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We hereby approve the thesis of

Dayse Urias

candidate for the Master of Science in Dentistry

degree.

Signed: Donald H. Enlow

(Chairman)

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A LONGITUDINAL STUDY OF FACIAL GROWTH USING THE COUNTERPART ANALYSIS

by

DAYSE URIAS

Submitted in partial fulfillment of the requirements for the Degree of Master of Science in Dentistry

Department of Orthodontics

School of Dentistry

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A LONGITUDINAL STUDY OF FACIAL GROWTH

USING THE COUNTERPART ANALYSIS

Abstract

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Recent knowledge of craniofacial biology has recognized growth as a dynamic process throughout life.

However, little is known about the morphological alterations undergone by individual bones, their interrelationships and their effect on the facial profile.

The purpose of this investigation is to assess some of the multiple, regional anatomical features of the facial complex, and its morphological alterations from very early in life until late adulthood. The counterpart analysis was used for serial headfilm evaluation.

The results of this study led to the following conclusions:

1. Group I and II presented similar tendencies toward a Class II skeletal and occlusal pattern. However, Group I presented a greater amount of compensatory features.

2. Ramus alignment showed a significant counterclockwise rotation in Group I. This fact in conjunction with the forward alignment of the

MCF decreased the relative dimension of PM (the posterior maxilla).

3. The backward alignment of MCF was progressive and increased the vertical dimension of PM in Group II.

4. The increase in the horizontal dimension of the mandibular corpus in Group I may demonstrate that the possibility for third molar eruption is greatly enhanced as the individual ages.

5. The severity of the counterclockwise rotation of the IMP observed in both groups were related to different mechanisms. In Group I there was a greater increase of ramus height relative to PM and a greater upward movement of the dentoaveolar region at SPr. In Group II ramus height did not offset the posterior dentoaveolar development and the counterclockwise rotation of IMP.

6. In Group I the palatal plane alignment changed to the opposite direction, that is, clockwise. In Group II this characteristic was already present and it was further increased. These changes may involve a tendency to deepen the bite and also may explain soft tissue alterations observed with age such as the downward movement of the tip of the nose. In this study the changes in the underlying skeletal structure would show an elongation of the upper lip related to the alveolar process.

7. Both groups demonstrated an upward rotation of the mandibular corpus. Consequently any alteration during orthodontic treatment in an opposite direction might be related to an improper use of mechanics rather than growth alone.

8. In Group I the mandibular corpus and ramus demonstrated a counterclockwise rotation. Besides, in both groups it was found that the lower mandibular dental arch was decreased relatively to the maxillary dental arch. The

above changes could participate in the development of secondary crowding and bite deepening in later ages.

9. The curve of spee demonstrated a greater increase in Group I and is related to the greatest potential for compensations observed in this group.

10. Statistically, changes in the direction of the ramus alignment and inferior maxillary plane observed in Group I were significant at .05 level.

ACKNOWLEDGEMENTS

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Particular thanks goes to all my classmates Korntip Aksharanugraha, Jeffrey A. Cavalancia, Fuang-Ling (Grace) Chen, Charles A. Krause, and Brian P. Radulovich, for these enjoyable years together. I wish them success in their future endeavors.

DEDICATION

TO

My beloved parents for all their unselfish love, support and constant wise advice.

"Like apples of gold in pictures of silver is a word spoken in right circumstances". Prov XXV, xi.

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INTRODUCTION

Knowledge of growth and development of the craniofacial complex has been of basic interest to the researcher and clinical orthodontist in the treatment and study of occlusion and related facial anomalies.

However, most morphological investigations in the field rarely go beyond the second decade of life. Accordingly, this does not promote a full appreciation of the complete sequence of the growth process from early development until late adulthood. Recent information indicates that the aging skeleton retains a potential for remodeling, both in the neural and visceral crania (Israel, 1973).

It is no longer appropriate to consider the postpuberal years as a termination point for growth. Although a person's continued "development" is subtle and not quantitatively comparable to the early years, it can not be disregarded because changes do occur and they are very likely to affect one's dentition.

The dramatic changes in the soft tissue through advanced aging and, also, the perplexities of orthodontic relapse at any age, are still listed among the "unanswered" questions.

New concepts of growth have discarded the idea that the craniofacial complex grows as a unit. Updated concepts include the process of remodeling and displacement which contributes to the complex nature of growth movements produced as bones grow in relation to each other (Enlow, 1968). It is of extreme relevance to consider such a process in cephalometric analysis to better visualize each component and its contribution to the whole craniofacial complex.

The assessment of an individual dentofacial pattern by cephalometric standards derived from population norms has been extremely useful for establishing guidelines for diagnosis, but such standards fail to explain how such a pattern occurs in a given person. Development of a satisfactory treatment plan is contingent upon the understanding of the eventuality of total growth. The counterpart analysis is the method of choice in this investigation in order to determine "the individual combinations of anatomical and developmental characteristics that have produced such a pattern" (Enlow et al., 1971 a).

LITERATURE REVIEW

Morphological alterations of the craniofacial complex has been a subject of study for centuries. Hellman (1927) recognized the importance of craniofacial growth as he stated, ".... to recognize the risk of attempting to do something with an orthodontic appliance that might be accomplished in the course of development..."

The introduction of the Broadbent Bolton cephalometer (1929) provided a standardized roentenographic method for studying the developmental changes of the human head. The advantages of this method were realized and different methods of study were employed.

Brodie (1941) published a serial quantitative study of the growth of the human face from the third month to the eighth year of life. The head was divided into several functional areas, specifically the nasal, dental, and mandibular regions and the brain case. These were studied as separate entities through regional cephalometric superimpositions. From his study he concluded that growth displayed a "constancy of pattern" and once growth was attained, such pattern does not change. His findings were in agreement with those of

Broadbent (1937) in that facial growth displays a forward and downward pattern.

Later Brodie (1953) recognized the individual variability of parts and proposed caution in evaluations based on population norms.

Bjork (1947) concluded, from a cross-sectional roentenographic comparison of males between 12 years of age and 20 to 22 years, that the face increased in vertical height with an accompanying increase in prognathism. Lengthening of facial height and uprighting of incisors were also noted.

In 1948, Downs introduced his analysis of facial form in which he sought to evaluate the balance and harmony of the individual profile.

One year earlier, Wylie (1947) had advanced his analysis of anteroposterior dysplasia. Instead of evaluating the profile as did Downs, he segmented the face according to anatomic landmarks.

Coben (1955) realized the importance of the configuration of the cranial base, the variation of facial height and the integration of such variants in the total facial pattern. His analysis of children examined at 8 and 16 years of age was based on a coordinated system at two different age levels. He observed that males exceeded females in vertical growth and that both sexes tended towards lower facial prognathism with age, thus decreasing the facial angle and convexity of the profile.

Lande (1952) investigated the behavior of the facial profile in a sample of 39 individuals between 3 and 18 years old. He determined that the mandible becomes more prognathic in relation to the brain case during growth. His findings of mandibular prognathism with aging were in accord with Bjork (1947) and Brodie (1941) for ages prior to 7 years.

Growth increments are also often appraised by cephalometric superimposition at successive age intervals. Elmajian (1960) undertook a longitudinal cephalometric study of children between 8 and 14 years of age to determine the more stable elements of the cranial base. After experimentation with four superimposition combinations utilizing seven different cranial base contours, he established that the intersection of the mid-point of the great wings of the sphenoid bone and the cribiform plate of the ethmoid bone provided a plane for superimpositioning. The assessment of the landmarks showed a downward or downward and backward rotation of sella while nasion moved irregularly in different directions.

Bergersen (1961) undertook a longitudinal study of

40 individuals up to the second decade of life to investigate different methods of superimposition. With this intersection method of registration it was observed that nasion and sella possessed a linear movement in an anterior-superior direction.

In another study, Bergersen (1966) investigated the migration of seven facial landmarks in a group of individuals from 1 to 30 years of age. His findings corroborated previous findings of growth following straight lines, except the mandible whose growth proceeded in a "wavelike" manner alternating vertically and horizontally.

However, in spite all the efforts toward new methods of approach in the field, conspicuous gaps still exist in our knowledge of craniofacial growth. Some of these are concerned with misrepresentation of cephalometric data. The accepted "forward and downward" mode of facial growth represents a cumulative composite of changes produced by remodeling and displacement (Enlow, 1968) and does not account for the actual growth of the individual parts. Enlow (1971) developed a cephalometric analysis in which measurements are not considered as such, and comparisons of individual populations means are not employed.

Another problem to be considered involves the concern with only childhood and adolescent years, and with those studies pertaining to adults focusing only on rate alterations from early adulthood through senility. Baer (1956) emphasized the need for the longitudinal approach of the same group of individuals over a period of years in order to provide more useful conclusions comparable with the findings resulting from skull collections.

It is recognized that the human skeletal aging undergoes apposition and resorption at the periosteal, endosteal, and trabecular surfaces in considerable amount, and that its magnitude is recognized over long periods of time (Israel, 1968).

Early cross-sectional anthropological studies on adulthood focus on certain variables of the skull, e.g. face height, bizygomatic width, and cranial thickness. Some of these studies do reveal continued growth increase of some variables of several millimeters from young adulthood through senility (Baer, 1965; Lasker, 1953). Thompson and Kendrick (1964) in their study of adult males confirmed this observation. Furthermore, a greater increase was found in lower facial height. However, contrasting results have also been found in cross-sectional studies undertaken by Nasjeleti and Kowalski (1975) on upper facial height. They support the contention that this area compared to total face height ratio remains relatively constant throughout adulthood. This finding is supported by Tallgren (1974).

Israel (1968) used selected measurements of skull dimensions to determine the related alterations. Taking cognizance of his previous findings, he undertook a study (1970) to observe size increments of the sella-turcica. A true-size sex dimorphism was observed in later years.

In 1973, Israel, attempting to elucidate the changes taking place at a greater age, reported about 4% to 5% increase in almost all skull dimensions in an analysis of 26 women. Two examinations were performed at intervals ranging between 13 and 28 years. The mandible was found to suffer a significant accretion in its length over the period studied. No tendency to decrease the gonial angle was observed. The enlargement observed was attributed to a magnification process, except for sella-turcica, cranial thickness and para-nasal sinuses.

Forsberg (1979) studying the adult face longitudinally from 24 to 29 years of age found major changes of the skeletal profile due to posterior mandibular rotation. This was followed by a compensatory uprighting of the upper incisors. Soft tissue measurements revealed forward growth of the nose and retrusion of the lips.

Solow (1980) studied a large sample of Swedish caucasians, gathering his data in two examinations five years apart. By a method of superimposition along the cribiform plate, the trabecular portion of the ethmoid bone, and the anterior wall of sella-turcica, Nasion and Sella points were transferred to the second film. These points served to represent stable structures in the cranial base. Little growth was observed despite the fact that males were still in the termination phase of pubertal growth. In both sexes nasion was found to move downward and forward, while sella point moved downward and backward. An increase was observed in dentalveolar height, and in the sagital jaw relationship with forward displacement of the maxilla.

Behrents (1984), in a recent long-term study of facial growth utilizing a sample of the Bolton-Brush study, has confirmed that "growth" is a continuous process throughout life. He found that considerable craniofacial alterations occur beyond 17 years of age to the old age span in an adaptive and decelerating manner. Changes in males during young adulthood were apparently specific to the individual pattern, (vertical growers grew vertically, and so forth). At later ages sexual dimorphism was also a significant finding.

All those findings of continued craniofacial change lead to several important considerations regarding orthodontic treatment. Now a deep scrutiny of the structural alterations is necessary to better appreciate the new results of continued bony remodeling in the face and cranium.

STATEMENT OF THESIS

The objective of this investigation is to assess some of the regional anatomical features of the craniofacial complexes, the nature of its morphological alterations and expression during growth from early life to late adulthood.

For this purpose the Counterpart analysis was the method used in this investigation.

MATERIALS AND METHODS

The lateral cephalograms of the individuals utilized in this study were obtained from the collections of The Bolton-Brush Study Center housed at Case Western Reserve University. The sample chosen consists of longitudinal data of 56 individuals divided into two groups.

GROUP I

This group is a sample of 25 males and 15 females exhibiting a Class I normal occlusion as determined from cephalometric headfilms.

GROUP II

This group is a sample of 9 males and 7 females. All individuals presented a Class II malocclusion as determined from cephalometric headfilms.

Both groups were selected on the basis of the following criteria:

1. Availability of records

   Four age intervals were utilized during the life of the individual to provide more complete information of growth changes. Age intervals were as follows: The first examination was taken between 11 and 14 years of age, the second between 15 and 18 years of age, the third between 19 and 28 years of age, and the fourth between 29 up to and over 50 years of age.

2. Untreated

Subjects who had undertaken any kind of othodontic procedures previously or during the years studies were excluded.

3. Dental Health

The individuals selected were of good dental health and presented no more than three units loss during the age period studied.

Technical Details

The films available were taken utilizing a Broadbent cephalometer. Tracings of the headfilms were accomplished with 0.003" acetate and a Pental (0.3 mm; 2H) lead drawing pencil. A total of 27 landmarks were identified and are listed below. (Definitions are found in Table I)

1. Me
2. B
3. IPr
4. The incisal edge of the mandibular central incisors
5. SPr
6. A
7. ANS

8. The most posterior occlusal point of the last fully erupted maxillary and mandibular molars

9. The distal surface of the mandibular first molar

10. The distal surface of the maxillary first molar

11. The most anterior maxillary-mandibular first premolar occlusal contact

12. The cementoenamel junction of the last fully erupted maxillary molar

13. ARa

14. Go

15. PRa

16. Ar

17. O

18. PNS

19. The inferior most point of the pterygomaxillary fissures

20. Foramen rotundum in the pterygomaxillary fissure

21. SE

22. The posterior boundary of the cribiform plate

23. Or

24. The anterior boundary of the cribiform plate

25. The most anterior point of the endocranial surface of the frontal bone

26. Sella

27. Nasion

Each of the 27 points, given x and y coordinates, were registered using a digitizer. The linear measurements were then calculated by a computer, suitably programmed (Behrents, 1984).

Enlargement Adjustment

A procedure was utilized by using the midline-lateral film distance (ML) to adjust the x/y coordinate of each x-ray to a standard 6% enlargement.

Measurements

From the point registration 19 variables were evaluated for each tracing. These variables include:

1. Aggregate cranial floor/maxilla and ramus/corpus horizontal dimensions at A and B points.
2. Aggregate cranial floor/maxilla and ramus/corpus horizontal dimensions at Spr and Ipr.
3. Middle cranial fossa (MCF) and posterior maxillary (PM) relative alignment.
4. Ramus alignment.
5. Ramus/MCF horizontal dimensions (skeletal).
6. Ramus/MCF horizontal dimensions (dental).
7. Molar positions (composite).
8. Maxillary/mandibular arches, skeletal dimensions, A point compared with B point.
9. Maxillary/mandibular arches, dental dimensions, A point compared with B point.
10. Maxillary/mandibular arches, skeletal dimensions, SPr compared with IPr.

11. Maxillary/mandibular arches, dental dimensions, SPr compared with IPr.

12. PM as compared with ramus/MCF vertical dimensions.

13. Corpus-occlusal alignment.

14. Gonial angle alignment.

15. Curve of Spee

16. Palatal plane alignment.

17. Inferior maxillary plane.

18. Maxillary nerve/palatal plane alignment.

19. Vertical anterior maxillary plane.

The measurements of the comparative dimensions were symbolized as mandibular retrusive (+) effect, a neutral (o) effect, or a mandibular protrusive (-) effect. If the extent of the mandibular protrusive or retrusive effect was up to 2.5 mm, a single (+) or (-) is indicated. If more extreme, effects are indicated by double (++) or (--). If the effect exceeds 5.0 mm, more extreme values are attributed (+++) or (---). The latter designations are included to point out the severity of certain characteristics.

Statistics

The chi-square test was used to evaluate the statistical significance of directional changes in each variable, either in a protrusive or retrusive direction.

For this purpose, the initial measurement was compared with the final one. Among the 19 variables tested the chi square was significant at the 5 percent level, only for the following variables: Ramus Alignment (Group I) and Inferior Maxillary Plane (Group I). The other 3, the Molar Position (Group II); Maxillary/Mandibular Arches, dental dimension at A/B point (Group II); and Inferior Maxillary Plane (Group II) attained borderline significance at the .05 level.

TABLE I

DEFINITIONS OF ANATOMIC LANDMARKS

Points	Definition
A	A point, the deepest middle point on the labial premaxillary surface between the anterior nasal spine and superior prosthion.
ANS	Anterior nasal spine, the tip of the spinous process of the maxilla forming the most anterior projection of the bony floor of the nasal cavity.
Ar	Bjork's Articulare, the point of intersection of the external inferior surface of the basicranium and the posterior margin of the condylar neck.
ARa	Anterior ramus, the point of intersection of the anterior margin of the ramus with the functional occlusal plane.
B	B point, the deepest middle point on the anterior surface of the symphysial outline of the mandible between infradentale (inferior prosthion) and pogonion.
Go	Construction gonion, intersection of lines tangent to the posterior border of the ramus and inferior border of the mandible.
IPr	Inferior prosthion, the point of contact of the alveolar process between the mandibular central incisors.
Me	Menton, the most inferior point on the symphysis of the mandible.
O	Occipital point, the inferior most point on the endocranial surface of the occipital fossa.
PNS	Posterior nasal spine, the tip of the spinous process formed by the most posterior projection of the junction of the palatine bones in the midline of the roof of the oral cavity.
PRa	Posterior ramus, the point of intersection of the posterior surface of the ramus with the functional occlusal plane.
SE	Sphenoethmoidal junction, intersection of the averaged image of the right and left shadows of the great wings of the sphenoid with the floor of the alveolar cranial fossa.

TABLE II

DEFINITION OF CEPHALOMETRIC PLANES

Line	Description
Ar to Go	A line from Ar to constructed Go used to determine the alignment of the ramus.
ARa	Anterior ramus plane, a line from the intersection of FOP and the anterior border of the ramus drawn parallel to PRa up to Ref.
FOP	Functional occlusal plane, a line from the most posterior occlusal contact point to the last fully erupted maxillary and mandibular molars to the most anterior maxillary-mandibular first premolar occlusal contact.
MCF	Middle cranial fossa plane, represented by a line from SE to Ar.
NOA	Neutral occlusal axis, a line perpendicular to PM through the most posterior occlusal contact point of the last fully erupted maxillary and mandibular molars.
NRa	Neutral ramus, a line from Ar to a point midway between Ar and neutral PM line at the level of gonion.
PM	PM vertical, a line from SE through the averaged inferior most point of the pterygomaxillary fissures.
PRa	Posterior ramus plane, from Ar to the posterior margin of the ramus where it intersects FOP.
Ref	Reference line, a line parallel to FOP from Ar anteriorly.

TABLE III

DETERMINATIONS OF THE PM VERTICAL DIMENSION

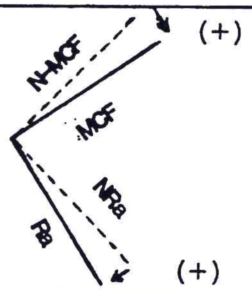
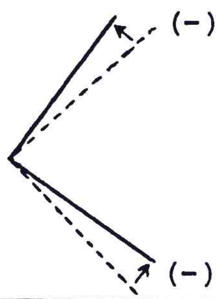
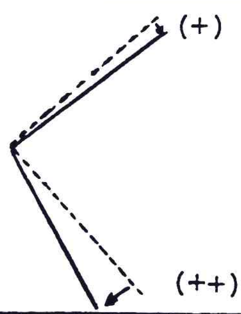
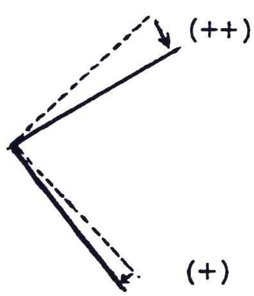
	Description	Effect
	Forward rotation of MCF and backward rotation of ramus are equal in extent	Neutral (0) effect
	Backward rotation of MCF and forward rotation of ramus are equal in extent and direction	Neutral (0) effect
	Backward ramus rotation is greater than forward rotation of MCF	Long (+) PM vertical Extent determined by the difference between the two values.
	Forward rotation of MCF is greater than backward rotation of ramus.	Short (-) PM vertical Extent determined by the difference between the two values.

TABLE III - continued

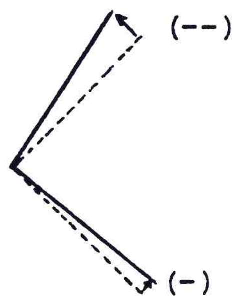
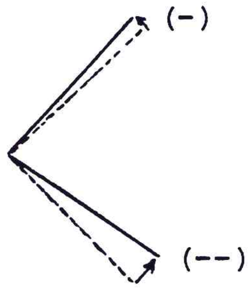
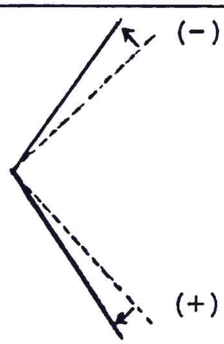
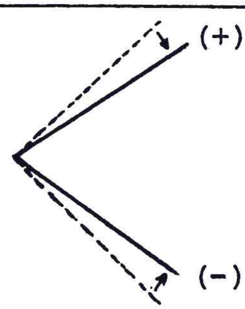
	Description	Effect
	Backward rotation of MCF is greater than forward rotation of ramus.	Long (+) PM vertical. Extent determined by the difference between the two values.
	Forward rotation of ramus is greater than backward rotation of MCF.	Short (-) PM vertical. Extent determined by the difference between the two values.
	Backward rotations of MCF and ramus are equal in extent.	Long (+) PM vertical. Extent determined by adding the two values.
	Forward rotations of MCF and ramus are equal in extent.	Short (-) PM vertical. Extent determined by adding the two values.

Figure 1. All the points and planes used in the counterpart analysis are demonstrated in this diagram. The solid lines represent the subject's own relationships while the dashed lines represent neutral positions. This diagram includes additions to the original construct and procedure presented by Enlow (1971).

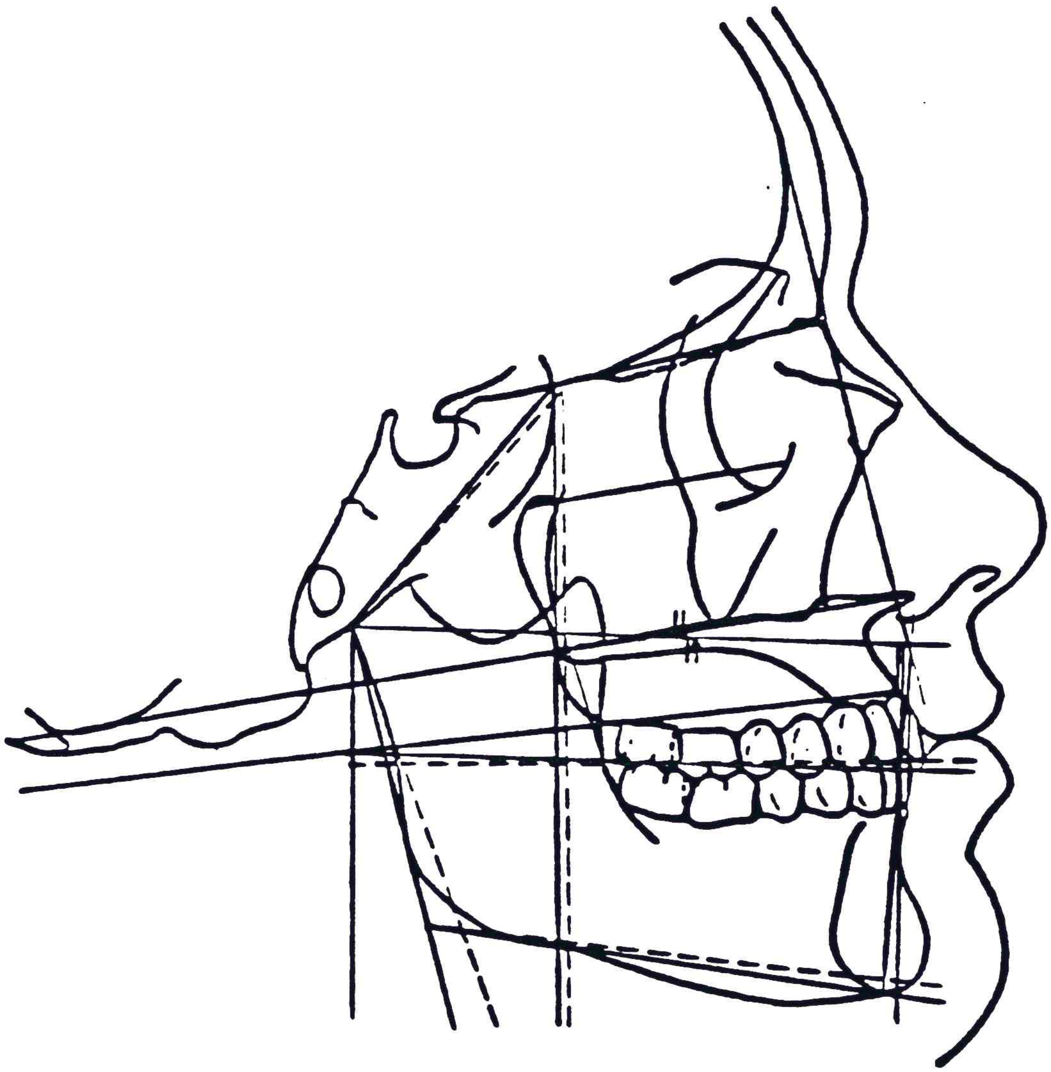


Figure 2. <u>Aggregate cranial floor/maxilla and ramus/corpus horizontal dimensions at A and B points</u>. This diagram demonstrates the comparison of lengths from Ar to A point and Ar to B point. The measurements are made in millimeters along REF. The lines from A point to REF and B point to REF are drawn perpendicular to REF.

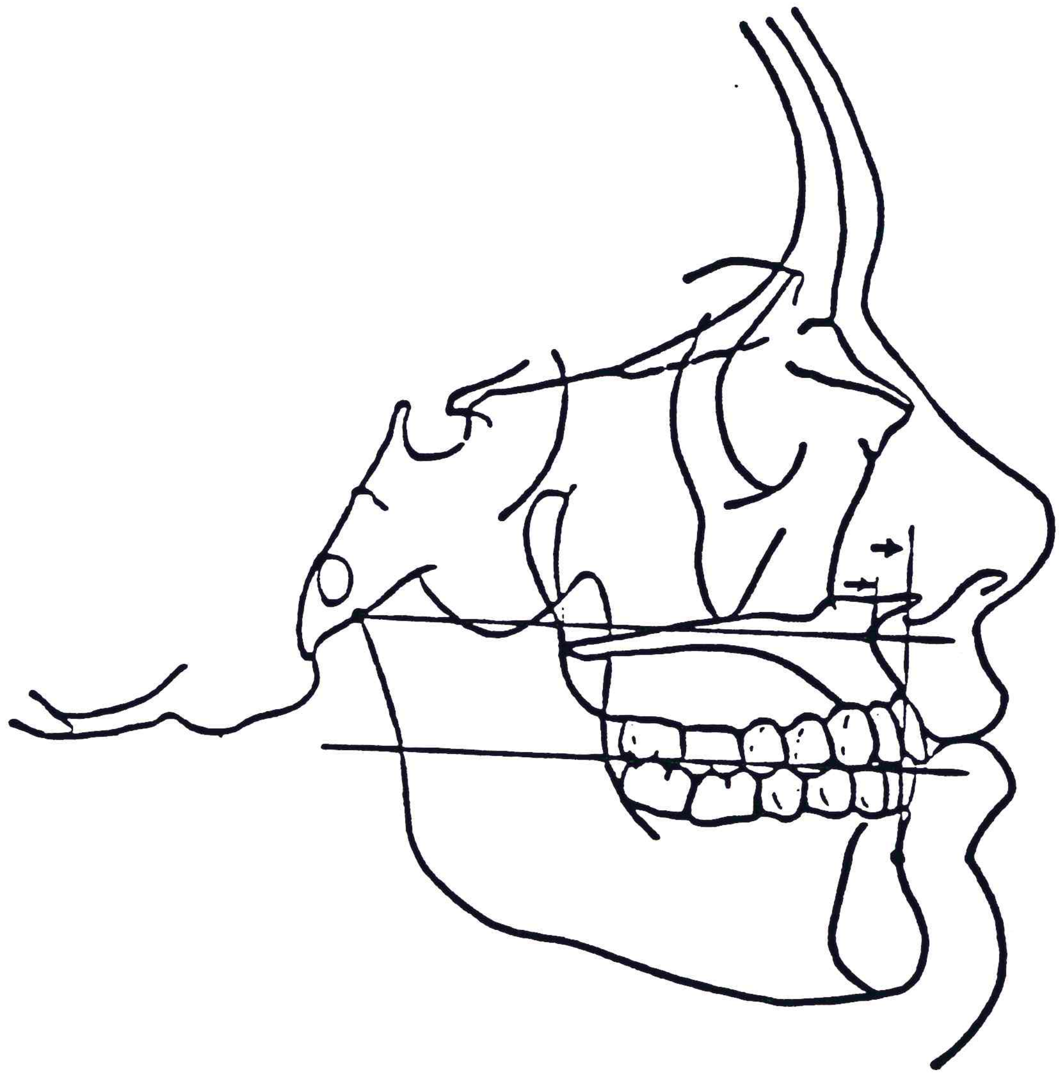


Figure 3. Aggregate cranial floor/maxilla and ramus/corpus horizontal dimensions at SPr and IPr. This diagram demonstrates the comparison of lengths from Ar to SPr and Ar to IPr. The measurements are made in millimeters along REF. The lines from SPr to REF and IPr to REF are drawn perpendicular to REF.

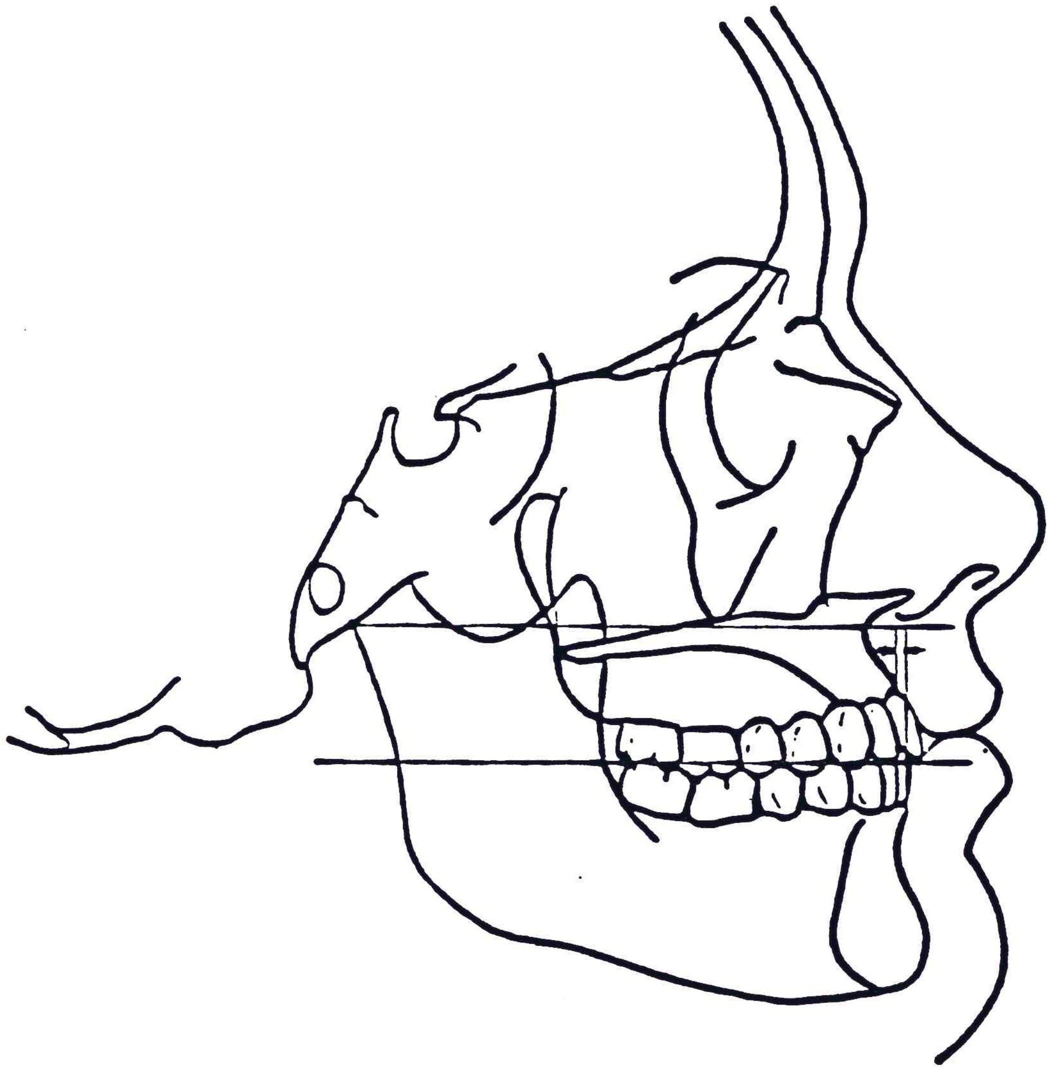


Figure 4. Middle cranial fossa (MCF) and posterior maxillary (PM) relative alignment. This diagram compares the neutral MCF/PM alignment (dashed line), which has an internal angle of 40.3° to the patient's MCF/PM alignment. The neutral MCF/PM alignment is drawn using a pre-constructed template which has a 40.3° internal angle. The template is used by: (1) measuring the length of the MCF, and (2) transfering this length to the corresponding line on the template (with the vertex representing SE). (3) Place the tracing of the subject over the template superimposing on Ar and orienting the PM vertical of the patient and the neutral PM parallel to each other. (4) Draw the neutral MCF/PM alignment with a dashed line on the tracing. The distance between the neutral PM and the subject's PM vertical can now be measured along REF in millimeters. When the PM vertical lies behind the neutral PM it is recorded as a negative number. When it is in front of the neutral PM it is a positive number. This measurement determines the effects of anterior/ posterior directions of middle cranial fossa alignment on corresponding retrusive/protrusive placement of the maxilla and mandible.

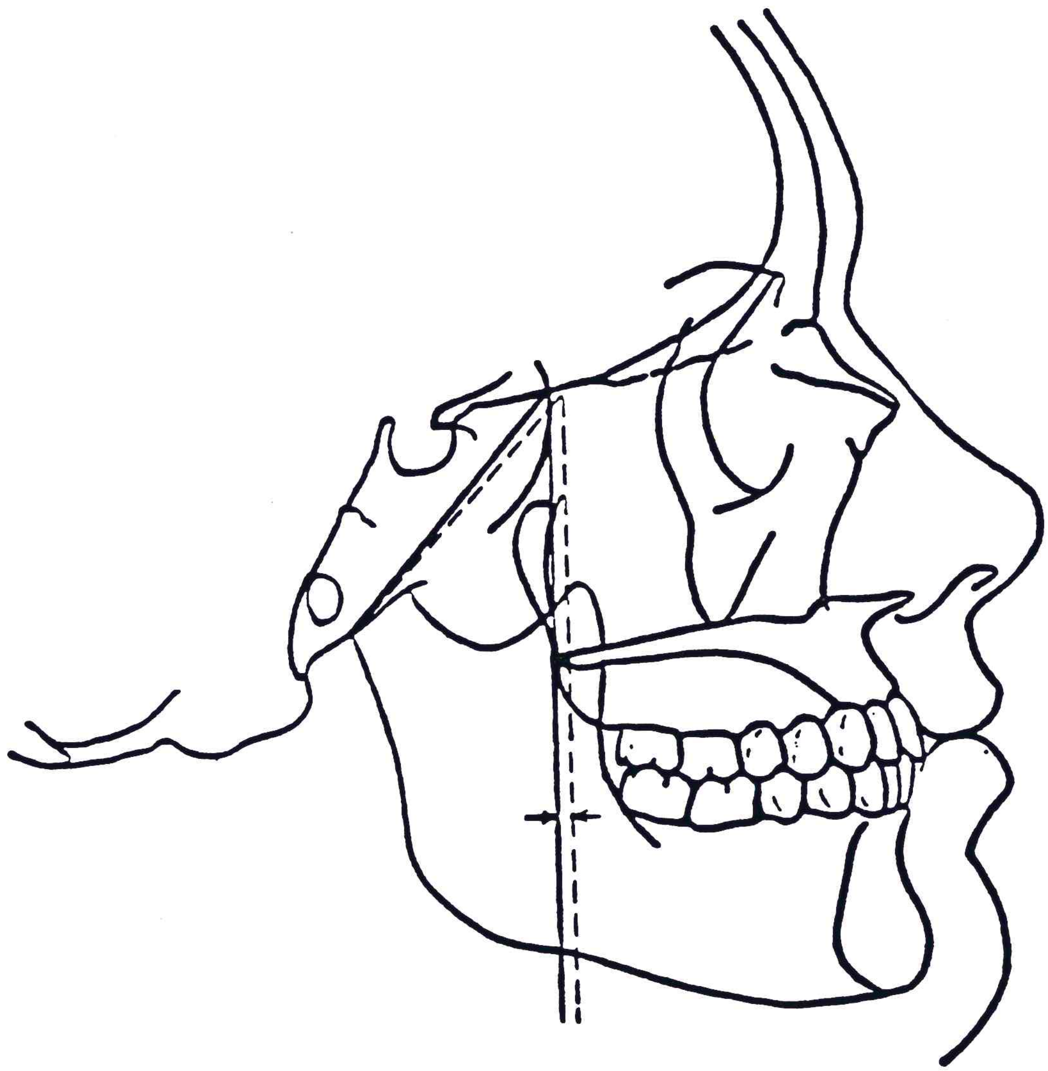


Figure 5. Ramus alignment. This diagram demonstrates the alignment of the subject's ramus plane and its relationship to the neutral ramus plane. A line from Ar to Go represents the individual's ramus plane. The neutral ramus plane is represented by a line from Ar to the midpoint between Ar and the neutral PM vertical at the level of Go. The comparison of their alignment effects on retrusive/protrusive placement of the mandible is made along FOP. The distance between Ar-Go and NRa is measured in millimeters along FOP. If Ar-Go is behind NRa, the distance is recorded as a positive number. If it is in front of NRa it is recorded as a negative number.

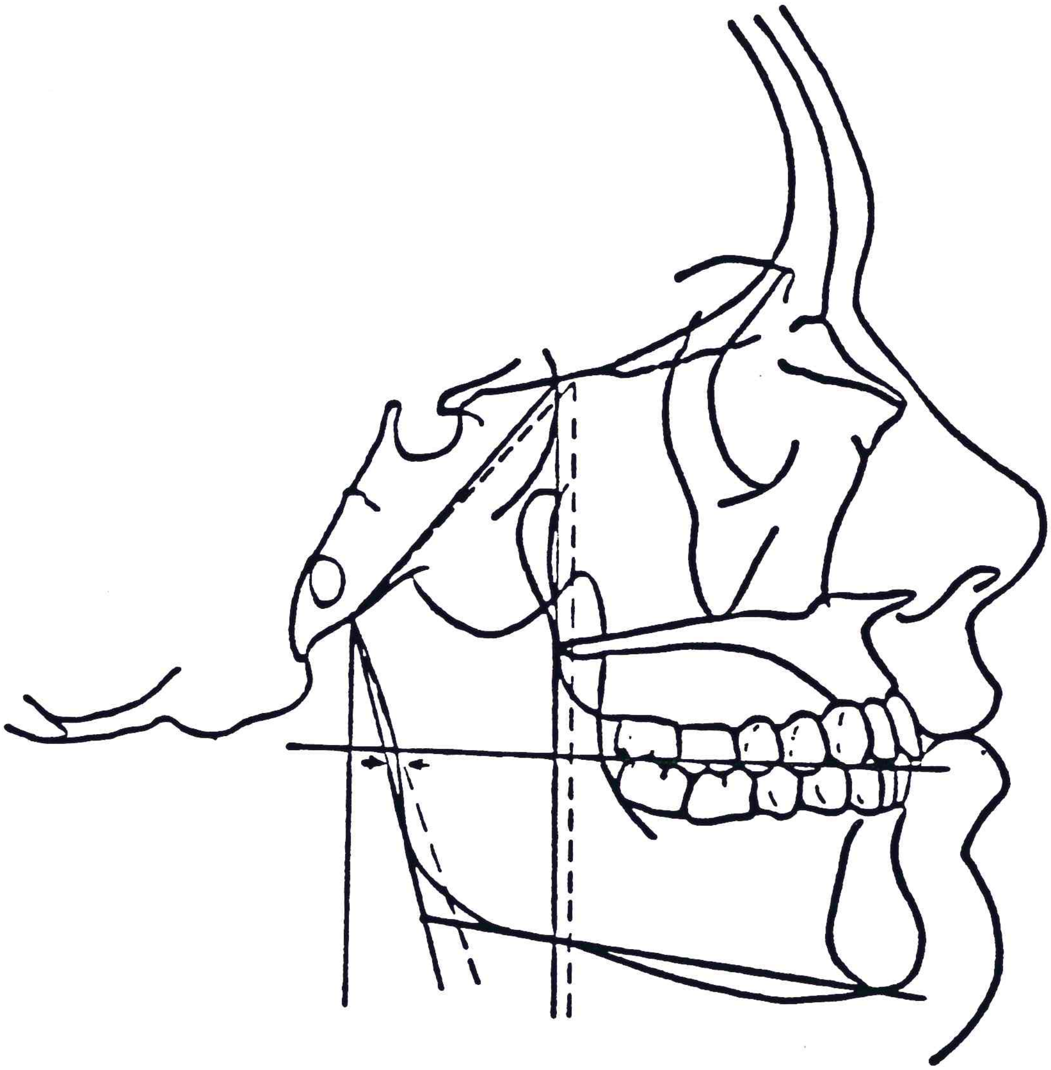


Figure 6. Ramus/MCF horizontal dimensions (skeletal). This diagram demonstrates the comparison of the horizontal dimensions of the middle cranial fossa (Ar to PM neutral) with the width of the ramus (Ar to ARa), and resultant effect on retrusive/protrusive placement of the maxilla and mandible. This measurement is made along REF in millimeters. The line PRa is drawn from Ar to FOP where it intersects the posterior border of the ramus. A line parallel to PRa is drawn from the anterior border of the ramus where it intersects FOP up to REF. The line indicates ARa. The distance from AR to ARa and Ar to PM neutral are now measured along REF.

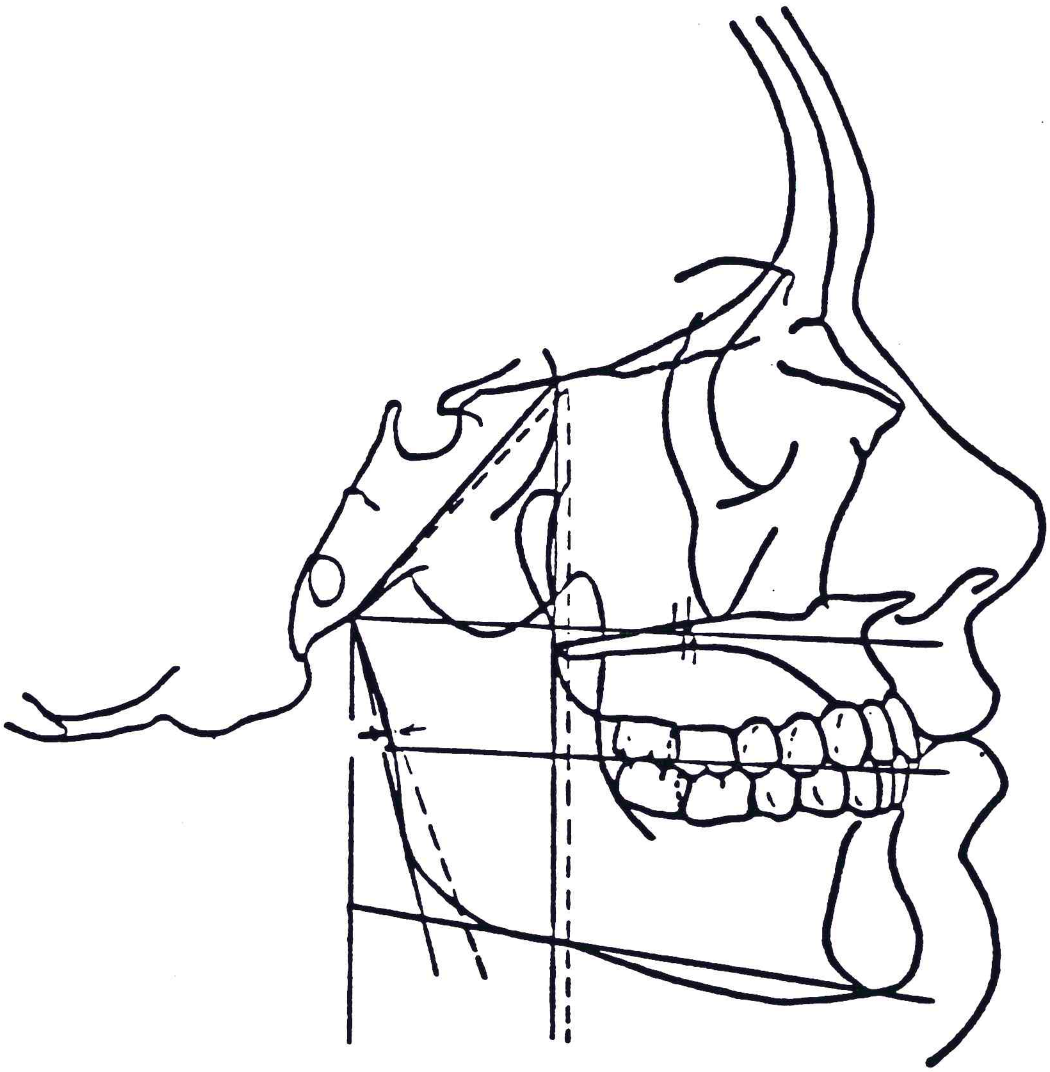


Figure 7. Ramus/MCF horizontal dimension (dental). The neutral positions of the molars are demonstrated with this measurement. The distal surfaces of the maxillary and mandibular first molars are indicated on REF by short vertical lines. The maxillary molar is corrected to its neutral position by adding or subtracting the distance between PM and neutral PM. When the MCF/PM rotation is forward (PM is in front of neutral PM) the correction is made by subtracting the PM-PM neutral difference from the Ar to maxillary molar length along REF. The mandibular molar is corrected to its neutral by adding or subtracting the distance from NRa to PRa along FOP. If PRa is behind NRa then the correction is made by adding the distance between them to the length from Ar to the mandibular molar along REF. Arrows on REF demonstrate these neutral positions. The maxillary and mandibular molar neutral positions can now be measured in millimeters from Ar along REF.

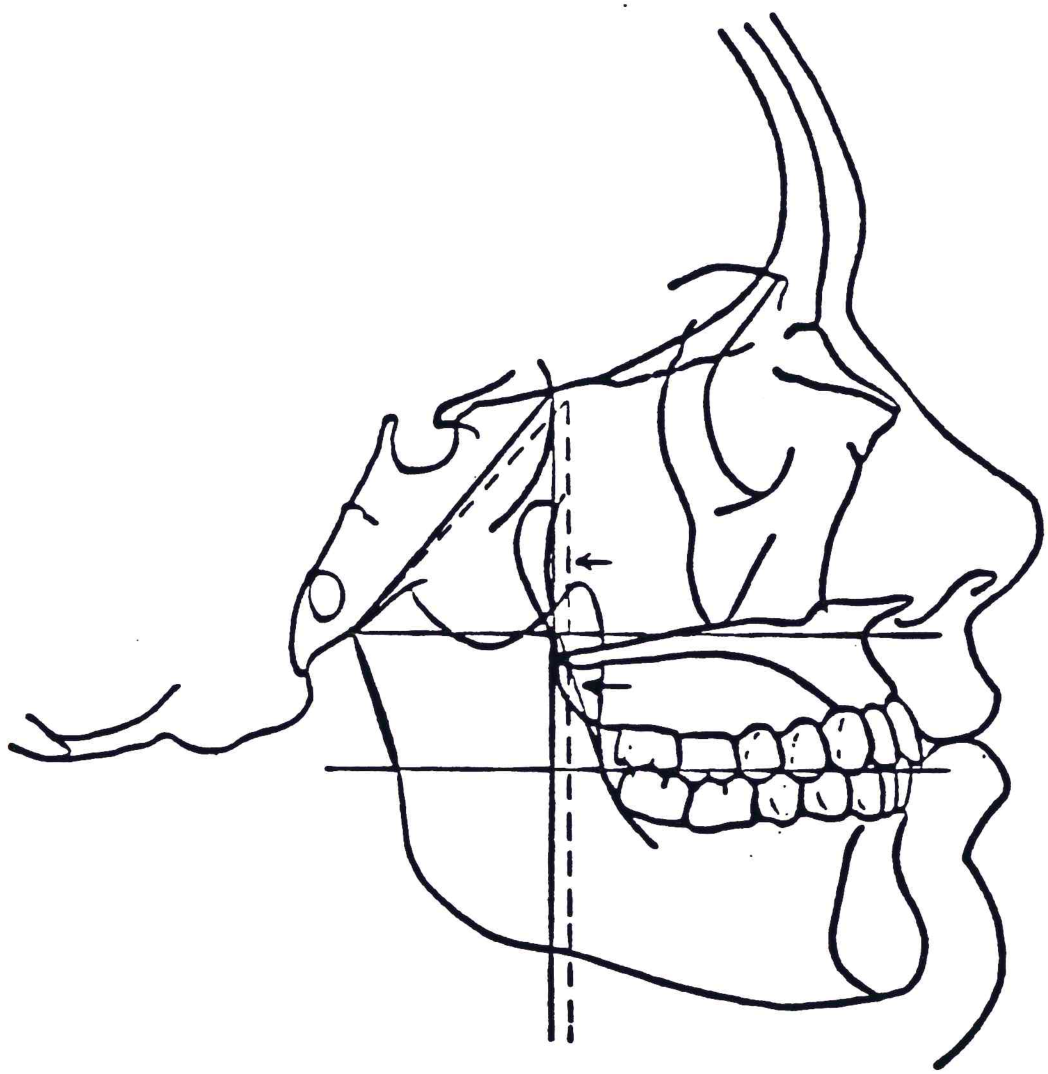


Figure 8. Molar positions (composite). Short vertical lines along REF indicate the distal surfaces of the maxillary and mandibular first molars. The measurement is made in millimeters along REF from Ar to the short vertical lines.

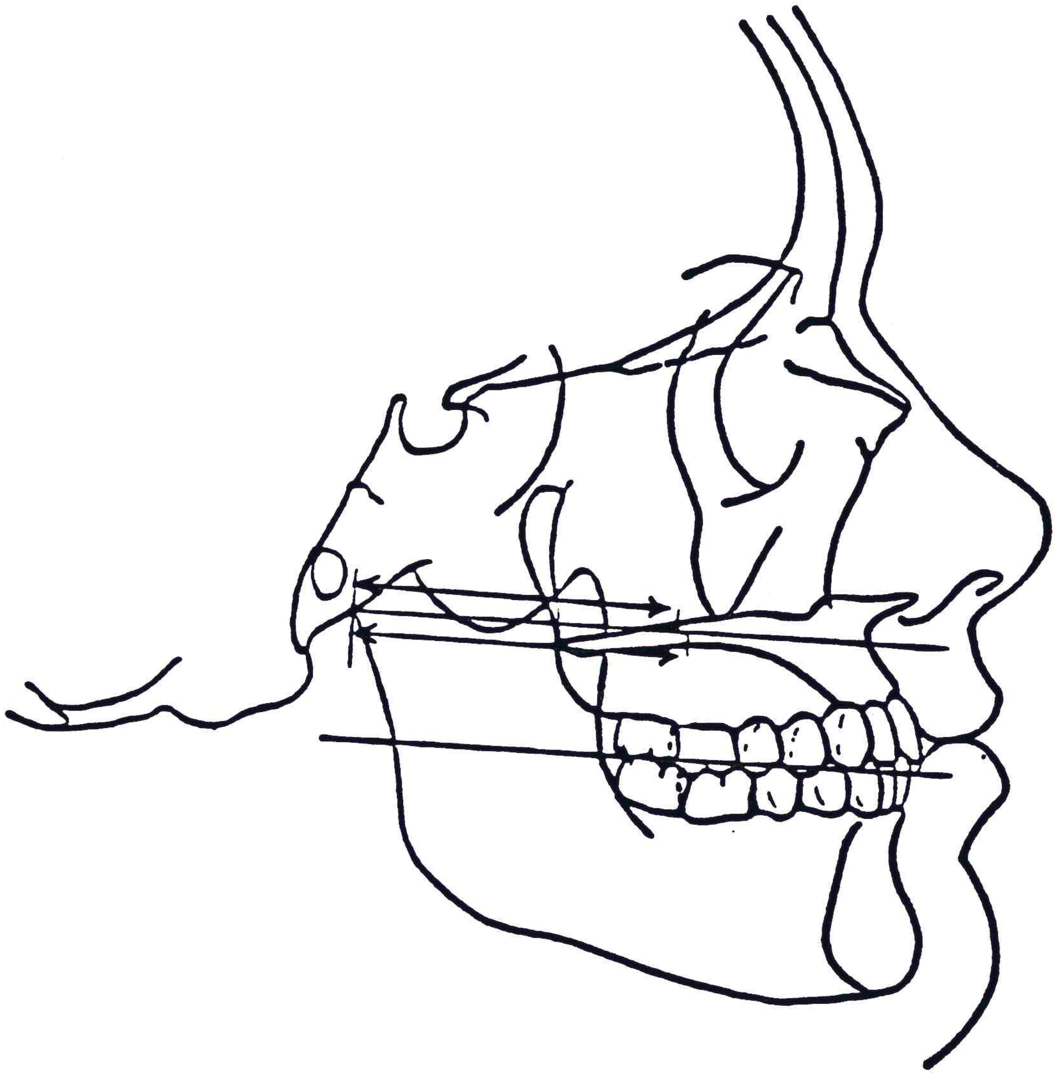


Figure 9. Maxillary/mandibular arches, skeletal dimensions, A point compared with B point. This diagram compares the length of the maxillary skeletal arch with the length of the mandibular skeletal arch. The maxillary skeletal arch is measured in millimeters from PM (solid line) along REF to A point. The mandibular skeletal arch is measured in millimeters from ARa where it intersects REF to B point along REF.

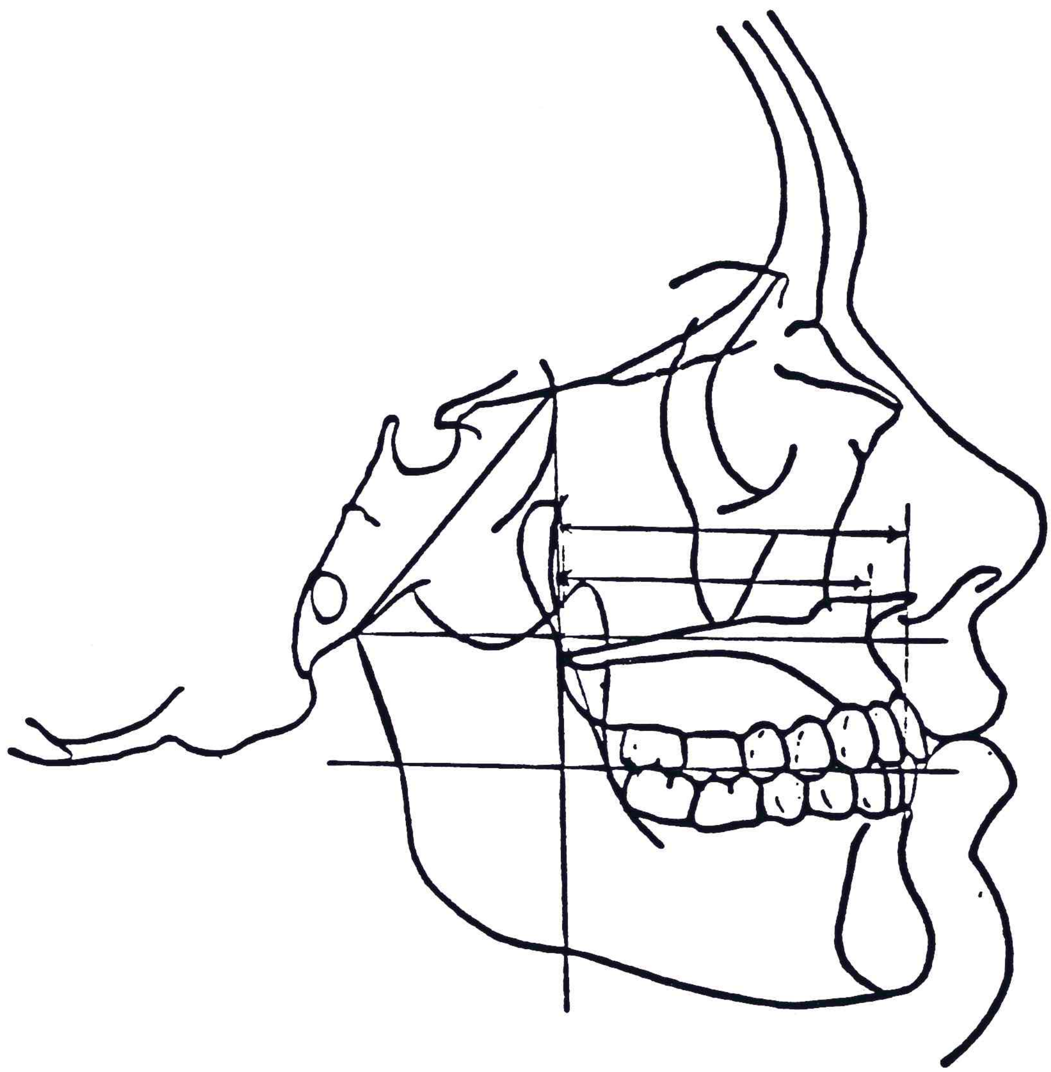


Figure 10. Maxillary/mandibular arches, dental dimensions, A point compared with B point. This is similar to the previous measurement except that the distances are measured to the distal surfaces of the first molars.

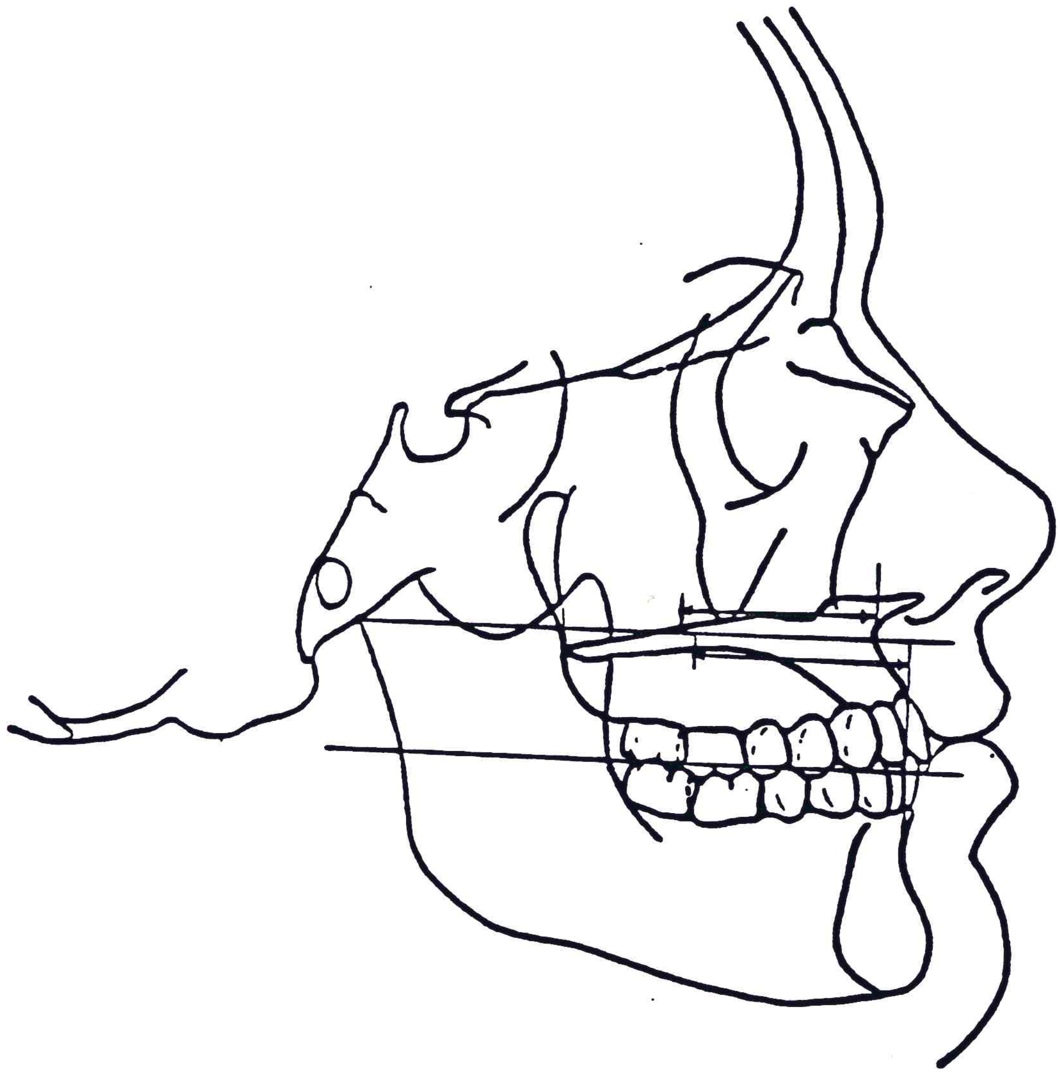


Figure 11. _Maxillary/mandibular arches, skeletal dimensions, SPr compared with IPr._ This comparison is identical to Figure 11 except that PM is measured to SPr and ARa is measured to IPr.

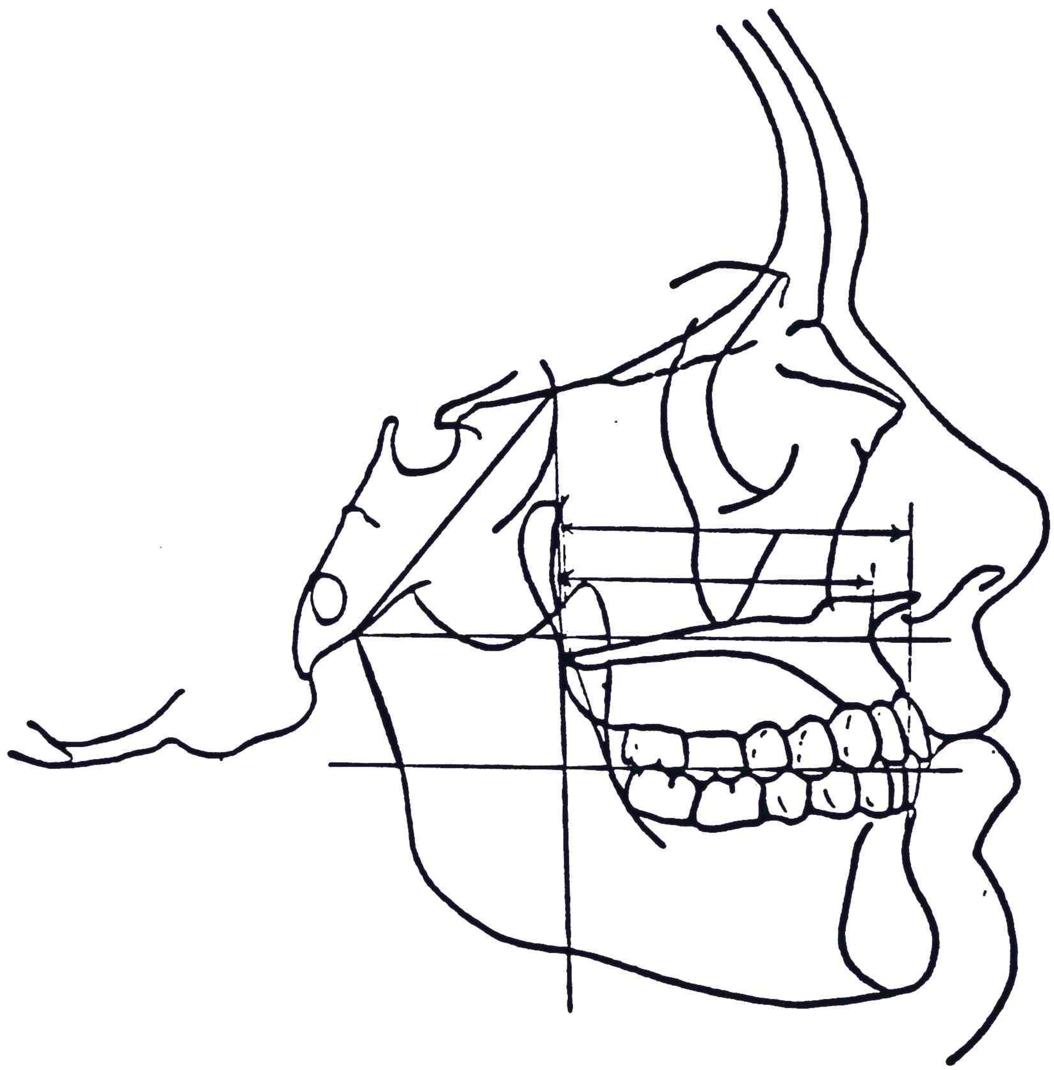


Figure 12. Maxillary/mandibular arches, dental dimensions, SPr compared with IPr. This measurement is identical to that in Figure 12 except that the distal of the maxillary first molar is measured to SPr and the distal of the mandibular first molar is measured to IPr.

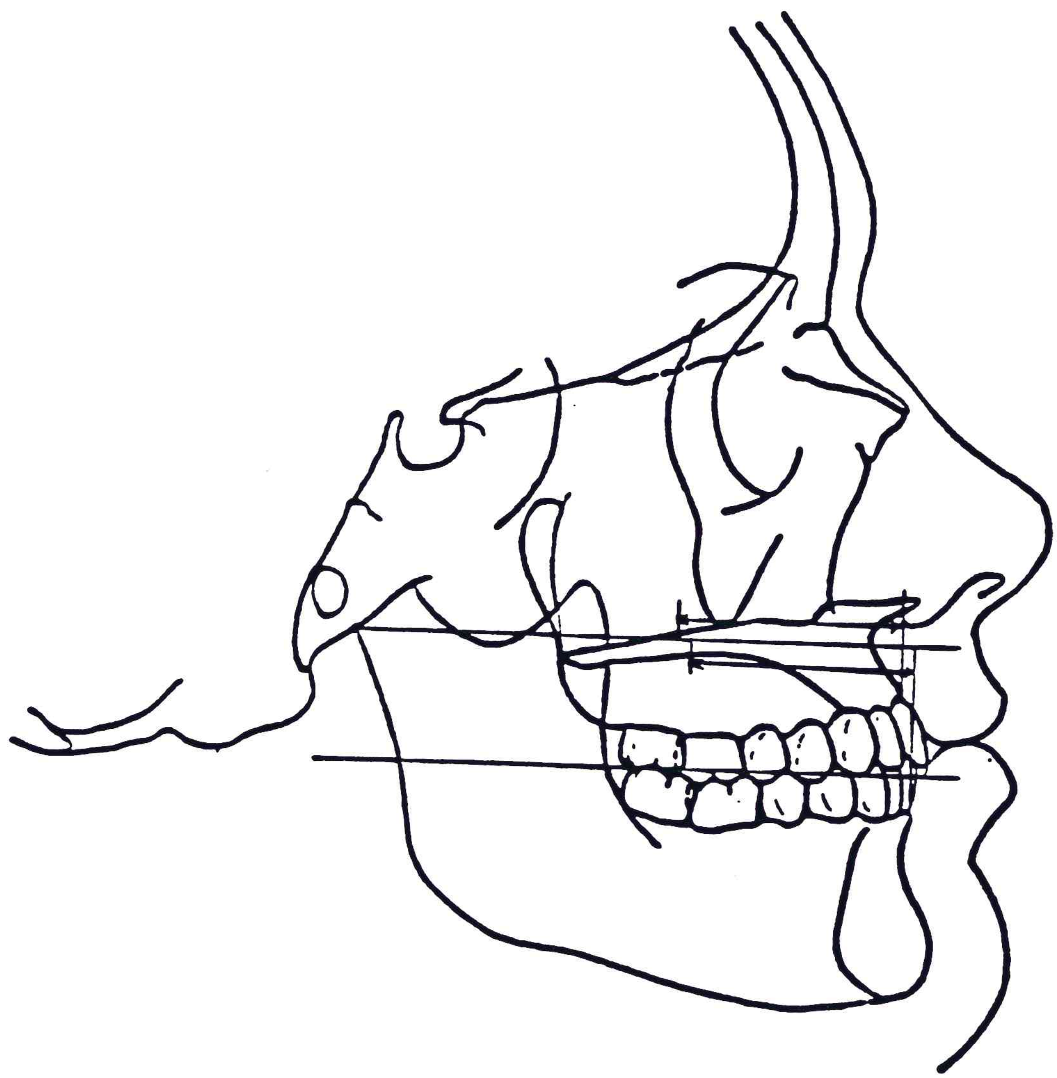


Figure 13. PM as compared with ramus/MCF vertical dimensions. The individual's relative posterior vertical nasomaxillary height is determined by this measurement. When the MCF rotates forward or backward, and the ramus rotates the same amount in the corresponding direction, no vertical disproportion in PM dimension has occurred relative to the composite vertical dimension of the middle cranial fossa and the ramus. The MCF rotation is determined by measuring the difference between PM and neutral PM along FOP. If PM is ahead of neutral PM, the MCF has a downward and forward rotation and is recorded as a positive value. If the PM is behind the neutral PM, the MCF has an upward and backward rotation and is recorded as a negative value. The ramus rotation is determined by measuring the difference between PRa and NRa along FOP. If PRa is ahead of NRa then the ramus has a forward rotation and is recorded as a negative value. If PRa is behind NRa then the ramus has a backwards rotation and is recorded as a positive value. Positive rotations of the MCF and the ramus will cause a "long" PM to occur. Negative rotations will cause a "short" PM to occur. (Ethnic variations and populations tendencies were not considered in this study.) A schematic explanation is provided in Table IV.

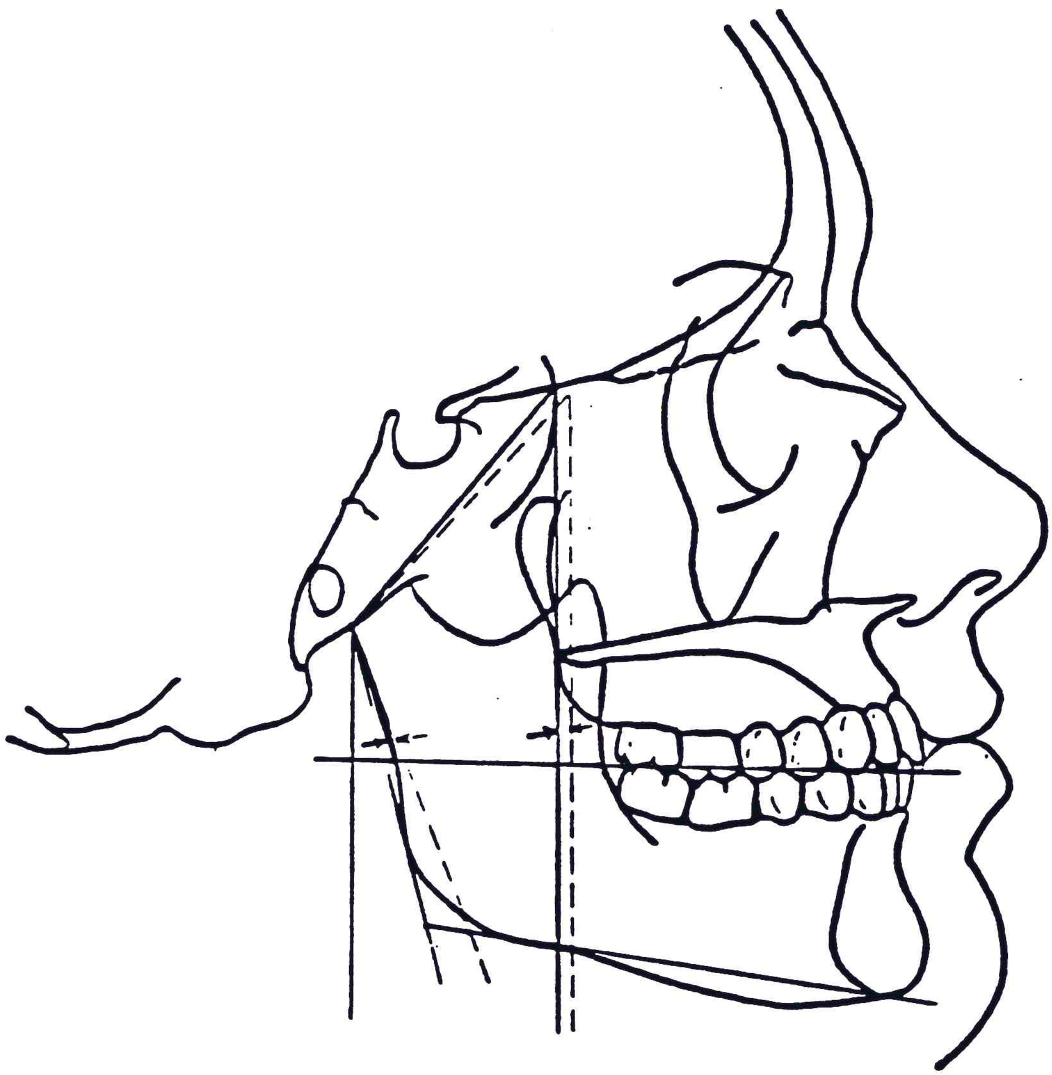


Figure 14. Corpus-occlusal alignment. This diagram demonstrates the extent of occlusal rotation as compared to the extent of ramus rotation. NOA acts as a reference line to determine the amount and direction of the occlusal rotation. NRa acts as a reference line to determine the amount of ramus rotation. Two arcs are drawn in this diagram. The radius of both arcs are equal in length. The length of the radius is determined by measuring the distance from the last occlusal contact point of the last fully erupted maxillary and mandibular molar to the point where the perpendicular from B point to REF crosses FOP along FOP. One arc is drawn from Ar, as the vertex, crossing the lines Ar to Go and NRa. The other arc is made from the last molar contact point, as the vertex crossing NOA and FOP. The distance between Ar to Go and NRa is measured at the points of intersection with the arc. If Ar to Go is behind NRa it is a positive number, if in front it is a negative number. The distance between FOP and NOA is measured at the point of intersection with the arc. If FOP is above NOA it is a positive number, if below it is a negative number. If FOP and Ar to Go have rotated equally in the same direction, the occlusal/corpus rotation is neutral. Any differential between them which involves an upward rotation of the corpus/occlusal plane relative to the ramus rotation results in a maxillary protrusive effect, and a downward corpus/occlusal rotation relative to the ramus rotation produces a mandibular protrusive effect.

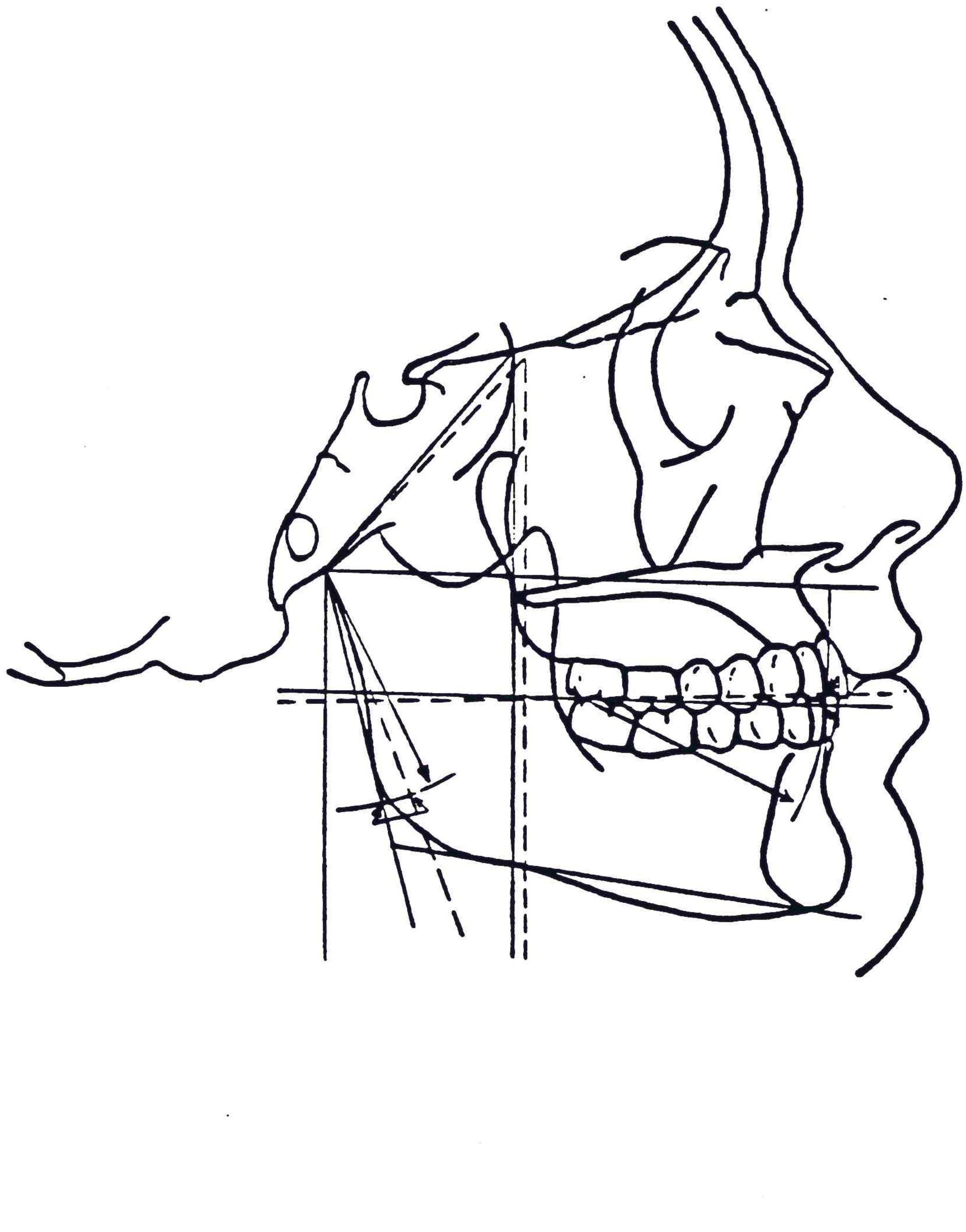


Figure 15. Gonial angle alignment. The mean gonial angle as presented in the Michigan Standard (Riolo et al., 1975) is used as a neutral value, as indicated by a dashed line. The individual's mandibular plane is indicated by the line Me to Go. The measurement here is of two angles made in degrees. The neutral gonial angle and Ar to Go to Me.

Figure 16. _Curve of Spee_. This is demonstrated by measuring the distance between the incisal edge of the mandibular central incisors and FOP. If the central incisors are above FOP it is a positive number, if below FOP it is a negative number.

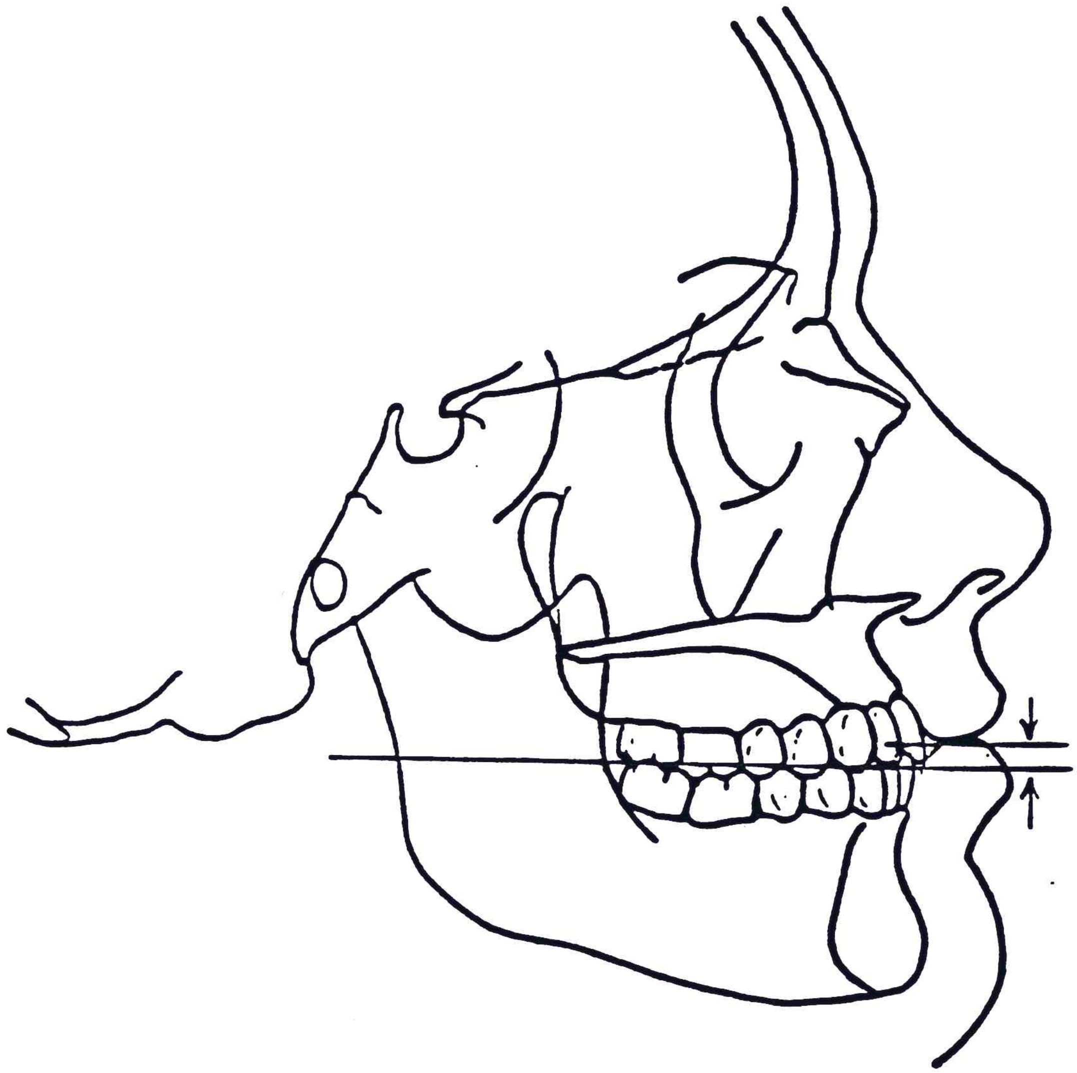


Figure 17. _Palatal plane alignment_. This diagram demonstrates the alignment between the palatal plane and the occipital fossa. The palatal plane is represented by a line from ANS through PNS. The distance between the plane and occipital point is measured. If the palatal plane is above 0 it is a positive number. If it is below 0 it is a negative number. Positive and negative values represent clockwise and counterclockwise rotations, respectively.

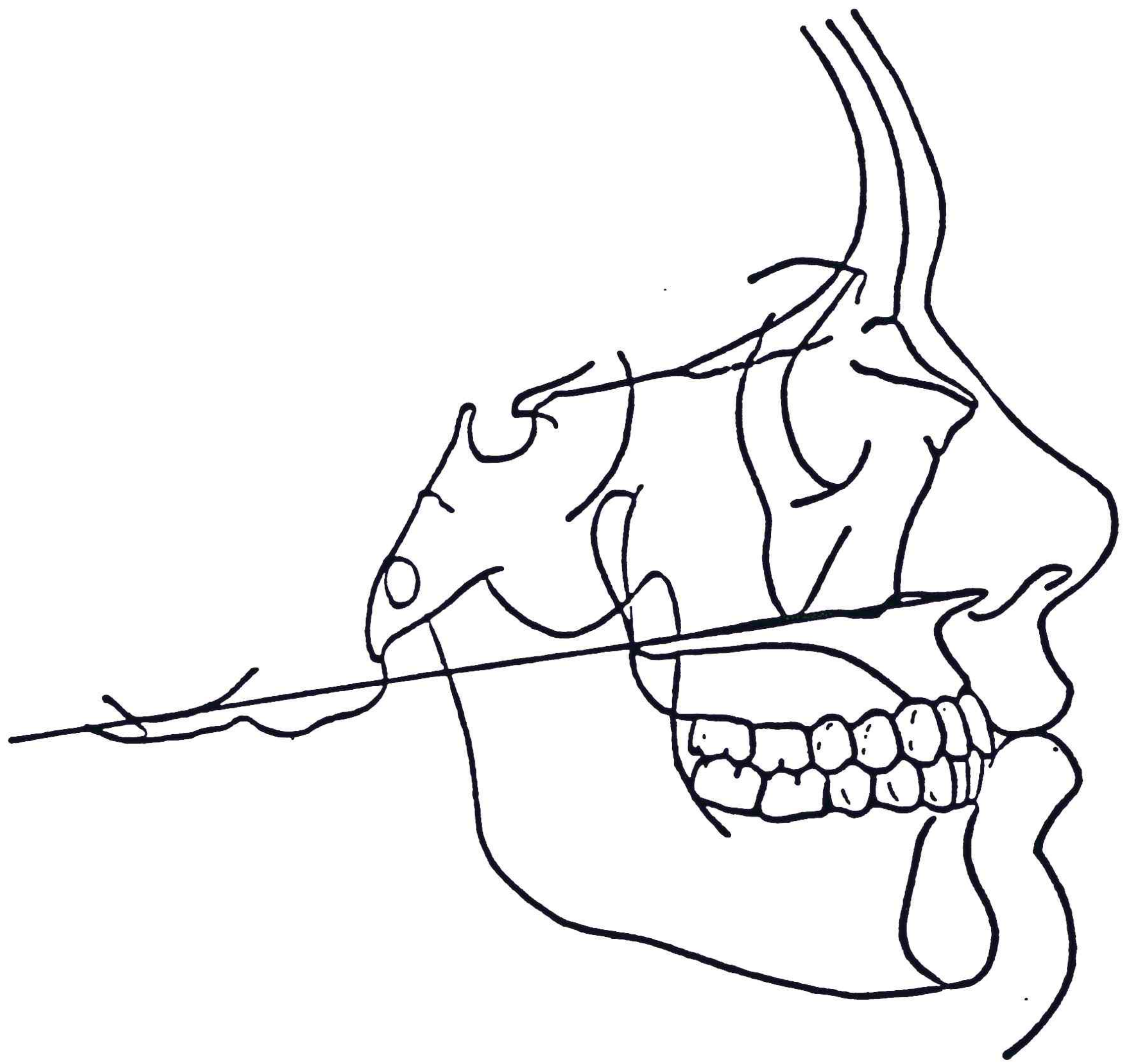


Figure 18. Inferior maxillary plane. This diagram demonstrates the alignments relationship between the inferior boundry of the nasomaxillary complex and the occipital fossa, theoretically representing the position establishing the inferior boundry for the nasomaxillary growth field. The line from SPr through the cementoenamel junction of the last fully erupted maxillary molar represents the inferior maxillary plane. The distance between this plane and occipital point is then measured. If IMP is above 0 it is a positive number, if IMP is below 0 it is a negative number. Positive and negative values represent clockwise and counterclockwise rotations, respectively, of IMP in relation to 0.

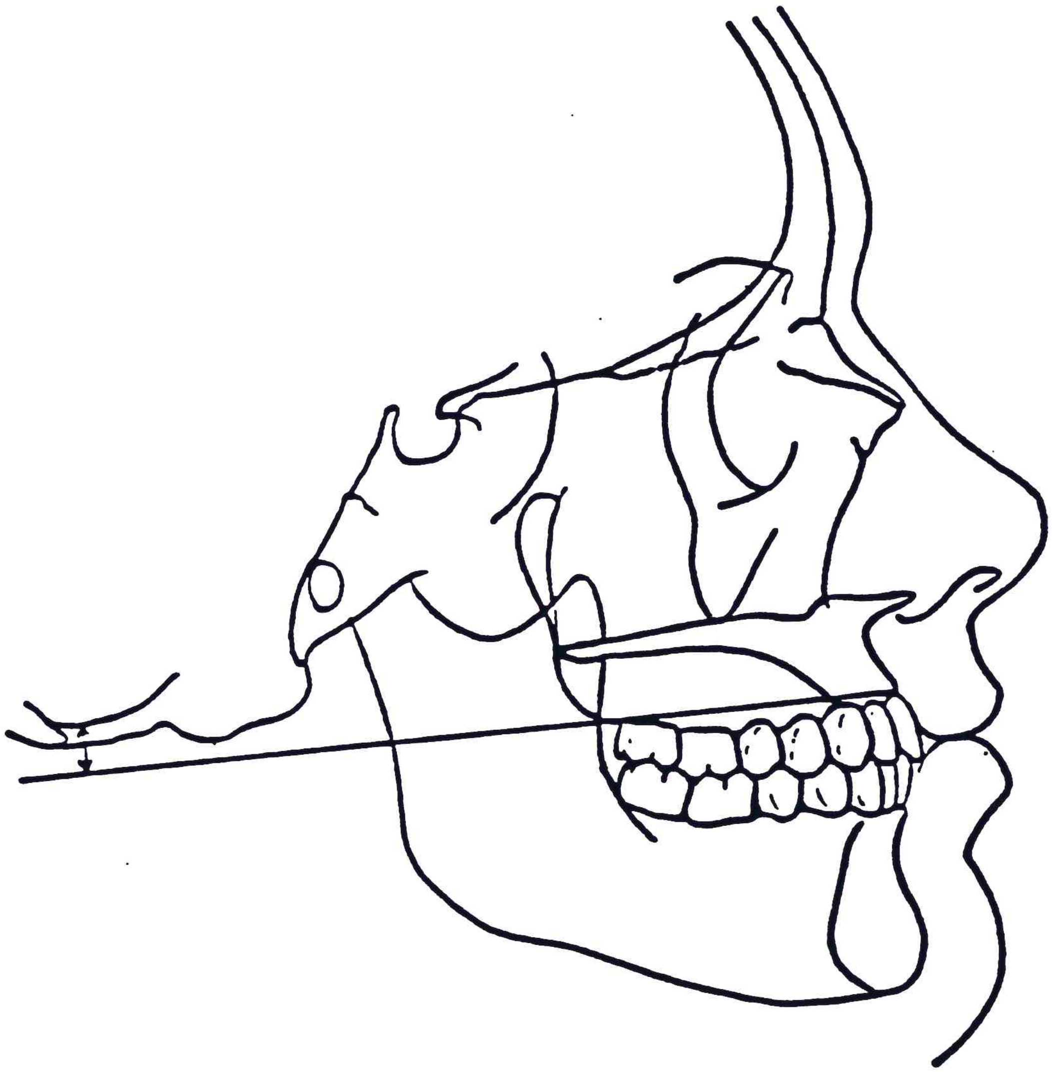


Figure 19. Maxillary nerve/palatal plane alignment. This diagram demonstrates the alignment relationship between the maxillary nerve and the palatal plane. The plane of the maxillary nerve is represented by a line from foramen rotundum in the pterygomaxillary fissure to a point 3 mm above orbitale (representing the course of the nerve prior to its downturn into the orbital floor). The palatal plane is determined as illustrated in Figure 17. An angular intersection is made between these two planes. If the angle is zero, the planes are in a neutral position. If the vertex of the angle is behind the subject, the angle is positive and indicates a clockwise rotational alignment of the palate. If the vertex is in front of the patient, the angle is negative and indicates a counterclockwise rotational alignment of the palate relative to the maxillary nerve.

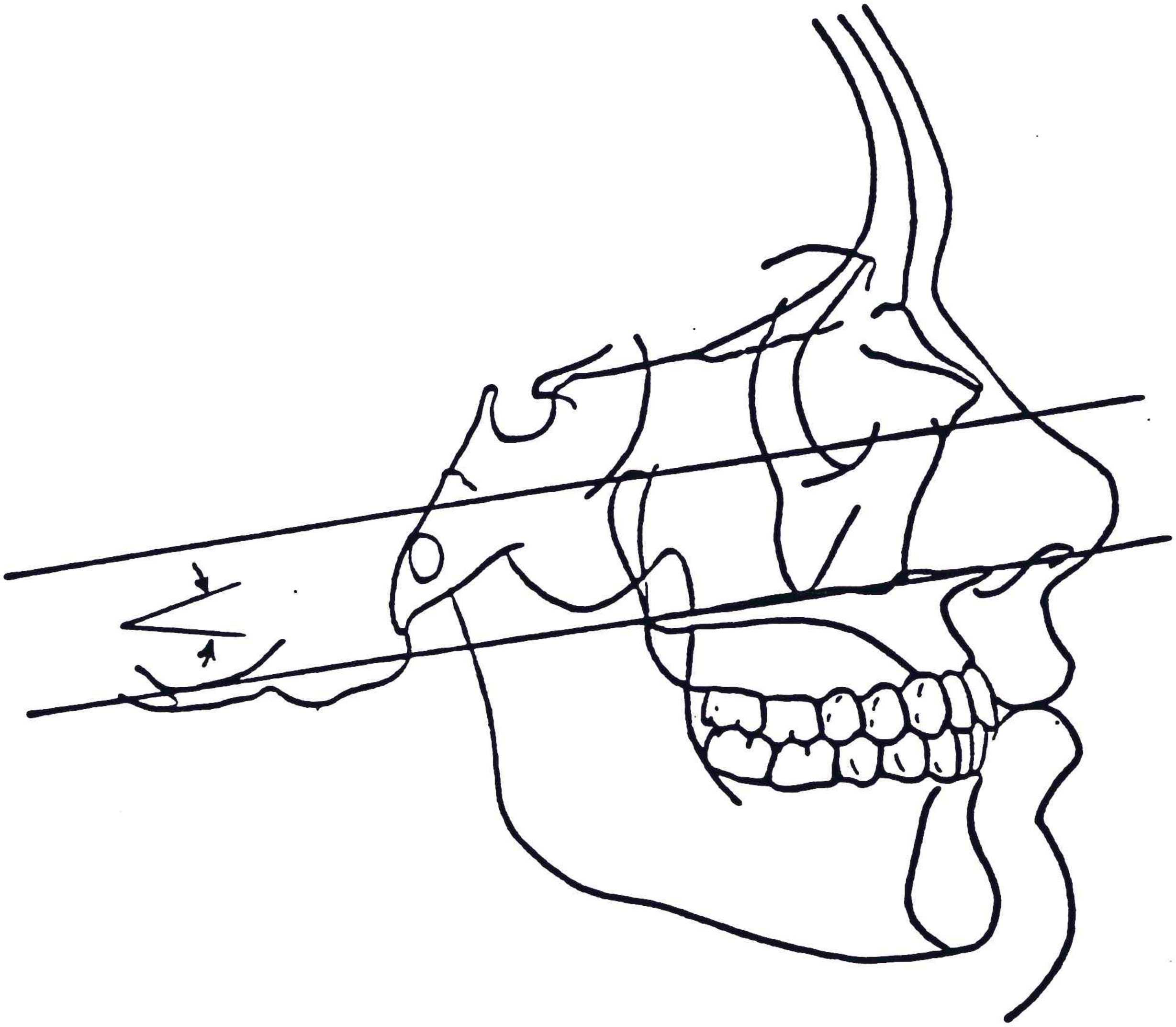
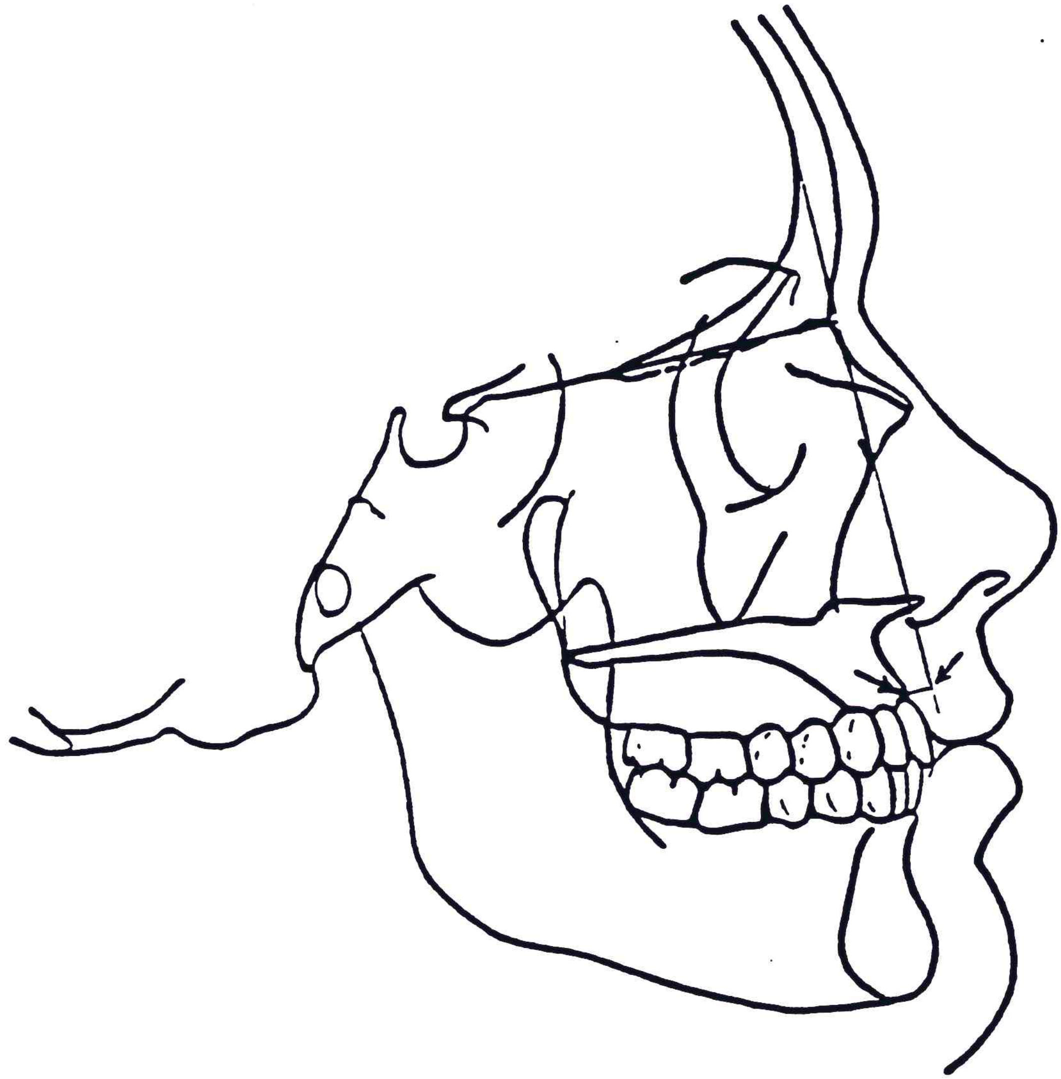


Figure 20. Vertical anterior maxillary plane. This diagram demonstrates the anterior boundary of growth of the nasomaxillary complex. A line from the most anterior point of the endocranial surface of the frontal bone (representing the frontal lobe of the cerebrum) is drawn perpendicular to a line from the posterior boundry of the cribiform plate to the anterior boundry of the cribiform plate. The distance from SPr to the perpendicular is measured in millimeters. If SPr is in front of the perpendicular it is a + value, if SPr is behind the perpendicular it is a - value. A + value can normally be expected until full naso-maxillary growth is attained.



RESULTS

Aggregate Cranial Floor/Maxilla and Ramus/Corpus Horizontal Dimensions at A and B Points

Group I: The initial evaluation of this group of individuals showed a predominance of a mandibular protrusive B point.

No change from this characteristic was observed in 47.5%. Twenty-five percent were observed to undergo change in a negative direction, that is, toward a mandibular protrusion. Fifteen percent underwent changes in a positive direction, that is, toward a maxillary protrusion.

Group II: The occurrence of a mandibular protrusive effect measured at B point was observed in only 25% of this group. However, the most significant changes were in a negative direction, which increased this characteristic in 37.5%.

Eighteen percent of this group demonstrated a constant variation in both directions (positive and negative).

Comparison: In both groups the most significant change was in a negative direction with Group II experiencing slightly greater change.

Aggregate Cranial Floor/Maxilla and Ramus/Corpus Horizontal Dimensions at SPr and IPr points

Group I: Initially, 72.5% demonstrated a maxillary dental arch protrusion measured at SPr. This characteristic did not change in 50% of this group.

There was no significant change in either a positive or negative direction. Hence, the maxillary protrusion tendency was maintained.

Group II: An incidence of 100% of maxillary protrusion was observed at SPr, with no appreciable changes.

MCF Alignment

Group I: Fifty percent of this group demonstrated a forward alignment of MCF. Twenty-five percent of this group demonstrated a constant oscillation in different directions throughout the time period studied, and 12.5% moved in a positive direction exacerbating the maxillary protrusion tendencies.

Group II: Forty-four percent of this group demonstrated a backward alignment of MCF, and consequent mandibular protrusion tendency. The incidence for this characteristic increased in 37.5%.

Comparison: In Group I the progressive clockwise rotation of MCF demonstrated a tendency to a Class II skeletal pattern. In contrast, Group II displayed a progressive counterclockwise rotation of MCF offsetting the underlying Class II skeletal tendencies.

Ramus Alignment

Group I: Eighty-two percent of this group displayed a clockwise rotation of mandibular ramus.

There was a significant change in an opposite direction as 45% of this group underwent a counterclockwise rotation ($p < .01$; Table IV).

Group II: Seventy-five percent of this group displayed a clockwise rotation of the mandibular ramus. No change of this relationship was observed during the time examined.

Comparison: Both groups demonstrated a maxillary protrusion tendency. However, Group I demonstrated a mandibular protrusive change as the ramus rotated counterclockwise.

Ramus MCF Skeletal

Group I: The short horizontal dimension of the ramus observed in 80% of this group was further decreased in relation to the horizontal dimension of MCF alignment.

Group II: Similar to Group I, it was observed that 81% of this group exhibited a short horizontal dimension of the mandibular ramus. No change in this relationship was observed with growth.

Comparison: A progressive increase in maxillary protrusion effect was observed in both groups as the MCF displaced the maxilla anteriorly a greater extent than the ramus displaced the mandibular corpus in the same direction.

Ramus/MCF Horizontal Dimensions (dental)

This relationship demonstrated the neutral molar position when ramus to cranial floor rotational effects had been eliminated.

Group I: fifty-two percent of the individuals displayed a mandibular protrusive effect.

The most significant changes observed were in a negative direction, increasing the occurrence of this characteristic in 25%.

Group II: In contrast, the elimination of backward rotation of cranial fossa in Group II illustrated the maxillary protrusive tendency initially and throughout the period studied.

The most significant change brought about by growth increased the above tendencies in 31%.

Molar Positions

This relationship presented the conventional molar positions as shown in the headfilm.

Group I: The most significant changes observed were in a negative direction increasing the occurrence of this characteristic in 32.5%.

Group II: Ninety-four percent of the subjects displayed a maxillary protrusion effect. This anatomical relationship was maintained in 81% of the cases.

The only changes were in a negative direction ($p < .05$; Table V), decreasing the incidence of this characteristic in 19%.

Maxillary/Mandibular Arch, Skeletal Dimensions A Point Compared with B Point

Group I: Measurement of this dimension reviewed a long mandibular corpus in 77.5% of this group. This incidence was further increased as 22% of the cases displayed a greater lengthening of the mandibular skeletal arch.

This mandibular increase was progressive up to 19 and 28 years of age.

Group II: Similarly, 69% of this group had a long mandibular skeletal arch. This anatomical characteristic did not change in 62% of the cases.

No significant change toward a maxillary protrusive effect was observed.

Maxillary/Mandibular Arches, Dental Dimensions, A Point Compared with B Point

Group I: The incidence toward a longer mandibular dental arch was increased in 31% of the cases.

Group II: There was a similar finding in this group. The most significant growth alteration was in a negative direction ($p < .05$; Table VI).

Maxillary/Mandibular Arches, Skeletal Dimensions, SPr Compared with IPr

Group I: Fifty percent exhibited a relatively long mandibular arch. This anatomical feature did not change in 42.5% of this group.

No significant tendencies were observed in either a positive or negative direction.

Group II: Conversely, 62% of this group exhibited an incidence of long maxillary skeletal arch. This anatomical feature was maintained in 31%. Nineteen percent demonstrated a change in a positive direction increasing the occurrence of long maxillary skeletal dimensions.

Comparison: Group I and II exhibited opposite maxillary protrusive expression when measurements were taken at SPr. Growth exacerbated the underlying tendencies.

Maxillary/Mandibular Arches, Dental, SPr Compared with IPr

Group I: Eighty-two percent of this group exhibited a relatively long maxillary dental arch at SPr. This anatomical feature did not change in 62% of this group.

No significant tendency in either a positive or negative direction was observed.

Group II: Similarly, 81% of this group exhibited a relative long maxillary dental arch at SPr. This anatomical feature was maintained in 75%.

The most significant change observed was in a positive direction increasing the maxillary protrusion tendency.

PM as Compared with Ramus-PCF Vertical Relationships

Group I: A long PM vertical was observed in 77.5% of this group. This anatomical feature did not change in 57.5%. However, 17% exhibited a shortening of the vertical PM producing a mandibular protrusive effect.

Group II: In this group 94% demonstrated a tendency toward a long PM vertical. Seventy percent did not change this anatomical feature.

No significant tendencies in either a positive or negative direction were observed with growth.

Comparison: In Group I the midface was becoming progressively shorter with age in relative vertical size. However, in Group II no significant changes decreased the long facial height tendencies.

Corpus Occlusal Alignment

Group I: Eighty percent of this group exhibited an upward rotation of the corpus occlusal alignment. This anatomical feature resulted in a maxillary protrusion effect. This characteristic did not change in 62.5% of the cases.

Seventeen percent underwent a downward rotation of the occlusal plane producing a mandibular protrusion tendency.

A great percentage of the individuals of this group displayed a constant oscillation in different directions of these relationships during the period studied.

Group II: In this group 100% exhibited a counterclockwise rotation of the corpus occlusal alignment. This anatomical feature was maintained in fifty-six percent of the individuals. There was a progressive trend toward a mandibular protrusive effect. The incidence of this tendency was increased in 25%.

Comparison: Both groups demonstrated a significant clockwise rotation of the corpus occlusal alignment with age and a consequent mandibular protrusion tendency.

Gonial Angle

Group I: Fifty-five percent demonstrated a closed gonial angle. This anatomical feature was maintained in 42.5% of the cases. A further increase of gonial angle was observed as the incidence toward this characteristic increased in 22.5%.

Group II: Similarly, this group presented a closed gonial angle in 69% of the cases. Sixty percent did not change this characteristic during the period studied.

No significant directional changes were found in either a positive or negative direction, hence the maxillary protrusion tendency was maintained about the same during the period studied.

Curve of Spee

Group I: Seventy percent of this group exhibited a positive curve of spee and consequent maxillary protrusion effect.

The most significant changes observed increased the incidence of this characteristic in 27.5%.

Group II: One hundred percent of this group exhibited a pronounced curve of spee. No significant tendency in either a positive or negative direction was observed during the period examined.

Palatal Plane Alignment

Group I: This group presented similar distribution of upward and downward rotation of the palatal plane. However, with growth the tendency toward a downward rotation of this plane was increased in 27.5%. Only 5% of the clockwise rotators underwent a rotation in the opposite direction.

Group II: Initially, 50% of this group exhibited a clockwise rotation of the palatal plane. Forty-four percent maintained the same anatomical expression throughout the period studied. The incidence for this characteristic was increased as 25% of the remaining sample underwent a clockwise rotation of the palatal plane.

Inferior Maxillary Plane

Group I: Initially, 65% of this group displayed a counterclockwise rotation of IMP. Sixty percent did not change this anatomical feature.

The growth changes observed demonstrated a significant tendency toward a counterclockwise rotation ($p < .01$; Table VII).

Group II: In this group 50% exhibited a counterclockwise rotation of IMP. Forty-four percent maintained this anatomical feature unchanged. A significant change as observed in a counterclockwise direction during the period studied ($p < .05$; Table VIII).

Maxillary Nerve/Palatal Plane Alignment

Group I: One hundred percent of this group exhibited a clockwise rotation of the maxillary nerve palatal plane and no change was observed during the period studied.

Group II: The same effect was observed in this group.

Vertical Anterior Maxillary Plane

Group I: One hundred percent of this group exhibited a retrusion of SPr related to a line representing the anterior growth boundary of the nasomaxillary complex.

Group II: The same effect was observed in this group.

TABLE IV

RAMUS ALIGNMENT

Group I

	Initial		Final	
	N	%	N	%
-	3	7.5	14	35
+	33	82.5	18	45
N	4	10	8	20
	40	100	40	100

Chi-square = 12.861

p < .01

TABLE V

MOLAR POSITION

Group II

	Initial		Final	
	N	%	N	%
-	1	6	0	0
+	15	94	12	75
0	0	0	4	25
	16	100	16	100

Chi-square = 5.33^{ns}

TABLE VI

MAXILLARY/MANDIBULAR ARCHES, DENTAL DIMENSIONS

A POINT COMPARED WITH B POINT

Group II

	Initial		Final	
	N	%	N	%
-	7	43	10	62.5
+	4	25	6	37.5
N	5	31	0	0
	16	100	16	100

Chi-square = 5.92^{ns}

TABLE VII

INFERIOR MAXILLARY PLANE

Group I

	Initial		Final	
	N	%	N	%
-	26	65	36	90
+	10	25	1	2.5
N	4	10	3	7.5
	40	100	40	100

Chi-square = 9.11

$p < .01$

TABLE VIII

INFERIOR MAXILLARY PLANE

Group II

	Initial		Final	
	N	%	N	%
-	8	50	12	75
+	5	31	0	0
N	3	18	4	25
	16	100	16	100

Chi-square = 5.94^{ns}

TABLE IX

SUMMARY OF DISTRIBUTION PERCENTAGES: GROUP I

	I Age Interval - 11-14 Y +		II Age Interval - 15-18 Y +		III Age Interval - 19-28 Y +		IV Age Interval - 29-over 50 Y +	
Ar-A, Ar-B	62%	27.5%	67.5%	25%	77.5%	15%	72.5%	17.5%
Ar-SPr, Ar-IPr	17	72.5	25	65	20	70	20	70
MCF Alignment	45	50	42.5	42.5	42.5	35	37.5	60
Ramus Alignment	7.5	82.5	20	62.5	30	52.5	35	45
Ramus MCF (sk)	12.5	80	5	92.5	2.5	90	5	90
Ramus MCF (de)	52.5	32.5	47.5	27.5	47.5	27.5	57.5	20
Molar Positions		40	7.5	32.5	47.5	27.5	7.5	30
Max/Md AB (sk)	77.5	17.5	92.5	7.5	95	5	90	10
Max/Md AB(de)	40	40	55	32.5	55	30	55	32.5
Max/Md SPr/IPr (sk)	57.5	30	75	17.5	72.5	22.5	75	22.5
Max/Md SPr/IPr (de)	7.5	82.5	5	70	7.5	82.5	10	85
PM Vertical	12.5	77.5	7.5	77.5	15	72.5	22.5	65
Corpus/occl.	20	80	17.5	77.5	25	75	32.5	67.5
Gonial Angle	30	55	17.5	72.5	20	67.5	22.5	75
C. Spee/I. Pos.	22.5	70	32.5	65	15	75	20	50
Palatal plane Alignment	35	35	20	47.5	15	55	22.5	0
Inf. Max. Plane	65	25	80	7.5	90	2.5	90	100
Max. Nerve Palatal Plane	0	100	0	100	0	100	0	0
Vertical Ant. Max. Plane	100	0	100	0	100	0	100	0

TABLE X

SUMMARY OF DISTRIBUTION PERCENTAGES: GROUP II

Age Interval	11-14 Y		15-18 Y		19-28 Y		29 up to over 50 Y	
	-	+	-	+	-	+	-	+
Ar-A, Ar-B	25%	25%	50%	37.5%	50%	37.5%	56%	37.5
Ar-SPr, Ar-IPr	0	100	6	88	0	88	0	94.5
MCF Alignment	44	19	56	25	75	12.5	69	12.5
Ramus Alignment	12.5	80	19	62.5	25	62.5	25	62.5
Ramus MCF (sk)	12.5	81	6	94	0	94	6	94
Ramus MCF (de)	12.5	50	19	62.5	19	62.5	12.5	62.5
Molar Positions	6	94	0	94	0	88	0	75
Max/Md AB (sk)	69	25	75	19	75	25	75	25
Max/Md AB(de)	44	25	44	31	56	31	0	37.5
Max/Md SPr/IPr (sk)	31	62.5	37.5	50	25	62.5	25	62.5
Max/Md SPr/IPr (de)	0	81	12.5	88	0	88	12.5	81
PM Vertical	0	94	12.5	81	12.5	88	12.5	88
Corpus/occl.	0	100	19	81.2	25	69	25	69
Gonial Angle	25	69	12.5	69	12.5	75	25	75
C. Spee/I. Pos.	0	100	6	94	12.5	87.5	12.5	87.5
Palatal plane Alignment	25	50	12.5	69	12.5	75	19	69
Inf. Max. Plane	50	31	75	19	81	6	75	0
Max. Nerve Palatal Plane	0	100	0	100	0	100	0	100
Vertical Ant. Max. Plane	100	0	100	0	100	0	100	0

TABLE XI

SUMMARY OF FREQUENCY DISTRIBUTIONS OF DIRECTIONAL CHANGES TOWARD A MAXILLARY OR MANDIBULAR PROTRUSION: GROUP I

	-	No Change		+	Change to +		Change to -		Variation
	N	%	N	%	N	%	N	%	%
Ar-A, Ar-B	19	47.5	2	5	6	15	10	25	7.5
Ar-SPr, Ar-IPr	3	7.5	20	50	5	12.5	5	12.5	15
MCF Alignment	10	25	14	35	5	12.5	1	2.5	25
Ramus Alignment	1	2.5	15	37.5	2	5	18	45	10
Ramus MCF (sk)	1	2.5	30	75	5	12.5	2	5	5
Ramus MCF (de)	8	20	4	10	6	15	10	25	25
Molar Positions	0	0	4	10	3	7.5	13	32.5	27.5
Max/Md AB (sk)	26	65	0	0	4	10	9	22.5	2.5
Max/Md AB(de)	8	20	7	17.5	6	15	14	35	12.5
Max/Md SPr/IPr (sk)	17	42.5	2	5	7	17.5	7	17.5	17.5
Max/Md SPr/IPr (de)	1	2.5	25	62.5	4	10	2	5	20
PM Vertical	2	5	23	57.5	1	2.5	7	17.5	15
Corpus/occl.	4	10	25	62.5	1	2.5	7	17.5	7.5
Gonial Angle	5	12.5	17	42.5	9	22.5	2	7.5	12.5
C. Spee/I. Pos.	2	5	18	45	11	27.5	6	15	7.5
Palatal plane Alignment	3	7.5	11	27.5	11	27.5	2	5	25
Inf. Max. Plane	24	60	1	2.5	2	5	13	32.5	0
Max. Nerve Palatal Plane	0	0	40	100	0	0	0	0	0
Vertical Ant. Max. Plane	40	100	0	0	0	0	0	0	0

TABLE XII
SUMMARY OF FREQUENCY DISTRIBUTIONS OF DIRECTIONAL CHANGES TOWARD A MAXILLARY OR MANDIBULARY PROTRUSION: Group II

	-	No Change		+	Change to +		Change to -		Variation
	N	%	N	%	N	%	N	%	%
Ar-A, Ar-B	4	25	2	12.5	1	6.2	6	37.5	18.7
Ar-SPr, Ar-IPr	0	0	14	87.5	0	0	1	6.2	6.2
MCF Alignment	5	31	2	12.5	2	12.5	6	37.5	6.2
Ramus Alignment	1	6.2	10	62.5	1	6.2	2	12.5	9.2
Ramus MCF (sk)	0	0	13	81	2	12.5	0	0	6.2
Ramus MCF (de)	1	6.2	6	37.5	5	31.2	2	12.5	12.5
Molar Positions	0	0	13	81	0	0	3	18.7	0
Max/Md AB (sk)	10	62.5	2	12.5	2	12.5	2	12.5	0
Max/Md AB(de)	3	18.7	3	18.7	2	12.5	5	31	18.2
Max/Md SPr/IPr (sk)	2	12.5	5	31	3	18.7	0	0	37.5
Max/Md SPr/IPr (de)	0	0	12	75	1	6.2	0	0	12.5
PM Vertical	0	0	12	75	1	6.2	1	6.2	12.5
Corpus/occl.	0	0	9	56	0	0	4	25	18.7
Gonial Angle	2	12.5	10	62.5	2	12.5	1	6.2	6.2
C. Spee/I. Pos.	0	0	13	81	0	0	2	6.2	6.2
Palatal plane Alignment	1	6.2	7	43.7	4	25	1	6.2	25
Inf. Max. Plane	7	43.7	0	0	0	0	7	43.7	6.2
Max. Nerve Palatal Plane	0	0	15	94	0	0	1	6.2	0
Vertical Ant. Max. Plane	16	100	0	0	0	0	0	0	0

TABLE XIII

FREQUENCY DISTRIBUTION OF DIRECTIONAL CHANGES FOR:
AGGREGATE CRANIAL FLOOR/MAXILLA AND RAMUS/CORPUS
HORIZONTAL DIMENSIONS AT A AND B POINTS

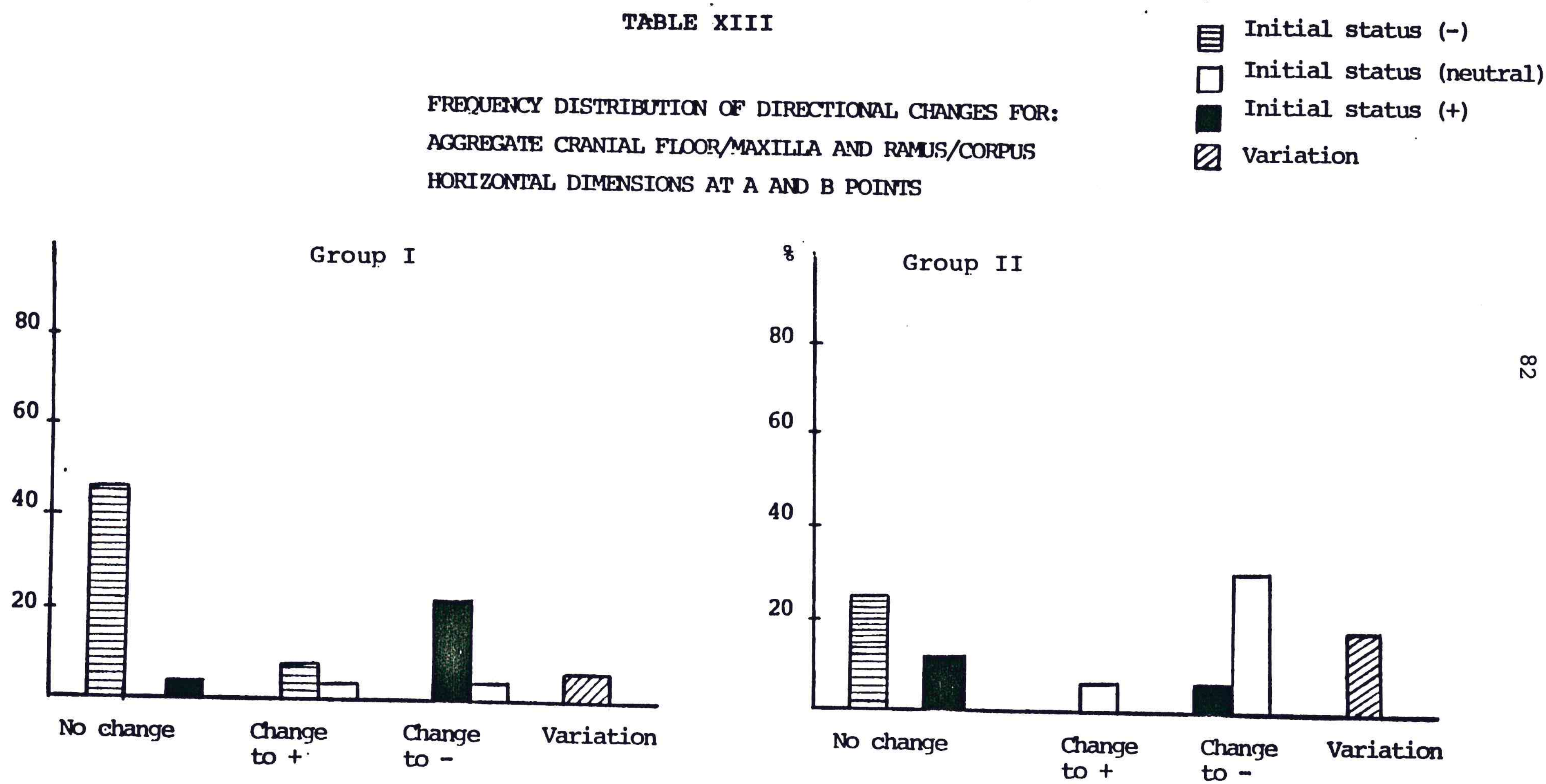


TABLE XIV

FREQUENCY DISTRIBUTION OF DIRECTIONAL CHANGES FOR:
AGGREGARE CRANIAL FLOOR/MAXILLA AND RAMUS/CORPUS
HORIZONTAL DIMENSIONS AT SPr AND IPr

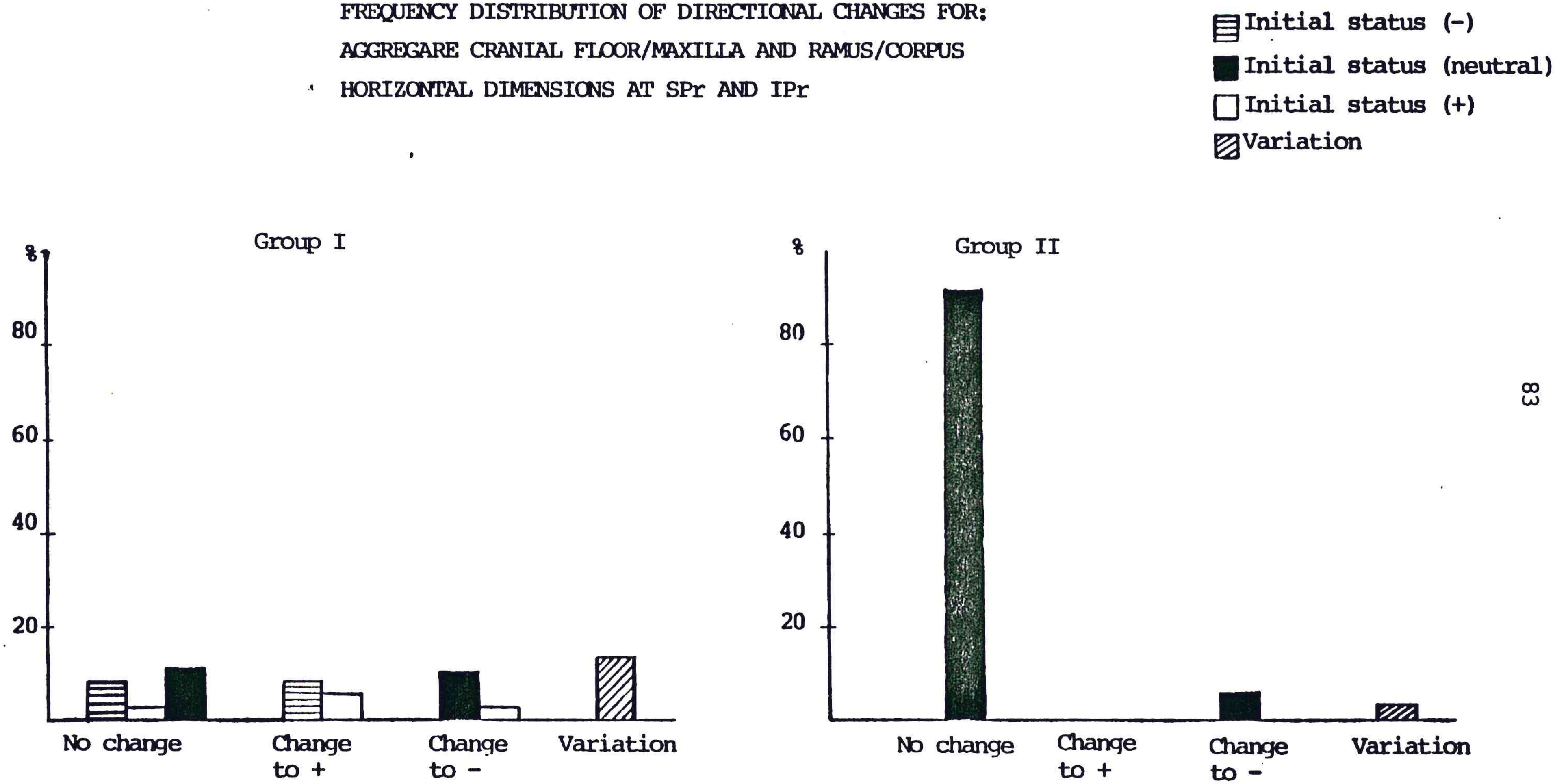


TABLE XIV

FREQUENCY DISTRIBUTION OF DIRECTIONAL CHANGES FOR:
AGGREGARE CRANIAL FLOOR/MAXILLA AND RAMUS/CORPUS
HORIZONTAL DIMENSIONS AT SPr AND IPr

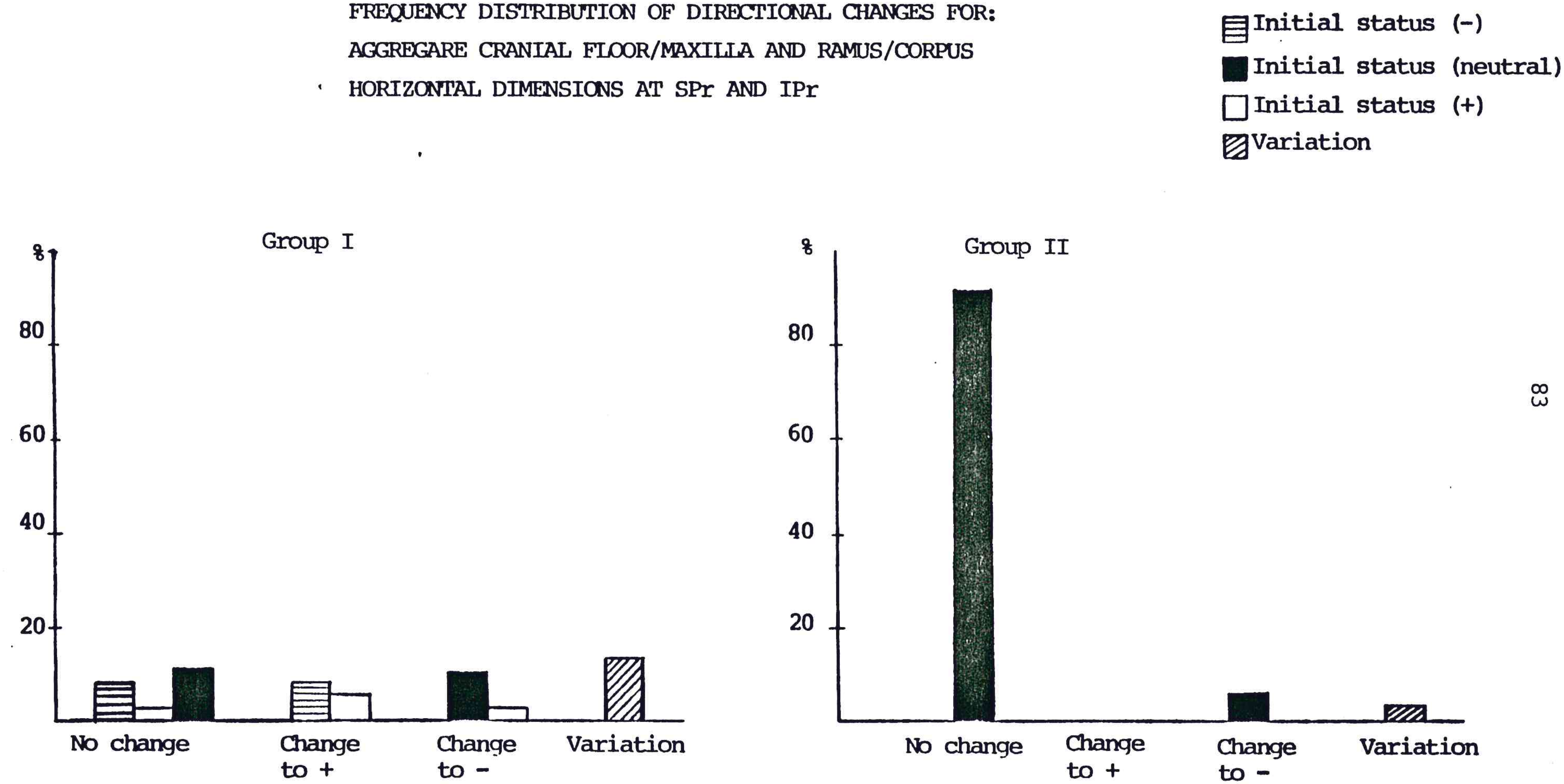


TABLE XV

FREQUENCY DISTRIBUTION OF DIRECTIONAL CHANGES FOR:
MIDDLE CRANIAL FOSSA (MCF) AND POSTERIOR
MAXILLARY (PM) RELATIVE ALIGNMENT

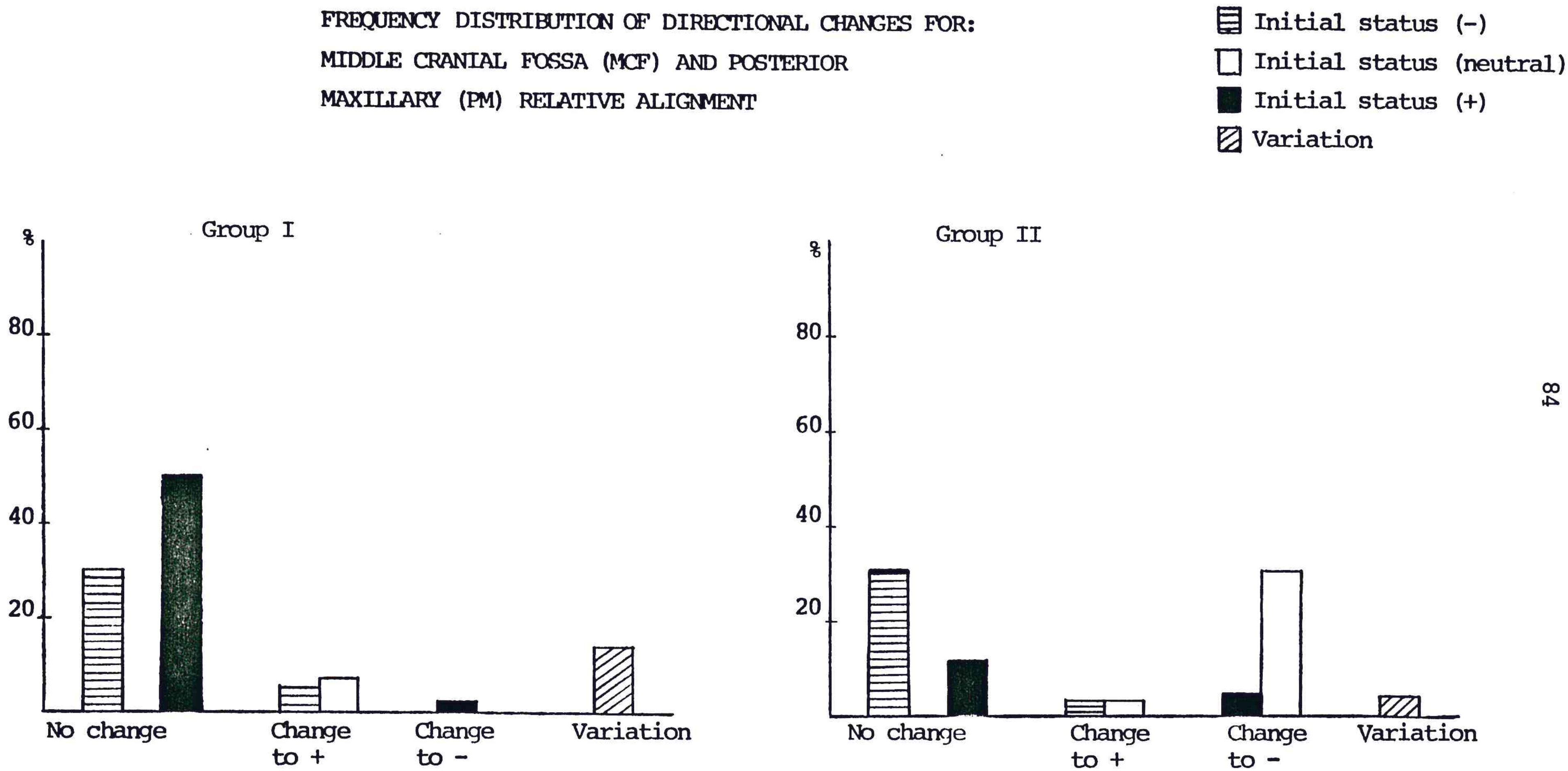


TABLE XVI

FREQUENCY DISTRIBUTION OF DIRECTIONAL CHANGES FOR:
RAMUS ALIGNMENT

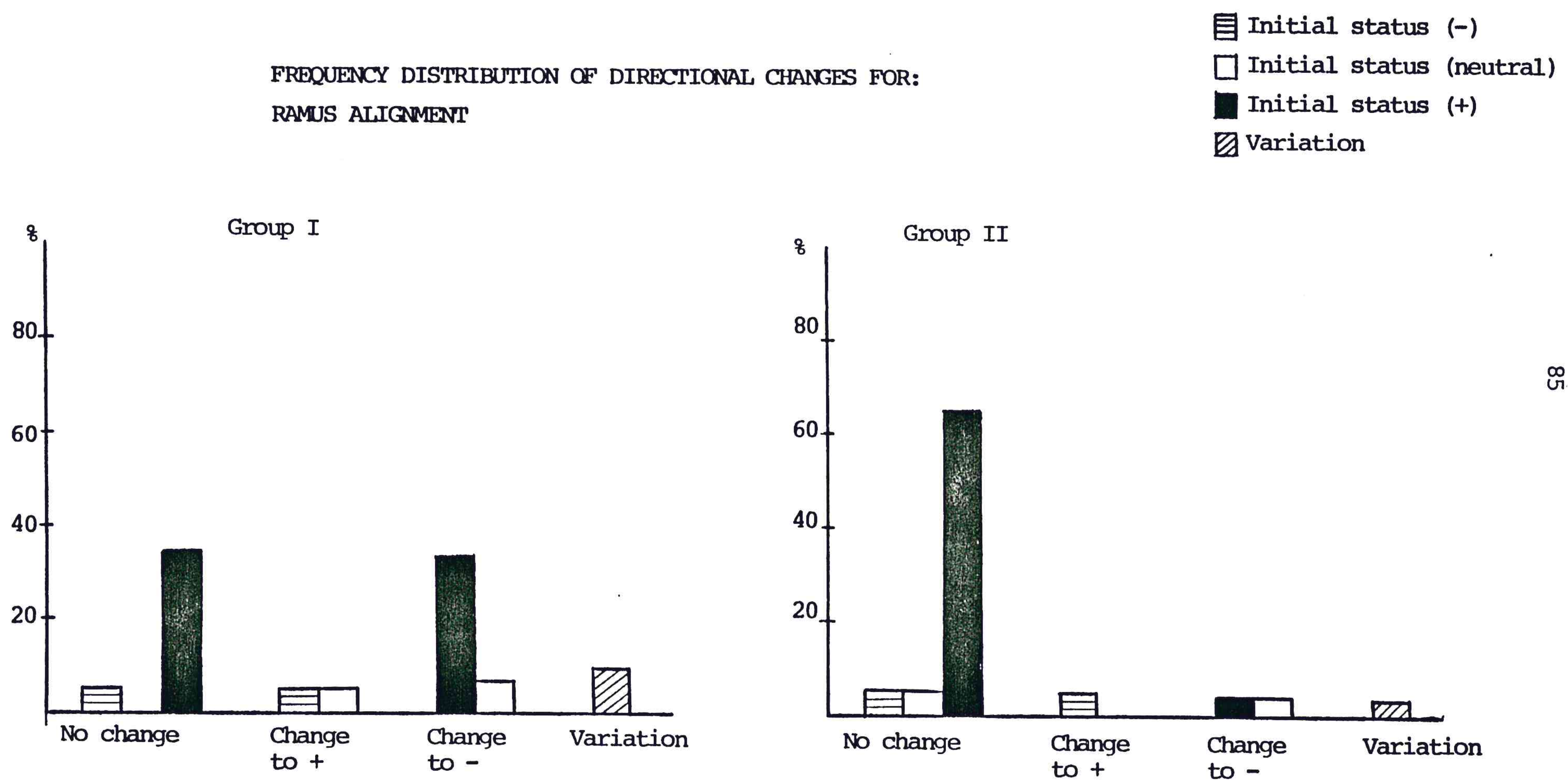


TABLE XVII

FREQUENCY DISTRIBUTION OF DIRECTIONAL CHANGES FOR:
RAMUS/MCF HORIZONTAL DIMENSION (SKELETAL)

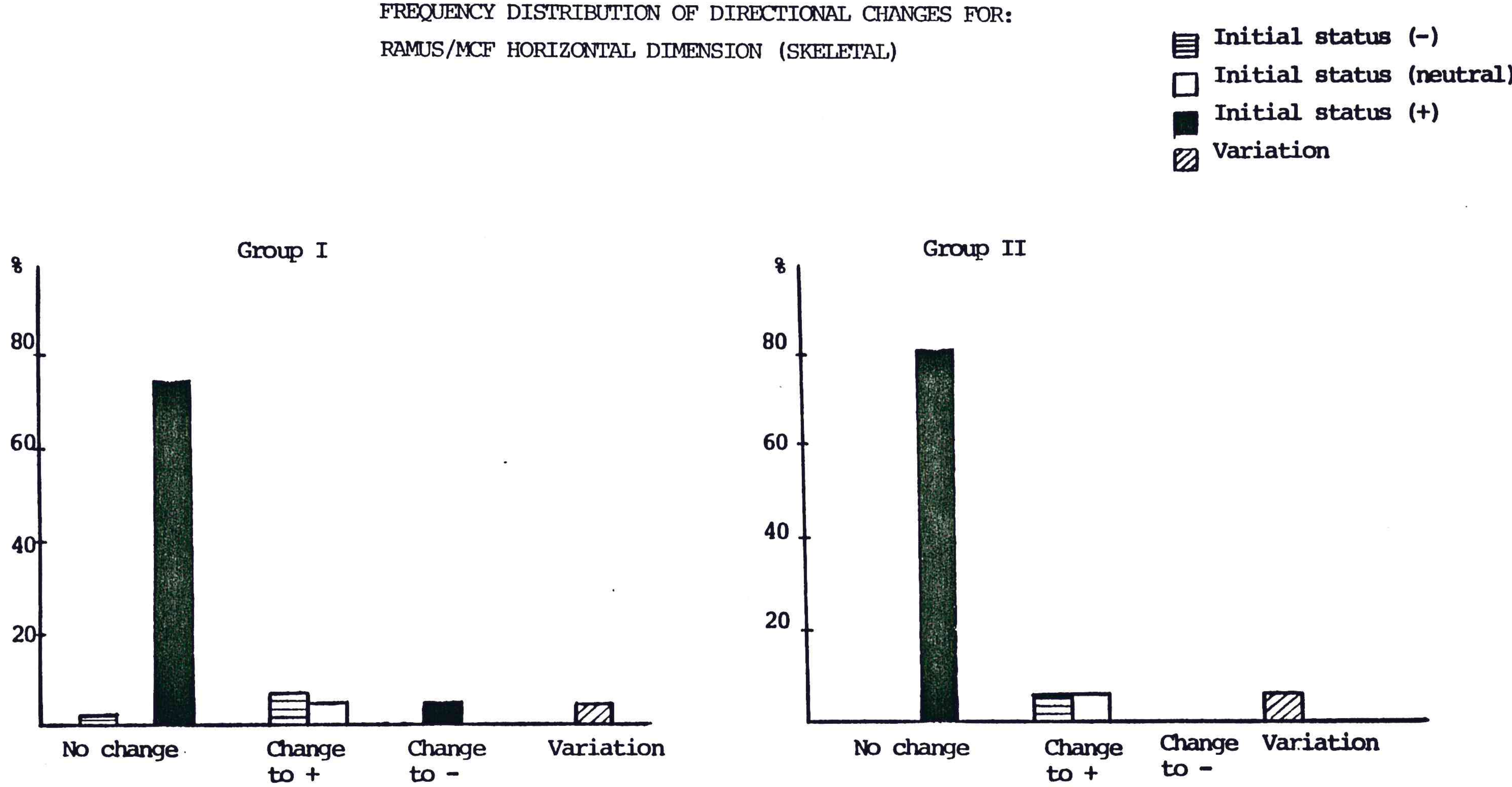


TABLE XVIII

FREQUENCY DISTRIBUTION OF DIRECTIONAL CHANGES FOR:
RAMUS/MCF HORINZONTAL DIMENSION (DENTAL)

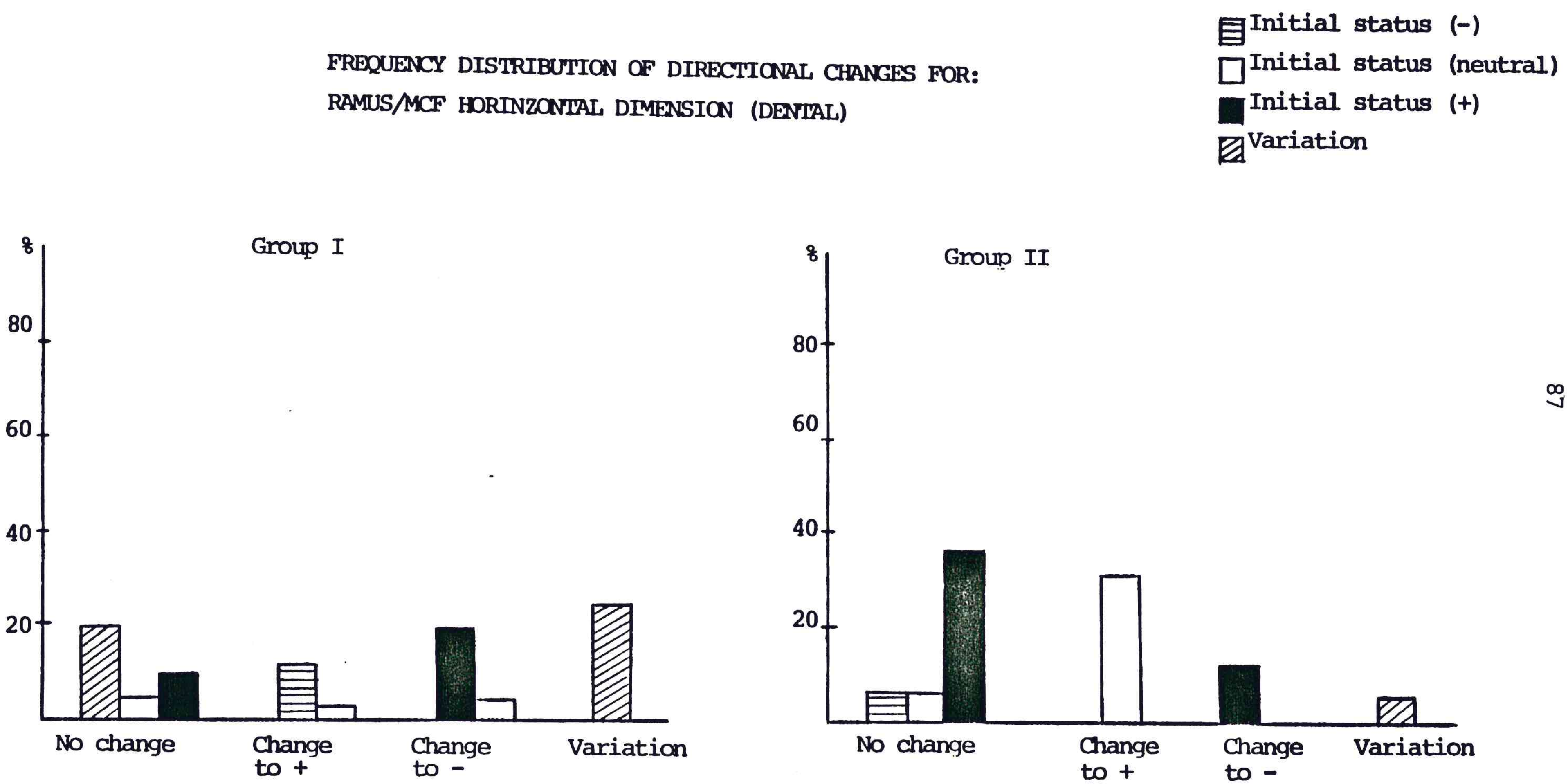


TABLE XIX

FREQUENCY DISTRIBUTION OF DIRECTIONAL CHANGES FOR:
MOLAR POSITIONS

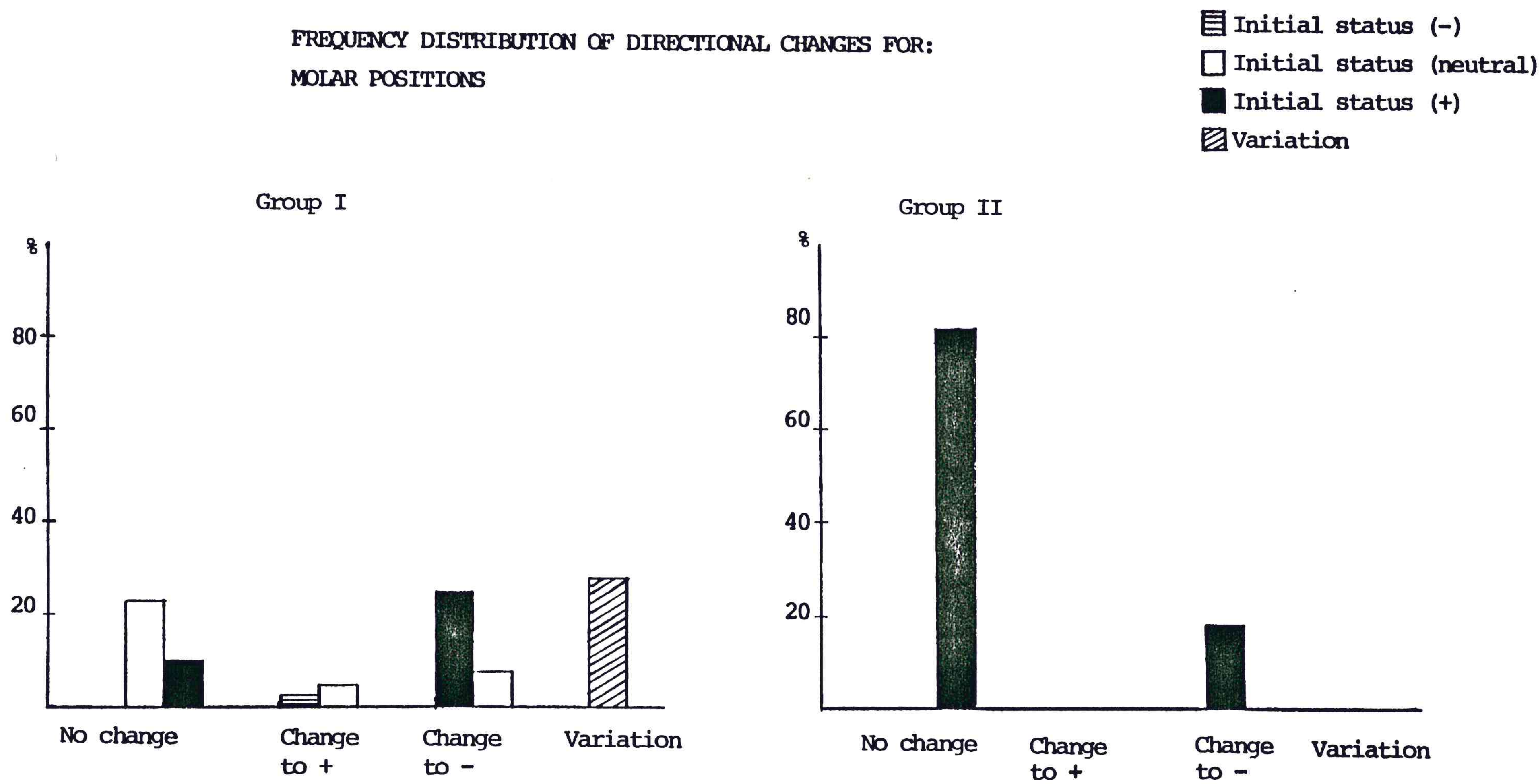


TABLE XX

FREQUENCY DISTRIBUTION OF DIRECTIONAL CHANGES FOR:
MAXILLARY/MANDIBULAR ARCHES, SKELETAL DIMENSIONS,
A POINT COMPARED WITH B POINT

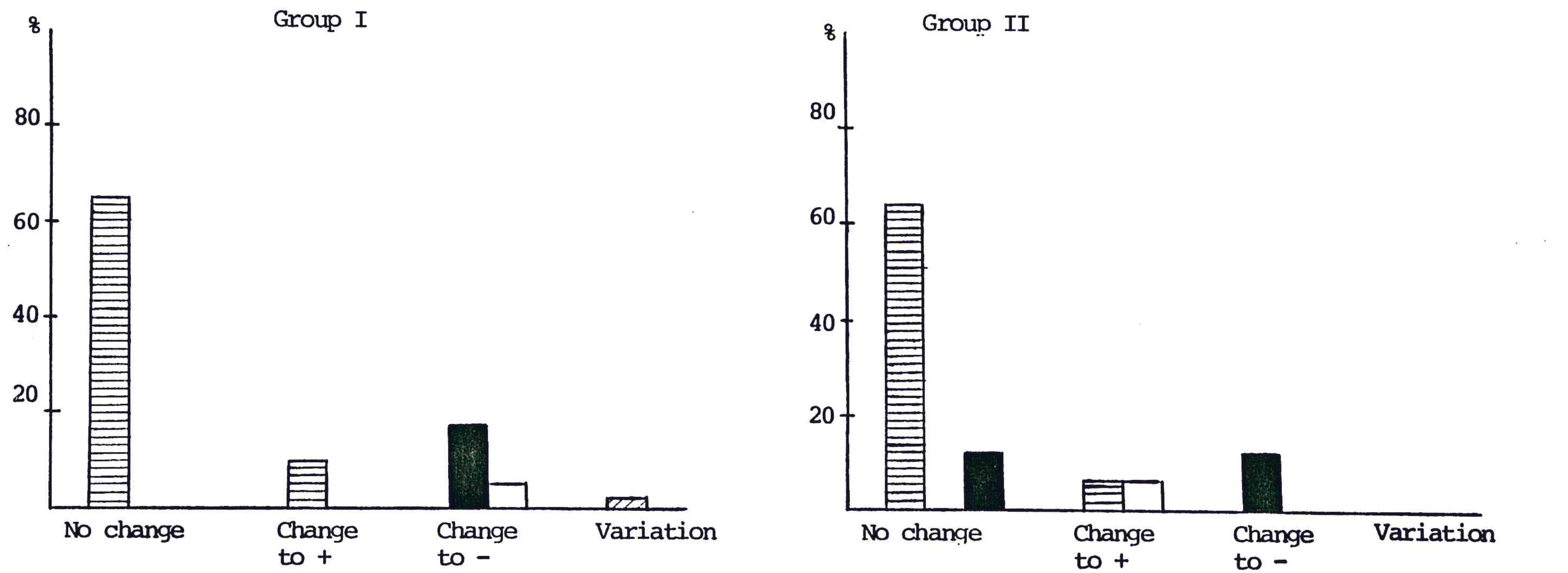


TABLE XXI

FREQUENCY DISTRIBUTION OF DIRECTIONAL CHANGES FOR:
MAXILLARY/MANDIBULAR ARCHES, DENTAL DIMENSIONS,
A POINT COMPARED WITH B POINT

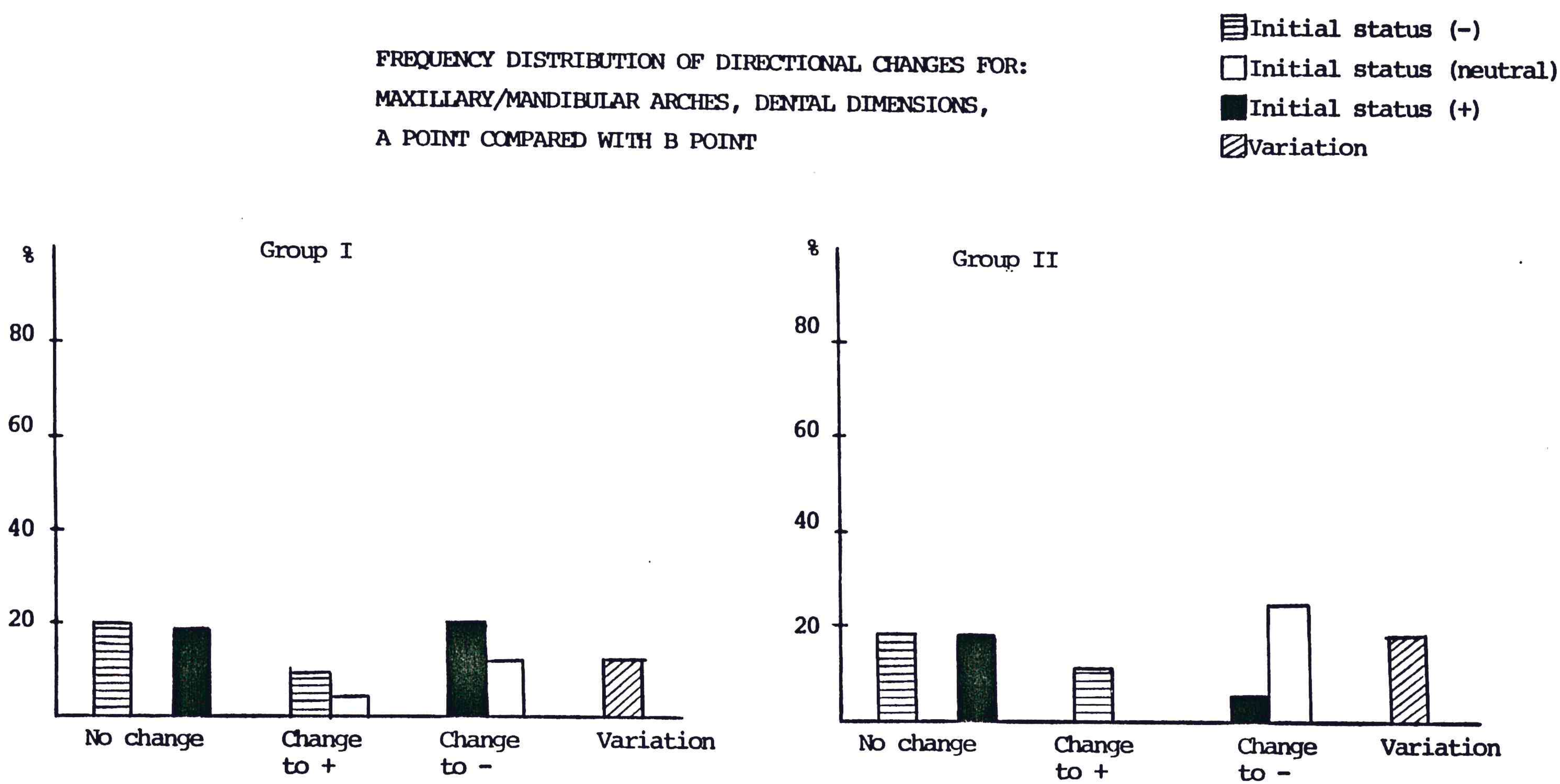


TABLE XXII

FREQUENCY DISTRIBUTION OF DIRECTIONAL CHANGES FOR: MAXILLARY/MANDIBULAR ARCHES, SKELETAL DIMENSIONS, SPr COMPARED WITH IPr

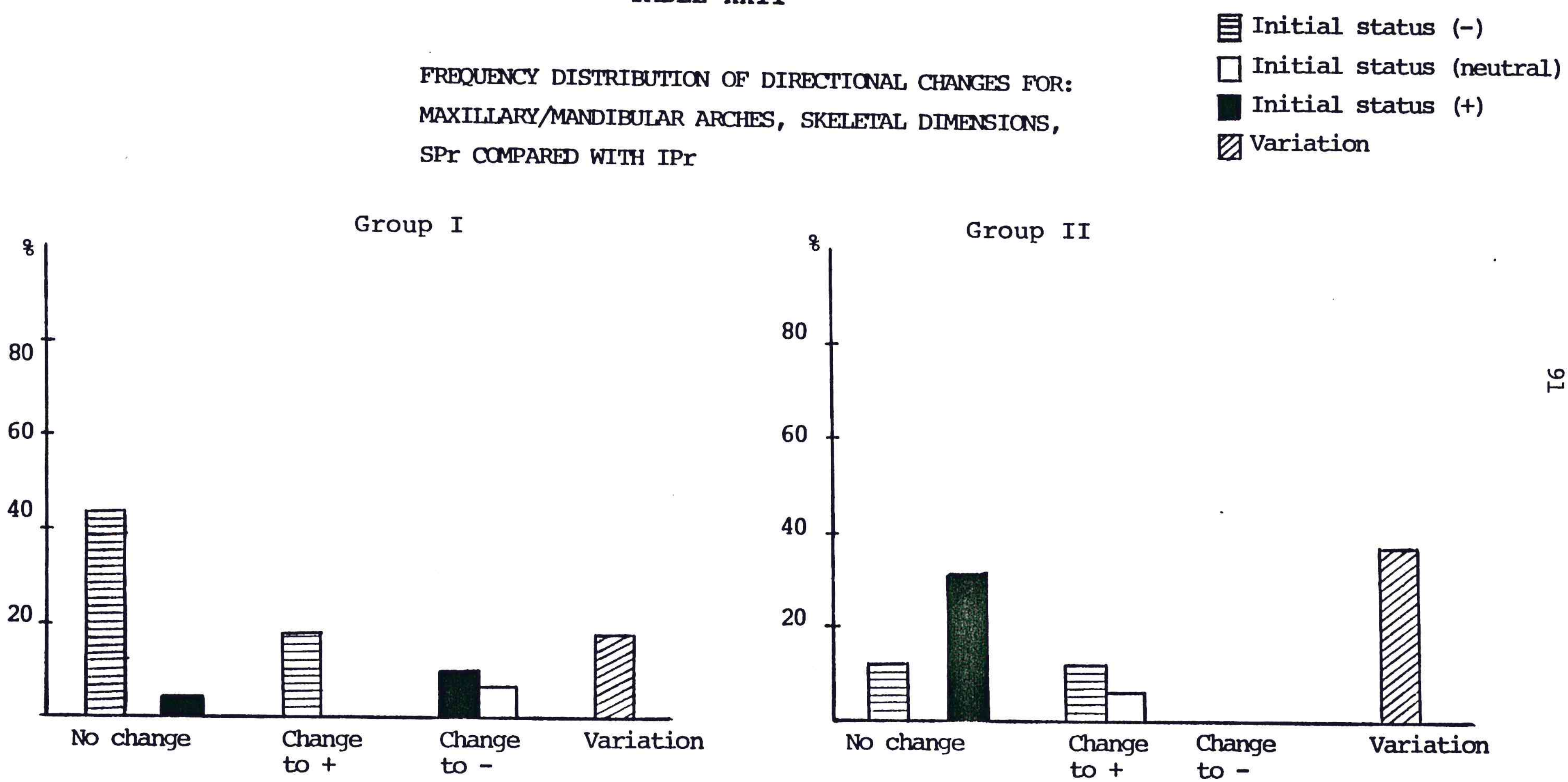


TABLE XXIII

FREQUENCY DISTRIBUTION OF DIRECTIONAL CHANGES FOR:
MAXILLARY/MANDIBULAR ARCHES, DENTAL DIMENSIONS,
SPr COMPARED WITH IPr

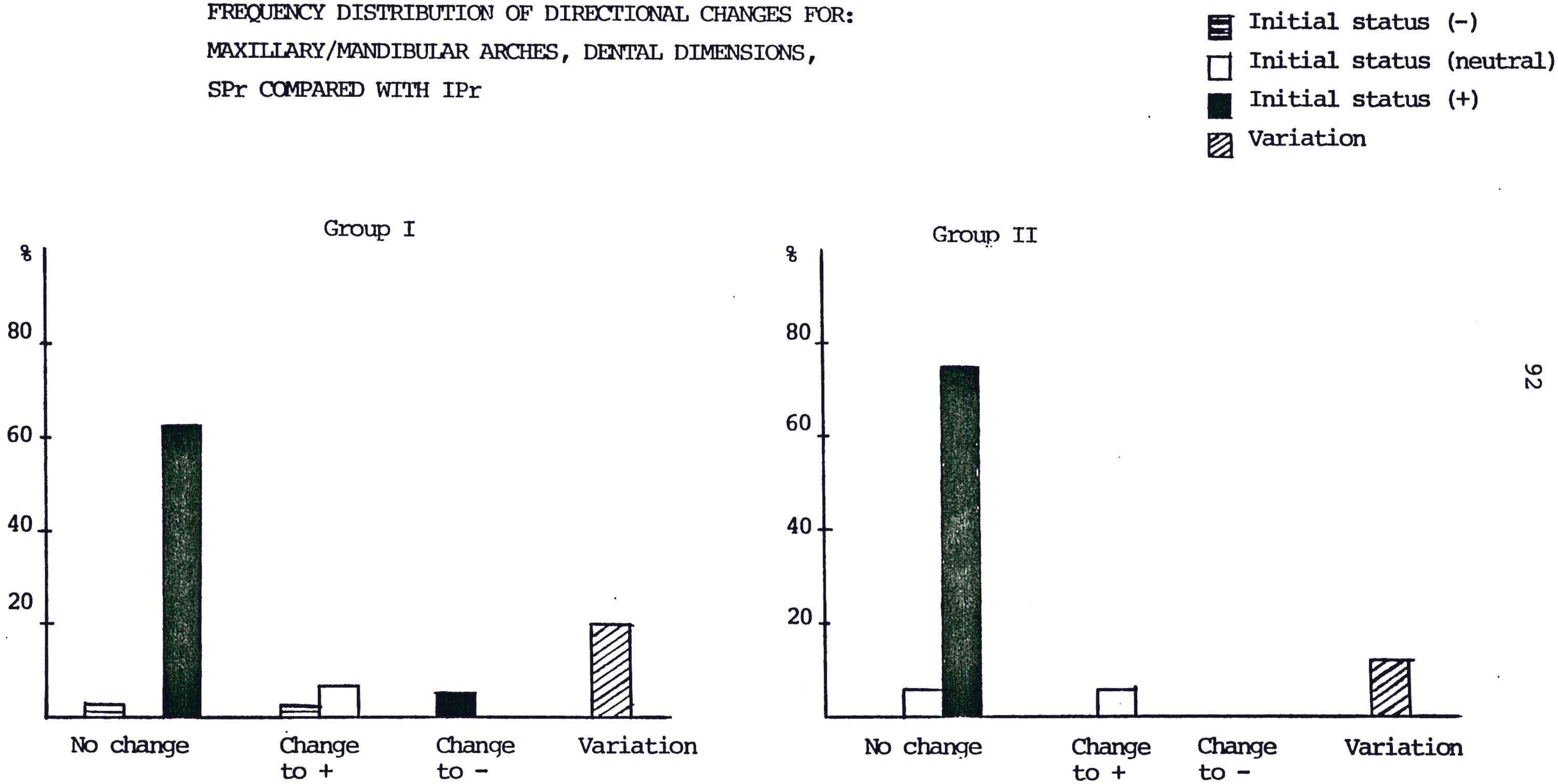


TABLE XXIV

FREQUENCY DISTRIBUTION OF DIRECTIONAL CHANGES FOR:
PM AS COMPARED WITH RAMUS/MCF VERTICAL DIMENSIONS

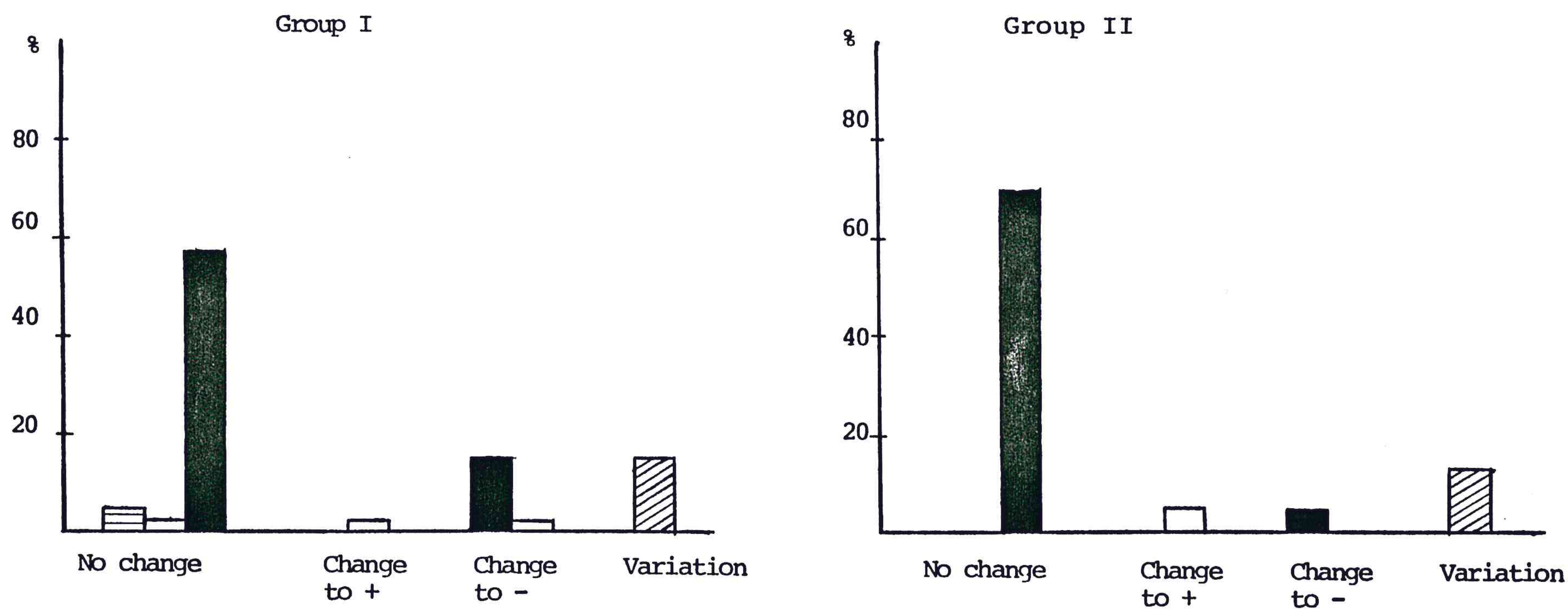


TABLE XXV

FREQUENCY DISTRIBUTION OF DIRECTIONAL CHANGES FOR:
CORPUS-OCCLUSAL ALIGNMENT

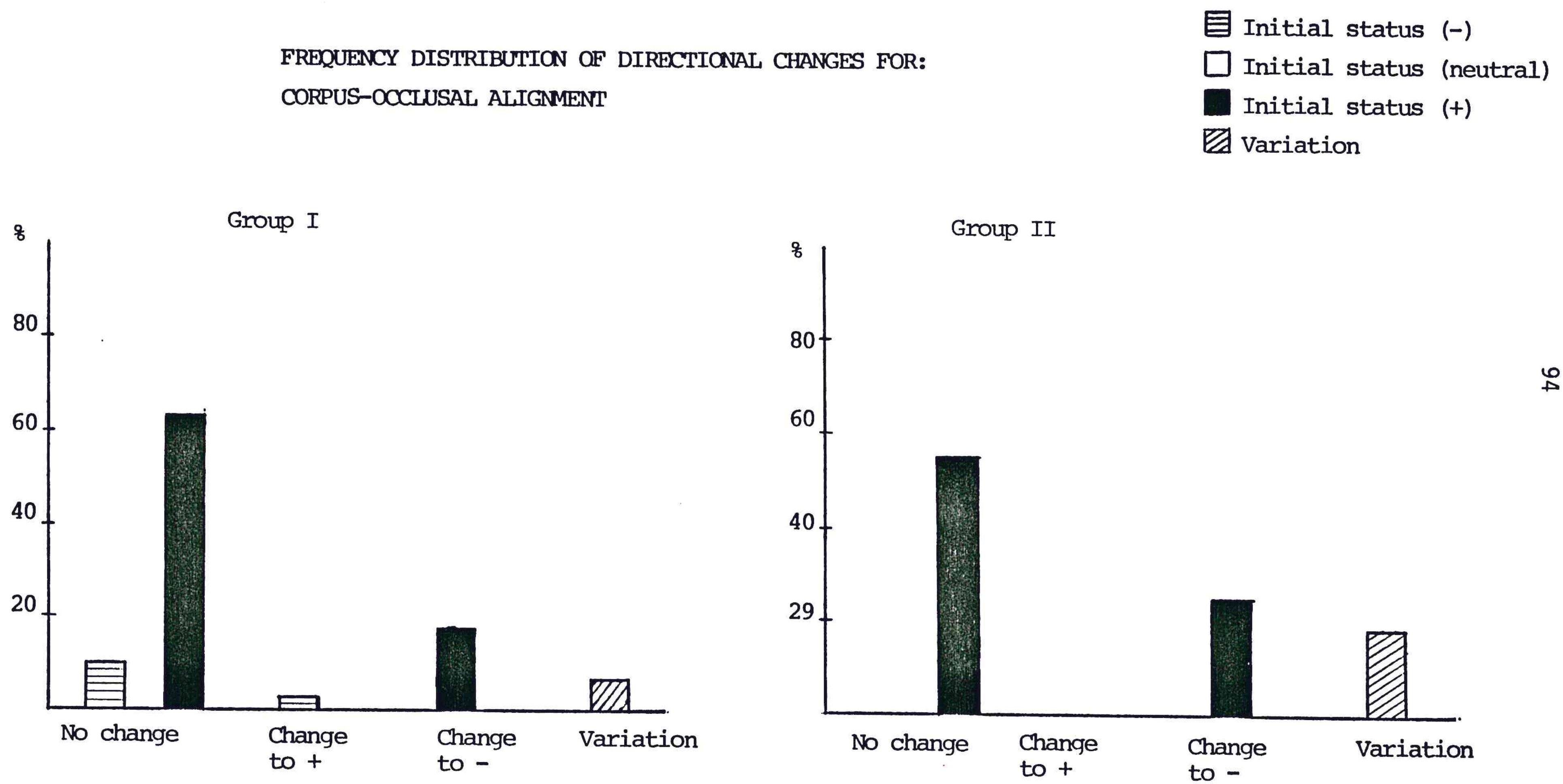
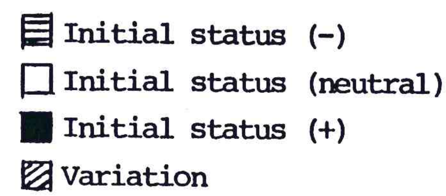


TABLE XXVI

FREQUENCY DISTRIBUTION OF DIRECTIONAL CHANGES FOR:
GONIAL ANGLE ALIGNMENT



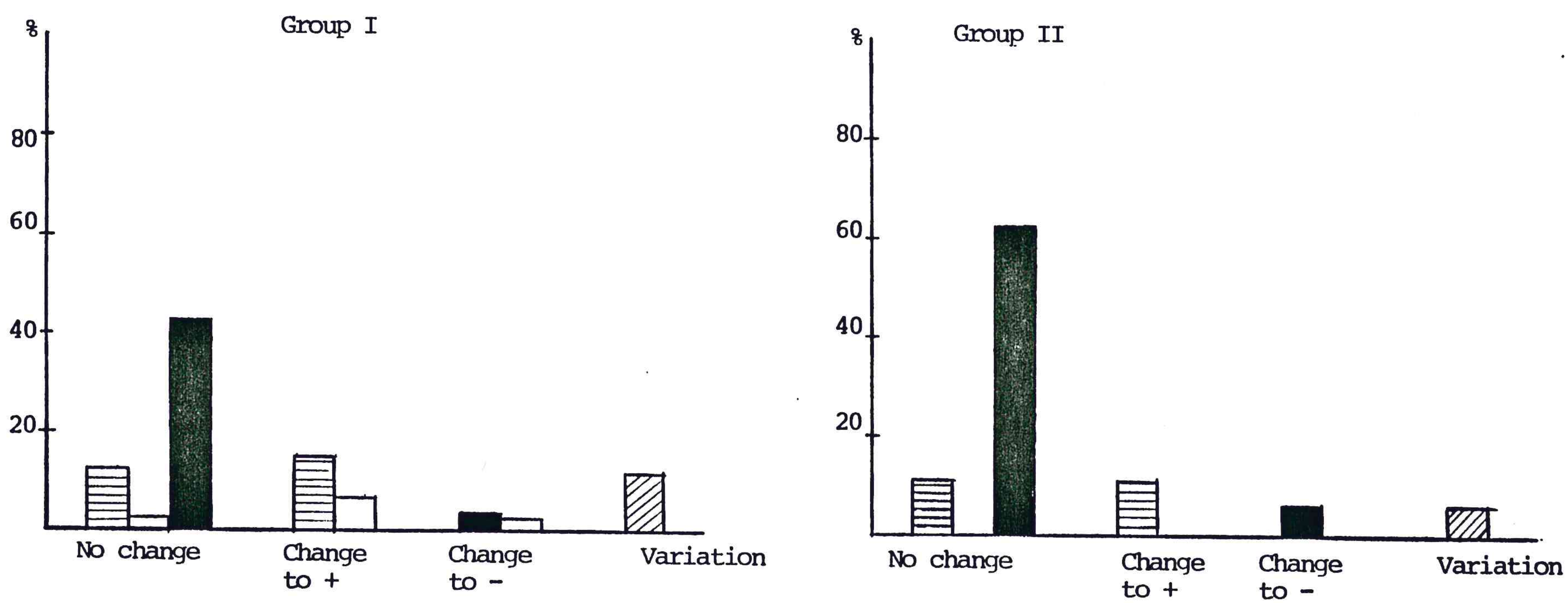


TABLE XXVII

FREQUENCY DISTRIBUTION OF DIRECTIONAL CHANGES FOR:
CURVE OF SPEE

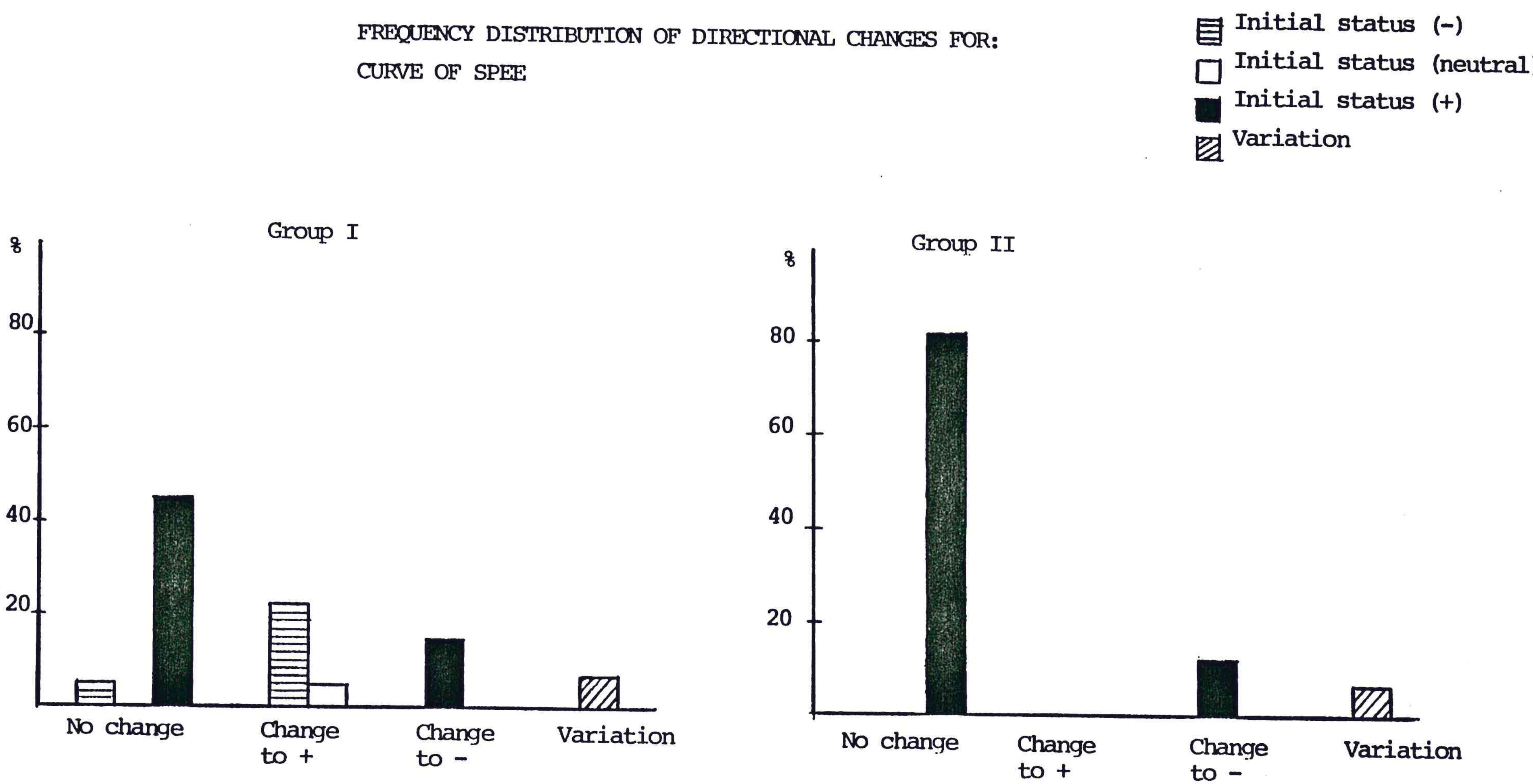


TABLE XXVIII

FREQUENCY DISTRIBUTION OF DIRECTIONAL CHANGES FOR:
PALATAL PLANE ALIGNMENT

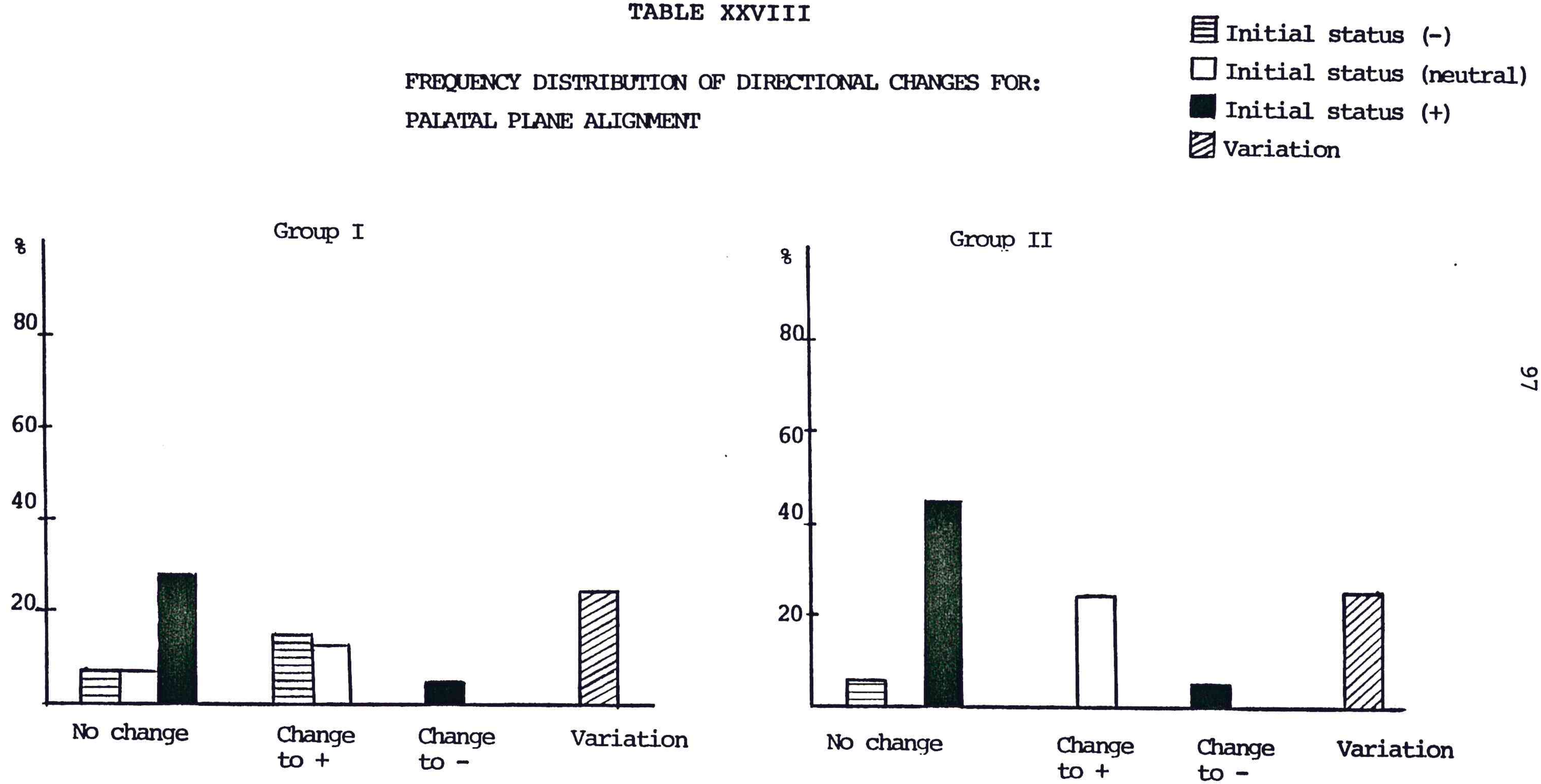


TABLE XXIX

FREQUENCY DISTRIBUTION OF DIRECTIONAL CHANGES FOR:
INFERIOR MAXILLARY PLANE

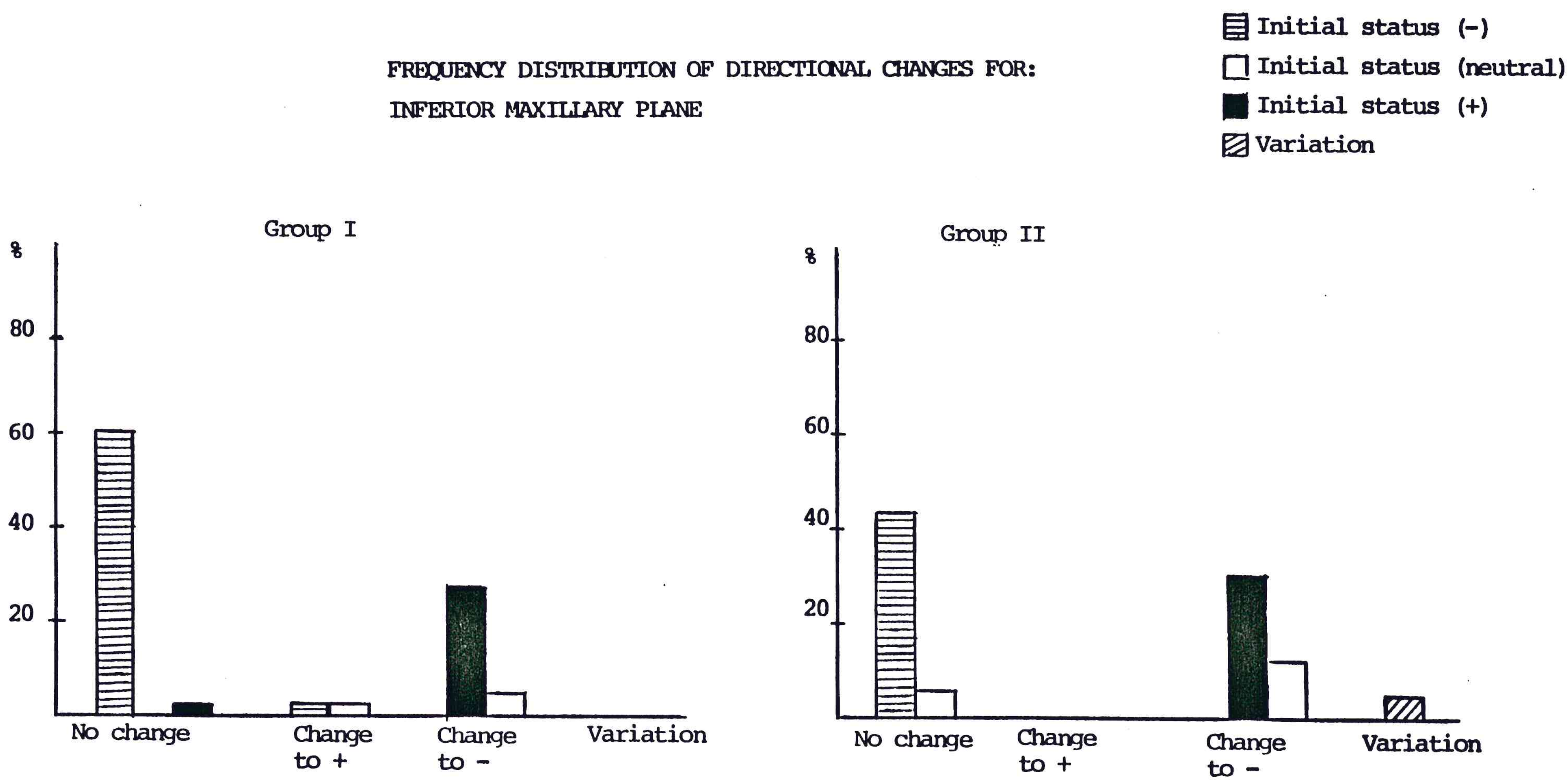


TABLE XXX

FREQUENCY DISTRIBUTION OF DIRECTIONAL CHANGES FOR:
MAXILLARY NERVE/PALATAL PLANE ALIGNMENT

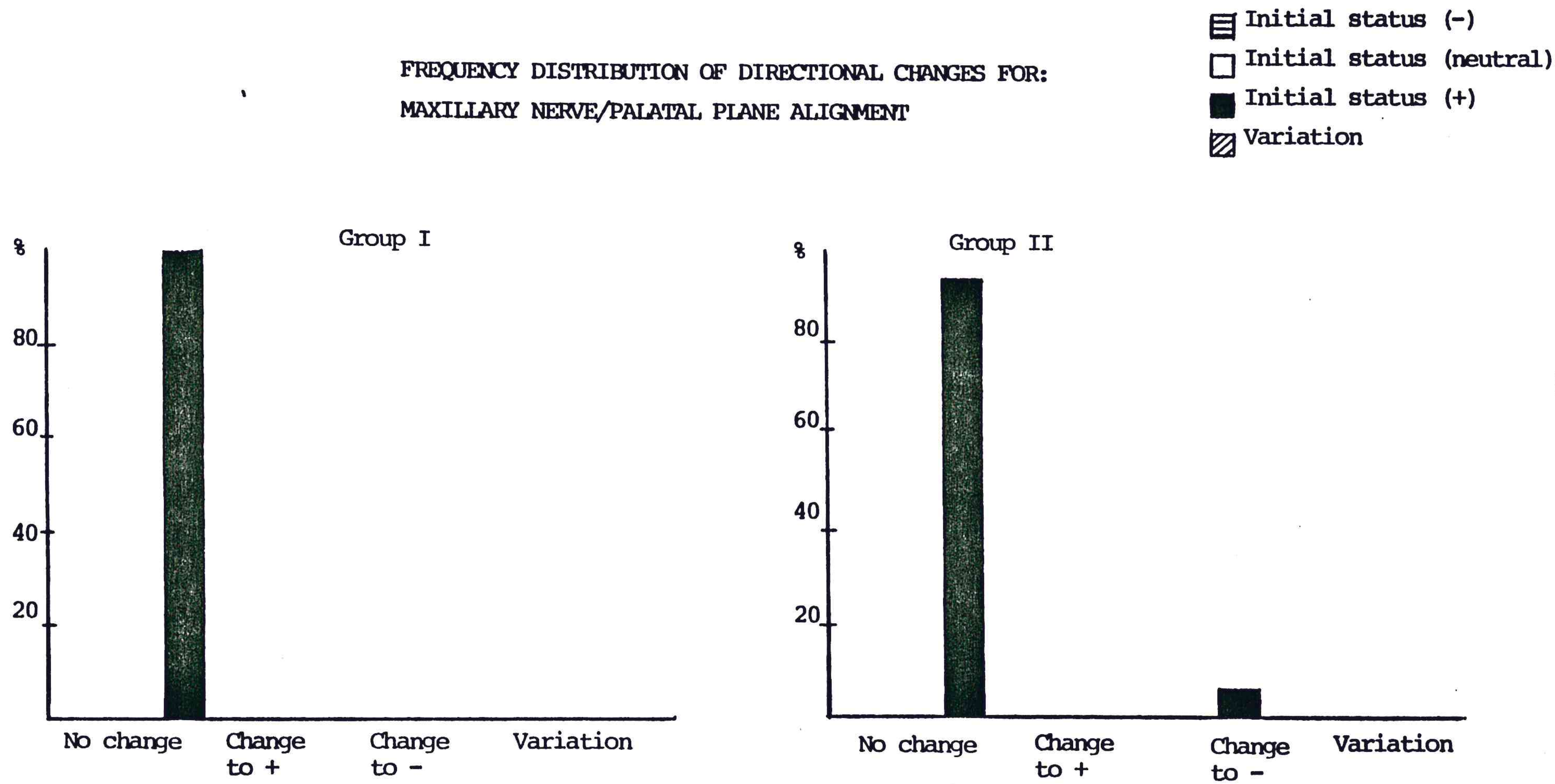
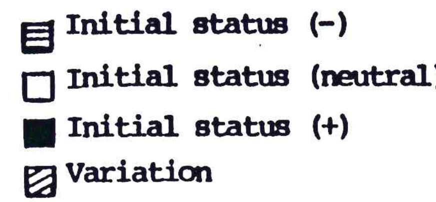
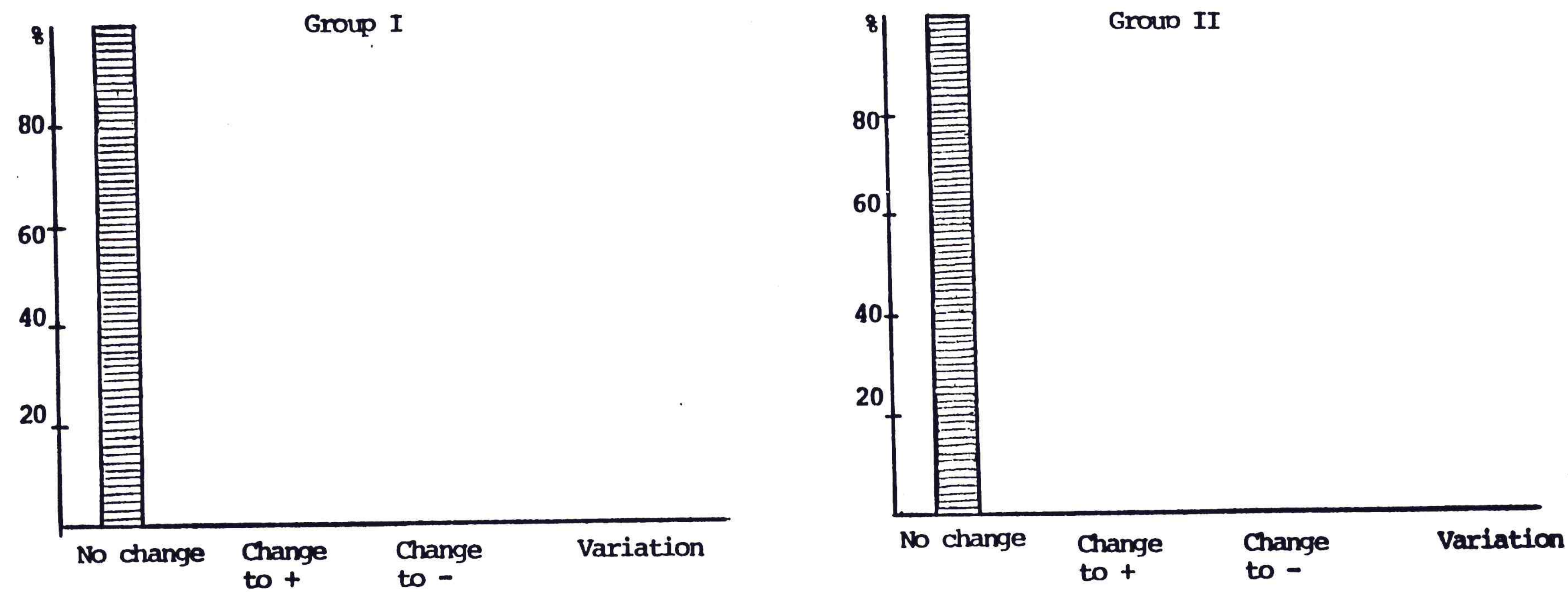


TABLE XXXI

FREQUENCY DISTRIBUTION OF DIRECTIONAL CHANGES FOR:
VERTICAL ANTERIOR MAXILLARY PLANE





DISCUSSION

The present investigation is concerned with an analysis of the changes in facial growth, anatomical interactions and trends developed in the pattern of the individual.

Growth is a process that involves more than just an overall enlargement of cranial facial bones. It also consists of differential rates of growth and direction of individual components.

The counterpart analysis was used to assess some of the multiple, regional anatomical features that contribute to that process from childhood to late adulthood.

The anatomical features identified in Group I explain the high incidence of Class II skeletal and occlusal type of malocclusion observed in Caucasions.

These characteristics include a forward alignment of middle cranial fossa, a backward alignment of the mandibular ramus, a vertically long midface, and a narrow width of ramus relative to the horizontal dimension of the middle cranial fossa.

In a similar manner, Group II presents a similar configuration except by the alignment of middle cranial fossa that is rotated backwards.

In addition, most of the anatomical features leading to the development of Class II features tended to be more pronounced and exacerbated with growth.

Evaluating the horizontal skeletal dimension of Group I revealed a predominance of long mandibular corpus at B point. The continuous dimensional changes observed in this area demonstrated that this characteristic was enhanced with growth.

Similarly, Group II presented the same anatomic configuration of a long mandibular corpus which, similar to the first group, counteracted some of the maxillary protrusion tendencies characteristic of this group. However, little or no dimensional increase occurred at this area.

When middle cranial fossa and ramus alignment were evaluated for their contribution to the mandibular position, it was observed that mandibular B point tended to be more protrusive in Group I and retrusive in Group II.

In Group II this effect may be attributed to a greater extent of backward rotation of mandibular ramus and subsequent development of mandibular retrognathism.

A compensatory growth in the horizontal dimension of the ramus relative to middle cranial fossa alignment would help to reduce the extent of mandibular retrusion. However, the narrow width of the ramus, also observed in Group I, was maintained or even decreased with growth.

In Group I, the long mandibular corpus counteracted the maxillary protrusion tendencies resulting from the forward alignment of MCF.

Part of the remodelling process operating in the mandibular ramus involves resorption on the anterior border and deposition on the posterior border. The result of this process is a relocation of the ramus in a posterior direction which causes an increase in length of the mandibular corpus (Enlow, 1975). It is possible that this process is maintained throughout life, because a high percentage of Group I individuals demonstrated a continuous increase in the horizontal dimension of the mandibular corpus. Also, an increase of the forward movement of MCF was found in some individuals of Group I showing an increase of the horizontal expression relative to its counterpart, the mandibular ramus.

Both groups of individuals demonstrated an increase of the mandibular dental arch at B point. Moreover, the dimension of the dentoalveolar base measured at IPr revealed a short mandibular arch length compared to the maxillary arch.

In Group II growth increments sustained this characteristic with no change.

Conversely, it was observed that maxillary skeletal arch at SPr was increasing at a greater extent than its counterpart, the mandibular arch measured at IPr. Consequently, the maxillary protrusion tendencies observed would contribute to an increase in the overjet.

The nature of the MCF alignment and its effect upon the nasomaxillary complex and mandibular was opposite in both groups.

In Group I the forward rotation of middle cranial fossa tended to place the maxilla in a more protrusive position. In Group II, contrary to what would be expected, a backward-inclined middle cranial fossa and consequent mandibular protrusive effect was found.

The extent of rotation demonstrated by the follow-up examinations showed a continuous increase of the former upward rotation. The progressive alterations observed may be subtle, and not sufficient to compensate for the maxillary protrusion tendency demonstrated in this group. However, those changes do reveal that there are no such "stable" areas and point out the continuity of the growth process.

The alterations observed in the MCF might be regarded also as an adaptation in reaction to the functional components operating in the area.

One particular feature shared by both groups at the initial age was the backward rotation of mandibular ramus. This anatomical feature served to increase the vertical expression of the nasomaxillary complex.

In group II, this fact, added to the upward rotation of MCF had a synergic effect, that is, it was cumulative in nature and therefore disadvantageous for the Class II developing individuals.

In Group I, the posterior maxillary dimension underwent a very significant alteration. The relative vertical length of the nasomaxillary complex progressively decreased in dimension from the first to the last age group studied. This finding was directly associated with the forward rotation of the mandibular ramus. In Group II, facial height increased significantly and it was associated with the intrinsic morphology of the developing face rather than a characteristic of aging. In addition, the severe backward ramus rotation leads to a possible tendency toward an anterior open bite.

A number of investigations have recognized the continuous increase of the vertical dimensions of the face (Baer, 1956; Israel, 1973).

Some of them have demonstrated the constancy of vertical facial proportions during growth.

Brodie (1940) stated that the upper facial height constitutes 43% of the total face height, and the proportion is maintained in different stages of life.

Likewise, Nasjleti and Kowalski (1975) support the contention that the upper face height - total face height ratio - remains relatively constant throughout adulthood. Forsberg (1979), in his study of young adults, found a significant increase in facial height. The only changes observed were related to the lower face and they were attributed to a change in mandibular position.

Another important consideration correlated with the nasomaxillary complex is a significant counterclockwise rotation of the inferior maxillary plane observed in both groups. This rotational characteristic tended to increase the initial maxillary protrusion tendencies. Besides, it would contribute to a posterior rotation of the mandibular ramus and subsequent development of a hyperdivergent pattern. Therefore, such a pattern is not produced in Group I.

A significant forward rotation of the ramus expressed a compensatory feature to the retrognathic tendencies and the long facial height of Group I individuals.

The counterclockwise rotation of the inferior maxillary plane without a posterior rotation of the ramus demonstrates that little dentoalveolar development took place in the molar area in the Class I group.

Conversely, the fact that the mandibular ramus did not rotate anteriorly in Group II could be attributed in part to an excessive dentoalveolar development in the posterior area, or to insufficient growth of the vertical dimension of the mandibular ramus relative to PM vertical dimension.

In Group II the degree of upward rotation of MCF and inferior maxillary plane greatly increased the extent to which the anterior maxilla must grow inferiorly into full occlusion with the mandible.

The evaluation of the curve of spee confirmed the severity of the underlying skeletal imbalance. Enlow (1975) describes the development of the curve of spee as a compensatory mechanism to the vertical disproportions.

This long alveolar region present in Group II is caused by the anterosuperior drift of the mandibular incisors toward the occlusion. The extent of dental compensation observed might have helped to decrease the overjet. Both groups displayed the same clockwise rotation of the palatal plane. Consequently, point A was being dislocated downwards. Another significant finding was related to the gonial angle.

A number of investigations on the gonial angle have demonstrated a great variability of results (Israel, 1973; Fish, 1979).

The change observed in both groups revealed that this angle was becoming more acute with time. The cause of such changes are attributed to the upward rotation of the mandibular corpus observed, and may have several different implications in facial development. In both groups it provides an indication of the severe rotational alterations in the maxilla.

According to the developmental pattern of the nasomaxillary complex previously described for Group I, the alterations in both ramus and corpus position contributed to decrease the anterior lower facial height. This fact, in conjunction with the clockwise rotation of the palate, may contribute to deepen the bite.

As well, secondary crowding of the anterior dentition, a common occurrence during aging, might be partially explained as an adjustment of the lower incisors to accommodate to this new mandibular position observed in Group I.

As a consequence of the downward movement of the palatal plane observed in both groups, it is possible that the upper incisors had to be dislocated further forward in the apical base. This fact explains the increase in alveolar protrusion observed, especially in Group II.

Many long-term investigations have recognized the alterations in the dentition as the individual ages. Forsberg (1979) observed that the upper and lower incisors tended to become upright with time. He attributed those changes as an adjustment of the incisors to the backward rotation of the mandible.

In this study the dentoalveolar changes observed in both groups revealed a progressive maxillary protrusion of the alveolar base, while the lower incisors might have been maintained upright without any change.

In essence, a continuous change in the vertical and horizontal relationships of the craniofacial complexes was observed.

A thorough understanding of the morphological characteristics of each component of the craniofacial complex during growth is needed before a proper diagnosis and treatment plan can be undertaken.

SUMMARY AND CONCLUSIONS

The purpose of this investigation is to assess some of the multiple, regional anatomical features of the facial complex and its morphological alterations from early in life until late adulthood.

The counterpart analysis was used for serial headfilm evaluation.

The sample utilized in this study consisted of lateral cephalometric headfilms of 56 individuals from the Bolton-Brush Study Center, housed at Case Western Reserve University.

The individuals were grouped according to Class I and Class II angle classification. In order to follow the morphological alterations brought about by growth, the individuals were studied at different age intervals.

The results of this study led to the following conclusions.

1. Group I and II presented similar tendencies toward a Class II skeletal and occlusal pattern. However, Group I presented a greater amount of compensatory features.

2. Ramus alignment showed a significant counterclockwise rotation in Group I. This fact in conjunction with the forward alignment of the MCF decreased the relative dimension of PM (the posterior maxilla).

3. The backward alignment of MCF was progressive and increased the vertical dimension of PM in Group II.

4. The increase in the horizontal dimension of the mandibular corpus in Group I may demonstrate that the possibility for third molar eruption is greatly enhanced as the individual ages.

5. The severity of the counterclockwise rotation of the IMP observed in both groups were related to different mechanisms. In Group I there was a greater increase of ramus height relative to PM and a greater upward movement of the dentoaveolar region at SPr. In Group II ramus height did not offset the posterior dentoaveolar development and the counterclockwise rotation of IMP.

6. In Group I the palatal plane alignment changed to the opposite direction, that is, clockwise. In Group II this characteristic was already present and it was further increased. These changes may involve a tendency to deepen the bite and also may explain soft tissue alterations observed with age such as the downward movement of the tip of the nose. In this study the changes in the underlying skeletal structure would show an elongation of the upper lip related to the alveolar process.

7. Both groups demonstrated an upward rotation of the mandibular corpus. Consequently any alteration during orthodontic treatment in an opposite direction might be related to an improper use of mechanics rather than growth alone.

8. In Group I the mandibular corpus and ramus demonstrated a counterclockwise rotation. Besides, in both groups it was found that the lower mandibular dental arch was decreased relatively to the maxillary dental arch. The above changes could participate in the development of secondary crowding and bite deepening in later ages.

9. The curve of spee demonstrated a greater increase in Group I and is related to the greatest potential for compensations observed in this group.

10. Statistically, changes in the direction of the ramus alignment and inferior maxillary plane observed in Group I were significant at .05 level.

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