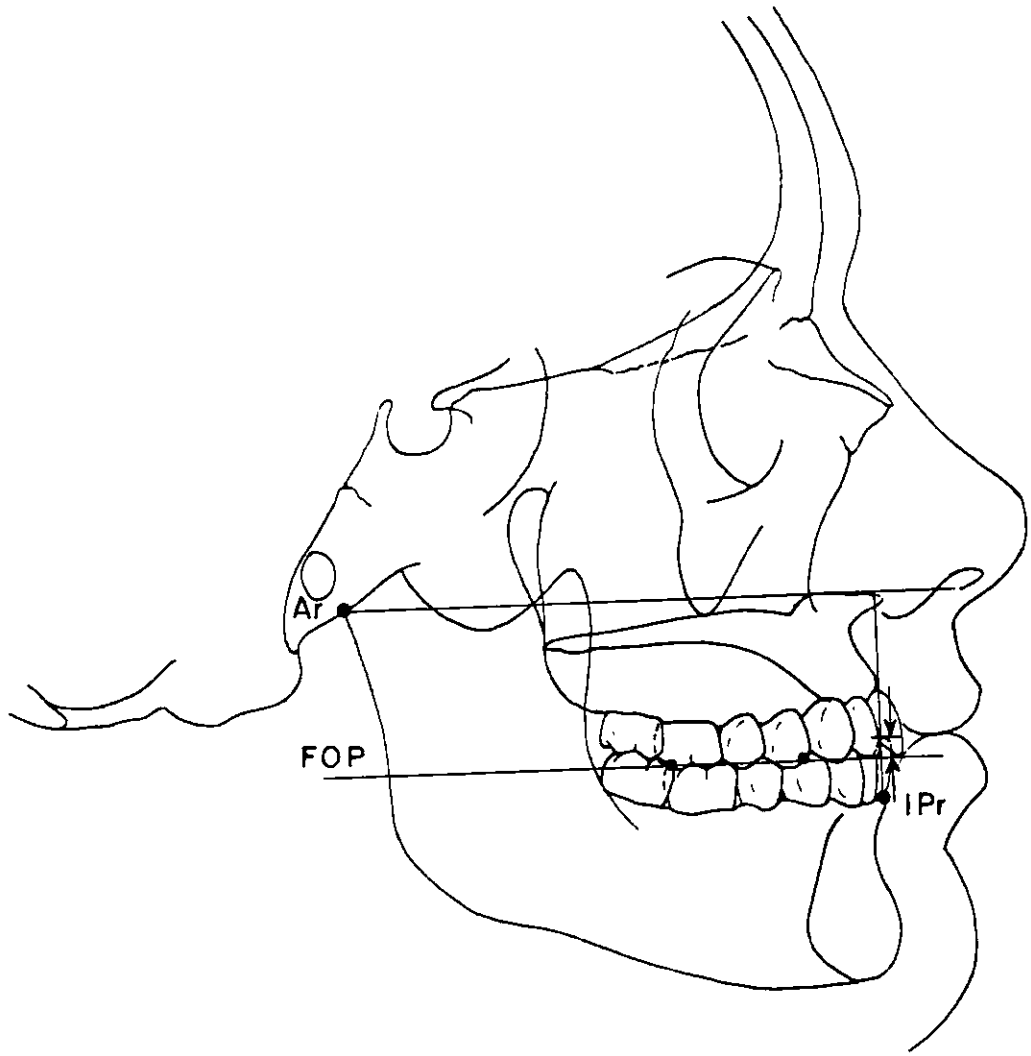


Figure 15

Figure 16. ANS-PNS depth. The greatest distance from the center of the maxilla to a line connecting ANS-PNS is recorded. The center is in the area of the bicuspids, approximately 8 mm behind the junction of the maxilla and premaxilla. When the center is below ANS-PNS, a (-) measurement is recorded. If above, a (+) is noted. A (0) measurement is recorded when the center coincides with ANS-PNS.

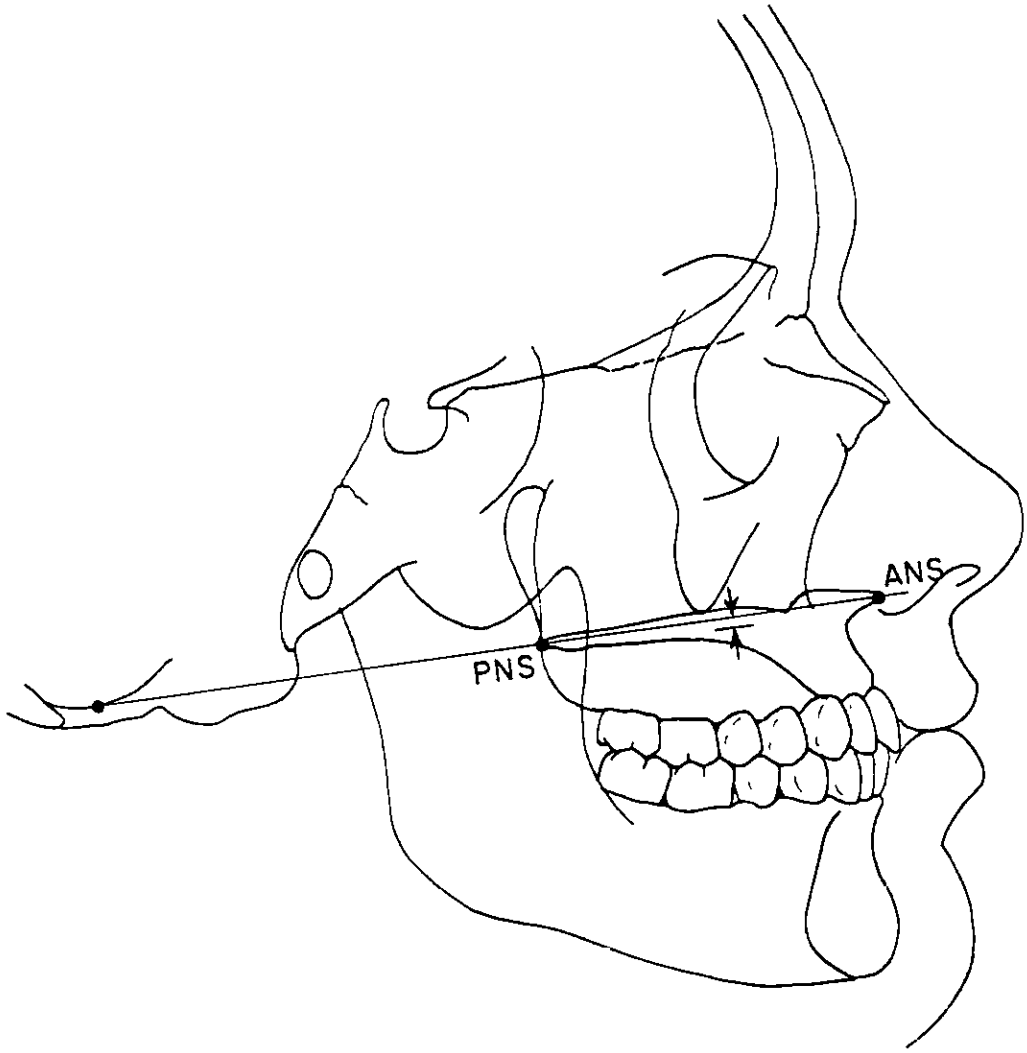


Figure 16

Figure 17. Inferior maxillary plane. The inferior growth boundary of the nasomaxillary complex is indicated by a line connecting the deepest surface of the occipital fossa, the maxillary tuberosity, and SPr. This measurement is valid only for individuals 12 years old or older, because the occipital fossa has not yet descended to its definitive adult position.

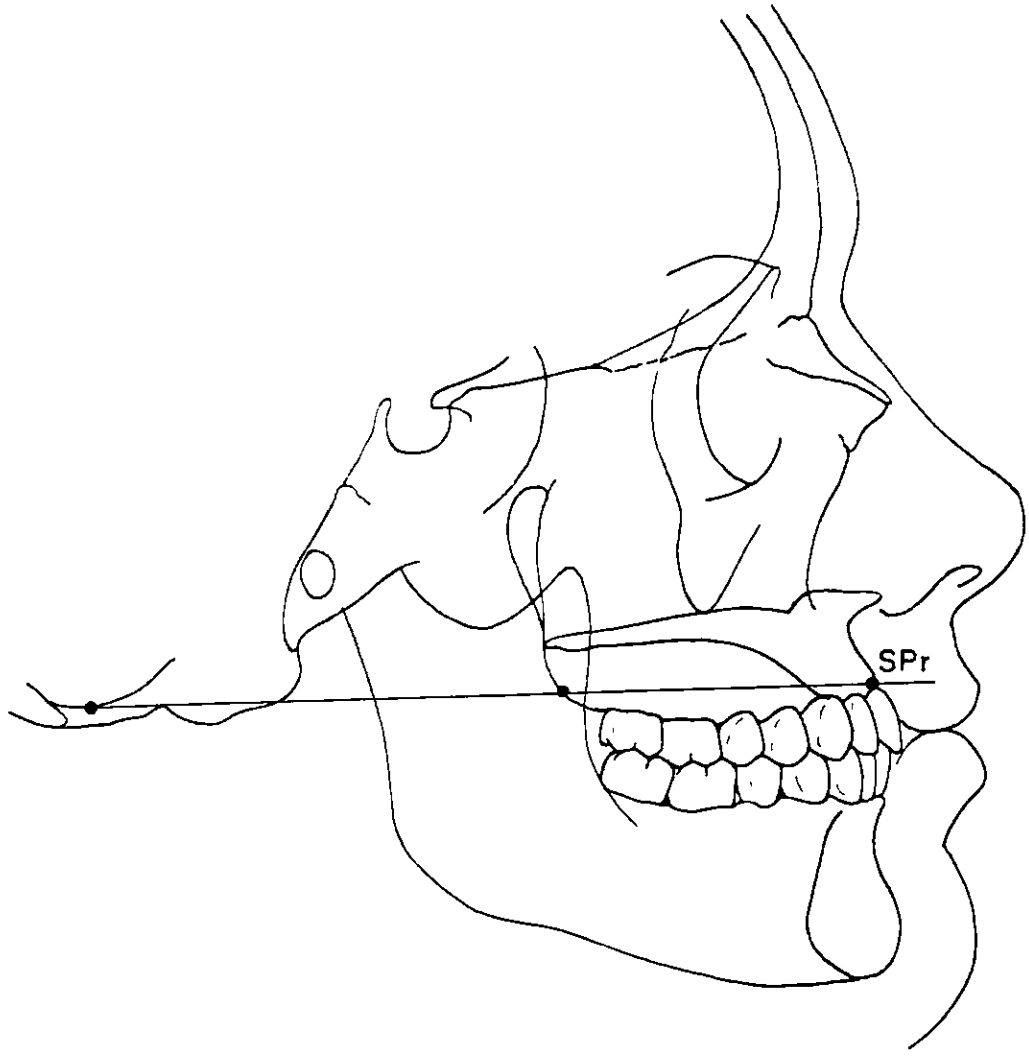


Figure 17

Figure 18. Inferior maxillary plane/palatal plane alignment. The line described in Figure 17 and the ANS-PNS line should cross at the deepest surface of the occipital fossa in normal individuals. The person must be at least 12 years old for this measurement to be valid.

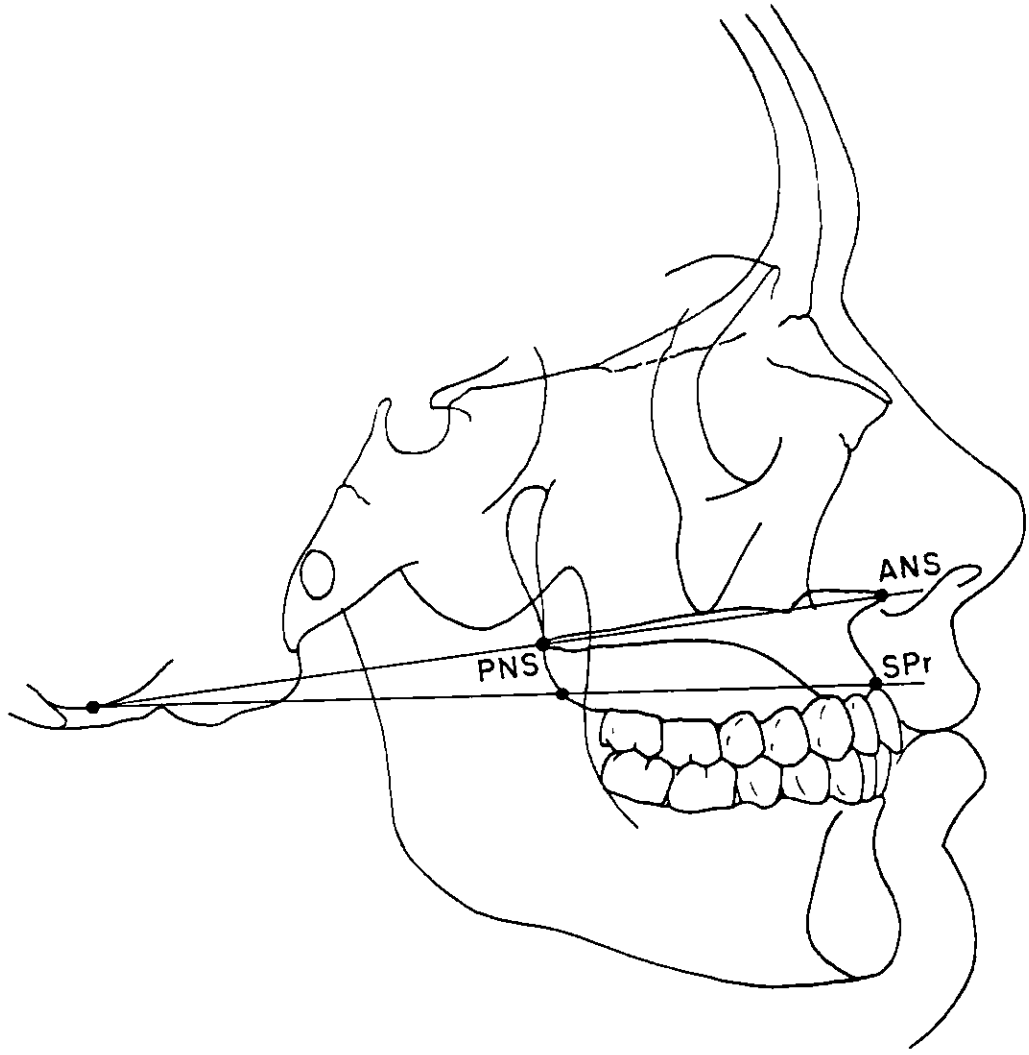


Figure 18

Figure 19. SNA. The sella-nasion-A point angle was recorded as indicated.

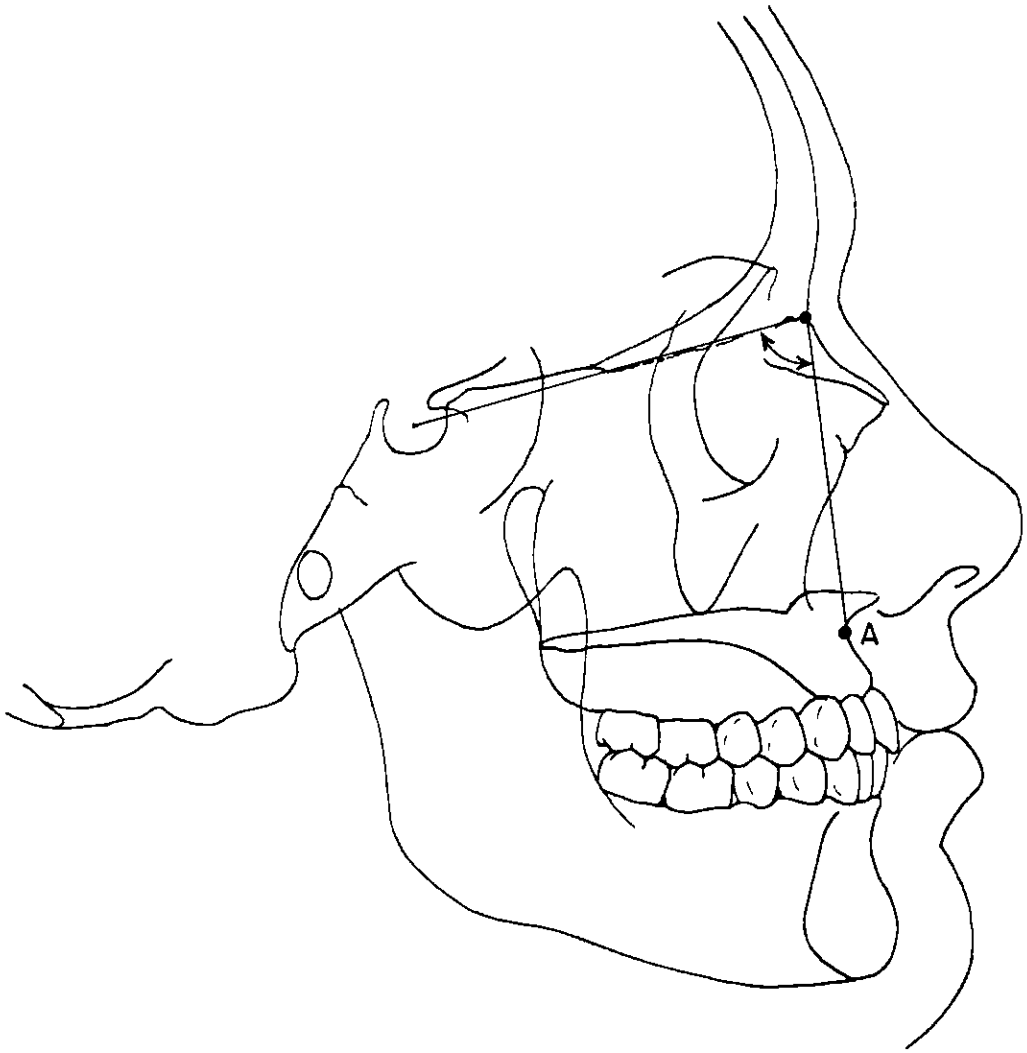


Figure 19

Figure 20. SNB. The sella-nasion-B point angle was recorded as indicated. The A point-nasion-B point angle was then calculated and recorded.

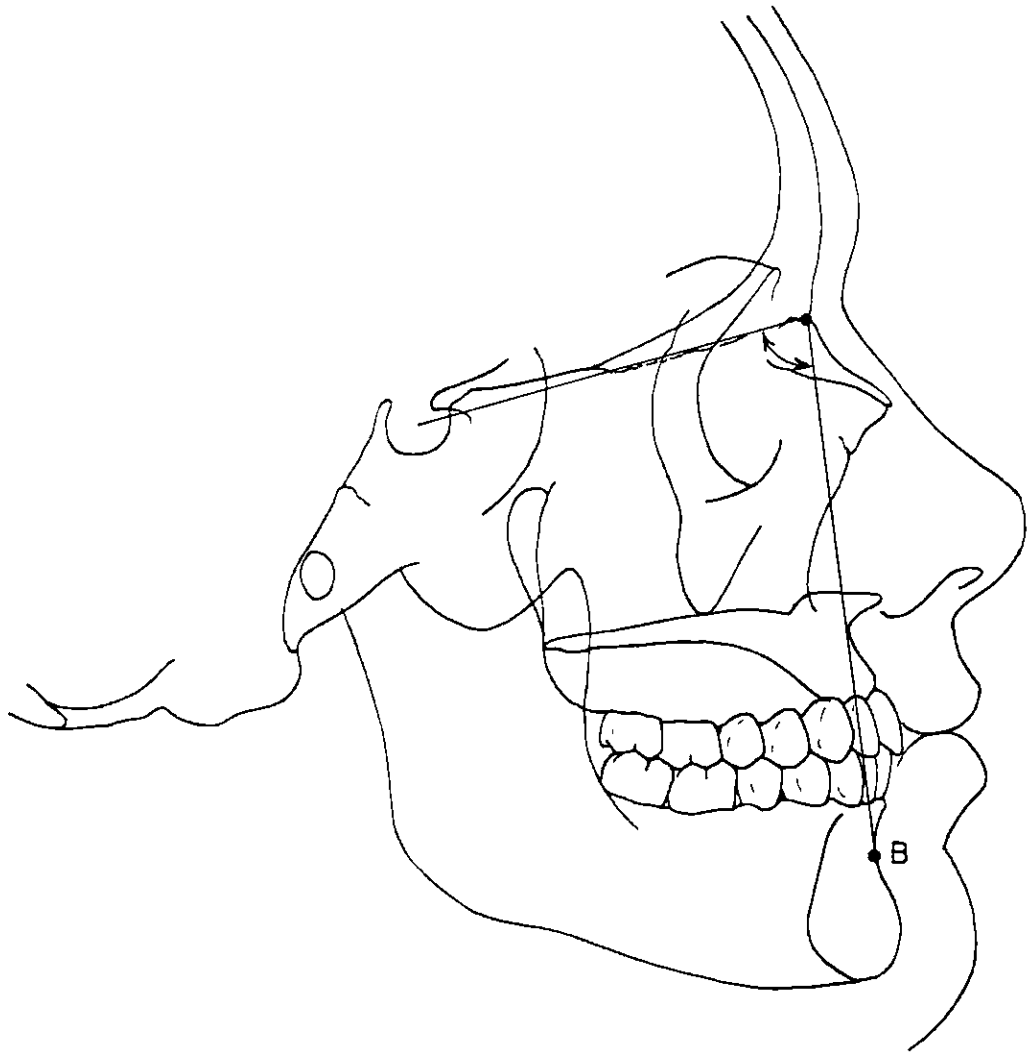


Figure 20

COMPARATIVE FINDINGS

Open Bite

The results of statistical analysis (analysis of variance) were examined, and differences between Class I and II open bite cases were not sufficient to warrant classifying them separately (Table XII). This was also true of deep bite cases. Therefore, open bite cases (Class I and II) were pooled for further statistical analysis (as were deep bite cases).

1. Gonial angle deviation. The difference between open and deep bite groups was significant ($p < .001$). The gonial angle was more open (larger) in open bite than the normal or deep bite group. At debanding, the angle had increased. When the dentition had settled at post-retention, the gonial angle closed slightly, but still was greater than before treatment. In the control group, the gonial angle was slightly less than the norm of the Michigan Standards (Riolo et al., 1975). However, it was intermediate between open bite and deep bite cases. The gonial angle was more closed (smaller) in deep bite cases than in normal or open bite cases before treatment. At debanding, the angle became smaller than before treatment (Table III, Figure 13).
2. Mandibular plane alignment. The difference between open and deep bite groups was significant ($p < .001$). The individual's mandibular plane was below the neutral mandibular plane in

open bite cases. At debanding, the distance increased. The mandibular plane to neutral mandibular plane distance decreased at post-retention, but it still was at a greater distance than before treatment. In the control group, the mandibular plane was above the neutral mandibular plane, but intermediate between open and deep bite cases. The mandibular plane was above the neutral mandibular plane in deep bite cases more than in the control cases before treatment. At debanding, the distance between the mandibular plane and the neutral mandibular plane decreased. At post-retention, the mandibular plane was further above the neutral mandibular plane than before treatment (Table III, Figure 12).

3. Occlusal plane. The difference between open and deep bite groups was significant ($p < .05$). The occlusal plane had rotated downward anteriorly in open bite cases (more than in deep bite cases). At debanding and post-retention the distance from the occlusal plane to the neutral occlusal axis decreased, although it remained below the neutral occlusal axis anteriorly. In the control group, the occlusal plane was below the neutral occlusal axis, but less than in open bite and deep bite cases. In the deep bite cases, the occlusal plane was below the neutral occlusal axis anteriorly before treatment, but not as much as in open bite cases. This distance decreased at debanding. At post-retention, there was a very slight increase from debanding, but the occlusal plane was still closer to the neutral occlusal axis than before treatment (Table IV, Figure 14).

4. Curve of Spee. The difference between open and deep bite groups was significant ($p < .001$). There was a negative Curve of Spee before treatment in the open bite cases. At debanding, there was a Curve of Spee (the incisal edge of the mandibular central incisor was above the functional occlusal plane). The Curve of Spee decreased at post-retention. There was a Curve of Spee in the control cases which was intermediate between open and deep bite cases. In the deep bite cases, there was a deep Curve of Spee before treatment. At debanding, there was a small Curve of Spee which increased at post-retention (Table IV, Figure 15).
5. ANS-PNS Depth. The difference between open and deep bite groups was significant ($p < .05$). The ANS-PNS depth was greater in open bite cases than in control and deep bite cases. At debanding, the depth increased. At post-retention, there was a slight decrease in depth. In the control group, there was a slight ANS-PNS depth which was intermediate between open bite and deep bite cases. The ANS-PNS depth was less in deep bite cases than in open bite cases or the control group which decreased at debanding and post-retention (Table V, Figure 16).
6. ANB. The difference between open and deep bite groups was significant ($p < .001$). The mean ANB value for Class I and II open bite cases was intermediate between the control group and deep bite cases. The ANB value of the control cases was the smallest of the three groups (open bite, control, deep bite).

In the deep bite cases, the ANB value was greatest of the three groups (open bite, control, deep bite).

7. Aggregate cranial floor/maxilla and ramus/corpus dimensions at A and B points. The difference between open and deep bite groups was significant ($p < .001$). There was a slight tendency towards mandibular protrusion in open bites before treatment but less than in the control group. At debanding, this changed to a slight maxillary protrusion tendency. At post-retention there was a decrease in the maxillary protrusion tendency. There was mandibular protrusion tendency in the control cases which was greater than in open bite and deep bite cases. There was a tendency towards maxillary protrustion before treatment in deep bite cases. At debanding and post-retention, this tendency decreased (Table V, Figure 2).
8. Aggregate cranial floor/maxilla and ramus/corpus dimensions at SPr and IPr. The difference between open and deep bite groups was significant ($p < .001$). In open bite cases, there was a maxillary protrusive effect of SPr before treatment but less than in deep bite cases. At debanding and post-retention, this effect decreased slightly. There was a mandibular protrusive effect of IPr in the normal cases. In the deep bite cases, there was a maxillary protrusive effect of SPr before treatment, much greater than in open bite cases. At debanding and post-retention, this effect decreased (Table VI, Figure 3).

9. Cranial floor (MCF) and posterior maxillary (PM) relative alignment. The difference between open and deep bite groups was significant ($p < .05$). There was a forward alignment of MCF and PM in open bite cases before treatment which was greater than in the control group, but not as great as in deep bite cases. At debanding, there was a decrease in the forward alignment of MCF and PM. At post-retention, there was a slight posterior alignment of MCF and PM. In the control group, there is a slight forward alignment of MCF, but less than in open or deep bite cases. In the deep bite cases, there was a forward alignment of the MCF and PM before treatment which was greater than in the control group or open bite cases. At debanding and post-retention, there was a slight decrease in anterior alignment of the MCF and PM (Table VI, Figure 4).
10. Ramus alignment. The difference between open and deep bite groups was significant ($p < .05$). The ramus was aligned more posteriorly in open bite than in control and deep bite cases. The extent of posterior alignment increased at debanding and post-retention. The ramus was aligned posteriorly the least amount of the three groups (open bite, control, deep bite). There was a posterior alignment of the ramus (in relation to the neutral ramus plane) before treatment which was greater than in the normal cases but less than in the open bite cases. This extent of posterior alignment increased at debanding. This decreased slightly at post-retention (as a result of the settling of the dentition) (Table VII, Figure 5).

11. Molar positions (composite). The difference between open and deep bite groups was significant ($p < .05$). In open bite cases, the maxillary and mandibular molars were in a neutral position before treatment, at debanding and at post-retention. The maxillary and mandibular molars were in a neutral position in the control cases. In the deep bite cases, the maxillary molars were in a slightly anterior position (in relation to the mandibular molars) before treatment. At debanding and post-retention, they were in a neutral position (Table VII, Figure 8).
12. PM as compared with ramus/MCF vertical dimensions. The difference between open and deep bite groups was significant ($p < .05$). There was an excess vertical PM dimension before treatment in open bite cases, which was greater than in control or deep bite cases. The dimension increased at debanding and at post-retention. In the control group, there was a slight excess in vertical PM dimension which was intermediate between open and deep bite cases. In the deep bite cases, there was a short PM vertical dimension before treatment. This dimension increased at debanding, but the overall effect at debanding was still a very slight decrease in PM vertical dimension. At post-retention, the dimension decreased to almost two thirds of the original measurement (Table VIII, Figure 9).
13. Corpus-occlusal alignment. The difference between open and deep bite groups was significant ($p < .05$). In the open bite cases, there was a greater backward ramus rotation than

downward corpus-occlusal rotation before treatment which was greater than in control or deep bite cases. The downward corpus-occlusal rotation decreased in relation to the backward ramus rotation at debanding and post-retention. In the control group, there was an upward corpus-occlusal alignment relative to the ramus rotation which was greater than in open bite cases, but approximately the same as in deep bite cases. In the deep bite cases, there was an upward corpus-occlusal rotation in relation to the ramus rotation before treatment which was greater than in open bite cases, but approximately the same as in the control group. This rotation increased at debanding. The extent of upward corpus-occlusal rotation decreased slightly at post-retention (Table VIII, Figure 10).

14. Palatal plane. The difference between open and deep bite was significant ($p < .001$). The palatal plane in the majority of open bite cases was below the deepest surface of the occipital fossa. In the control group, the palatal plane, in the majority of cases, coincided with the deepest surface of the occipital fossa. In the majority of deep bite cases, the palatal plane was above the deepest surface of the occipital fossa. This indicates in open bite that there is a counterclockwise rotation during vertical development of the nasomaxillary complex, and a clockwise rotation during vertical development of the nasomaxillary complex in deep bite (Figure 18).

Discriminant Analysis

The variables that were found to be statistically significant on the basis of bite may more likely contribute in linear combination to the basis for of an open bite or deep bite.

A discriminant analysis of all the variables, on the basis of bite (open bite vs. deep bite) was computed. The combination of variables that were the most discriminating between open bite cass and deep bite cases was the palatal plane alignment, occlusal plane alignment, Curve of Spee, ANS-PNS depth, aggregate cranial/maxilla and ramus/corpus dimensions at A and B points, and the ramus/MCF horizontal dimensions (skeletal). The percent of cases correctly classified by this combination of variables was 100.00%.

A discriminant analysis on the basis of bite (open bite vs. deep bite) was computed for the variables of the original hypothesis of open bite in the protocol for this study. The variables were the Curve of Spee, ANS-PNS depth, palatal plane, cranial floor (MCF) and posterior maxillary (PM) relative alignments, PM as compared with ramus/MCF vertical dimensions, ramus alignment, and the gonial angle. The combination of variables from this select group that were most discriminating between open bite cases and deep bite cases was the Curve of Spee, palatal plane, cranial floor (MCF) and posterior maxillary (PM) relative alignments, ramus alignment, PM as compared with ramus/MCF vertical dimensions, and the gonial angle. The percent of cases correctly classified by this combination was 98.33%.

DISCUSSION

In the control group, there are imbalances in certain anatomical regions that are compensated for by other offsetting anatomical imbalances, as also pointed out by Enlow et al. (1971). This results in an overall reasonably well balanced face. However, when certain regional imbalances are not offset, the result can be an open bite or a deep bite. One or more of the variables previously discussed may be present in persons without open bite. However, when there is a specific combination of the variables present, an open bite usually occurs.

Often in open bite cases, the gonial angle is more open than "normal", although an open gonial angle by itself is not to be regarded as a sole factor underlying open bite. The presence of a large gonial angle, however, in conjunction with a posteriorly aligned ramus, a negative Curve of Spee, and an increased vertical PM dimension, the morphological basis for an open bite exists.

The Curve of Spee is a dental compensation for a skeletal imbalance (Enlow, 1975). Skeletal development that otherwise could lead to open bite can be compensated for by a deep Curve of Spee, with the result being a closed occlusion.

Skeletal imbalances as such may not represent a primary biological cause for open or deep bite. Such imbalances could be a result, say, of an airway problem (that requires breathing through

the mouth because of decreased or no air passage through the nose). This, or other possible conditions presumably lead, in turn, to the skeletal consequences associated with open or deep bite.

The values of the means for some of the variables seem to indicate that deep bite and open bite are opposite anatomic entities. Opposite rotational directions and dimensional relationships occur for these particular variables. In open bite, the gonial angle has rotated "open" during development. In deep bite, the gonial angle has rotated "closed". The ANS-PNS depth increases throughout development in open bite but decreases in deep bite. There is a negative Curve of Spee in open bite, and a positive (deep) Curve of Spee in deep bite. There is an increased vertical PM dimension in open bite, and a decreased vertical PM dimension in deep bite. During vertical development of the nasomaxillary complex, both the inferior maxillary plane and the palatal plane become aligned in a counter-clockwise manner in open bite. In deep bite, the inferior maxillary plane and the palatal plane but are aligned in a clockwise manner.

The palatal plane in the majority of open bite cases was below the deepest surface of the occipital fossa. In the control group, the palatal plane, in the majority of cases, coincided with the deepest surface of the occipital fossa. In the majority of deep bite cases, the palatal plane was above the deepest surface of the occipital fossa. This indicates

in open bite that there is a counterclockwise rotation during vertical development of the nasomaxillary complex, and a clockwise rotation during vertical development of the nasomaxillary complex in deep bite.

In the control group, the gonial angle deviation, mandibular plane alignment, Curve of Spee, ANS-PNS depth, PM as compared with ramus/MCF vertical dimensions, corpus-occlusal alignment, and the palatal plane were intermediate between the open bite and deep bite groups. The molar position (composite) of the control and open bite groups were neutral and approximately the same, while the deep bite group had a protrusive effect. The control group had the greatest mandibular protrusive effect for the aggregate cranial floor/maxilla and ramus/corpus dimensions at A and B points and at SPr and IPr and the least rotational effect for the cranial floor (MCF) and posterior maxillary (PM) relative alignment and the ramus alignment. The control group had the least downward rotational alignment anteriorly of the occlusal plane from the neutral occlusal axis.

Anatomic effects associated with orthodontic treatments were evaluated, although of course it cannot be determined whether the effect is treatment-caused or a change that might have occurred during growth with or without treatment. In the open bite cases, the gonial angle was larger at debanding than before treatment. It did decrease by post-retention, but was still larger than before treatment. A more clockwise (open) position of the corpus resulted. This contributed to a partial return of the open bite. In

deep bite cases, the gonial angle was the same at debanding, but decreased to a smaller angle (than before treatment) by post-retention. As a result, a more clockwise (closed) position of the corpus existed. This contributed to a partial return of the deep bite. The mandibular plane rotated downward more at debanding in open bite cases, rotated upward by post-retention but still was further downward than before treatment. The result was a more open position of the mandibular dentition than before treatment. This contributed to a partial return of the open bite. The mandibular plane in deep bite cases rotated upward at debanding, and (more than before treatment) at post-retention. As a result, there was a more closed position of the mandibular dentition than before treatment. This contributed to a partial return of the deep bite. The occlusal plane rotated upward at debanding and rotated upward slightly more at post-retention in open bite cases. An overlap of the mandibular central incisal edge and the maxillary central incisal edge resulted. This contributed to the decrease of the open bite. In deep bite cases, the occlusal plane rotated upward at debanding, then downward slightly at post-retention but less than before treatment. As a result, there was an increased overlap of the maxillary incisal edge and mandibular incisal edge. This contributed to a partial return of the deep bite. In open bite cases, the Curve of Spee increased at debanding, with a slight decrease at post-retention. An overlap of the mandibular central incisal edge and the maxillary central incisal edge resulted. This contributed to a decrease of open bite. The

Curve of Spee was decreased greatly at debanding, with a slight increase at postretention (but overall Curve of Spee was much less than before treatment) in deep bite cases. This contributed to a decrease of the deep bite. The ANS-PNS depth continued to increase until debanding in open bite cases, but decreased slightly at post-retention. The overall effect, however, was to contribute to a greater opening of the bite. In deep bite cases, the ANS-PNS depth continued to decrease from before treatment until post-retention. This contributed to a partial return of the deep bite. The aggregate cranial floor/maxilla and ramus/corpus dimensions at A and B points and SPr and IPr demonstrated an overall increase in maxillary protrusive effect in open bite cases and a decrease in deep bite cases. As a result, in open bite, the mandible was positioned in a more closed (counterclockwise) manner, and in deep bite, the mandible was positioned in a more open (clockwise) manner. No treatment effect was found on the cranial floor (MCF) and posterior maxillary (PM) relative alignment. During treatment, the ramus became aligned even further posteriorly and this continued until post-retention in open bite cases. As a result the mandible rotated open in a clockwise manner. This contributed to partial return of the open bite. In deep bite cases, the ramus also became aligned more posteriorly until debanding, but there was a slight forward movement until post-retention. This contributed to a decrease of the deep bite. The molar relationships were corrected to neutral positions in open and deep bites. The vertical PM dimension continued to increase

throughout treatment and until post-retention in open bite cases. As a result, the mandible rotated open in a clockwise manner. This contributed to a partial return of the open bite. In deep bite cases, the dimension increased at debanding, thus contributing to an actual decrease in deep bite. However, it rebounded to a slight extent at post-retention. This contributed to a partial return of the deep bite. The occlusal plane rotated downward less in relation to the ramus rotation from at debanding and post-retention in open bite cases. A counterclockwise rotation of the corpus resulted. This contributed to a decrease of the open bite. The occlusal plane rotated downward less in relation to ramus rotation in deep bite cases at debanding, followed by a slight upward rotation (rebound) at post-retention. A counterclockwise rotation of the corpus resulted. This contributed to a partial return of the deep bite. Therefore, orthodontic treatment (and/or growth with or without treatment) did have an effect on the gonial angle, the mandibular plane alignment, the occlusal plane, the Curve of Spee, the aggregate cranial floor/maxilla and ramus/corpus dimensions at A and B points and SPr and IPr, the ramus alignment, and the corpus-occlusal alignment. Orthodontic treatment (and/or growth) did not have an effect on ANS-PNS depth, cranial floor (MCF) and posterior maxillary (PM) alignment, and the PM as compared with ramus/MCF vertical dimensions (PM vertical dimension).

SUMMARY AND CONCLUSIONS

The purpose of this study was to determine the particular combinations of skeletal characteristics of the craniofacial complex, utilizing the counterpart analysis, that are associated with skeletal open bite, and to evaluate the anatomic effects of treatment of these anatomic variables. The sample was divided into three groups: (1) "normal" untreated (Class I individuals with good occlusion and ANB value of 0-4.5°); (2) open bite cases before treatment, at debanding, and post-retention, divided into Class I (ANB value of 0-4.5°) and Class II (ANB value 4.5°); and (3) deep bite cases before treatment, at debanding and post-retention, divided into Class I (ANB value of 0-4.5°) and Class II (ANB value 4.5°).

Anatomic counterparts (both dimensions and alignment) were compared utilizing the counterpart procedure. This analysis is intended for actual anatomical evaluations, in contrast to standard cephalometric planes and angles. Unlike conventional cephalometric analyses, the planes utilized in the counterpart procedure coincide with specific, key fields and sites of growth and remodeling.

The findings of this investigation lead to the following conclusions:

1. The gonial angle was larger in open bite than in normal or deep bite. The gonial angle increased from before treatment until post-retention.
   In deep bite, the gonial angle was smaller than in normal or open bite. The gonial angle increased slightly at debanding, but became smaller at post retention than before treatment in deep bite.

2. The mandibular plane in open bite is aligned downward anteriorly from the neutral mandibular plane. The distance between the neutral mandibular plane and the individual's mandibular plane increased from the before treatment position to the post-retention position. The mandibular plane in deep bite tends to be aligned upward anteriorly from the neutral mandibular plane. At debanding, the distance between neutral mandibular plane and the individual's mandibular plane decreased. At post retention, the mandibular plane was further above the neutral mandibular plane than before treatment.

3. The occlusal plane was rotated downward anteriorly from the neutral occlusal axis in open bite (more than in normal or deep bite). The downward rotation decreased slightly from before treatment until post-retention. In deep bite, the occlusal plane was below the neutral occlusal axis anteriorly before treatment, but not as much as in open bite caes. This distance decreased at debanding. At post retention, there was a very slight increase from debanding, but the occlusal plane was still closer to the neutral occlusal axis than before treatment.

4. The Curve of Spee was negative before treatment in open bite. There was a small Curve of Spee at post-retention. In deep bite, there was a deep Curve of Spee before treatment. At debanding, there was a small Curve of Spee which increased at post-retention.

5. The ANS-PNS depth was greater in open bite than in normal or deep bite. The depth increased from before treatment until post-retention. In deep bite, there was a small ANS-PNS depth before treatment which decreased at debanding and post-retention

6. The ANB angle was less in open bite than deep bite, but greater than the control group. The deep bite had the greatest ANB angle of the three groups (open bite, control, deep bite).

7. The aggregate cranial floor/maxilla and ramus/corpus dimensions at A and B points demonstrated a slight mandibular protrusive effect in open bite before treatment. At debanding and post-retention, there was a slight maxillary protrusive effect. In deep bite, there was a maxillary protrusive effect which decreased at debanding and post-retention.

8. The aggregate cranial floor/maxilla and ramus/corpus dimensions at SPr and IPr demonstrated a slight maxillary protrusive effect of SPr before treatment in open bite which

decreased at debanding and post-retention. In deep bite, there was a greater maxillary protrusive effect of SPr than in open bite before treatment, which decreased at debanding and post-retention.

9. In open bite, the cranial floor (MCF) and posterior maxillary (PM) relative alignment was forward of the neutral MCF/PM, but to a lesser extent than in deep bite. The forward alignment decreased from before treatment until post-retention. In deep bite, the forward alignment of MCF and PM before treatment was greater than in open bite which decreased slightly at debanding and post-retention.

10. In open bite, the ramus was aligned more posteriorly in relation to the neutral ramus axis than in normal or deep bite. The extent of posterior alignment increased from before treatment until post-retention. In deep bite, there was a posterior alignment of the ramus in relation to the neutral ramus axis before treatment which was greater than in the control group but less than in open bite. This extent of posterior alignment increased at debanding. This decreased slightly at post-retention.

11. The molar position (composite) did not have an effect on open bite. The molars were in a neutral position from before treatment until post-retention. In deep bite cases, the maxillary molars were in a slightly anterior position (in relation to the mandibular molars) before treatment. At debanding and post-retention, the molars were in a neutral position.

12. There was an excess vertical PM dimension in open bite as demonstrated by the PM as compared with ramus/MCF vertical dimension. This dimension increased from before treatment until post-retention. In deep bite, there was a short PM vertical dimension before treatment. This dimension increased at debanding but the overall effect at debanding was still a very slight decrease in PM vertical dimension. At post-retention, the dimension decreased to almost two-thirds of the original measurement.

13. In open bite, the occlusal plane rotated downward less than the backward rotation of the ramus. The extent of downward rotation of the occlusal plane was less than in normal or deep bite. The amount of downward rotation of the occlusal plane decreased from before treatment until post-retention. In deep bite cases, there was an upward corpus-occlusal rotation in relation to the ramus rotation before treatment which was greater than in open bite, but approximately the same as in the control group. This rotation increased at debanding. The extent of upward

corpus-occlusal rotation decreased slightly at post-retention.

14. Palatal plane. The palatal plane in the majority of open bite cases was below the deepest surface of the occipital fossa. In the control group, the palatal plane, in the majority of cases, coincided with the deepest surface of the occipital fossa. In the majority of deep bite cases, the palatal plane was above the deepest surface of the occipital fossa. This indicates in open bite that there is a counterclockwise rotation during vertical development of the nasomaxillary complex, and a clockwise rotation during vertical development of the nasomaxillary complex in deep bite.
15. It is a combination of several or all of the above factors, not any one by itself, that is associated with the development both of open bite and deep bite.
16. The most discriminating combination of variables between open and deep bite was the palatal plane alignment, Curve of Spee, ANS-PNS depth, aggregate cranial floor/maxilla and ramus/corpus dimensions at A and B points, and the ramus/MCF horizontal dimensions (skeletal). One hundred percent of the cases were correctly classified by this combination.

TABLE III

GONIAL DEVIATION (G_D) AND MANDIBULAR ALIGNMENT (A_1)
BY BITE AND STAGE

O = Open Bite; B = Bolton (control); D = Deep Bite

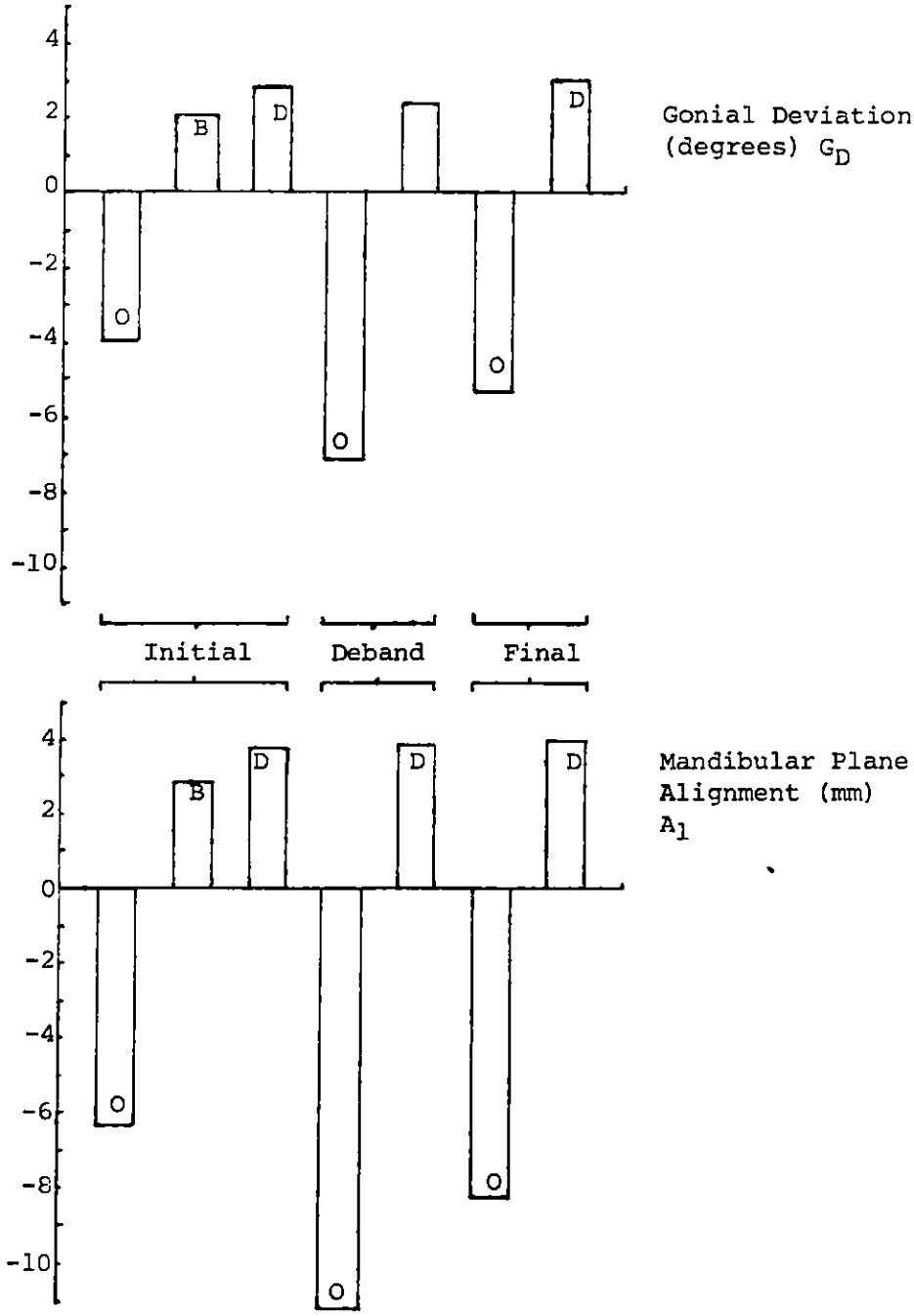


TABLE IV

OCCLUSAL PLANE ALIGNMENT (A_2) AND CURVE OF SPEE (A_3)
BY BITE AND STAGE

O = Open Bite; B = Bolton (control); D = Deep Bite

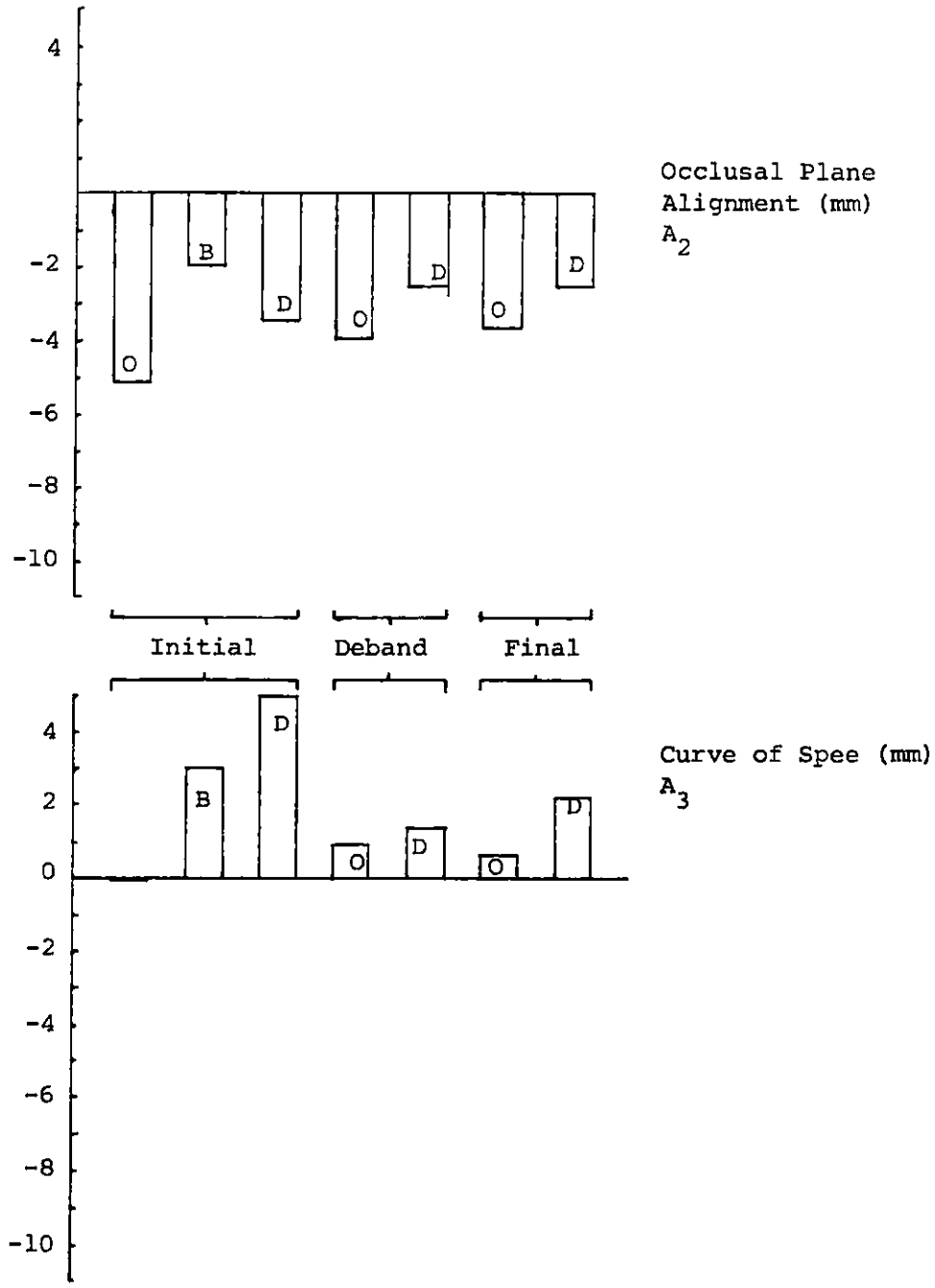


TABLE V

ANS-PNS DEPTH (A_4) AND AGGREGATE CRANIAL FLOOR/MAXILLA COMPARED WITH RAMUS/CORPUS HORIZONTAL DIMENSIONS AT A AND B POINTS (B_1) BY BITE AND STAGE

O = Open Bite; B = Bolton (control); D = Deep Bite

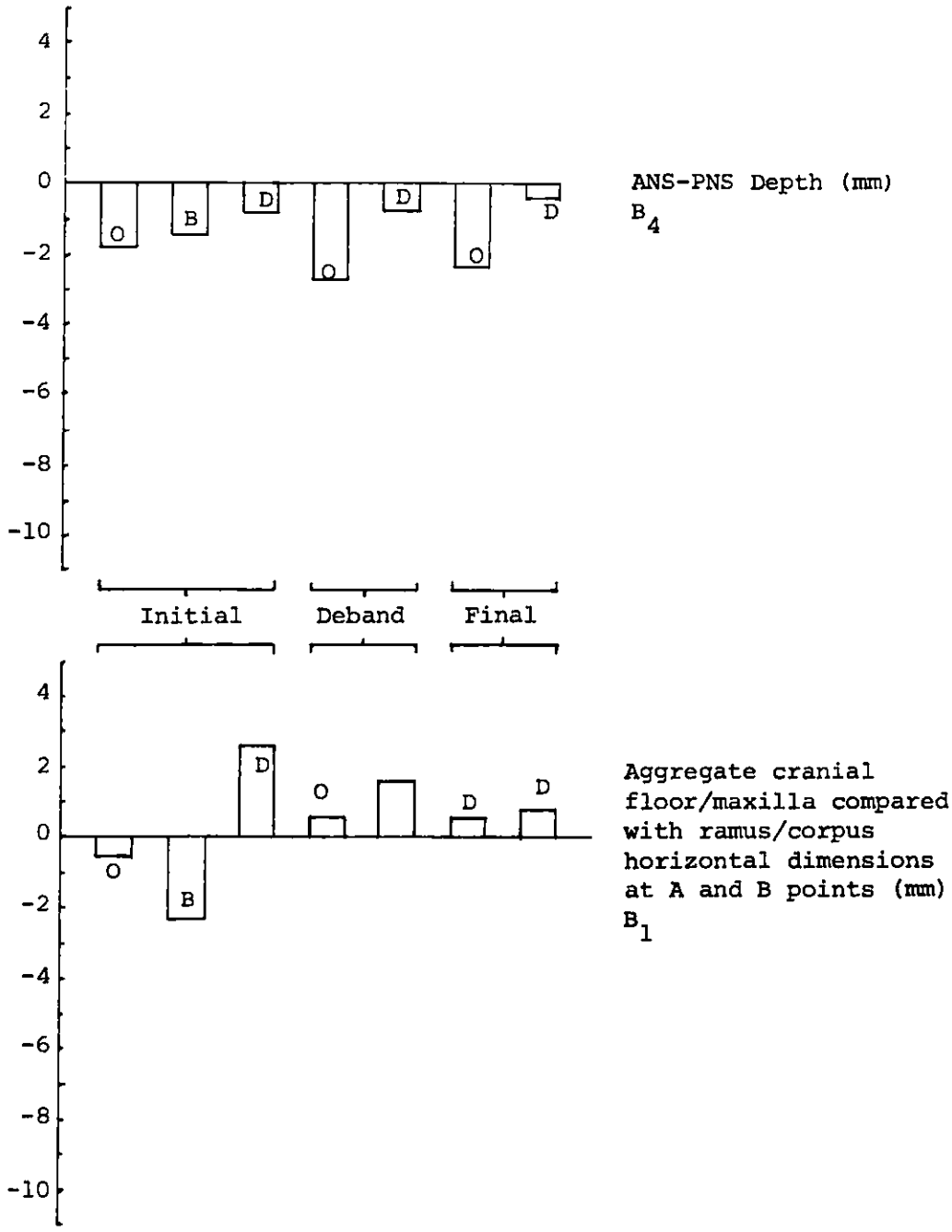
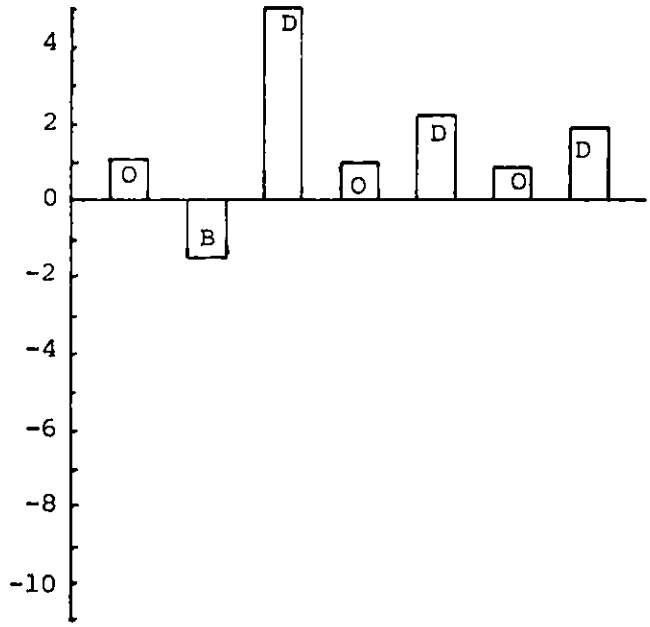


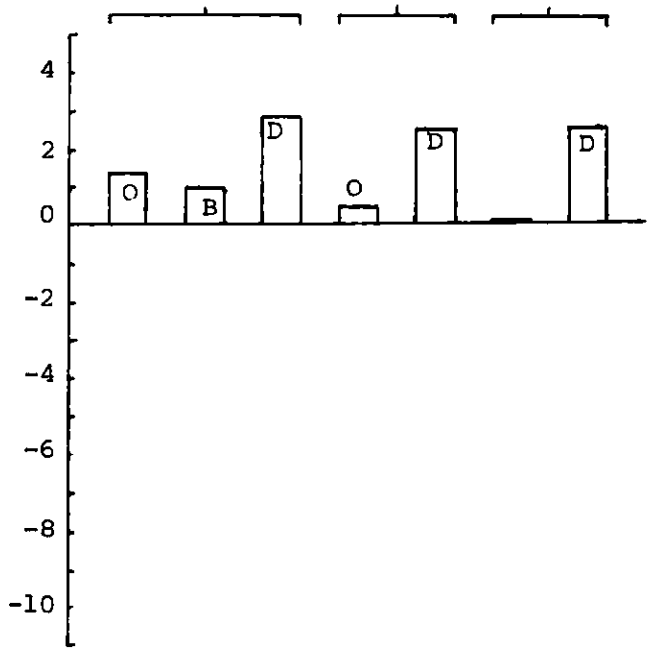
TABLE VI

AGGREGATE CRANIAL FLOOR/MAXILLA COMPARED WITH RAMUS/CORPUS HORIZONTAL DIMENSIONS AT SPr AND IPr AND CRANIAL FLOOR AND POSTERIOR MAXILLARY (PM) RELATIVE ALIGNMENTS (B_3)

O = Open Bite; B = Bolton (control); D = Deep Bite



Aggregate cranial floor/maxilla compared with ramus/corpus horizontal dimension at SPr and IPr (mm) B_2



Cranial floor (MCF) and posterior maxillary (PM) relative alignments (mm) B_3

TABLE VII

RAMUS ALIGNMENT (B_4) AND MOLAR POSITIONS, COMPOSITE (B_7)

O = Open Bite; B = Bolton (control); D = Deep Bite

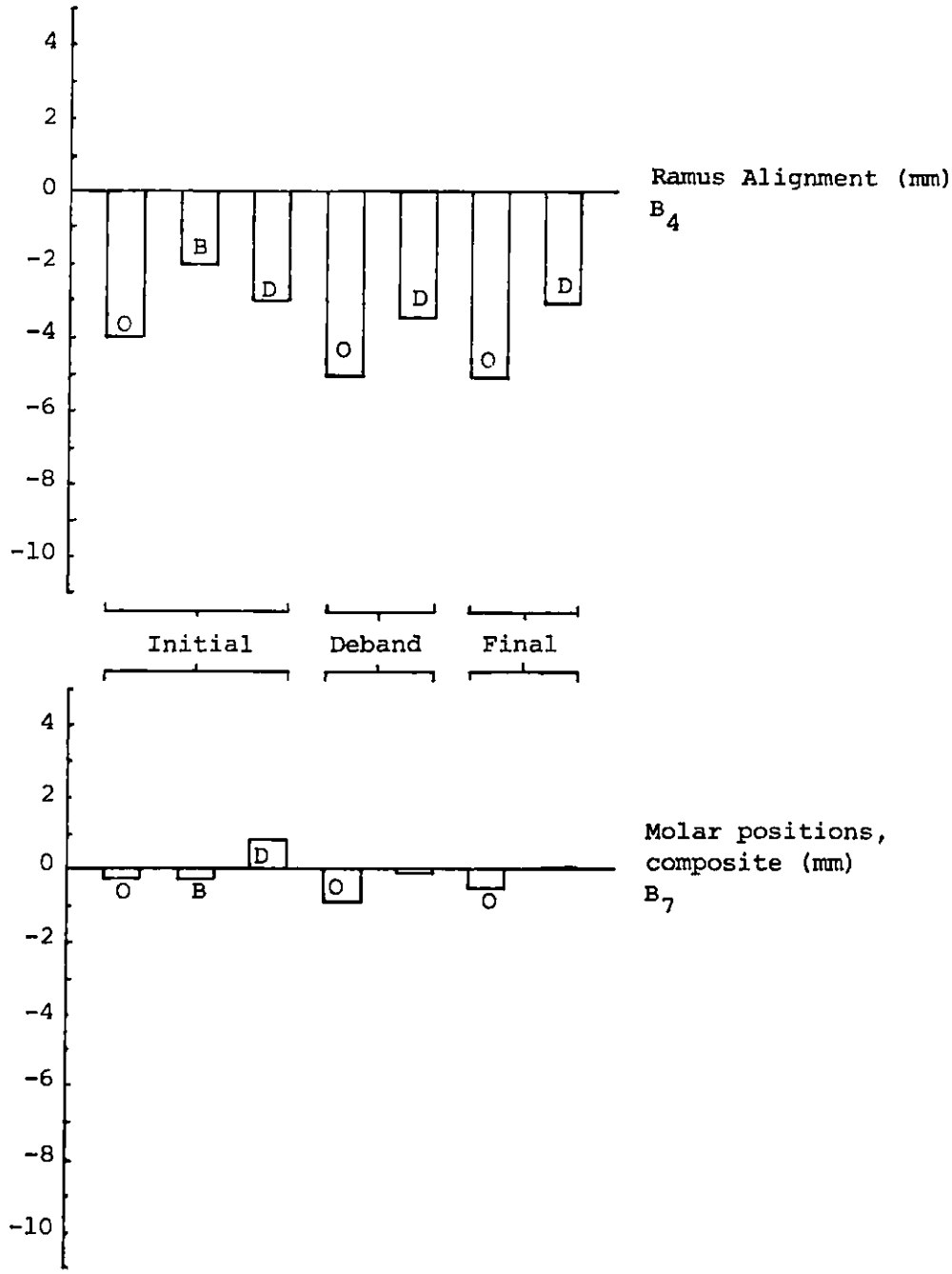


TABLE VIII

PM AS COMPARED WITH RAMUS/MCF VERTICAL DIMENSIONS (B_8) AND CORPUS-OCCLUSAL ALIGNMENT (B_9)

O = Open Bite; B = Bolton (control); D = Deep Bite

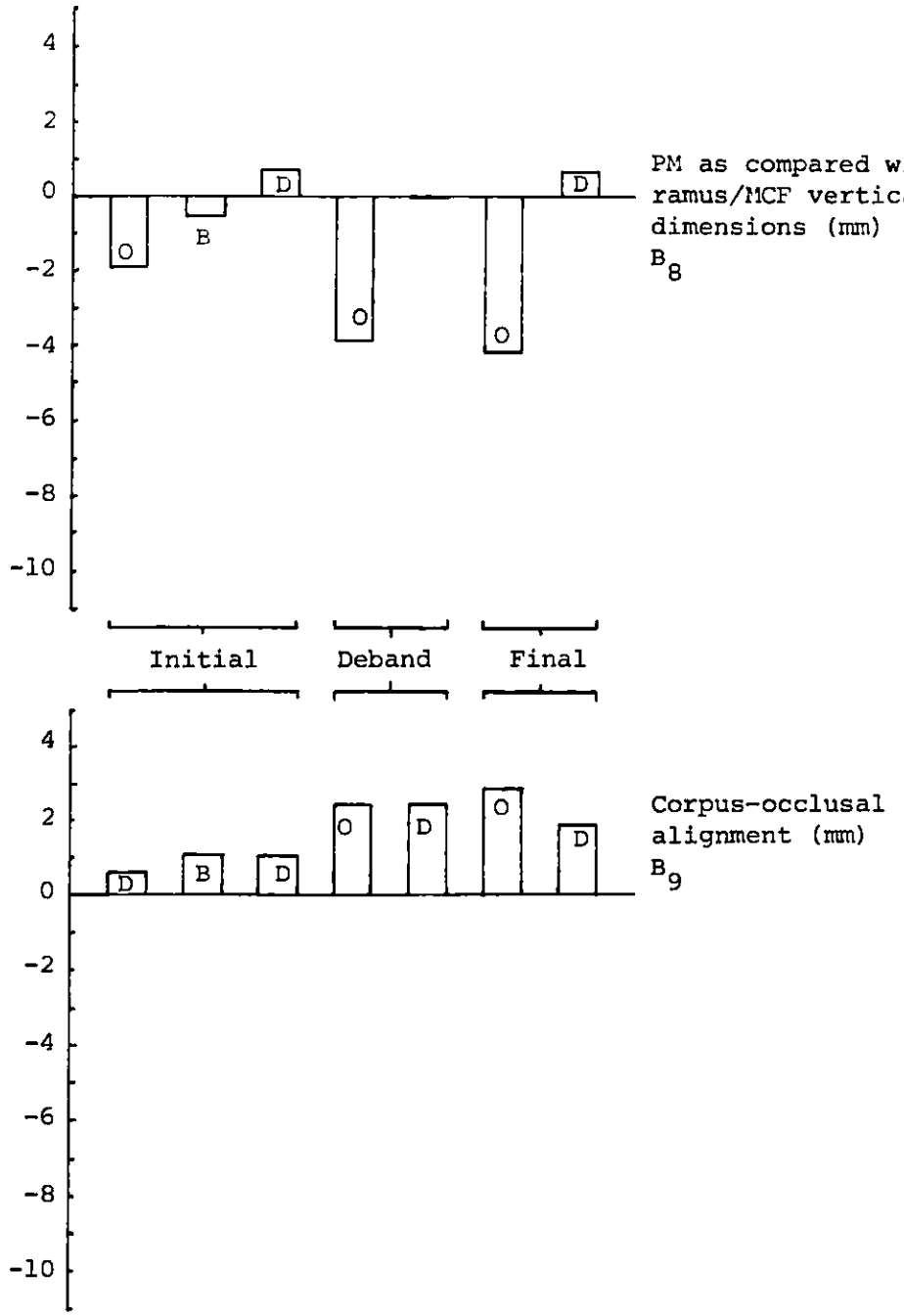


TABLE IX

MEANS OF MEASURED VARIABLES

(pooled stages of treatment)

Variable	Bolton	Open Bite	Deep Bite
Age (months)	174.67	181.97	184.58
G_n (degrees)	124.40	124.47	124.00
G_i (degrees)	122.33	129.84	121.20
A_1 (mm)	2.78	-8.40	-3.77
A_2 (mm)	-2.00	-4.34	-2.89
A_3 (mm)	3.02	0.46	2.84
A_4 (mm)	-1.65	--2.30	-0.68
A_5 (degrees)	81.77	80.50	81.22
A_6 (degrees)	79.57	75.95	76.27
A_7 (degrees)	2.20	4.55	4.97
B_1 (mm)	-2.27	0.17	1.68
B_2 (mm)	-0.16	0.93	3.00
B_3 (mm)	0.93	0.60	2.64
B_4 (mm)	-2.10	-4.63	-3.17
B_5 (mm)	0.67	-0.29	0.24
B_6 (mm)	-3.86	-6.28	-5.76
B_7 (mm)	-0.28	-0.54	0.24
B_8 (mm)	-0.59	-3.29	-0.40
B_9 (mm)	1.12	1.81	1.71
B_{10} (mm)	-3.32	-3.54	-5.30

TABLE X

MEANS OF MEASURED VARIABLES BY BITE AND STAGE OF TREATMENT

	Bolton	Open Bite			Deep Bite		
	Class I Untreated	Before Treatment	Deband	Post-Retention	Before Treatment	Deband	Post-Retention
G_D	2.07	-3.98	-7.12	-5.34	2.84	2.47	3.07
A_1	2.78	-6.34	-11.19	-8.21	3.79	3.39	4.10
A_2	-2.00	-5.22	-3.96	-3.72	-3.46	-2.57	-2.63
A_3	3.02	-0.25	0.86	0.63	4.98	1.36	2.13
A_4	-1.65	-1.86	-2.73	-2.41	-0.79	-0.76	-0.51
B_1	-2.27	-0.48	0.56	0.53	2.66	1.65	0.72
B_2	-1.60	1.12	0.93	0.73	4.99	2.18	1.80
B_3	0.93	1.23	0.48	0.27	2.87	2.44	2.60
B_4	-2.10	-3.93	-4.97	-5.11	-2.98	-3.38	-3.16
B_7	-0.28	-0.27	-0.82	-0.59	0.86	-0.21	0.38
B_8	-0.59	-1.88	-3.87	-4.30	0.70	-0.36	0.51
B_9	1.12	0.51	2.26	2.82	1.11	2.22	1.83
B_{11}	-0.27	-0.77	-0.77	-0.77	-0.10	-0.10	-0.10

TABLE XI

RESULTS OF ANALYSIS OF VARIANCE

Bite (Open vs. Deep)

Variable	F	Significance of F
G_n	20.21	0.001
A_1	23.19	0.001
A_2	5.28	0.024
A_3	155.73	0.001
A_4	4.94	0.029
B_1	22.48	0.001
B_2	37.74	0.001
B_3	6.53	0.013
B_4	5.46	0.022
B_7	4.34	0.040
B_8	10.66	0.002
B_{11}	17.52	0.001

TABLE XII

RESULTS OF

ANALYSIS OF VARIANCE
Class (I vs. II)

Variable	F	Significance of F
A_2	14.92	0.001
A_7	118.38	0.001
B_4	4.89	0.029
B_9	4.82	0.031

TABLE XIII

DISCRIMINANT ANALYSIS

Variables Tested: G_D, A_1, A_2, A_3, A_4, A_7, B_1, B_2, B_3, B_4, B_5, B_6, B_7, B_8, B_9, B_{10}, B_{11}

Discriminating Variables	Univariate f	Discriminant Coefficient
A_2	4.19	-0.22
A_3	154.42	-0.78
A_4	4.81	0.13
B_1	17.52	-0.20
B_5	21.57	0.15
B_{11}	1.94	-0.10

Percent of "grouped" cases correctly classified: 100%

TABLE XIV

DISCRIMINANT ANALYSIS

Variables Selected: A_3, A_4, B_3, B_4, B_8, B_{11}, G_D

Discriminating Variables	Univariate f	Discriminant Coefficient
A_3	154.42	-0.79
B_3	6.53	-0.53
B_4	5.13	0.42
B_8	11.03	-0.57
B_{11}	17.52	-0.15
G_D	20.29	-0.16

Percent of "grouped" cases correctly classified: 98.33%

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