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A MORPHOMETRIC EVALUATION OF CONGENITAL CLEFTS OF THE LIP AND PALATE

by

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

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A MORPHOMETRIC EVALUATION OF CONGENITAL CLEFTS OF THE LIP AND PALATE

Abstract

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The purpose of the present study was to identify and evaluate the morphologic components of the craniofacial complex in the growing individual with congenital cleft lip and/or palate. It was attempted to ascertain if the clefting phenomenon had a consistant effect on the anatomic components of the craniofacial complex. Enlow's counterpart analysis was utilized to identify particular anatomic characteristics in the craniofacial complex.

The study involved 54 individuals with congenital clefts of the lip and palate (bilateral and unilateral) and isolated clefts of the palate (provided from the longitudinal records of the Lancaster Cleft Palate Clinic, Lancaster, PA.). A non-cleft group of fifteen individuals was also examined in the study (provided from the records of the Bolton Study, C.W.R.U., Cleveland, OH). Each individual in this study was examined via lateral cephalometric evaluation at age 3, 6, 9 and 12 years. Similar surgical procedures were carried out for each cleft individual and all primary surgeries were performed by the same surgeon.

The sample of cleft individuals was divided into three groups based on the initial presentation of the individuals at age 3 years. Seven measurements were used to classify the sample. These measurements were: middle cranial fossa (MCF) alignment, ramus (RM) alignment, RM/MCF horizontal skeletal dimension, posterior maxillary (PM) vertical relationship; palatal plane alignment, gonial angle alignment and maxillary nerve alignment.

The classification scheme was such that 43% of the cleft sample (Group I) had a net mandibular retrusive effect based on the seven anatomic characteristics. Thiry-three percent of the sample (Group II) had a net mandibular protrusive effect. Twenty-four percent of the sample (Group III) had a net neutral effect at age 3. The non-cleft group (Group IV) consisted of class I individuals. This was determined by examination of headfilms for an ANB angle less than 4.5° and a Class I molar relationship.

Anatomic counterparts were compared relative to one another serially and among the different groups. The planes and angles used in this analysis are designed to coincide specifically with major fields and sites of growth and remodeling.

The findings lead to the following conclusions:

1. At age 3 years, three distinct groups could be identified in the cleft group. Though two of the groups (Group I & II) presented an aggregate mandibular retrusive profile there were significant differences in the two groups to consider them different. PM vertical relationship, width of the ramus compared to the MCF and palatal plane alignment all served to differentiate between the two groups. Group III at age 3 years presented with a more balanced facial profile.

2. The middle cranial fossa alignment changed considerably in the cleft group. The MCF rotated upward and backward in all three cleft groups. It remained unchanged in the non-cleft group. This resulted in a mandibular protrusive effect in the cleft sample. This was associated with the maxilla being positioned more posteriorly in the craniofacial complex.

3. In all 4 groups the ramus alignment rotated in a downward and backward direction. This rotation counteracted mandibular protrusive effects seen elsewhere in the craniofacial complex.

4. The vertical relationship of the posterior maxillary became progressively "longer" in the cleft group. This resulted in the other regional counterparts assuming a more mandibular retrusive effect. This measurement helped differentiate Group I from Group II at age 3 years. AT age 3 years the PM vertical showed a strong tendency to be "short" in Group II while Group I showed a tendency to be aligned in a mandibular retrusive position.

5. The gonial angle in all of the cleft groups was extremely obtuse at age 3 years. The angle rotated in all 3 groups in a counterclockwise manner thus counteracting mandibular protrusive effects seen in other areas of the face.

6. The "width" of the ramus compared to the horizontal dimension of the MCF is another important characteristic that served to differentiate between the groups at age 3 years. In Group II and III there were strong tendencies for a "wide" ramus while in Group I there was no real trend for either a wide or narrow ramus alignment. By age 12 years though, all three cleft groups tended to have a narrower ramus width relationship then at age 3 years. This served as one of the key adjustment sites in this study.

7. The comparison between the horizontal skeletal dimension of the maxilla and the corpus of the mandible revealed that in all three cleft groups there was a tendency for the mandible to be slightly larger than the maxilla at age 3 years. This imbalance changed slightly so that by age 12 years the mandible was still larger than the maxilla.

8. An examination of the aggregate measurements of the craniofacial complex measured at A point versus B point revealed that in Groups I and II there was a dramatic change from possessing a strong tendency for a mandibular retrusive effect to a slight tendency for a mandibular protrusive effect. Group III remained essentially unchanged in this regard.

9. The present study has shown that the contiguous structures are involved in the clefting process. They serve as an adjustive mechanism to compensate for the disturbances in the normal growth patterns caused by the clefting process.

10. It is possible to classify the cleft population according to anatomic characteristics without regard for cleft type or sex of the individual. There was no correlation between cleft type and sex of the individual and the presentation of specific morphologic characteristics of the sample population.

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DEDICATED

TO

MY PARENTS,

MR. AND MRS. GEORGE A. KRAUSE,

for without their love and support
none of this would have been possible

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INTRODUCTION

Congenital clefts of the lip and palate offer a unique opportunity to examine the interdependency of the various components that make up the craniofacial complex. Investigations into normal growth and development have shown that there is a pattern or balanced relationship between the various entities of this complex. The cleft phenomenon affects this interrelationship. The degree to which it does this, though, has not been completely established at this time.

Published data pertaining to the growth of the individual with clefts of the lip and/or palate point to the fact that the clefting process affects not just the nasomaxillary region but other, contiguous structures in the craniofacial complex. It has been suggested that cleft lip and palate must be considered an anomaly complex or part of a separate cleft syndrome.

Tissue insufficiencies, the displacement of structural members in the craniofacial complex and the inhibitory effect of surgical repair have all been mentioned as causal agents in the resultant growth disturbances seen in the cleft palate individual.

The purpose of the present investigation was to study the craniofacial growth patterns in growing individuals with congenital clefts of the lip and/or palate. The effects of the clefting process on adjacent structures in the craniofacial complex were evaluated to ascertain if the clefting phenomenon has a consistant effect on certain anatomic components in the craniofacial complex. The counterpart analysis was used in this study since it explains how a growth pattern occurs in an individual and accounts for the contributions of the various growth fields throughout the craniofacial complex.

REVIEW OF THE LITERATURE

Between the fifth and twelfth weeks of pregnancy important early developmental events are taking place in the developing face. At the end of the fourth week of embryonic life the embryo possesses no structures that resemble a face or head yet by the end of the twelfth week the face is fully formed and the palate is closed (Watson 1980). During this dramatic period various etiologic factors may interact to alter the normal growth pattern of the individual and contribute to cause a cleft of the lip or palate. The position of the tongue, rate of mesoderm migration, timing of the rotation of the palatal shelves and other structural and functional factors have all been implicated as etiologic entities in the clefting process (Krogman 1979). Genetic reasons have also been implicated as a contributing entity to the process (Fraser 1971). Once this anomaly has occurred the basic pattern of facial growth has to be affected by the defect in a key craniofacial field of growth.

Coccaro and Pruzansky (1965) stated that the "cleft lip and palate must be considered as an anomaly complex involving organs contiguous to the cleft." Others have suggested that the clefting process may be part of a syndrome phenomenon (Berkowitz et al., 1977).

Farkas and Lindsay (1972) identified that there was consistant variations in the facial morphology of the cleft palate population. The deformities they reported involved the ears, nose, orbits, lip and mandible. It was concluded that the cleft defect was not an isolated factor. They reported that the non-cleft side of the face in the unilateral cleft cases was not totally normal and that there was anamolous defects on both sides of the face.

Krogman et al. (1975) in a study of individuals with clefts of the lip, lip and palate, and palate only found significant differences not only in the nasomaxillary complex but also in the cranial base size, configuration and growth direction. They also found differences in other areas of the facial complex. They concluded that palatal clefting had repercussions in adjacent bony structures in both the cranial base and facial areas. In a continuation of this study (Krogman et al., 1982) it was found that the contiguous structures were affected differently with regard to cleft type and or sex of the individual.

The mandible was also found to be affected in the cleft population. Mazahari et al. (1971) found that the length and width of the mandible were significantly different in individuals with cleft palate only (CPO) versus those with cleft lip and/or (CL(P)). Krogman et al. (1982), though, reported that the mandible was smaller than normal and that the mandibular plane was steeper.

The question of how to manage the cleft lip and/or palate individual has spurred searches for better and more reliable habilitative regimens to treat these disadvantaged individuals.

The thrust of much of this research has dealt with attempts to understand the effect surgical procedures have on facial growth patterns.

In a series of studies Graber (1949a, 1949b, 1954) summarized what he felt was the state of cleft palate treatment at that time. In one of the reports (1954) he reported on the results of a study of 175 cleft cases that were either surgically treated or untreated. His description of the typical surgically treated individual found in his sample represented what has come to be recognized as the stereotypical cleft lip/palate face. They showed a severe maxillary hypoplasia. The maxillary heights of these individuals were decreased and the maxilla was retropositioned to the cranial base. The facial profile was grossly concave depicting a severe midfacial deficiency. The most severely affected were those that had undergone palatal closure prior to six months of age. The nonsurgically treated sample, though, showed near normal growth patterns. Graber concluded from this that early surgical treatment was the causative agent of deformities seen in his surgically habilitated group and advised that such surgery be avoided until later in the individual's development. Other authors tended to agree with Graber's findings (Snodgrasse 1954; Krogman 1954, Slaughter & Brodie 1949).

Coccaro and Pruzansky (1965), though, made contradictory observations. Their basic conclusion was that while the cleft palate face in their study differed from the norm, the difference was not so great as to render the individual strikingly different from facial types encountered in the general population. Jolley (1954) had similar findings and concluded, as did Coccaro and Pruzansky, that the surgical techniques in their studies were less traumatic and not as inhibitory to the growth processes of the face.

The recent literature on the effect of surgery on the growth pattern indicates that there is not complete agreement. Mapes _et al_. (1974) found that the growth rate of the maxillae in the cleft group lagged temporarily following surgery but then accelerated beyond the normal rate to a point where normal arch length was obtained. Wada and Miyazaki (1975) reported less temporary changes as a result of surgery. At four years of age their group was still significantly smaller than the control group.

Bishara _et al_. (1976) in a study of unoperated adults found no significant differences in maxillary and cranial base parameters between the cleft and normal groups. Crabb and Foster (1977) believed that the differences associated with surgical repair of cleft lip and palate may be present even in the absence of repair. Their data revealed localized defects that could not be associated with surgical procedures.

Subtelney and Nieto (1978), in a study of cleft individuals that had undergone pharyngeal flap procedures, found that the pattern of facial growth had changed. Compared to a non-flapped group the flapped group's growth pattern changed so as that growth proceeded in a more vertical direction than the non-flapped group. Dahl (1979), in a longitudinal study of transverse maxillary growth in individuals with combined clefts of the lip and palate. found that surgical closure of the palate resulted in decreased transverse maxillary growth. He concluded that the production of a bony ankylosis or scar tissue acting as a fibrous ankylosis could serve to inhibit maxillary growth. He advised caution, discretion and thorough treatment planning prior to early surgical repair of the palate.

The various components of the facial complex are interrelated and can be thought to be concomitantly involved in the changes ones sees with growth and development (Enlow 1982). It is advantageous, though, to examine several of the key areas independently so as to gain an understanding of the effect clefting plays on the facial complex. The nasomaxillary complex is the site of the clefting process. Researchers have attempted to study the effect clefting has on the form, relative position, size and growth direction of the maxilla in normal and cleft individuals. Most of the classification schemes for cleft lip and/or palate have dealt exclusively with methods to describe the type and extensiveness of the cleft as it effects the nasomaxillary complex (Berlin, 1971, Kernahan and Stark, 1958).

Dahl (1970) in a study of adult Danish males found that in individuals with isolated clefts of the secondary palate (CPO) the the maxilla was retrognathic with signs of an altered maxillary position in relation to the cranial base, there being a greater backward inclination and a tendency to retrusion of the maxilla.

Also, he found that in subjects with combined lip and palate (CL(P)) the maxilla was retruded and backwardly rotated. The maxillary retrognathism was accentuated by dento-alveolar changes in the CL(P) group. Aduss (1971), though, in a study of complete unilateral clefts of the lip and palate found that the position of the maxilla as measured by the angle SNA was within one standard deviation of that of a noncleft group.

Osborne (1966) in a study of 25 adolescent cleft lip and palate subjects examined the growth directions of the maxilla. Using angular and linear cephalometric measurements Osborne concluded that the maxilla became less prominent with age. This was the result of profound mandibular growth with little effective forward movement of the maxilla.

Nakamura _et al_. (1972) compared a group of 95 children that were classified according to the extent of their cleft deformity with a noncleft group. They found that children with clefts of the lip showed significantly greater bizygomatico-maxillary suture width.

Krogman _et al_. (1975) longitudinally examined the craniofacial growth pattern of children from birth to six years. In their report they examined the size and position of the maxilla in 101 cleft lip and or palate subjects. The maxilla in the CL(P) group grew more than in the CPO group. The authors associated this with a possible anterior displacement of the premaxilla. The maxilla was slightly shorter in their CPO group versus their CL(P). They also found that the maxilla was more forwardly placed in CL(P) than CPO. In a continuation of this study using a slightly different sample from the same longitudinal pool Krogman et al. (1982) examined the craniofacial growth characteristics in different cleft types from birth to ten years of age. They reported that the midfacial depth was different for each cleft type. Jain and Krogman (1983), using another subset of the general longitudinal pool, reported that the severity of clefting was related to the midfacial depth. The more severe the deformity the more the maxilla was affected.

Bishara et al. (1976) in a study of unoperated clefts of the lip and or palate found distinct differences in the dentoalveolar and skeletal relationships between cleft groups and a carefully matched control group. They also reported significant differences between the cleft groups; unilateral cleft lip and palate versus unilateral clefts of the alveolus. They reported that the alveolar process in the cleft area was rolled superiorly, was not fully in occlusion and the teeth adjacent to the cleft side were tipped toward the cleft alveolus. They also reported a medial collapse of the cleft segments. Ortiz-Monasterio et al. (1959) cephalometrically examined adult patients with unoperated complete unilateral and bilateral clefts. They concluded that normal or greater than normal forward maxillary growth was possible in the cleft group. They attributed this to the unrepaired lip not having a restraining effect.

In a cephalometric evaluation of the facial growth of twelve operated and eight unoperated individuals with clefts of the palate, Bishara (1973) reported that the maxilla and mandible were both positioned more posteriorly in the cleft groups. The two arches, though, were in an acceptable relationship to one another. The maxillary depth was also smaller in the cleft groups that he reported on. Bishara did not find any significant difference between the two cleft groups. He summarized that there was a tendency for the two arches to be in a more posterior position relative to the cranial base in both operated and non-operated cleft palate groups.

In two subsequent studies on unilateral cleft lip and palate Bishara (1979a, 1979b) reached similar conclusions. The longitudinal sample in this report spanned the ages five to ten years inclusive. The most significant differences in measured parameters were observed in the older age range between seven to ten years. In contrast, a study of adult males with complete UCLP, BLCP, and CPO, Smahel (1984a, 1984b) reported that there was a shortening of the maxillary depth and no reduction of vertical maxillary growth. There was also no posterior displacement of the maxillary complex.

Johnson (1980) in a study of unilateral and bilateral clefts reported that he found a definite decrease in the overall midfacial growth of the face in both horizontal and vertical directions. Concomitant with these findings he reported changes in the lower facial area. These he interpreted as being adjustments or compensations for the lack of midfacial development.

Shibaski and Ross (1967) found that in their study of CPO the mandible was essentially of normal length yet the chin was retrognathic. They reasoned that this was the result of a mandibular rotation and subsequent remodeling of the gonial area in response to altered muscle position. They reported an increased gonial angle and mandibular inclination.

Dahl (1970) reported that in CPO the mandible was changed in shape and in a different position than the control. He found the gonial angle larger and the mandibular base angle smaller. He also found that the mandible was retrognathically positioned. He believed that this was due to a high position of the condyles and a marked backward inclination of the ramus to the cranial base. In CLP he found an increased posterior mandibular width as well as the characteristics mentioned for cleft palate only.

Nakamura et al. (1972) reported that children with clefts of the palate showed significantly shorter mandibles than normal children and that children with clefts of the lip and palate possessed mandibles that were smaller than noncleft children. Fish (1973) indicated no significant differences, though, in any of the mandibular arch dimensions studied in normal of cleft palate individuals from birth to three years.

Hayashi et al. (1976) found in their study of Japanese children who possessed clefts of the palate that the mandibular rami were shorter, the gonial angle more obtuse and the chin to be positioned retrognathically. Vora and Joshi (1977) in a study of surgically repaired Indian children reported that there was poor vertical growth of the ramus. They also reported a high gonial angle, a tendency toward a retrognathic chin position and a retroinclination of the mandibular incisors.

Nakamura et al. (1972) found that the facial growth rates appeared to be the same in children with cleft deformities as in normal children. Krogman et al. (1975) found that individuals with cleft palate exhibited increased upper and lower facial heights while Hayashi (1976) found that the upper facial height was reduced while lower facial height was increased. Horwitz et al. (1976) in a study of 39 children with repaired cleft lip and palate used factor analysis and concluded that both upper and lower facial height was affected in cleft lip and palate: the upper anterior facial height is reduced while lower anterior facial height is increased. The authors found that the posterior facial height was affected in the same manner. Vora and Joshi (1977) reported that the upper anterior facial height in their sample was unaltered, while the lower anterior facial height was shown to be increased.

The cranial base is the structure upon which the entire facial complex is constructed. The configuration of the cranial base can affect the relationship and balance of the contiguous facial components. The literature thus far has not demonstrated a consensus of opinion on the configuration of the cranial base in cleft lip and palate.

Dahl (1970) reported that in CLP and CPO that the cranial base was shorter and more flattened with the flattening most pronounced in a lateral direction. In cleft lip there was no appreciable difference from the normal except in some measurements that were associated with the posterior cranial fossa. Aduss (1970), though, reported that there was no difference in the cranial base configuration between unilateral cleft lip and palate and the normal, and also no difference between sexes.

Krogman et al. (!975) found that the anterior cranial base length and clival length in children with cleft palate was greater than the noncleft control sample. They reported greater flexure of the sellar angle in the cleft group. Both linear and angular measurements were noted to be more severe in the cleft lip and palate group than in the cleft palate only group. Using superimpositioning they concluded that basion and foramen magnum are major areas of adjustment in the cleft lip and palate and cleft palate only groups.

Maue-Dickson et. al. (1976) in a study of human fetuses with and without clefts reported that the distances between the ptyergoid plates were increased in cleft fetuses versus noncleft. They suggested that cleft palate may be associated with an abnormally wide cranial base. Hayashi et al. (1976) noted that the cranial base angle was more obtuse in cleft individuals than noncleft. Bishara, Olin and Krause (1978) found that the size of the cranial base and the configuration of the various cranial base structures were comparable in cleft and noncleft individuals.

In a study of the growth of the nasopharynx, Coccaro et al. (1967) examined serial cephalograms of cleft lip and palate subjects from birth to seven years of age. The nasopharynx in the cleft group was slightly smaller vertically and horizontally than the normal group. The authors reported that there was a steady increase in the vertical growth of the nasopharynx. By age seven the vertical dimensions were not significantly different from the noncleft group. They also found that during the first year of life there was little increase in the horizontal dimensions. Thereafter they observed an increase in the anteroposterior directions until the age of seven.

Subtelney (1955) using laminographs on children with clefts of the lip and or palate studied the width of the nasopharynx. He reported that the transverse width of the nasopharynx in cleft individuals was significantly larger than in normal children. Subtelney concluded that with a wider nasopharynx, there would also be an increase in the width between the maxillary tuberosities.

Enlow et. al. (1971a) developed a method to analyze lateral head films that is unique to the field of cephalometrics. This analysis serves to identify specific anatomic relationships and structural equilibriums between regional components. Special planes and angles are constructed to correspond to anatomically specific parts and growth fields. These are utilized instead of more conventional cephalometric planes and angles. The analysis explains how a growth pattern has occurred in an individual and accounts for the contribution of the various fields throughout the craniofacial complex. The "Counterpart Analysis" has been used to evaluate many types of facial dysplasias (Goldberg and Enlow 1981, Trouten et al. 1983, Whitney, D. 1983, Pfister 1983). It has also been used to evaluate clefts of the lip and palate (Whitney, E. et al. 1984).

In this study the counterpart analysis was utilized to investigate cleft lip and palate individuals who had undergone orthopedics and early bone grafting. The authors reported that the ramus was vertically shorter and more horizontally narrow than their respective counterparts. This resulted in a posteroinferior rotational alignment of the ramus. The middle cranial fossa in the younger ages was more vertically aligned thereby giving a more mandibular protrusive effect. During development, though, the middle cranial fossa alignment did undergo an anterior rotation such that both cleft and control groups came to have similar middle cranial fossa alignments.

STATEMENT OF THESIS

The purpose of this investigation was to identify and evaluate the morphological components of the craniofacial complex in the growing individual with a congenital cleft of the lip and/or palate or cleft of the palate only. It was attempted to ascertain if the clefting phenomenon has any consistant effect on the anatomic components of the craniofacial complex.

MATERIALS AND METHODS

Sample

Lateral cephalometric radiographs were collected of fifty-four individuals who had clefts of the lip and/or palate. These records were obtained from the longitudinal research series of the H.K. Cooper Clinic (formerly the Lancaster Cleft Palate Clinic) in Lancaster, Pennsylvania. These records were graciously made available by Dr. Sheishi Oka, Executive Director and Dr. R.E. Long, Jr., Director of Research of the H.K. Cooper Clinic.

The surgical histories of the individuals elected for this study are such that the timing and sequencing of the primary surgeries for all the patients in this study are consistant. Cheiloplasties by a triangular flap procedure were performed at two to three months of age or ten pounds body weight. In bilateral cases the lip was closed in either one or two procedures. Palatal repair followed via a vomer flap plus a median palatal suture palatorrhaphy at fourteen months of age, with a range of twelve to sixteen months. All primary procedures were done by the same surgeon. Secondary refinement procedures were performed on an individual basis. These consisted of nose, lip and palatal refinements, or pharyngeal flap procedures. In two incidences premaxillectomies were performed on bilateral cleft lip and palate subjects.

Individuals were selected for this study according to the following criteria:

1. Records were available for each individual at age 3, 6, 9 and 12 years of age.

2. Individuals possessed congenital clefts of the palate only, bilateral clefting of the lip and palate, or unilateral clefting of the lip and palate.

3. Selection was made irregardless of sex, race or other congenital malady.

Lateral cephalometric radiographs of fifteen non-cleft individuals were selected from the longitudinal records of the Bolton Study (CWRU, Cleveland, Ohio). These records were graciously made available by Dr. B.H. Broadbent, Jr., Director of the Bolton-Brush Study.

Individuals were selected according to the following criteria:

1. Records were available for each individual at age 3, 6, 9 and 12 years of age.

2. ANB angle was less than 4.5 degrees

3. Angle Class I molar relationships were observable from a headfilm.

The distribution sample is presented in Table I.

Technical Details

Tracings of each lateral cephalogram were made on 0.003" acetate tracing paper using a Pental (0.5 mm, 2H) lead drawing pencil. Sufficient anatomic landmarks were traced so that the identification of the proper registration points could be made at a later time. Each tracing was done by the same investigator.

The resultant tracings were analyzed using a computerized cephalometric system in place in the Bolton Study and A.R. Jennings Computer Center (CWRU). This system utilized a digitizing pad (summagraphics) and a computer program developed previously (Behrents, 1984) specific for Enlow's Counterpart Analysis.

A total of twenty-seven points were entered in sequence along with a final standardization point (Table II Fig. 1). All radiographs were corrected for magnification. The object to film distance (ml) was utilized for each tracing and a final six percent magnification factor was used for all calculations. Calculations were performed by the computer package and stored in the Computer Center. Entry of all data was performed by the same investigator.

Measurements

Nineteen anatomic variables were evaluated for each tracing. These measurements were developed by Enlow _et al_. (1971a) and are known as the Counterpart Analysis. The results of the part-counterpart comparisons were recorded as a mandibular retrusive (+) effect, a neutral (0) effect, or a mandibular protrusive (-) effect. If the extent of the mandibular retrusive or protrusive effects was 2.5 mm or less in either direction it was given a (+) or (-) value. If the extent of mandibular retrusive or protrusive effect was between 2.5 mm and 5.0 mm in either direction, it was given a (++) or (--) value. If the effect is greater than 5.0 mm, it is given the more extreme (+++) or (---) value.

An explanation of how each measurement was made accompanies the appropriate figures.

The nineteen variables examined were as follows.

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.

Analysis of Data

In an attempt to ascertain the part-counterpart relationship of the sample population the sample was grouped without regard to sex or cleft type. Seven key variables were utilized to formulate a baseline grouping. These seven measurements were MCF/RM alignment, ramus alignment, PM vertical, palatal plane, maxillary nerve alignment and gonial angle alignment. The initial set of radiographs (3 years of age) were grouped according to these measurements. Three groups were obtained: one group consisted of those individuals that had a net mandibular protrusive (-) effect and a third that contained those individuals that presented a neutral (0) net effect. These groups were analyzed for their variability of expression during the growth period studied in this investigation (3 to 12 years). Proportional relationships were developed for the directional changes observed and for the sign changes.

Tracing error was accomplished by retracing fifteen headfilms and comparing them to the initial tracings. A paired t-test was used for this purpose. No significant differences were found.

TABLE I

CLEFT LIP AND/OR PALATE SAMPLE

	MALE	FEMALE	#
ULCP	13	8	21
BLCP	7	3	10
CPO	6	17	23
NONCLEFT	8	7	15
#	34	35	

ULCP = Unilateral Cleft Lip and Palate

BLCP = Bilateral Cleft Lip and Palate

CPO = Cleft Palate Only

TABLE II

POINTS USED FOR DIGITIZING CEPHALOMETRIC TRACINGS

1. Menton (Me)
2. B Point
3. Inferior Prosthion (IPr)
4. The incisal Edge of the mandibular Central Incisor
5. Superior Prosthion (SPr)
6. A Point
7. Anterior Nasal Spine (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 1ST Premolar Occlusal Contact
12. The Cementoenamel Junction of the Last Fully Erupted Maxillary Molar
13. Anterior Ramus (ARa)
14. Gonion (Go)
15. Posterior Ramus (PRa)
16. Articulare (Ar)
17. Occipital Point (O)
18. Posterior Nasal Spine (PNS)
19. The Inferior Most Point of the Pterygomaxillary Fissures
20. Foramen Rotundum in the Pterygomaxillary Fissure
21. Sphenoethmoidal Junction (SE)
22. The Posterior Boundary of This Cribiform Plate

TABLE II (CONT.)

23. Orbitale (Or)
24. The Anterior Boundary of the Cribiform Plate
25. The Most Anterior Point of the Endocranial Surface of the Frontal Bone
26. Sella (S)
27. Nasion (Na)

Registration Point Middle of the Ear Rod

Figure 1. Points used for the digitization of cephalometric tracings.

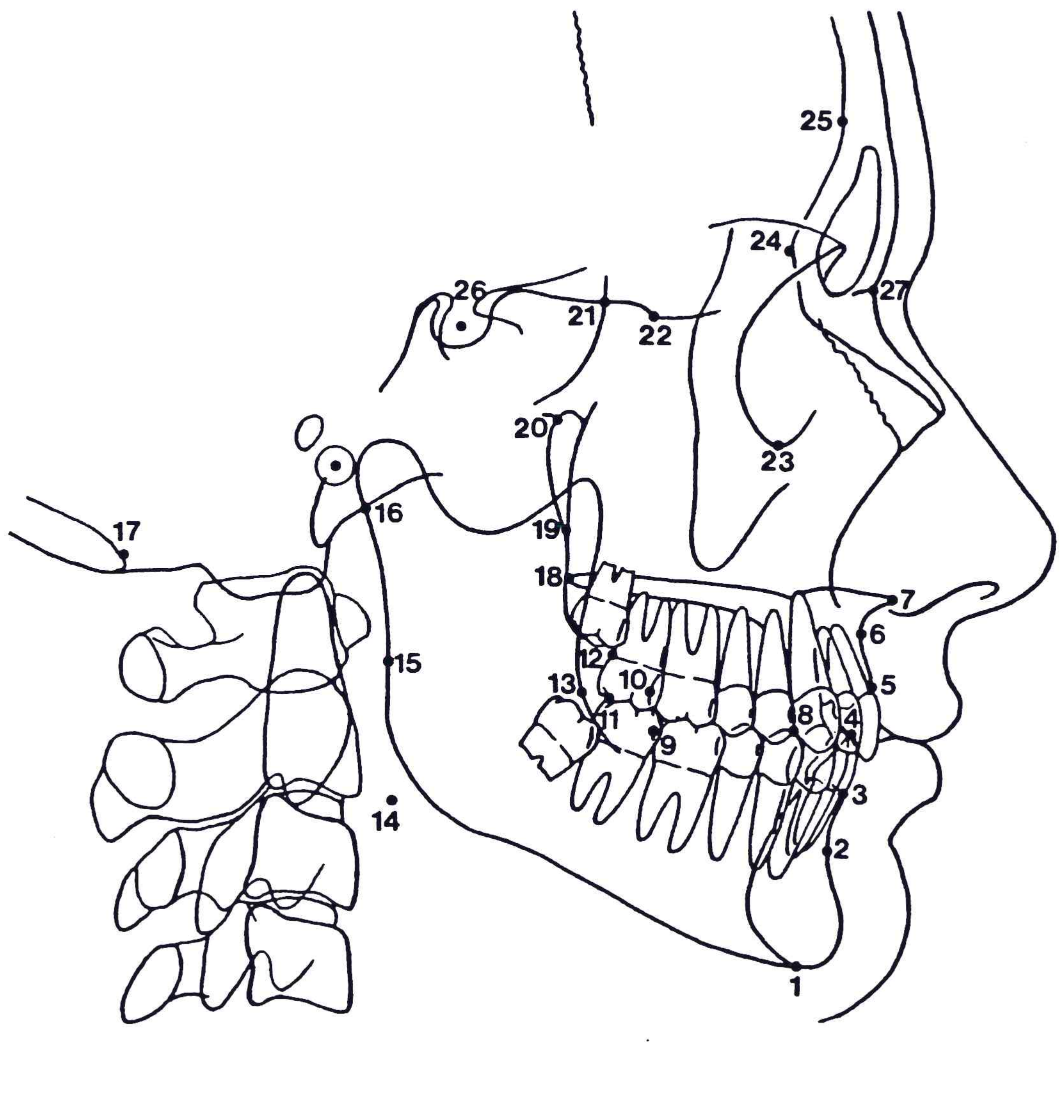
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TABLE III

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 symphysical 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

TABLE III (CONT.)

Points	Definition
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 IV

DEFINITION OF CEPHALOMETRIC PLANES

Line	Description
Ar to Go	A line 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 plant, 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 ptergomaxillary 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.

Figure 2. All the points and planes used in the counterpart analysis are demonstrated in this diagram. The solid line 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).

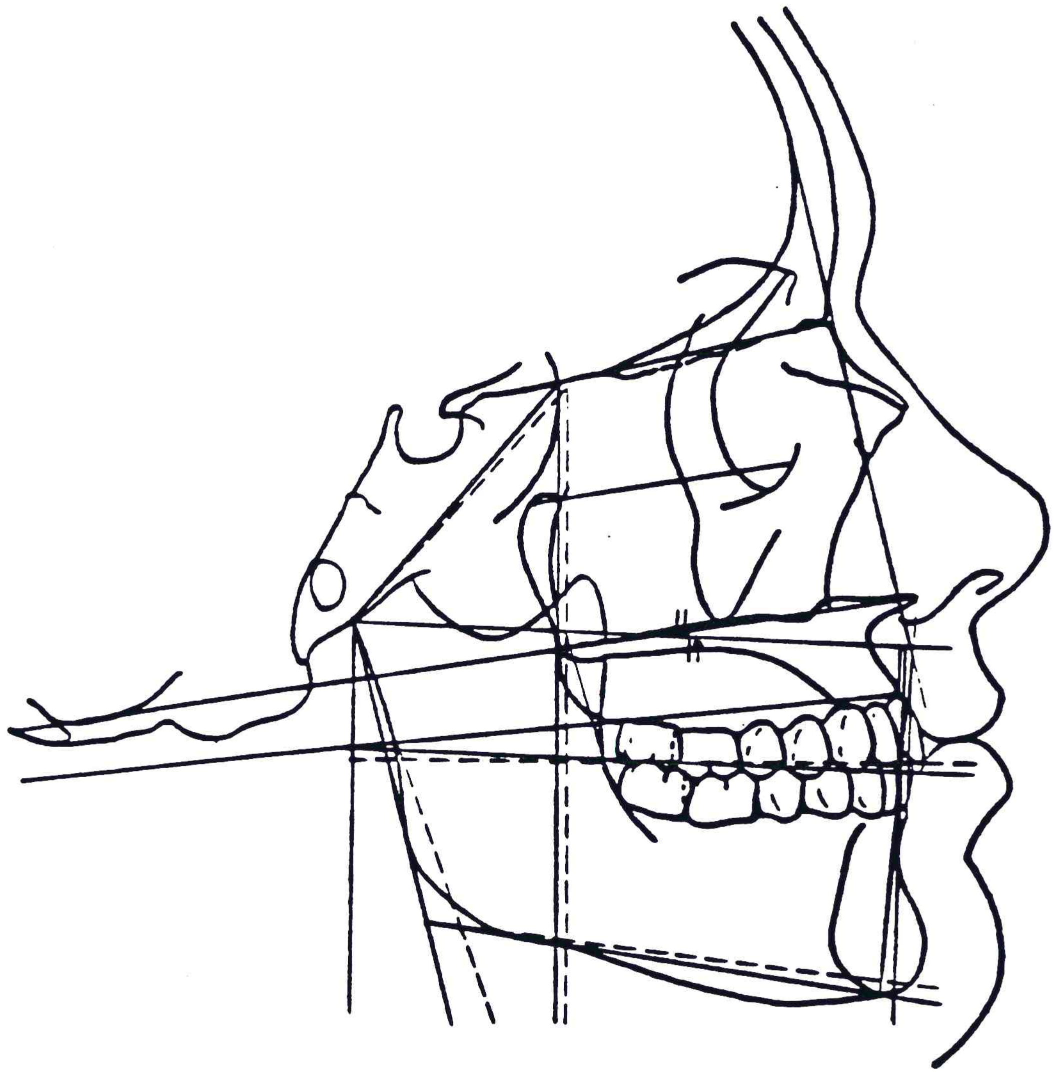


Figure 3. Aggregate cranial floor/maxilla and ramus/corpus horizontal dimensions at A and B points. This diagram demonstrates the comparison of lengths from Ar to A point and Ar to B point. The measurements are made in millimeters along REF. The lines from A point to REF and B point to REF are drawn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

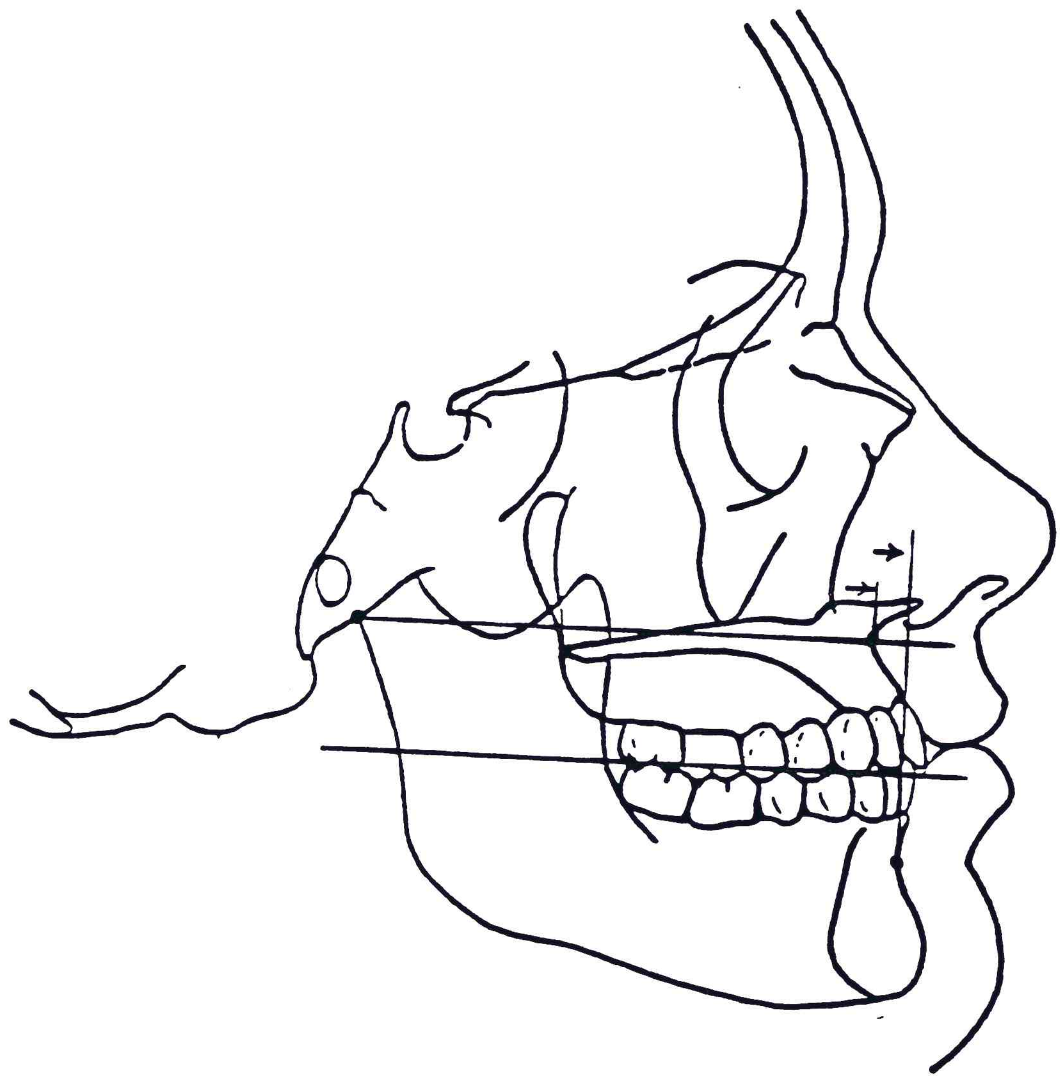


Figure 4. Aggregate cranial floor maxilla and ramus/corpus horizontal dimensions at SPr and IPr. This diagram demonstrates the comparison of lengths from Ar to SPr and Ar to IPr. The measurements are made in millimeters along REF. The lines from SPr to REF and IPr to REF are drawn perpendicular to REF.

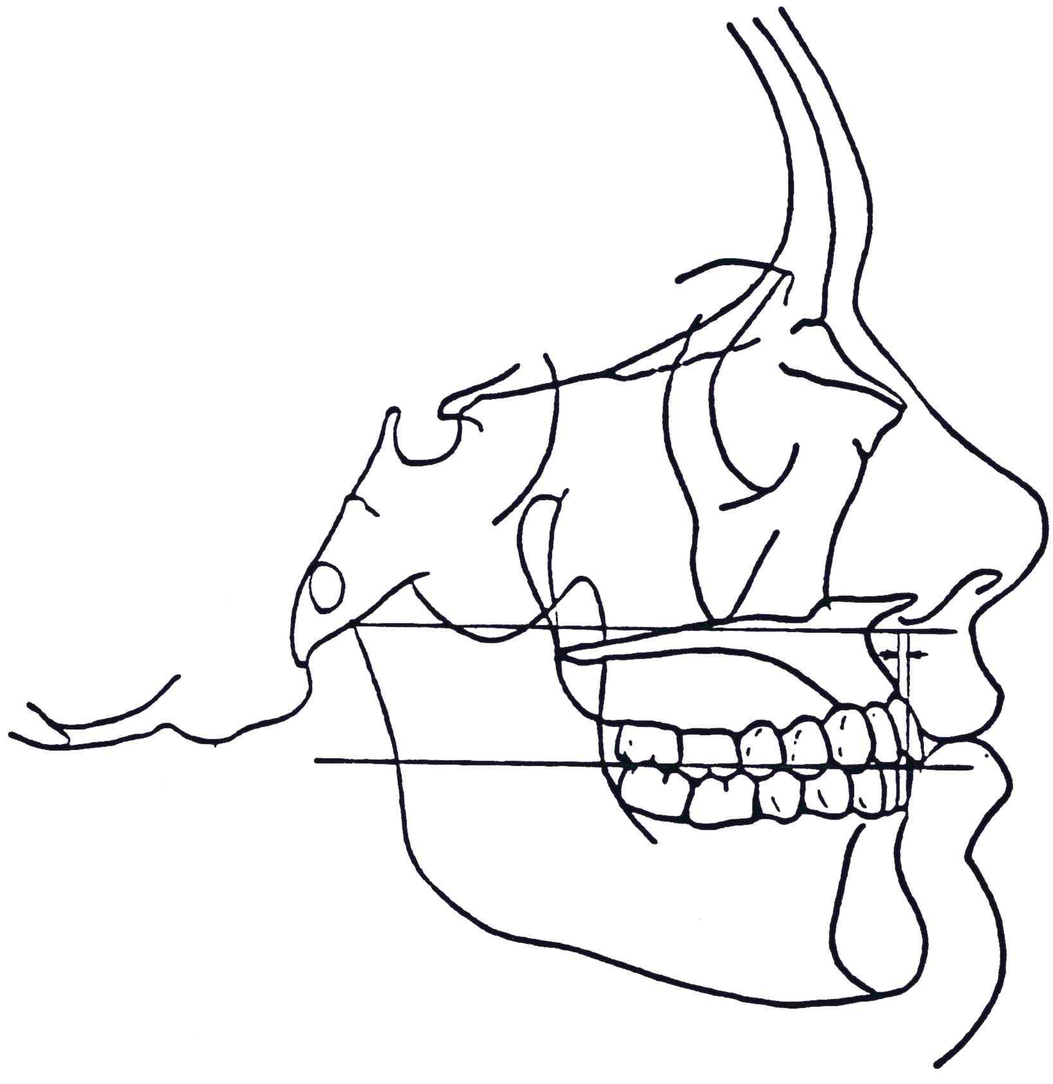


Figure 5. <u>Middle cranial fossa (MCF) and posterior maxillary (PM) relative alignment</u>. This diagram compares the neutral MCF/PM alignment (dashed line), which has an internal angle of 40.3° to the patient's MCF/PM alignment. The neutral MCF/PM alignment is drawn using a preconstructed template 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 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.

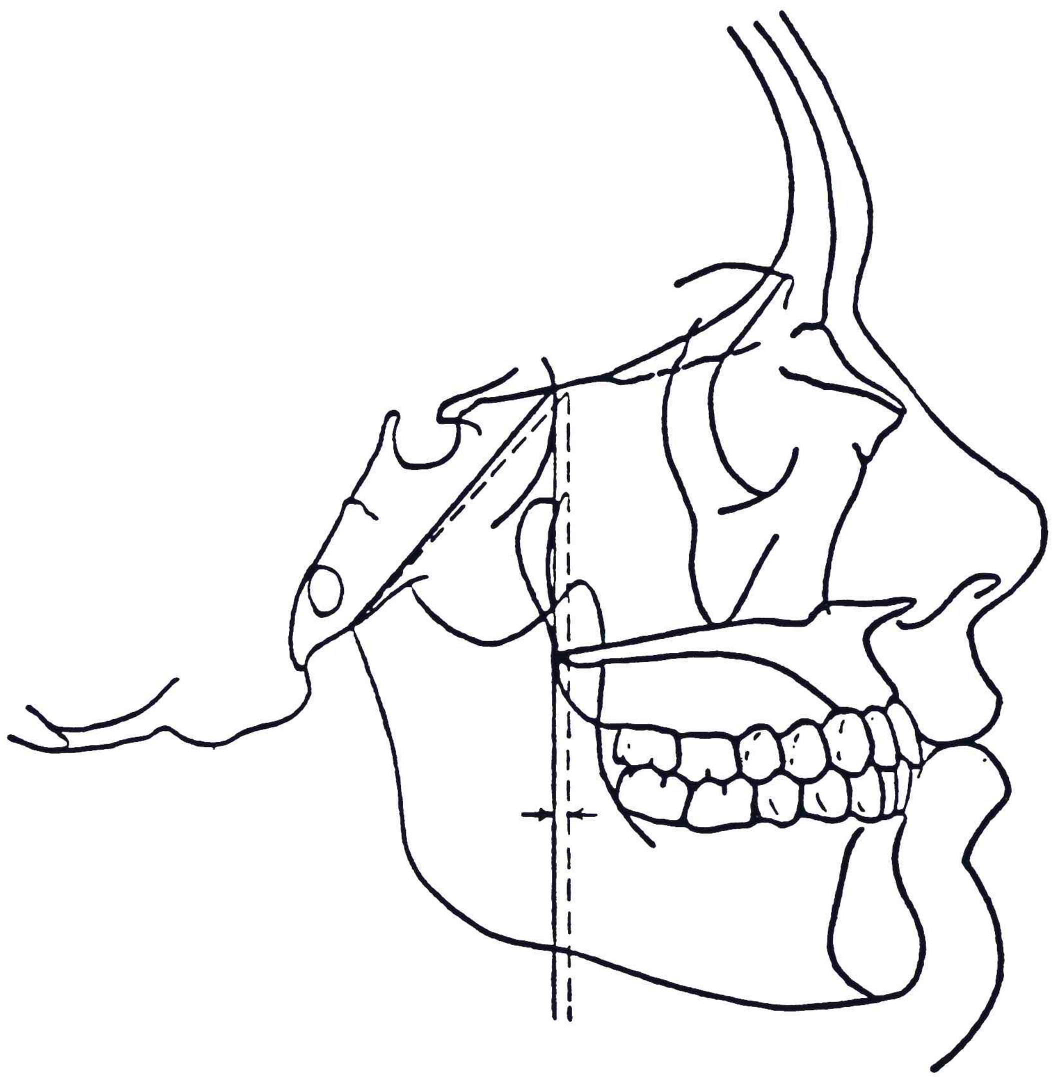


Figure 6. Ramus alignment. This diagram demonstrates the alignment of the subject's ramus plane and its relationship to the neutral ramus plane. A line from Ar to Go represents the individual's ramus plane. The neutral ramus plane is represented by a line from Ar to the midpoint between Ar and the neutral 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.

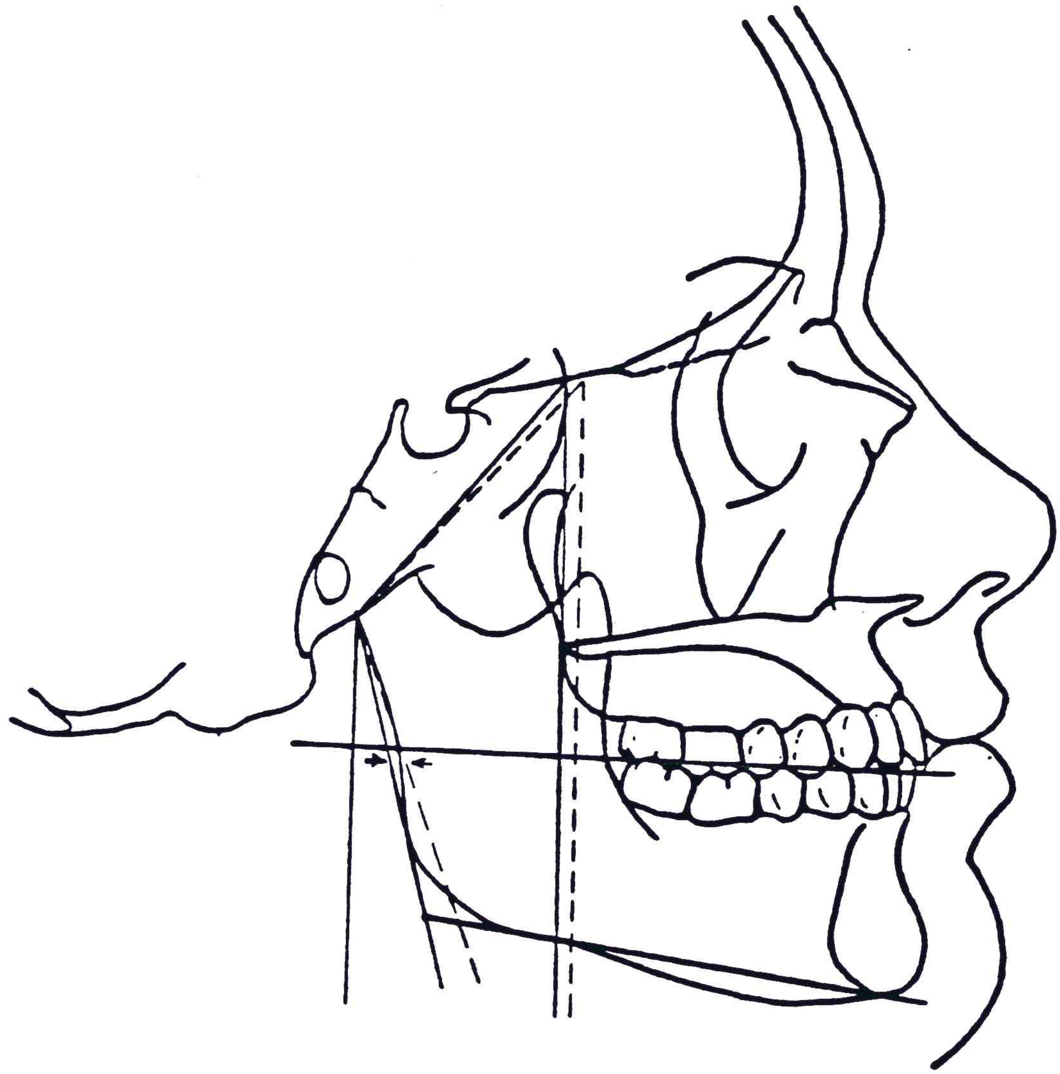


Figure 7. <u>Ramus/MCF horizontal dimensions (skeletal)</u>. This diagram demonstrates the comparison of the horizontal dimensions of the middle cranial fossa (Ar to PM neutral) with the width of the ramus (Ar to ARa), and resultant effect on retrusive/protrusive placement of the maxilla and mandible. 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 and Ar to PM neutral are now measured along REF.

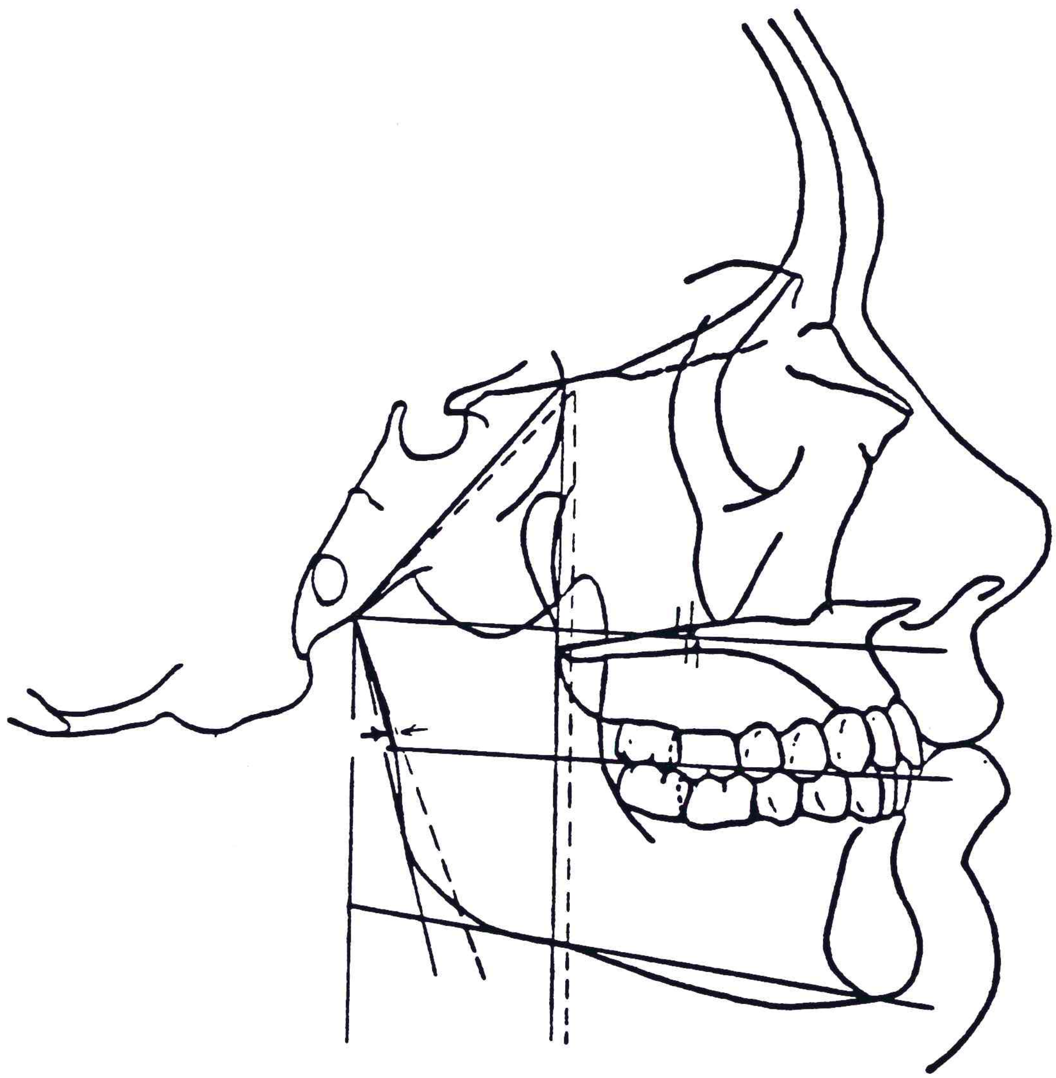


Figure 8. Ramus/MCF horizontal dimension (dental). The neutral positions of the molars are demonstrated with this measurement. The distal surfaces of the maxillary and mandibular first molars are indicated on REF by short vertical lines. The maxillary molar is corrected to its neutral position by adding 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.

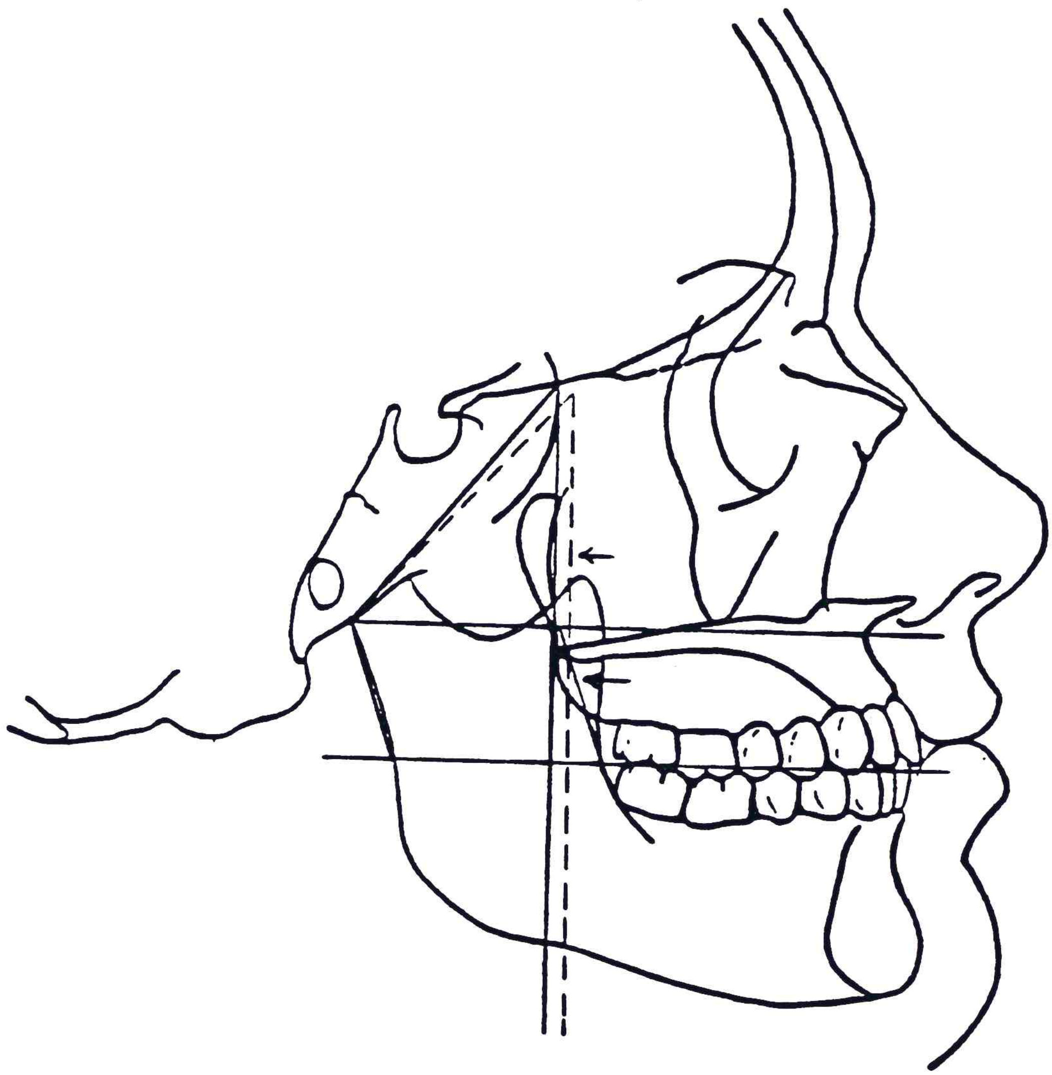


Figure 9. <u>Molar positions (composite)</u>. Short vertical lines along REF indicate the distal surfaces of the maxillary and mandibular first molars. The measurement is made in millimeters along REF from Ar to the short vertical lines.

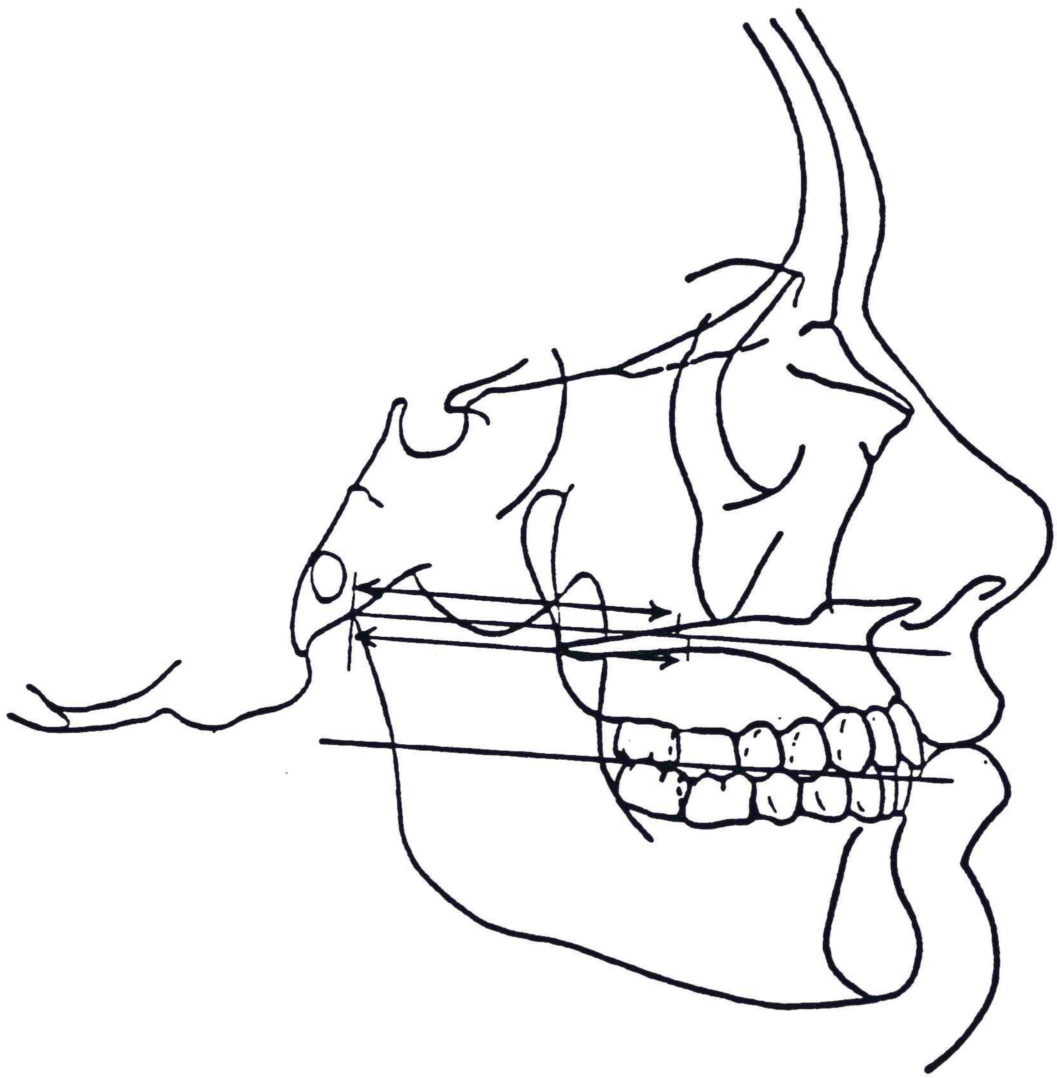


Figure 10. Maxillary/mandibular arches, skeletal dimensions, A point compared with B point. This diagram compares the length of the maxillary skeletal arch with the length of the mandibular skeletal arch. The maxillary skeletal arch is measured in millimeters from PM (solid line) along REF to A point. The mandibular skeletal arch is measured in millimeters from ARa where it intersects REF to B point along REF.

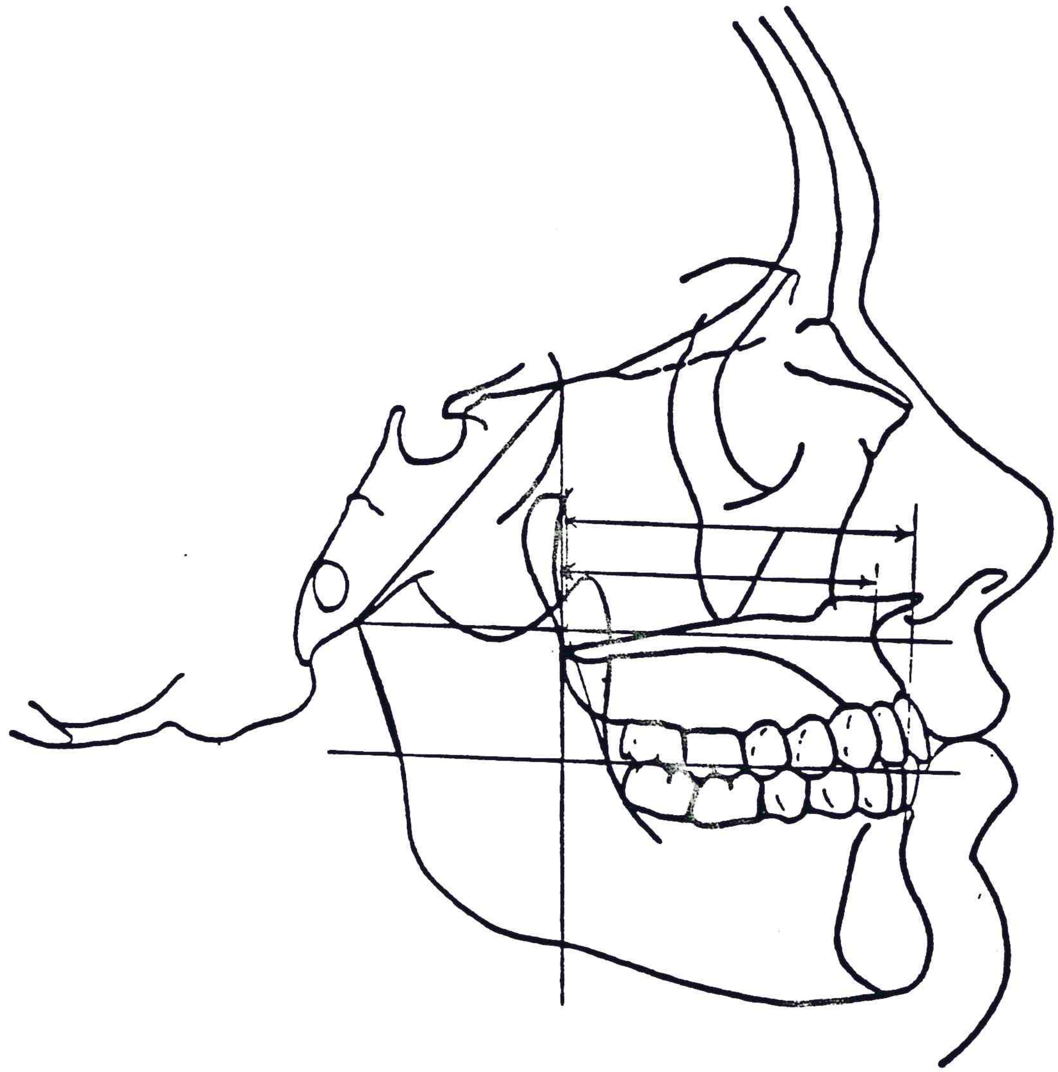


Figure 11. Maxillary/mandibular arches, dental dimensions, A point compared with B point. This is similar to the previous measurement except that the distances are measured to the distal surfaces of the first molars.

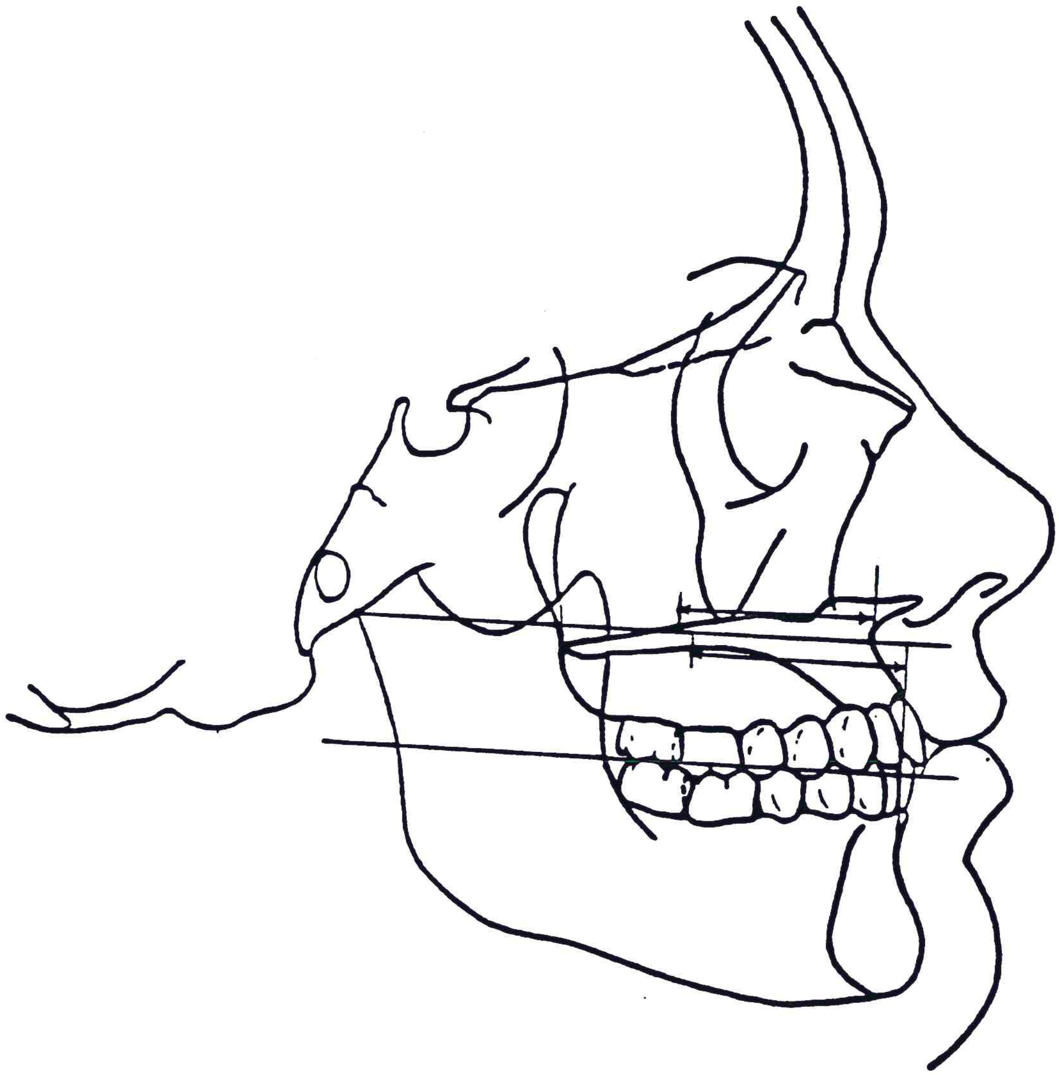


Figure 12. <u>Maxillary/mandibular arches, skeletal dimensions, SPr compared with IPr</u>. This comparison is identical to Figure 10 except that PM is measured to SPr and ARa is measured to IPr.

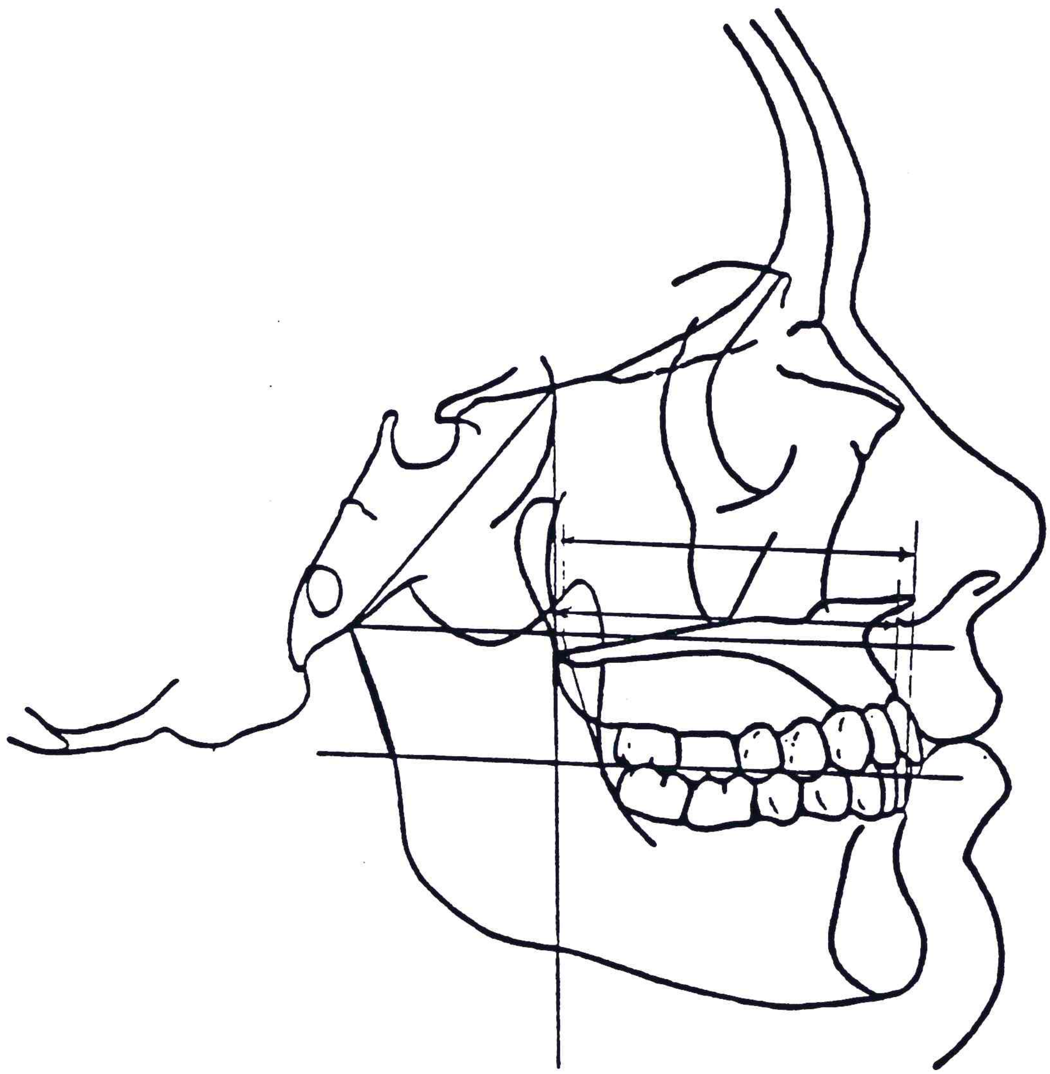


Figure 13. *Maxillary/mandibular arches, dental dimensions, SPr compared with IPr.* This measurement is identical to that in Figure 11 except that the distal of the maxillary first molar is measured to SPr and the distal of the mandibular first molar is measured to IPr.

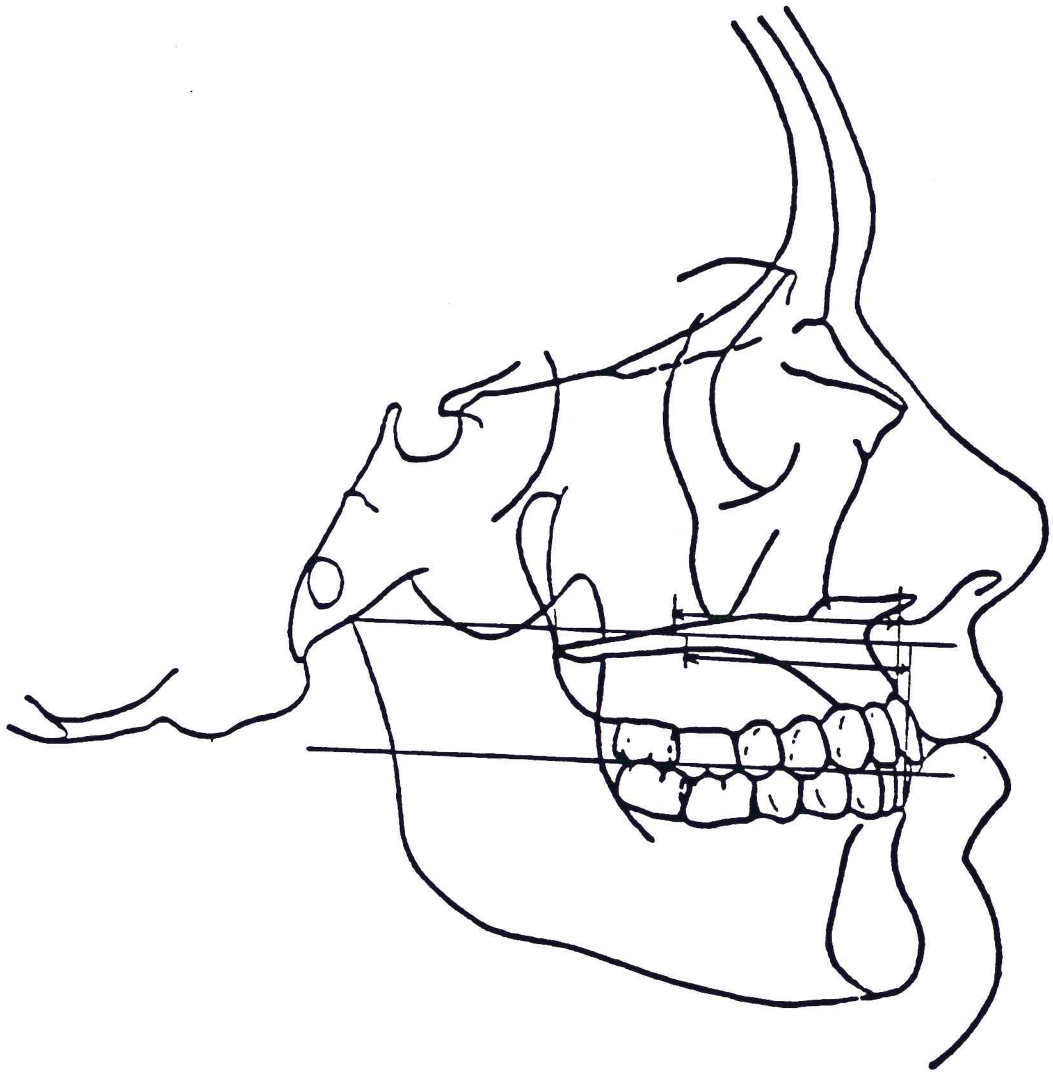


Figure 14. PM as compared with ramus/MCF vertical dimensions. The individual's relative posterior vertical nasomaxillary height is determined by this measurement. When the MCF rotates forward or backward, and the ramus rotates the same amount in the corresponding direction, no vertical disproportion 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 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.)

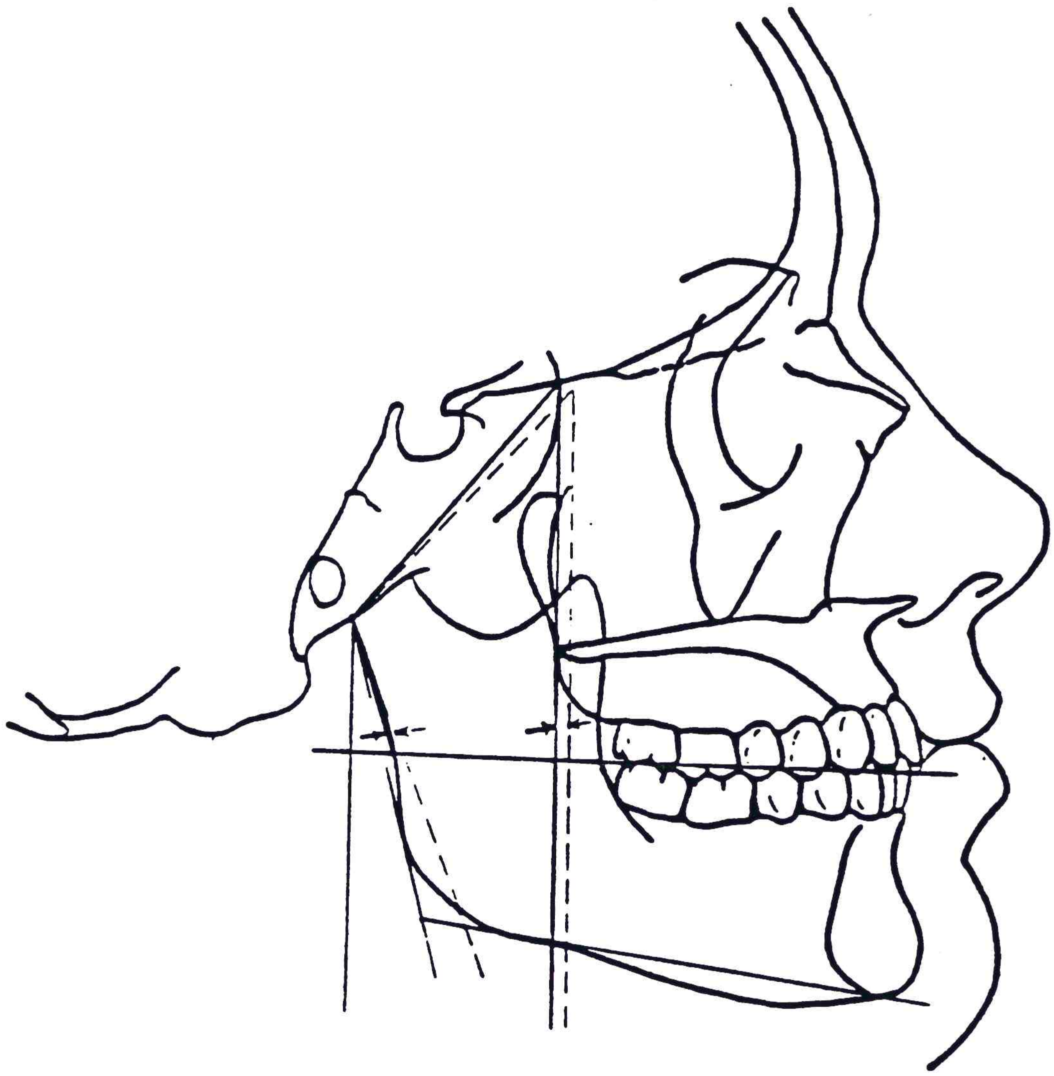


Figure 15. **Corpus-occlusal alignment.** This diagram demonstrates the extent of occlusal rotation as compared to the extent of ramus rotation. NOA acts as a reference line to determine the amount and direction of the occlusal rotation. NRa acts as a reference line to determine the amount of ramus rotation. 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 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.

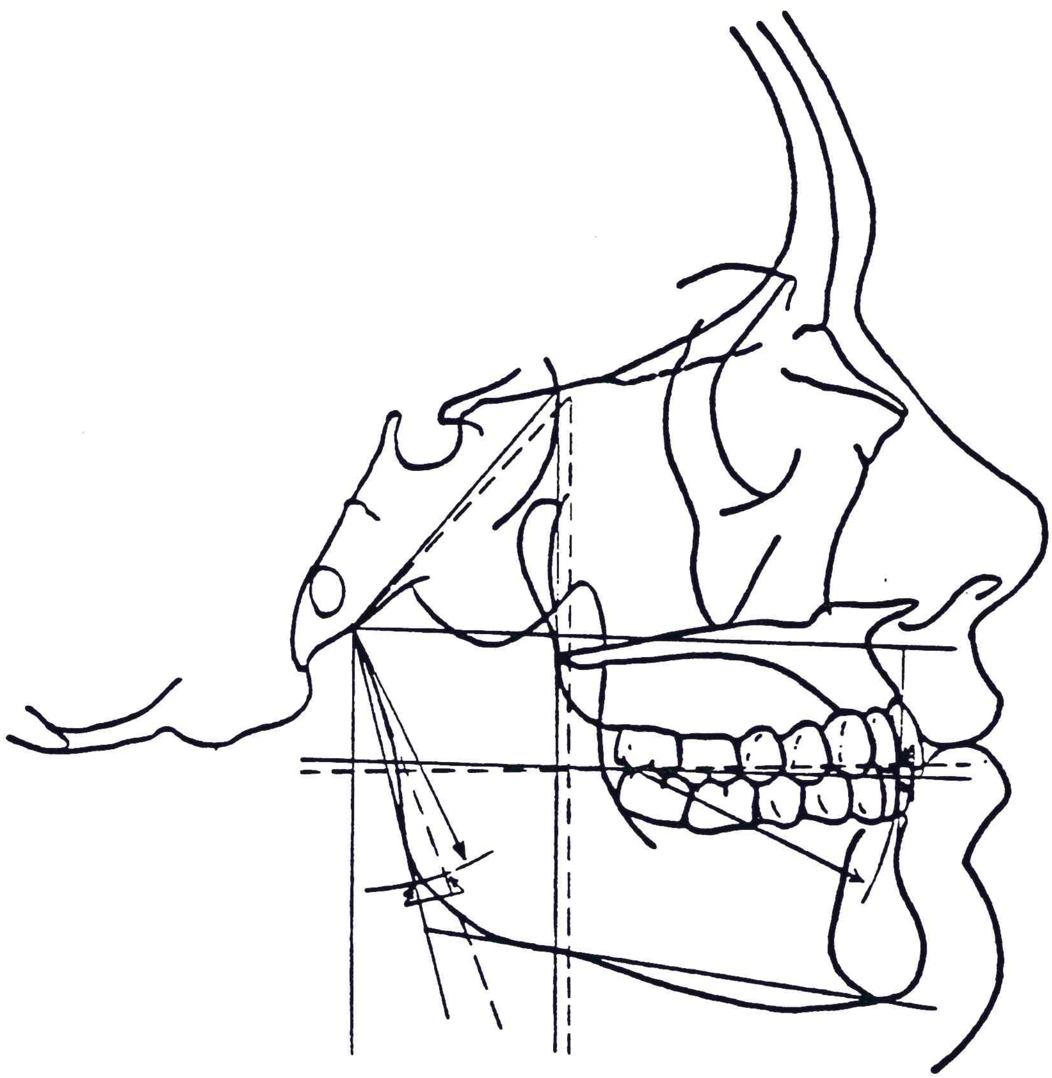


Figure 16. _**Gonial angle alignment**_. The mean gonial angle as presented in the _Michigan Standard_ (Riolo _et al_., 1975) is used as a neutral value, as indicated by a dashed line. The individual's mandibular plane is indicated by the line Me to Go. The measurement here is of two angles made in degrees. The neutral gonial angle and Ar to Go to Me.

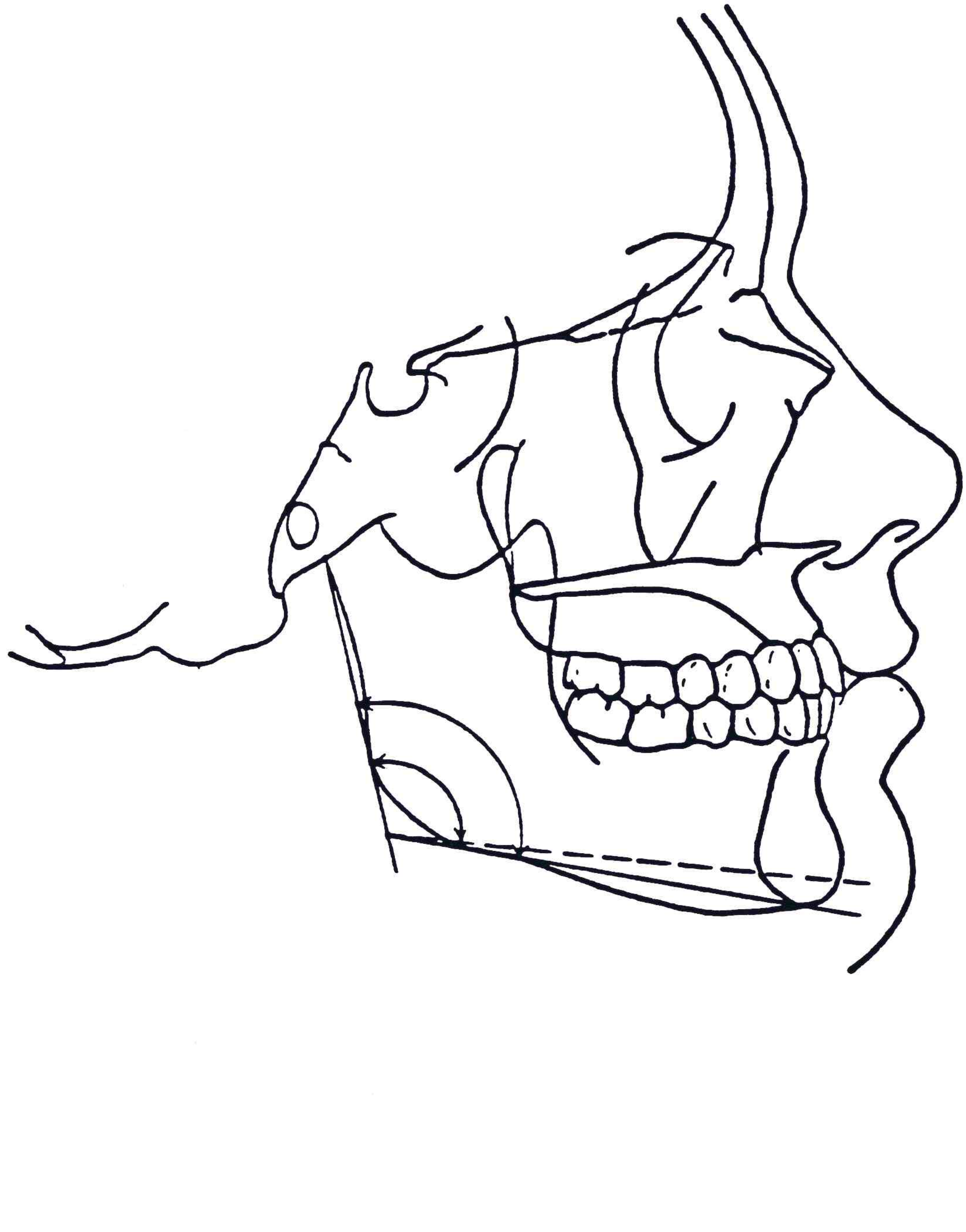


Figure 17. Curve of Spee. This is demonstrated by measuring the distance between the incisal edge of the mandibular central incisors and FOP. If the central incisors are above FOP it is a positive number, if below FOP it is a negative number.

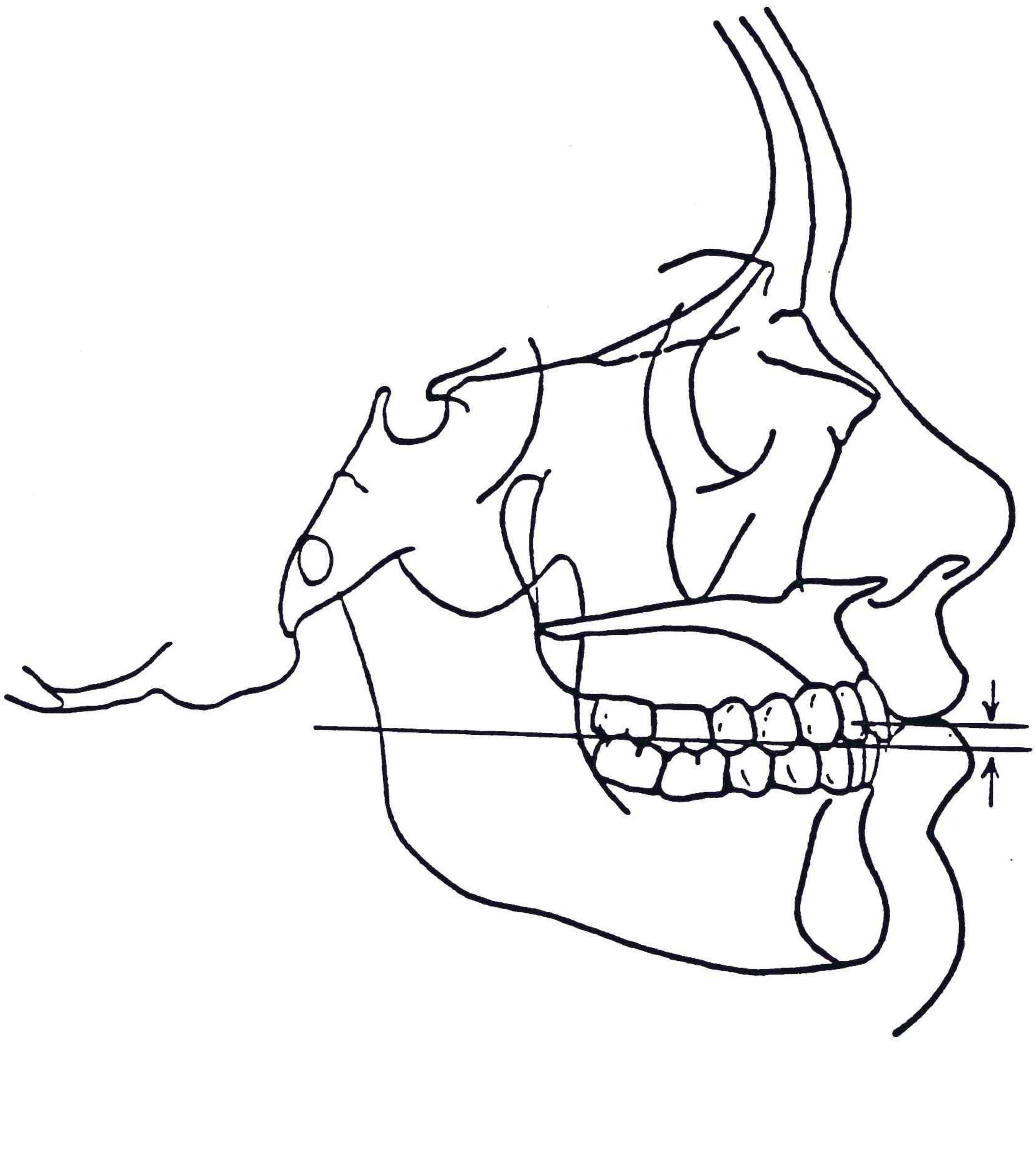


Figure 18. <u>Palatal plane alignment</u>. This diagram demonstrates the alignment between the palatal plane and the occipital fossa. The palatal plane is represented by a line from ANS through PNS. The distance between the plane and occipital point is measured. If the palatal plane is above 0 it is a positive number. If it is below 0 it is a negative number. Positive and negative values represent clockwise and counterclockwise rotations, respectively.

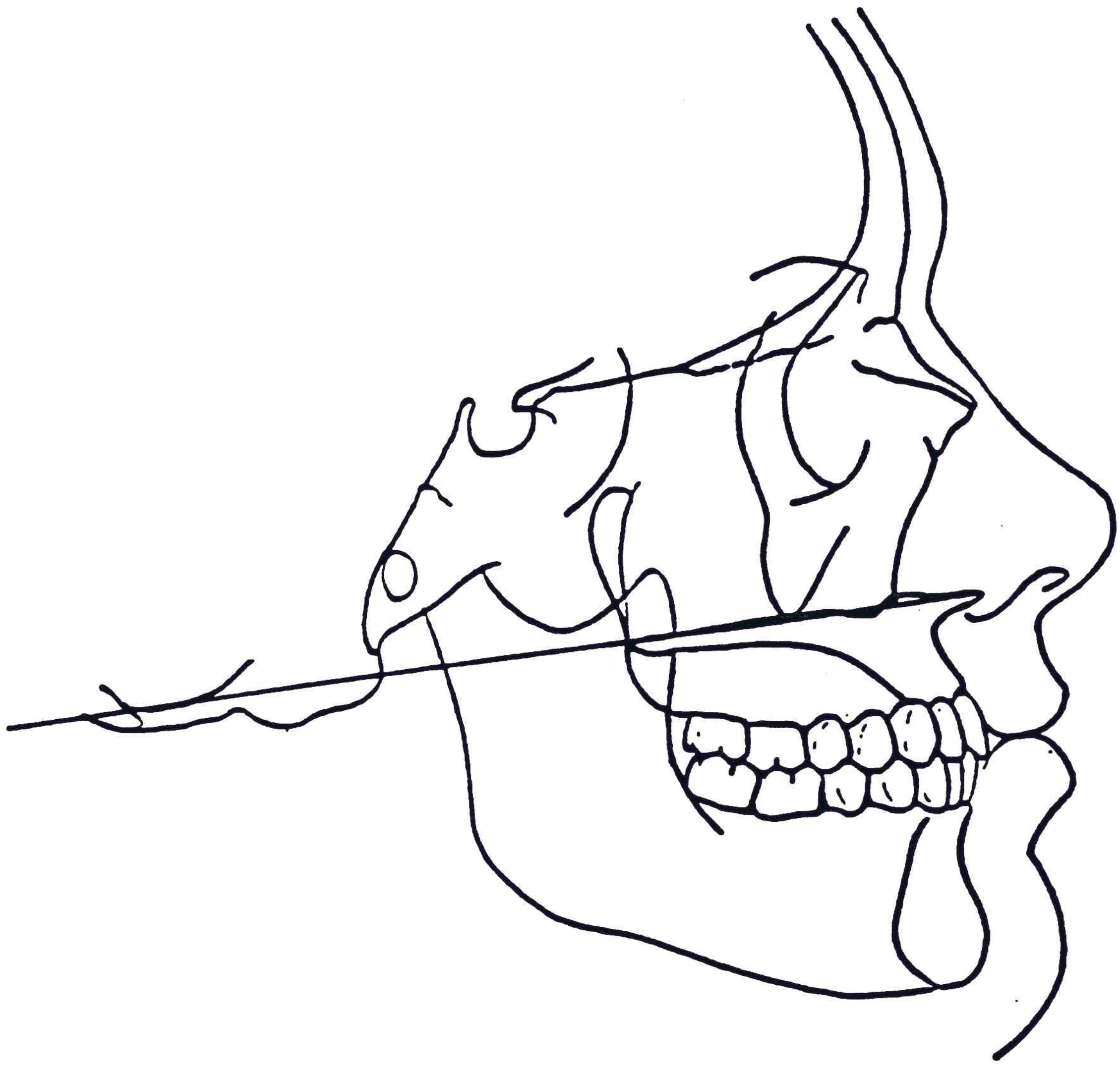


Figure 19. __Inferior maxillary plane__. This diagram demonstrates the alignments relationship between the inferior boundry of the nasomaxillary complex and the occipital fossa, theoretically representing the position establishing the inferior boundry for the nasomaxillary growth field. The line from SPr through the cemntoenamel 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.

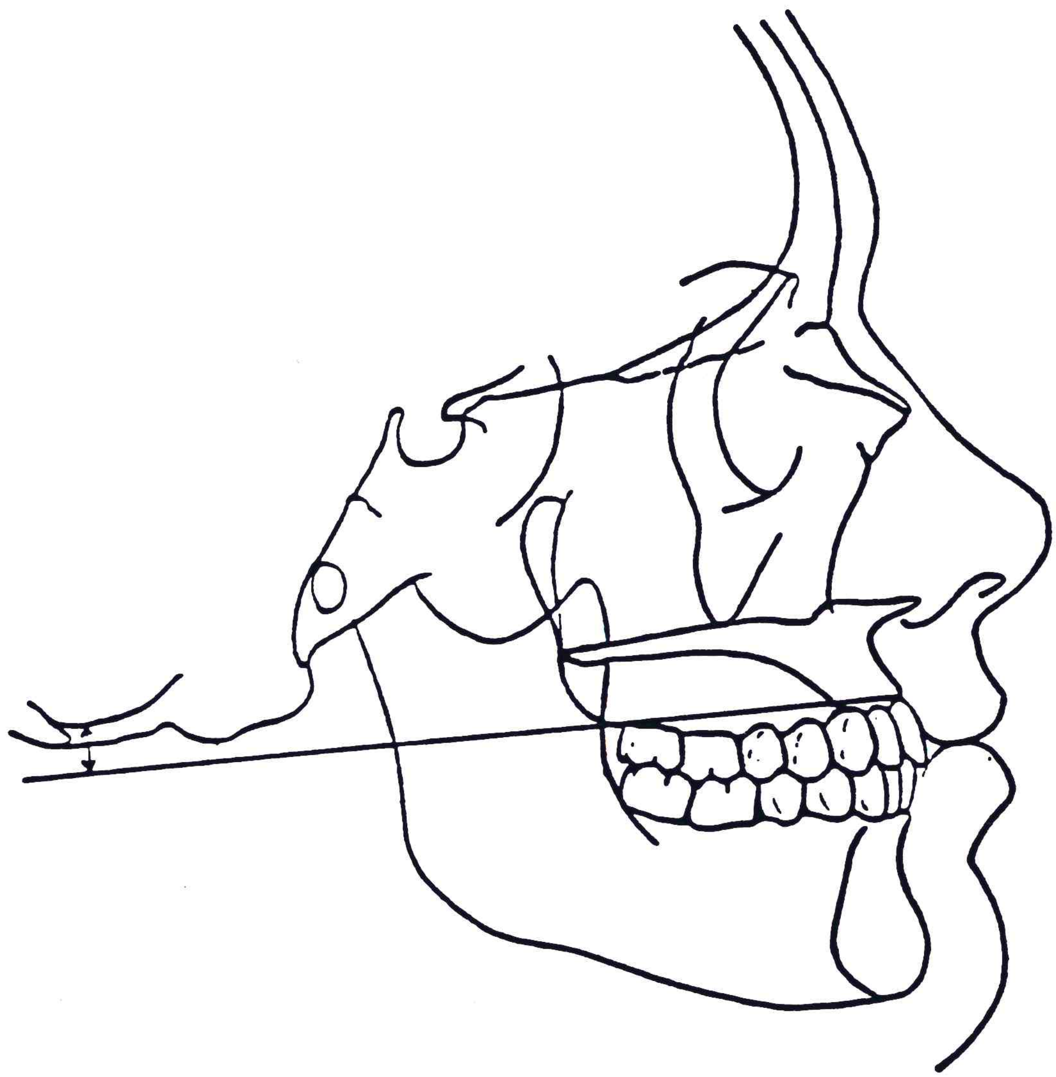


Figure 20. Maxillary nerve/palatal plane alignment. This diagram demonstrates the alignment relationship between the maxillary nerve and the palatal plane. The plane of the maxillary nerve is represented by a line from foramen rotundum in the pterygomaxillary fissure to a point 3 mm above orbitale (representing 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.

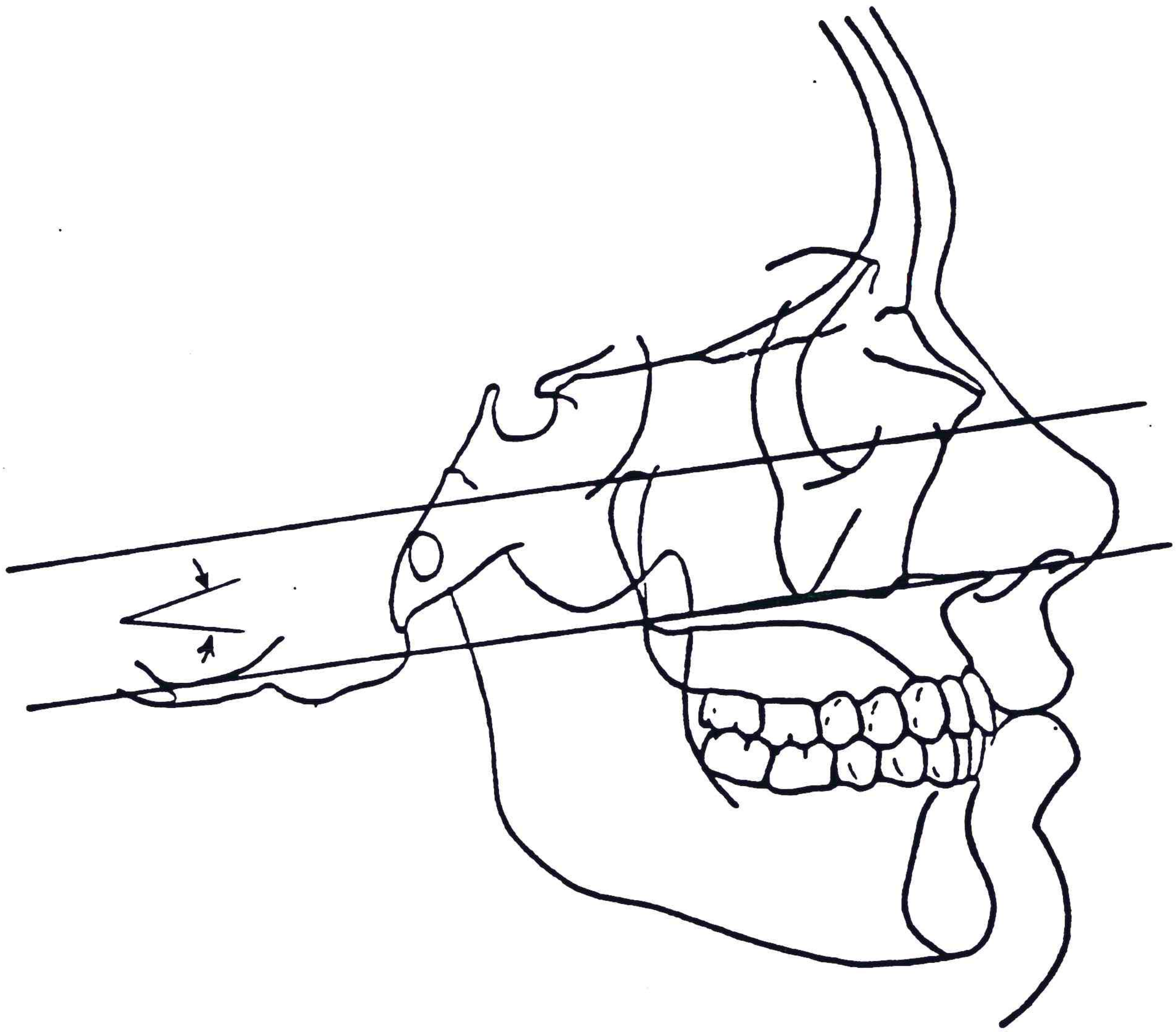
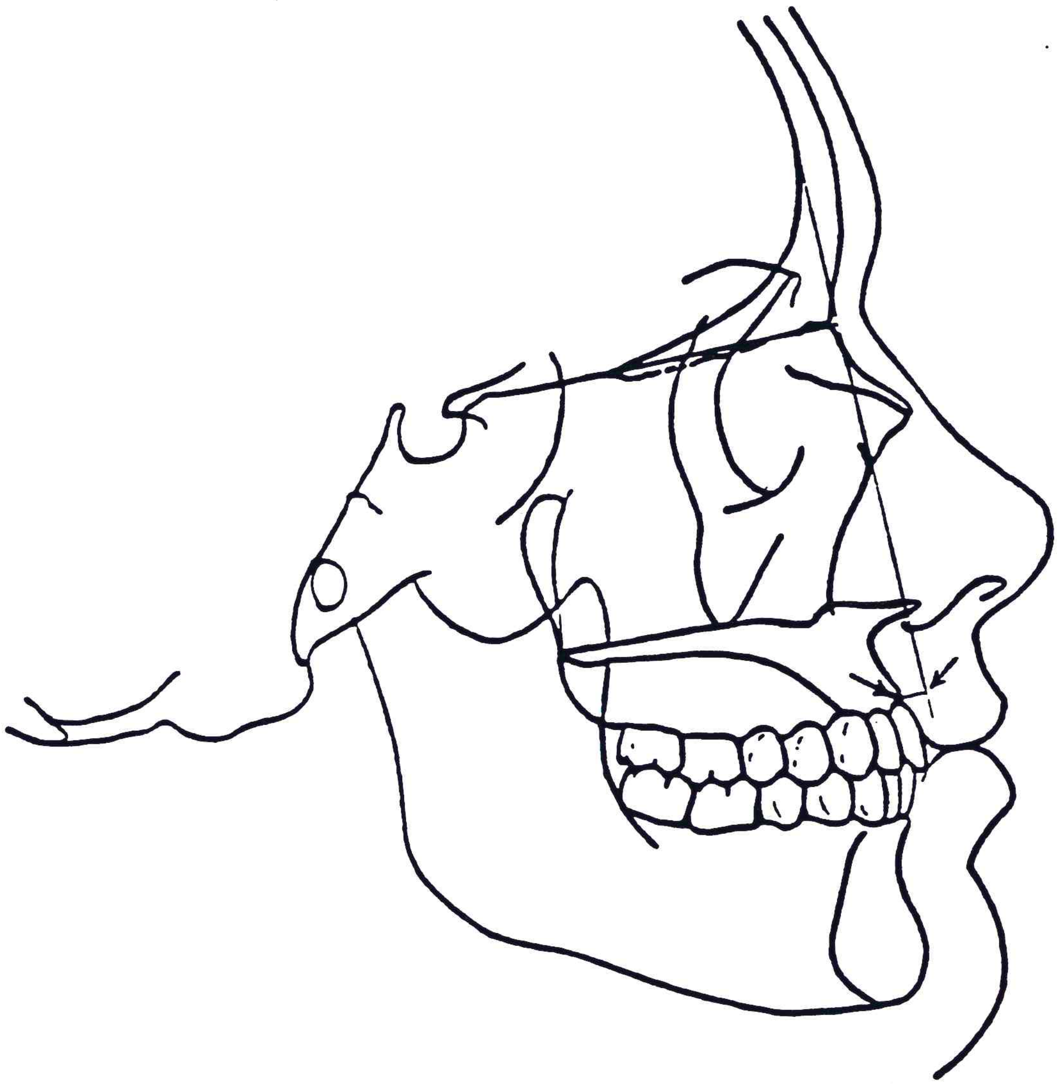


Figure 21. Verticle anterior maxillary plane. This diagram demonstrates the anterior boundary of growth of the nasomaxillary complex. A line from the most anterior point of the endocranial surface of the frontal bone (representing the frontal lobe of the cerebrum) is drawn perpendicular to a linefrom the posterior 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 nasomaxillary growth is attained.



RESULTS

In an attempt to ascertain the effect clefting has on associated structures in the craniofacial complex the counterpart analysis was applied to the sample population. The resultant data was further analyzed in an attempt to discover particular combinations of anatomic characteristics that could be used to catagorize the cleft group.

Development of Groups

Seven of the counterpart measurements were isolated that were believed to represent significant anatomic characteristics in the cleft lip and palate individual. These were 1. middle cranial fossa alignment (MCF), 2. ramus alignment (RM), 3. ramus/MCF horizontal dimensions (skeletal), 4. PM vertical, 5. gonial angle alignment (Go Ang.), 6. palatal plane alignment (Pal. Pl.) and 7. maxillary/nerve palatal plane alignment (Mx. Nrv.). These were selected because of their ability to examine the craniofacial complex in both horizontal and vertical dimensions. They also included measurements that involved the palatal area.

The result of this grouping demonstrated that by utilizing the initial set of headfilms (age 3 years) three groups could be identified in the cleft, lip and/or palate sample. The groups were established so that Group I included the subjects that possessed a net mandibular retrusive (+) effect for the seven selected measurements, Group II included those individuals that had a net mandibular protrusive (-) effect and Group III contained those subjects who had a net neutral (0) effect. These groups were constructed without regard to cleft type or sex. There are no differences in the groups with regard to sex (Table V). The only difference in the groups with regard to cleft type was that 54% of Group III was comprised of cleft palate only subjects. This is disproportionally higher than for the other two groups (Table V).

Tables VII to XIII contain frequency distributions for the seven anatomic characteristics used in categorizing the sample. Table XIV is a summary of the directional changes found for these seven variables. Table XV reports on the occurance of sign changes in these same seven variables variables. Tables XVI to XIX contain a summary of the frequency distributions for all 19 measurements used in this study.

TABLE V

Distribution of Males and Females in Groups

	MALE	FEMALE	#
GROUP I	12	11	23
GROUP II	8	10	18
GROUP III	6	7	13

GROUP I = net mandibular retrusive effect

GROUP II = net mandibular protrusive effect

GROUP III = net neutral effect

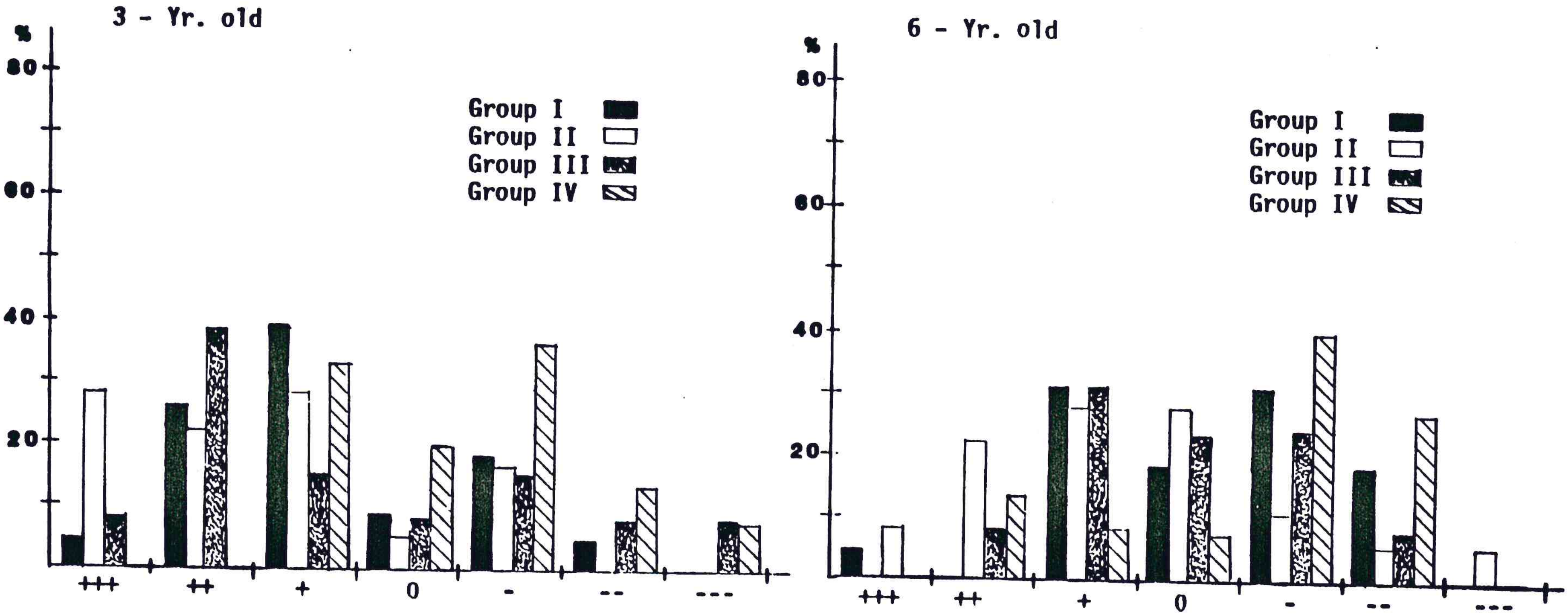
TABLE VI

Distribution of Cleft Type in Groups

	ULCP	BLCP	CPO
GROUP I	10	4	9
GROUP II	7	4	7
GROUP III	4	2	7

TABLE VII

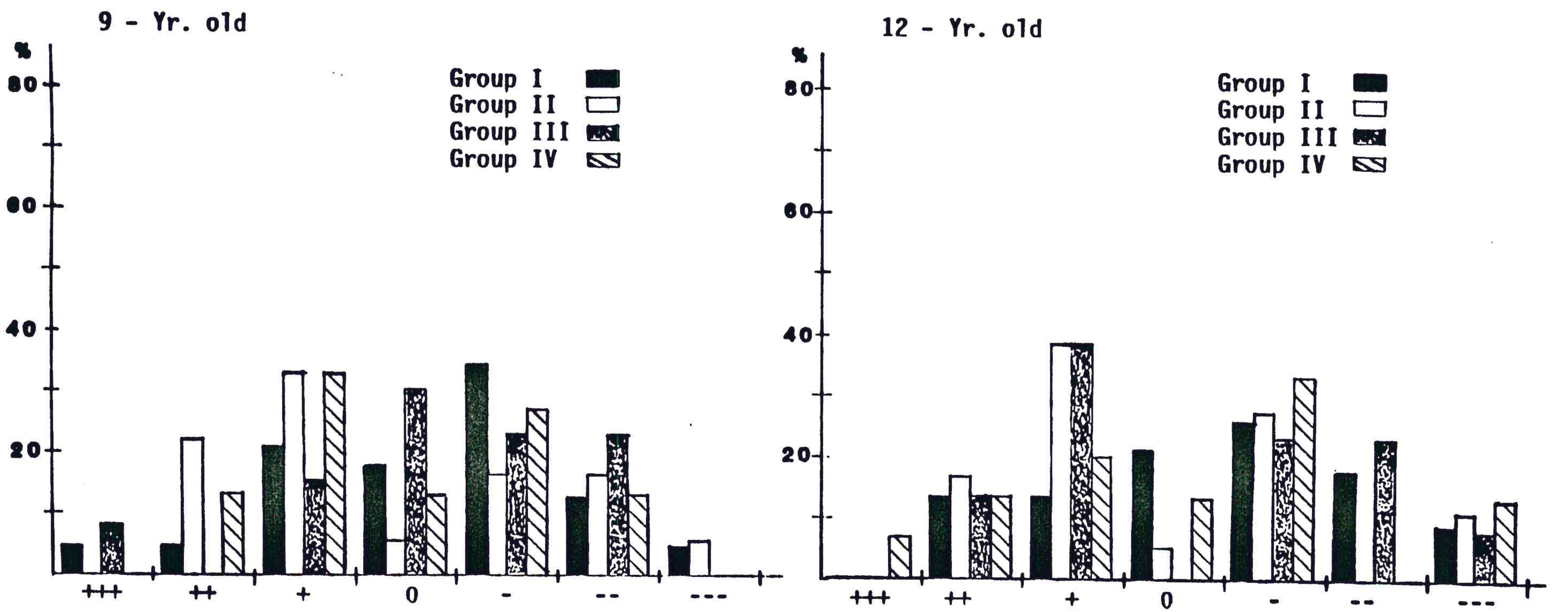
Frequency Distribution For: Middle Cranial Fossa (MCF) Alignment



PERCENT DISTRIBUTIONS FOR AGE 3 AND 6 YEARS

TABLE VII (CONT.)

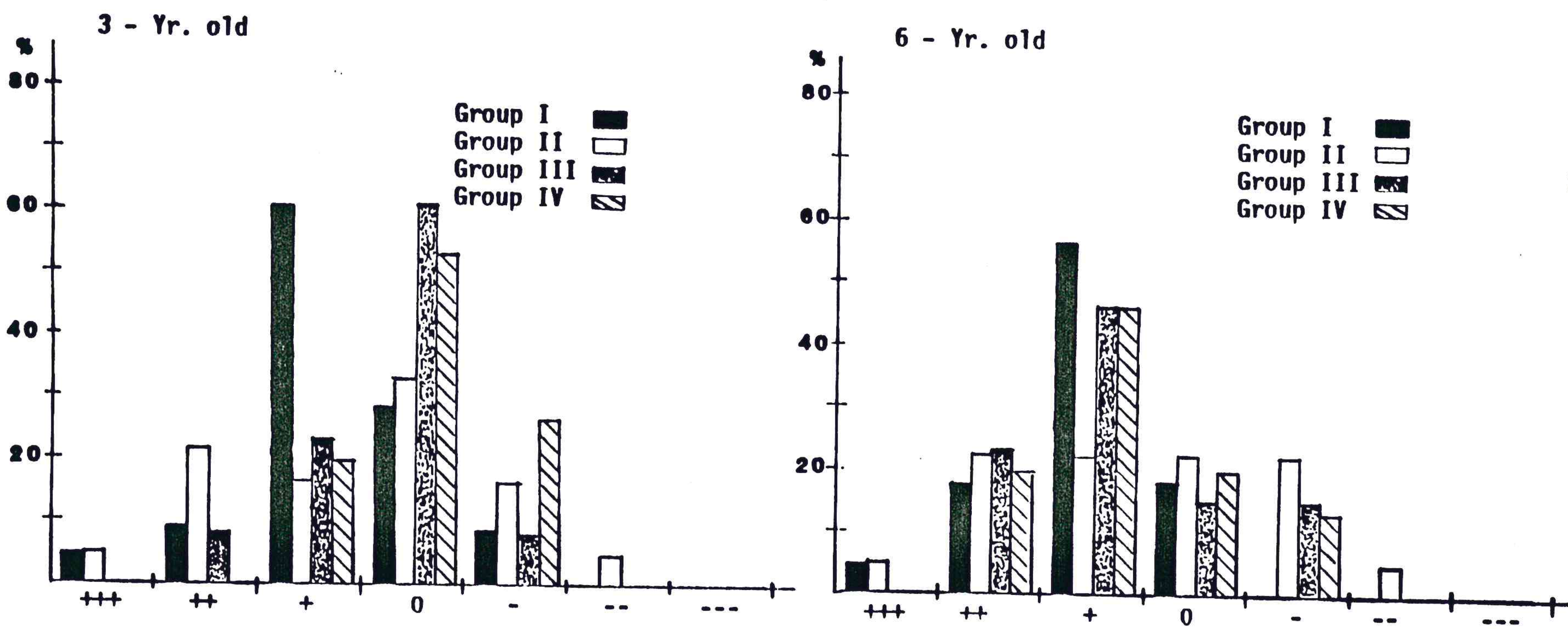
Frequency Distribution For: Middle Cranial Fossa (MCF) Alignment



PERCENT DISTRIBUTIONS FOR AGE 9 AND 12 YEARS

TABLE VIII

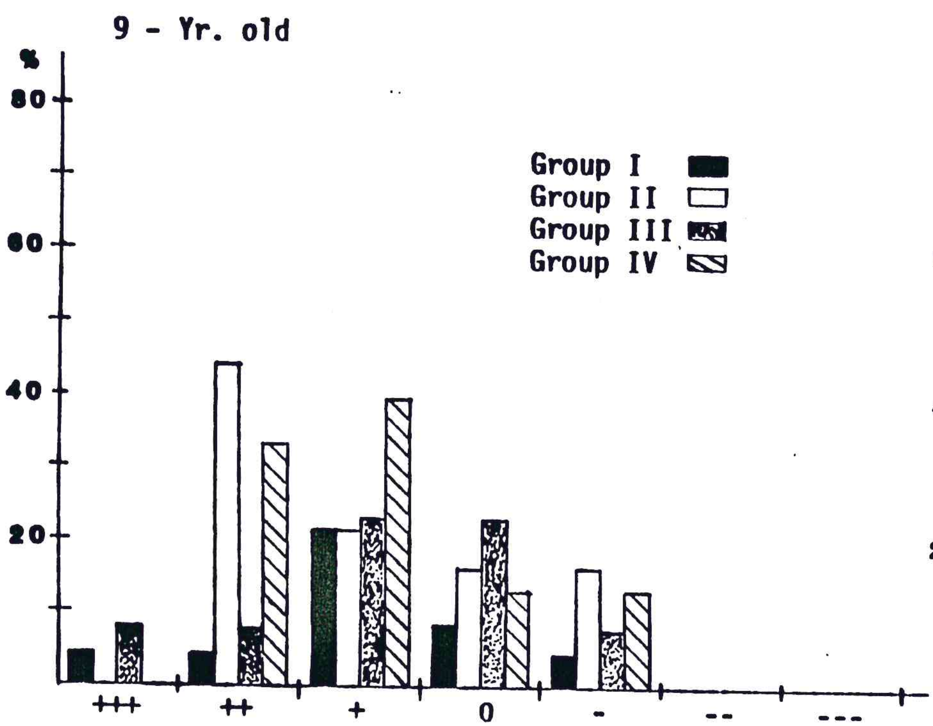
Frequency Distribution For: Ramus (RM) Alignment

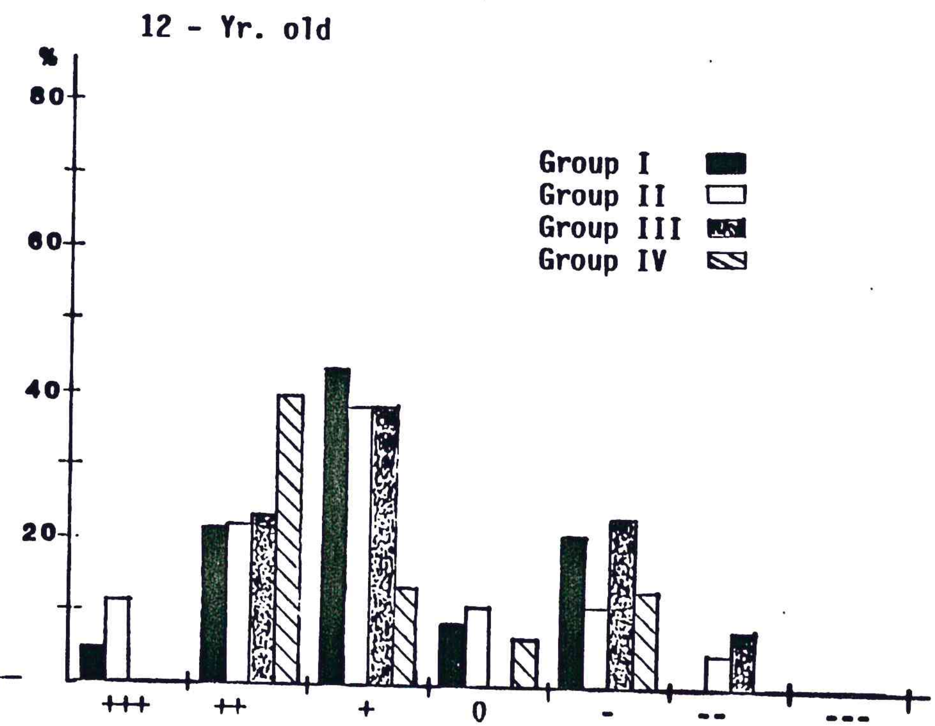


PERCENT DISTRIBUTION FOR AGE 3 AND 6 YEARS

TABLE VIII (CONT.)

Frequency Distribution For: Ramus (RM) Alignment

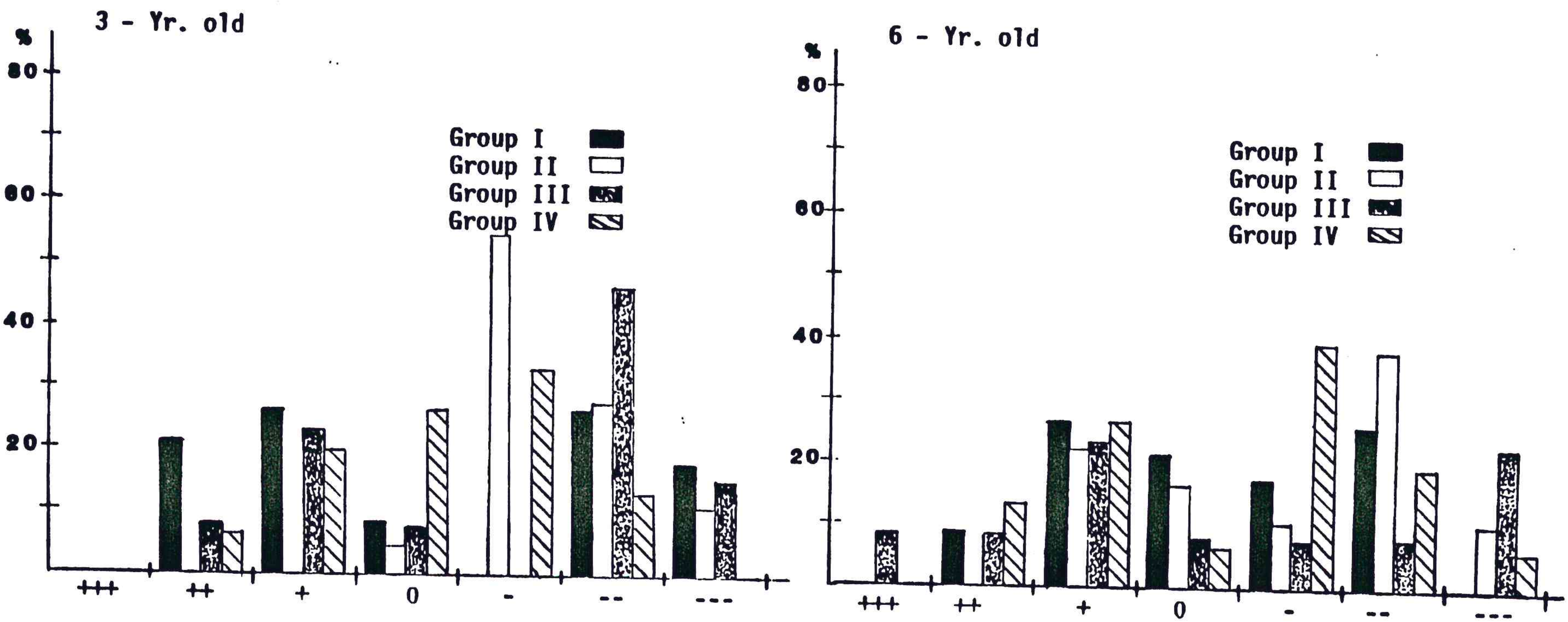




PERCENT DISTRIBUTIONS FOR AGE 9 AND 12 YEARS

TABLE IX

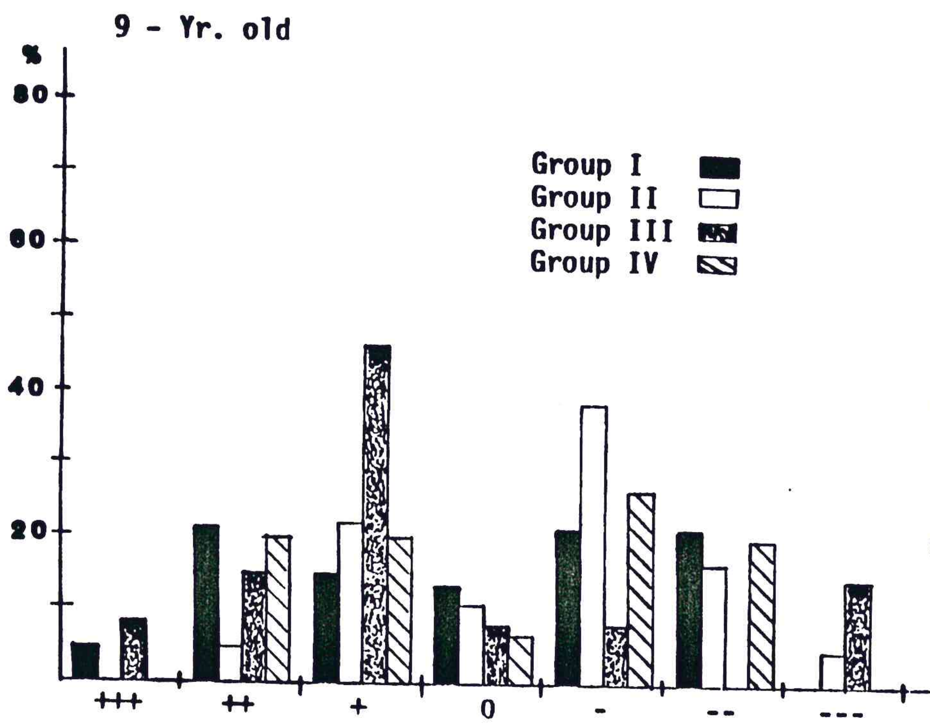
Frequency Distribution - Ramus/MCF Horizontal Dimensions (Skeletal)

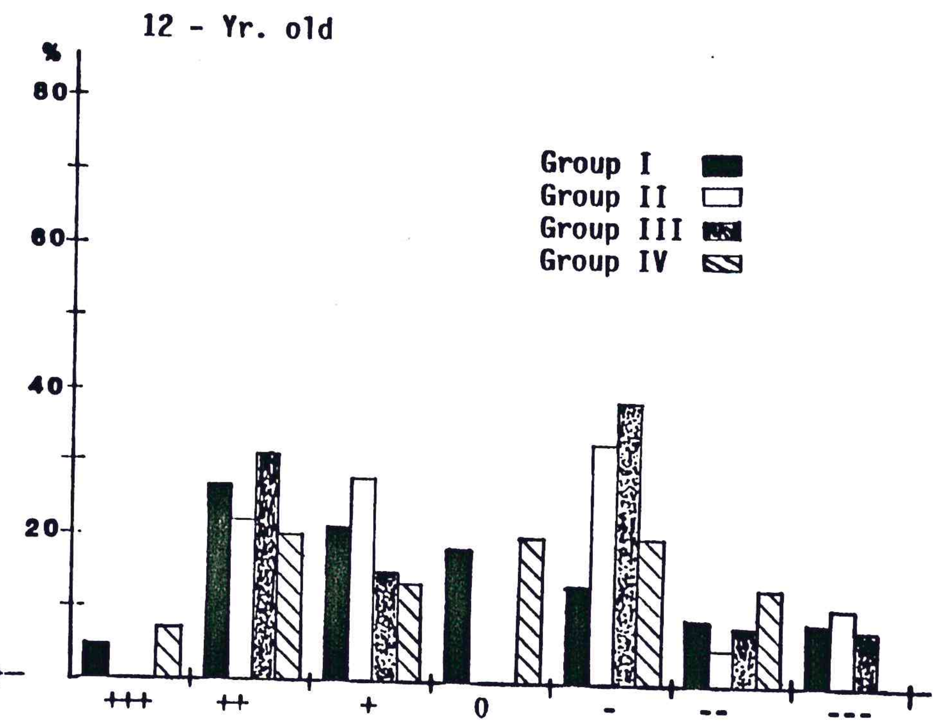


PERCENT DISTRIBUTIONS FOR AGE 3 AND 6 YEARS

TABLE IX (CONT.)

Frequency Distribution - Ramus/MCF Horizontal Dimensions (Skeletal)

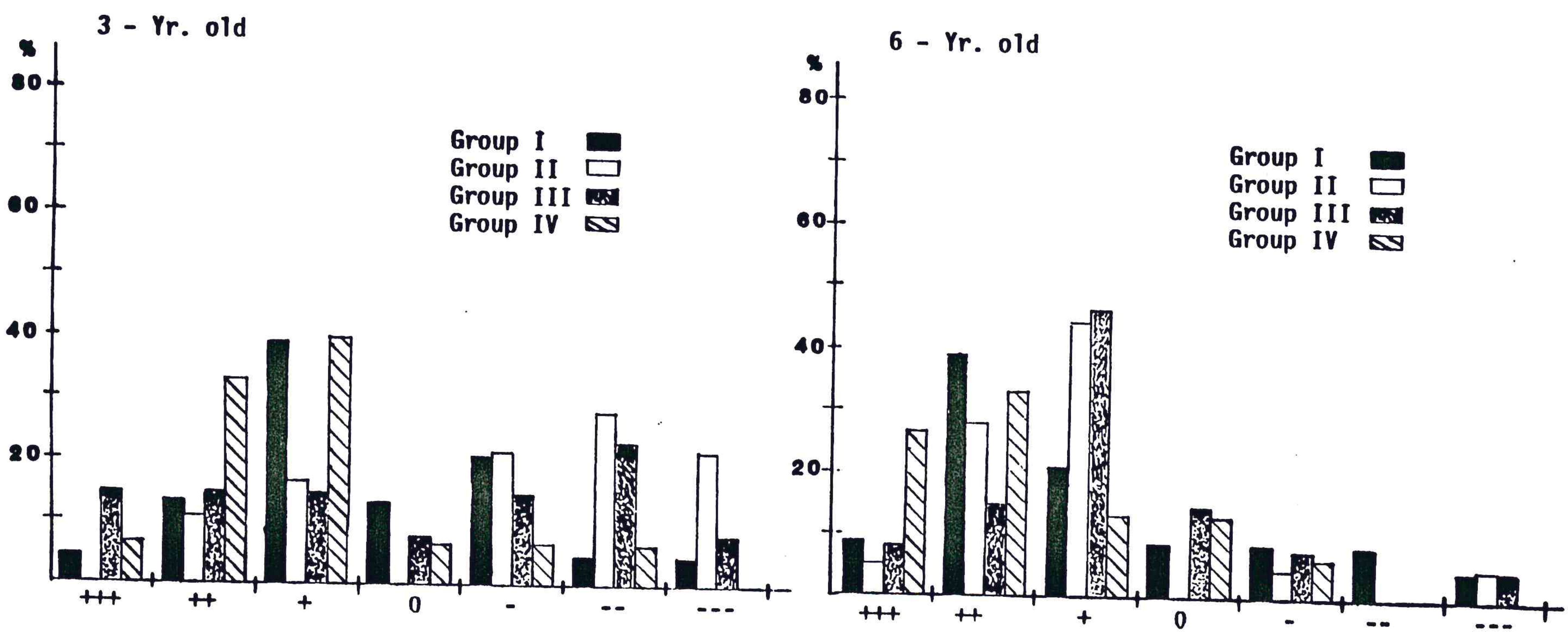




PERCENT DISTRIBUTIONS FOR AGE 9 AND 12 YEARS

TABLE X

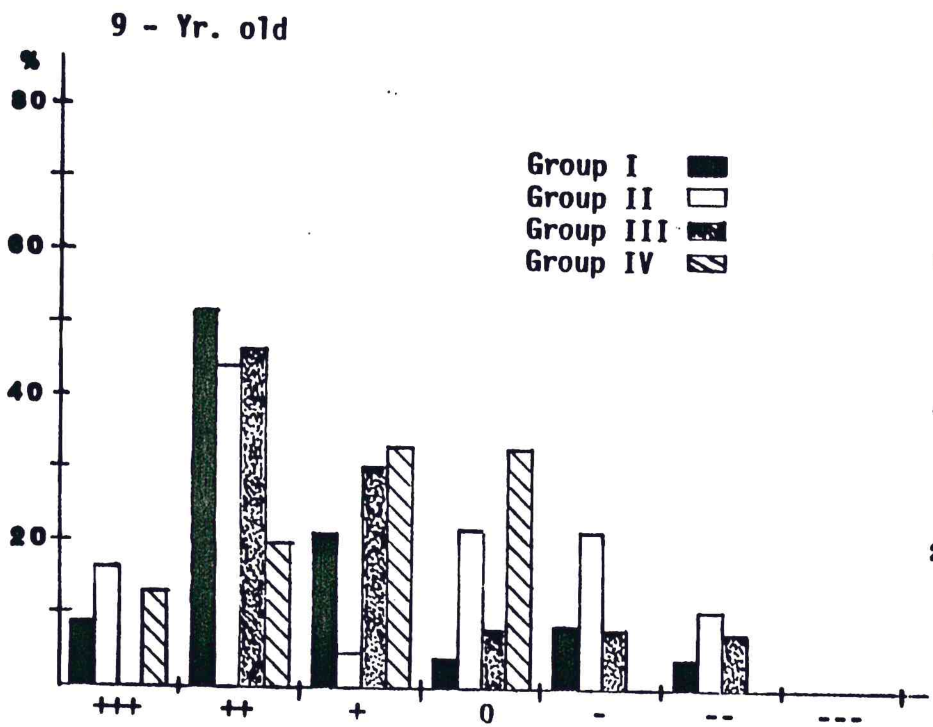
Frequency Distribution For: Posterior Maxillary (PM) Vertical Dimensions

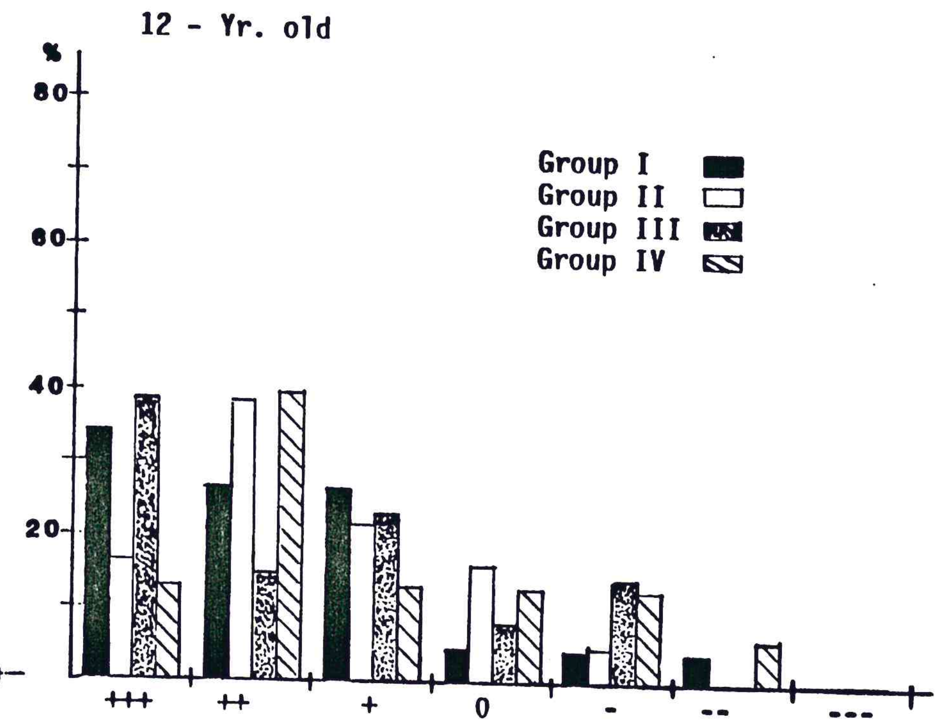


PERCENT DISTRIBUTIONS FOR AGE 3 AND 6 YEARS

TABLE X (CONT.)

Frequency Distribution For: Posterior Maxillary (PM) Vertical Dimensions

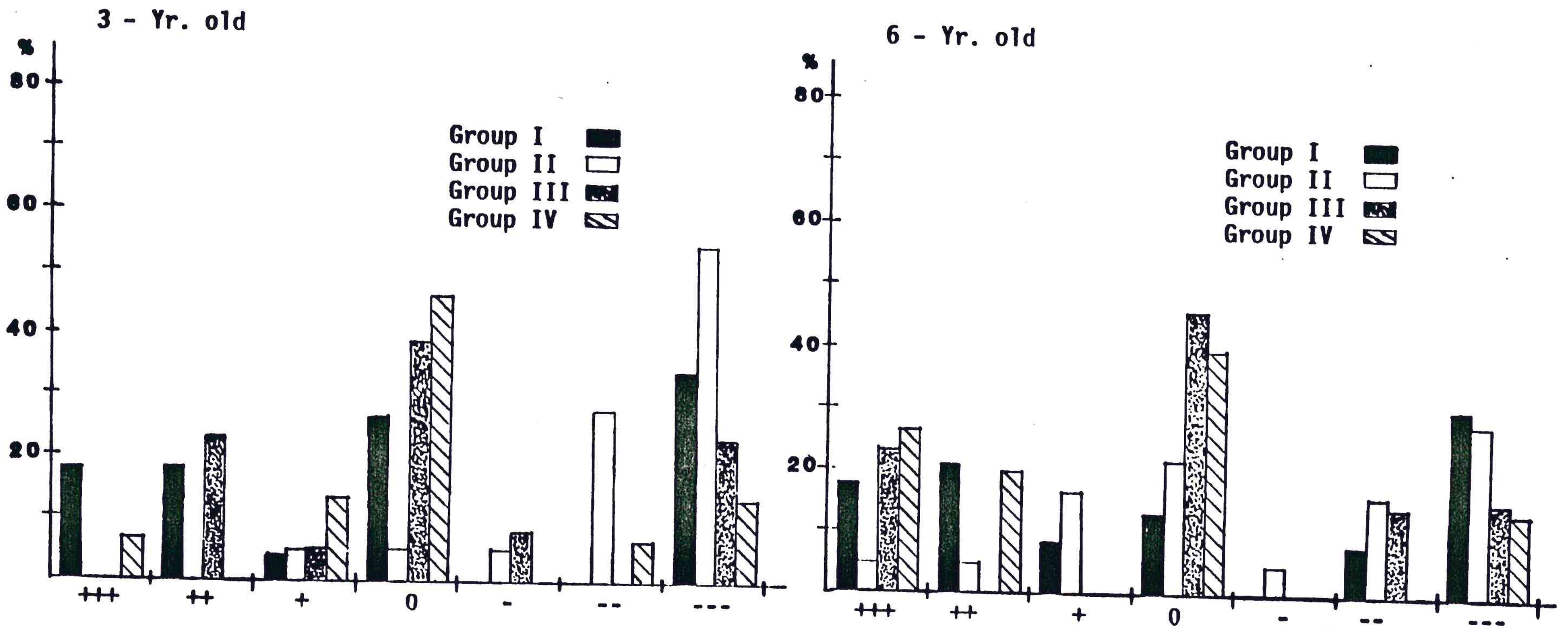




PERCENT DISTRIBUTIONS FOR 9 AND 12 YEARS

TABLE XI

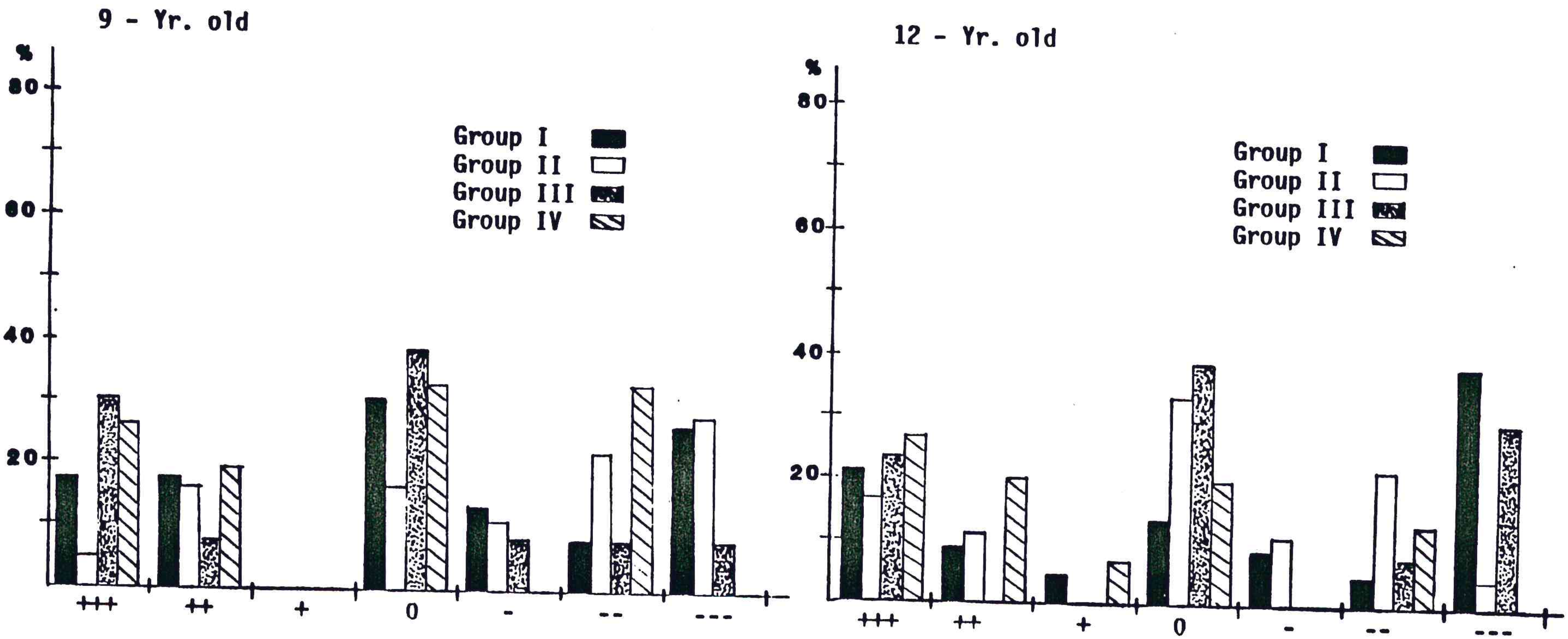
Frequency Distribution For: Palatal Plane Alignment



PERCENT DISTRIBUTIONS FOR AGE 3 AND 6 YEARS

TABLE XI (CONT.)

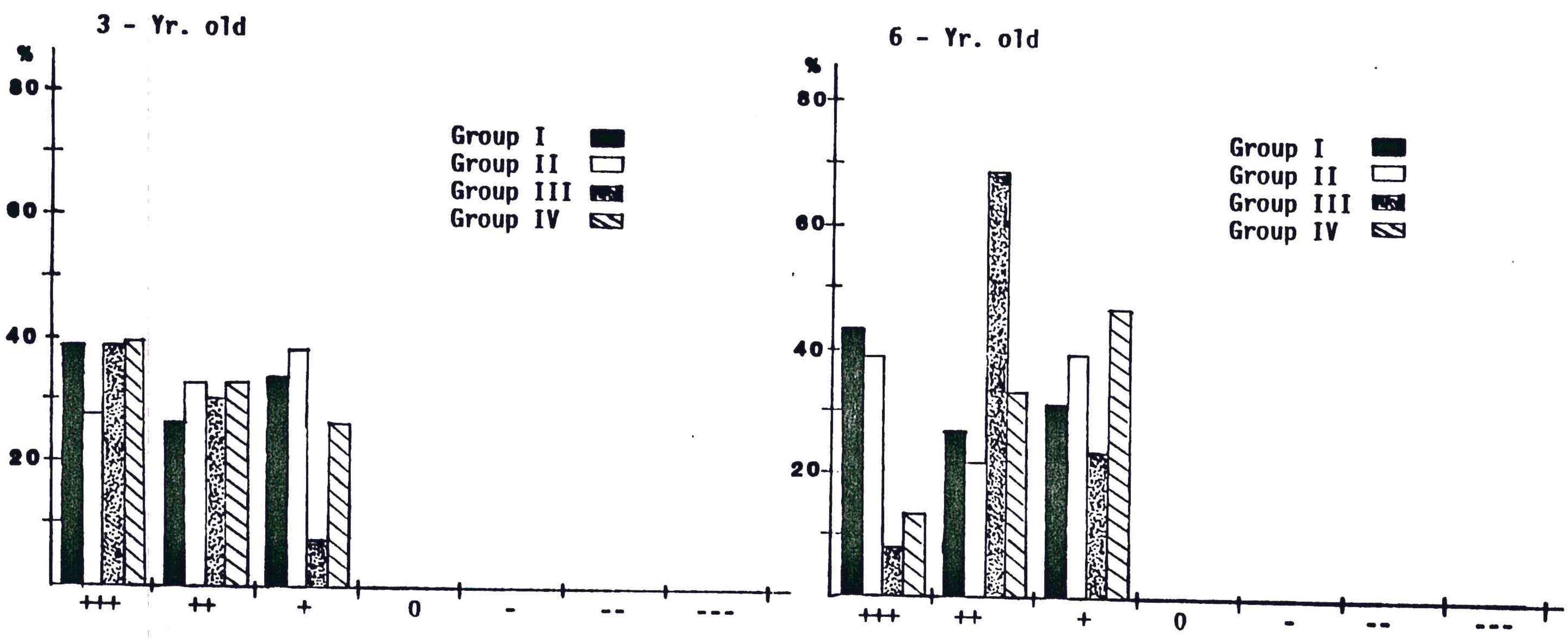
Frequency Distribution For: Palatal Plane Alignment



PERCENT DISTRIBUTIONS FOR AGE 9 AND 12 YEARS

TABLE XII

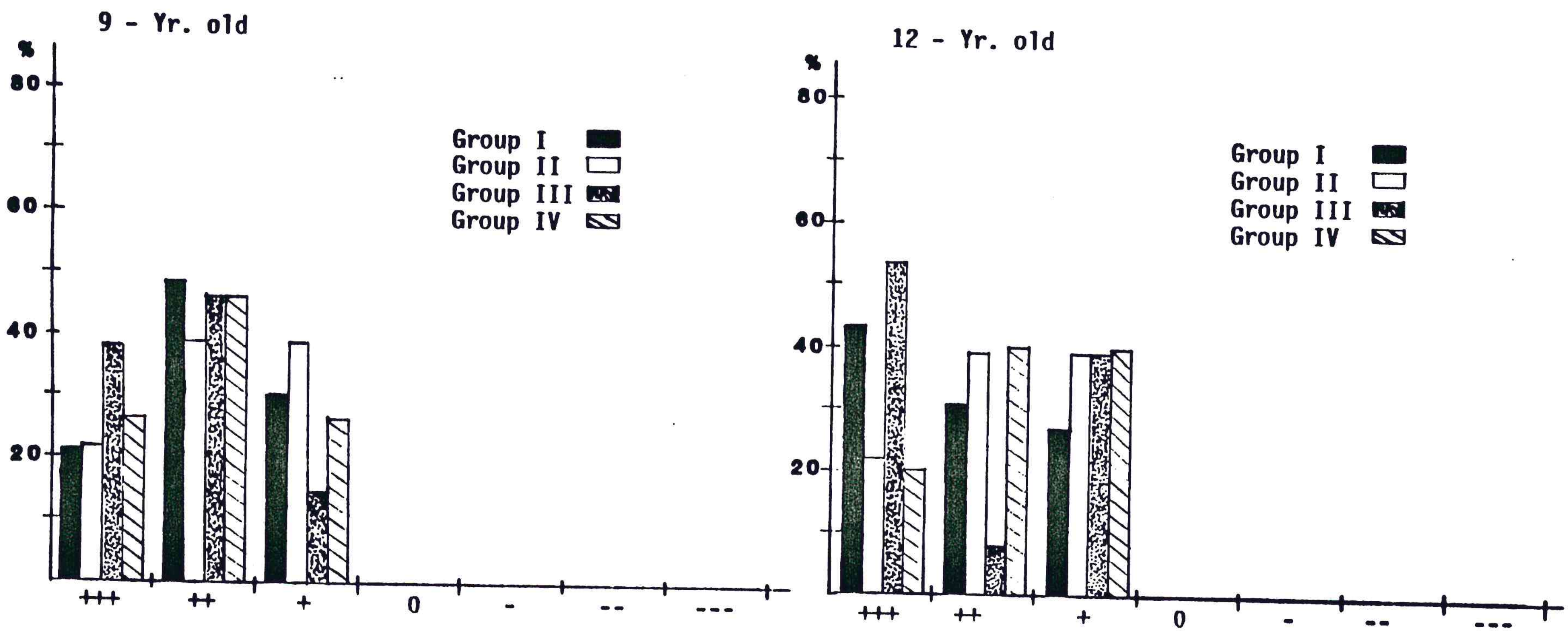
Frequency Distribution For: Maxillary Nerve Alignment



PERCENT DISTRIBUTIONS FOR AGE 3 AND 6 YEARS

TABLE XII (CONT.)

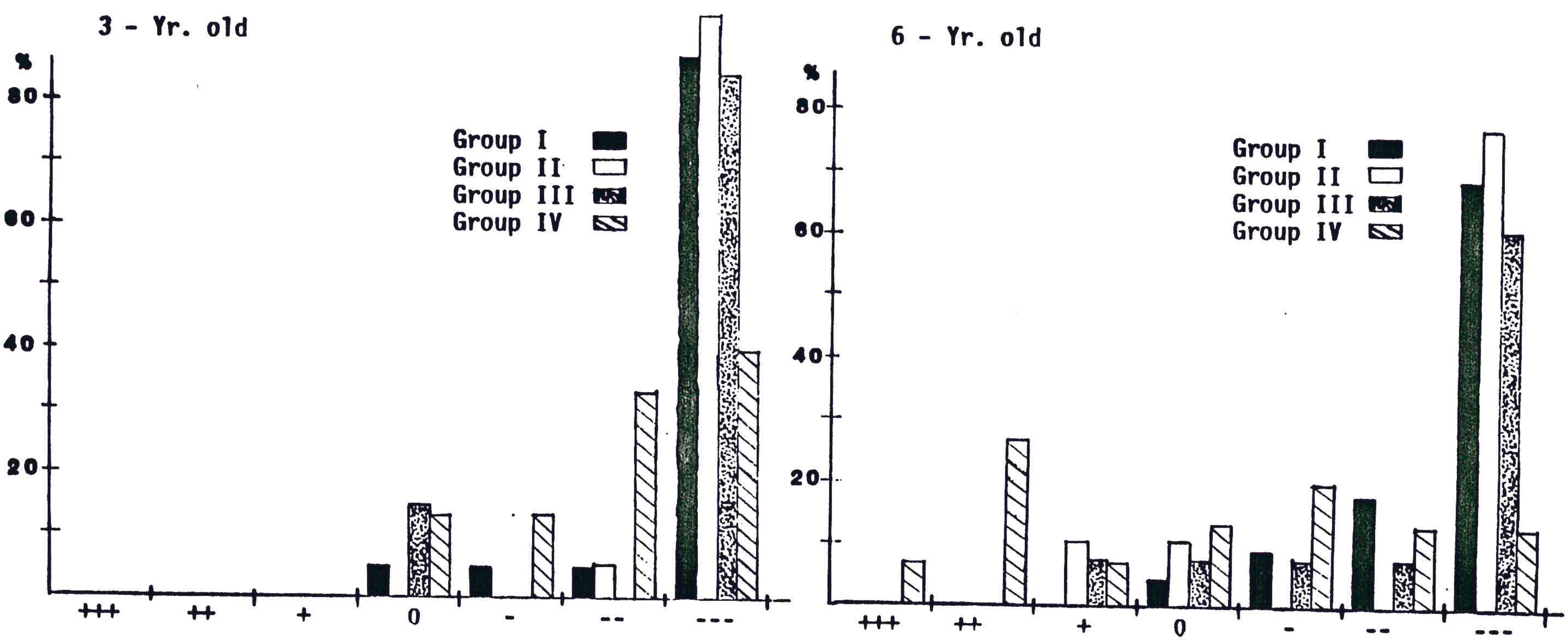
Frequency Distribution For: Maxillary Nerve Alignment



PERCENT DISTRIBUTIONS FOR 9 AND 12 YEARS

TABLE XIII

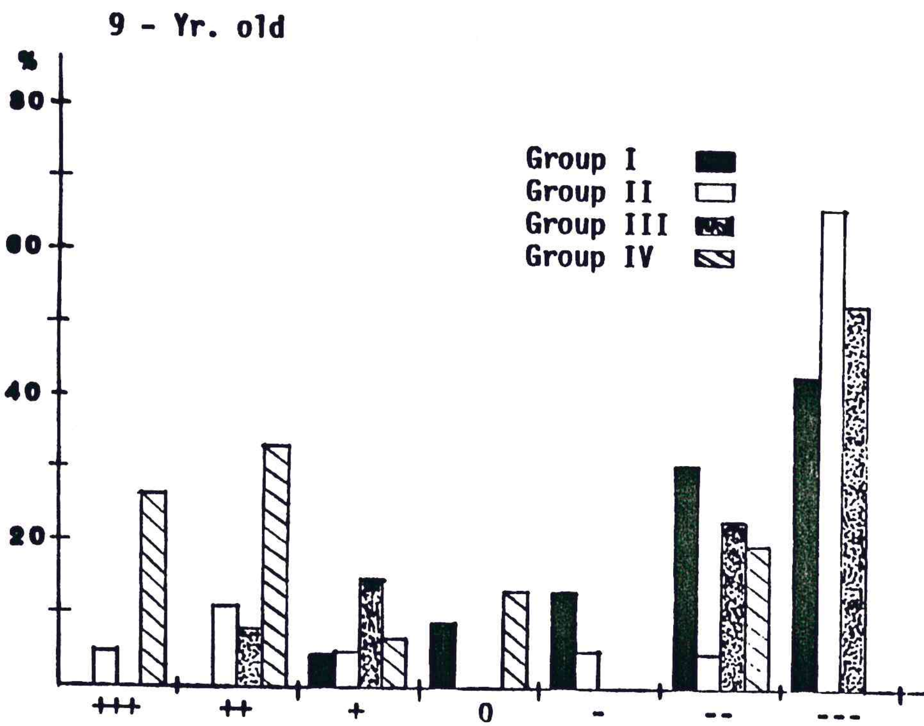
Frequency Distribution For: Gonial Angle

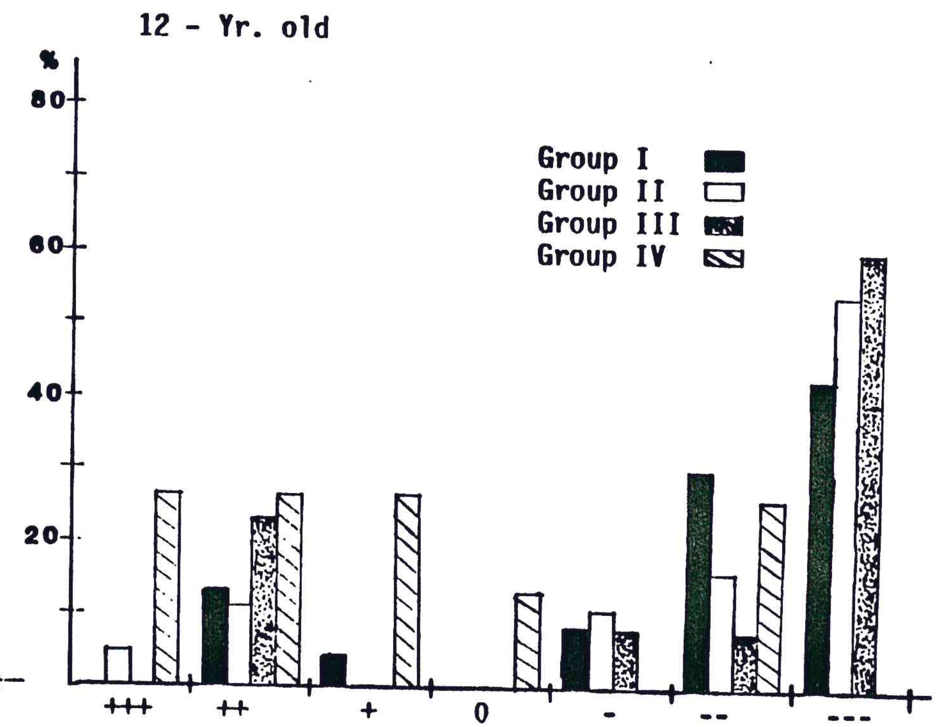


PERCENT DISTRIBUTIONS FRO AGE 3 AND 6 YEARS

TABLE XIII (CONT.)

Frequency Distribution For: Gonial Angle





PERCENT DISTRIBUTIONS FOR AGE 9 AND 12 YEARS

TABLE XIV

Net Rotational Effect for Specific Anatomic Characteristics for Age 3 to 12 years

	GROUP I			GROUP II			GROUP III			GROUP IV		
%	+	-	0	+	-	0	+	-	0	+	-	0
MCF	9	74	17	6	67	28	8	69	23	33	40	27
RM	26	30	44	61	28	11	46	31	23	67	13	20
RM/MCF (sk)	39	30	30	67	11	22	69	15	15	40	33	27
PM Vert.	78	4	17	83	6	11	62	8	31	40	33	27
Pal Pl	35	30	35	83	6	11	46	39	15	67	13	20
Mx Nrv.	39	30	30	33	39	28	46	23	31	27	47	27
Gon Ang.	52	13	35	39	6	56	39	8	54	87	7	7

'+' = Net change in individual resulted in a more mandibular retrusive effect

'-' = Net change in individual resulted in a more mandibular protrusive effect

'0' = There was no net directional change in the individual

TABLE XV

Sign Changes for Selected Measurements

	GROUP I				GROUP II				GROUP III			
	No Δ +	No Δ -	+--	--+	No Δ +	No Δ -	+--	--+	No Δ +	No Δ -	+--	--+
MCF	5	3	13	2	10	3	5		6	4	3	
RM	13	1*	5	3	7	2	2	6	2	1	4	6
RM/MCF (sk)	7	5*	5	5	3	2	7	6	2	5	2	4
PM	13	2	1	7	4	1	1	12	5	1	1	6
Pal Pl.	6	3	10	4	1	7		9	2	1**	4	3
Mx Nrv.	23				18				13			
Gon Ang.		17	1	5		15		3		6	1	6

* - No change group contains an additional member that stayed (0)

** - No change group contains two additional members that stayed (0)

TABLE XVI

Summary of Frequency Distributions for Group I

	3 Yrs.		6 Yrs.		9 Yrs.		12 Yrs.	
%	+	-	+	-	+	-	+	-
MCF	70	22	34	48	30	52	26	52
RM	74	9	78	0	87	4	70	22
RM/MCF (sk)	48	44	35	43	43	43	52	30
PM Vert.	56	30	70	22	83	13	87	9
Pal Pl.	39	35	48	39	22	48	35	57
Mx Nrv.	100	0	100	0	100	0	100	0
Gon Ang.	0	96	0	96	4	87	17	74
Ar-A,Ar-B	83	9	74	26	44	48	39	52
Ar-Spr,Ar-Ipr	87	0	70	13	61	26	65	22
Mx/Mn A-B (sk)	48	39	65	22	22	70	39	52
Mx/Mn Spr-Ipr (sk)	52	30	52	30	26	57	57	39
Corp/ Occ Pl.	30	61	57	39	48	57	48	44
Crv of Spee	65	26	70	22	87	9	87	9
Inf Mx Pl.	65	9	57	39	4	57	13	65
RM/MCF (den)	26	30	44	17	39	35	39	35
Molar Pos.	78	0	52	13	70	4	52	13
Mx/Mn A-B (den)	65	13	83	4	52	44	48	48
Mx/Mn Spr-Ipr (den)	91	0	91	9	65	30	61	30
Ant Vert Pl.	0	96	0	100	0	100	0	100

TABLE XVI

Summary of Frequency Distributions for Group II

	3 Yrs.		6 Yrs.		9 Yrs.		12 Yrs.	
%	+	-	+	-	+	-	+	-
MCF	78	17	50	22	56	39	56	39
RM	44	22	50	28	67	17	72	17
RM/MCF (sk)	0	94	22	61	28	61	50	50
PM Vert.	28	72	78	22	67	33	78	6
Pal Pl.	6	89	28	50	22	61	28	39
Mx Nrv.	100	0	100	0	100	0	100	0
Gon Ang.	0	100	11	78	22	78	17	83
Ar-A,Ar-B	72	17	72	22	44	50	33	50
Ar-Spr, Ar-Ipr	78	6	67	17	44	50	51	44
Mx/Mn A-B (sk)	39	56	61	39	44	56	28	67
Mx/Mn Spr-Ipr (sk)	33	44	56	28	33	56	39	61
Corp Occ Pl.	11	89	50	39	44	56	67	33
Crv of Spee	50	30	44	50	72	22	89	6
Inf Mx Pl.	100	0	39	50	33	50	0	89
RM/MCF (den)	11	72	17	61	17	44	11	72
Molar Pos.	72	0	50	6	39	17	39	11
Mx/Mn A-B (den)	67	11	89	17	66	39	61	28
Mx/Mn Spr-Ipr (den)	83	0	83	11	44	33	72	17
Ant Vert Pl.	0	94	0	100	0	100	0	100

TABLE XVII

Summary of Frequency Distributions for Group III

	3 Yrs.		6 Yrs.		9 Yrs.		12 Yrs.	
%	+	-	+	-	+	-	+	-
MCF	61	31	46	31	23	46	46	54
RM	31	8	69	15	69	8	62	31
RM/MCF (sk)	46	69	39	54	61	23	46	54
PM Vert.	46	46	69	15	77	15	77	15
Pal Pl.	31	31	23	31	39	23	23	39
Mx Nrv.	100	0	100	0	100	0	100	0
Gon Ang.	0	85	8	85	23	78	23	78
Ar-A, Ar-B	39	31	62	8	31	31	39	39
Ar-Spr, Ar-Ipr	69	0	69	15	54	23	39	31
Mx/Mn A-B (sk)	46	39	46	31	31	46	39	46
Mx/Mn Spr-Ipr (sk)	46	23	54	31	39	31	54	23
Corp/Occ Pl.	23	62	46	39	39	39	23	62
Crv of Spee	54	31	54	15	62	15	85	0
Inf Mx Pl.	69	15	23	46	23	54	0	17
RM/MCF (den)	23	62	15	54	39	15	39	31
Molar Pos.	54	15	62	0	54	0	54	8
Mx/Mn A-B (den)	54	46	85	8	39	31	54	39
Mx/Mn Spr-Ipr (den)	93	7	85	8	69	15	77	15
Ant Vert Pl.	0	100	0	100	0	100	0	92

TABLE XIX

Summary of Frequency Distributions for Group IV

	3 Yrs.		6 Yrs.		9 Yrs.		12 Yrs.	
%	+	-	+	-	+	-	+	-
MCF	53	33	27	67	47	40	40	47
RM	20	27	67	13	73	13	80	13
RM/MCF (sk)	27	47	40	67	40	47	40	33
PM Vert.	80	13	73	7	67	0	67	20
Pal Pl.	20	23	47	13	47	13	60	20
Mx Nrv.	100	0	100	0	100	0	100	0
Gon Ang.	0	87	40	47	67	20	60	27
Ar-A, Ar-B	33	47	27	53	20	60	27	60
Ar-Spr, Ar-Ipr	87	13	87	7	53	13	80	0
Mx/Mn A-B (sk)	27	53	47	27	27	33	47	40
Mx/Mn Spr-Ipr (sk)	53	33	80	20	67	33	60	33
Corp/Occ Pl.	13	73	73	13	80	20	87	13
Crv of Spee	80	7	53	40	87	13	100	0
Inf Mx Pl.	73	0	67	33	13	67	0	93
RM/MCF (den)	13	33	40	13	27	33	33	40
Molar Pos.	87	0	80	7	47	0	80	0
Mx/Mn A-B (den)	33	47	40	47	47	53	33	47
Mx/Mn Spr-Ipr (den)	87	13	100	0	80	13	87	0
Ant Vert. Pl.	0	100	0	100	0	100	0	93

Comparative Findings

MCF Alignment:

Group I (net mandibular retrusive effect): At age 3 years 70% of the cases demonstrated a mandibular retrusive effect. At age 12, only 26% of the sample still possessed a mandibular retrusive effect. An examination of the net directional change showed that 74% of the cases in this group underwent a backward rotation of the MCF. Fifteen (65%) of the cases changed signs, with 13 of these going from a + to a -.

Group II (net mandibular protrusive effect): At age 3, 78% of the cases demonstrated a forwardly rotated MCF effect. At age 12, 56% of these cases still possessed the mandibular retrusive effect. Sixty-seven percent of the cases had undergone a backward rotation of the MCF. Thirteen of the cases did not change signs (10 of these remained +), while all 5 that did change rotated in a backward direction.

Group III (net neutral effect): At age 3, 62% of the members showed a mandibular retrusive effect. The frequency decreased, yet by age 12, 46% of the cases still possessed a mandibular retrusive effect. Sixty-nine percent of the cases rotated in a backward direction. Seventy-seven percent of the cases, though did not change signs.

Group IV (non-cleft group): The net effect of the MCF alignment was unchanged between ages 3 and 12 years. No significant changes in the direction of rotational changes were evident.

Ramus Alignment

Group I: (net mandibular retrusive effect): At Age 3, 74% of the group had a mandibular retrusive (+) effect. At age 12, only 27% of the group had a mandibular protrusive effect (70% were still aligned in a backward direction). Forty-three point five percent of the group remained unchanged. Sixty-five percent of the group did not change signs. In those that did change signs there was no definite direction to the sign changes.

Group II (net mandibular protrusive effect): At age 3, 44% of the group had a mandibular retrusive effect. By age 9, 67% had a backwardly rotated ramus alignment. By age 12, 72% had undergone this backward rotation. As one would expect, 61% of the group rotated in a mandibular retrusive direction. Forty-four percent of the group changed signs and 75% of these changed to (+) value.

Group III (net neutral effect): At age 3, 62% of the group had a neutral alignment. By age 6, 69% of the group had a mandibular retrusive effect. By age 12, 62% of the group had a mandibular retrusive alignment. Sixty-one percent of the group changed signs (62% of these changed to a backwardly aligned position).

Group IV (non-cleft group): There is a strong tendency (67%) for this group to be rotated in a backward direction. At age 3, 53% of the group had a neutral alignment. By age 12, 80% had a mandibular retrusive effect.

RM/MCF Horizontal Dimension Skeletal Relationship

Group I (net mandibular retrusive effect): There is a great variability in the expression and directional changes in this group.

Group II (net mandibular protrusive effect): At age 3, 94% of the group displayed a mandibular protrusive effect. By age 12, though, there was an equal distribution of mandibular retrusive and protrusive effects. Sixty-one percent of the group rotated in a mandibular retrusive direction. Seven of the 18 individuals changed from a + to a - value.

Group III (net neutral effect): Sixty nine percent of this group displayed a mandibular protrusive value at age 3. Between age 3 and 12, 69% of the group underwent a change in alignment such that the middle cranial fossa became "wider" than the ramus. Though there was a tendency for the group to assume a more mandibular retrusive relationship, 54% of the group still had a "wide" ramus at age 12.

Group IV (non-cleft): There was no apparent tendency for either a mandibular retrusive or protrusive relationship. This remained the same throughout the age studied.

Posterior Maxillary (PM) Vertical Dimension Compared With Ramus/MCF Vertical Dimensions

Group I (net mandibular retrusive effect): Seventy-eight percent of the group rotated in a mandibular retrusive direction between the ages of 3 and 12 years. Seven of the 23 (30%) members of the group changed from a mandibular protrusive to a mandibular retrusive relationship. The result is that by age 12 a very strong tendency for a mandibular retrusive effect (87%) was present.

Group II (net mandibular protrusive effect): At age 3, 72% of the group displayed a short PM vertical. By age 6, 78% of the group displayed a tendency for a long PM vertical. This tendency remained the same throughout the remainder of the period studied. Sixty-eight percent of the sample changed from a (-) to a (+) effect.

Group III (net neutral effect): At age 3 there was no tendency in the group for either a long or short PM vertical. By age 6, 69% of the group had developed a long PM vertical. This relationship increased so that by age 12, 77% of the group had a long PM.

Group IV (non-cleft group): At age 3, 80% of the group possessed a long PM vertical relationship. This relationship stayed relatively constant throughout the period studied.

<u>Palatal Plane Alignment</u>

Group I (net mandibular retrusive effect): At age 3, 35% of the group displayed a severe (---) counterclockwise (upward) rotation of the palatal plane. At age 12, there were still 39% showing the same (---) alignment. The remainder of the group demonstrated no tendency towards either a clockwise or counterclockwise alignment.

Group II (net mandibular protrusive effect): At age 3, there is a strong tendency for a clockwise rotation of the palatal plane. Eighty-three percent of the group underwent a counterclockwise rotation between the ages of 3 and 12 such that at age 12 33% had a neutral effect.

Group III (net neutral effect): At age 3, 39% of the group displayed a neutral rotational alignment. This situation remained essentially constant throughout the study period. No strong tendency could be seen for any rotational changes.

Group IV (non-cleft group): Sixty-eight percent of the group rotated in a counterclockwise direction. By age 12, 60% of the group had a strong (--) counterclockwise alignment.

Maxillary Nerve / Palatal Plane Alignment:

Group I (net mandibular retrusive effect): All of the individuals in the group displayed a clockwise rotational alignment. From age 3 to 12, 52% of the group rotated further in a clockwise direction.

Group II (net mandibular protrusive effect): All of the individuals in the group displayed a clockwise rotational alignment. Between the ages of 3 and 12, 39% of the group rotated in a clockwise direction. Fifty-six percent of the group, though, remained unchanged.

Group III (net neutral effect): All of the individuals in the group had a clockwise alignment of the maxillary nerve. Between the ages of 3 and 12, 54% of the group remained unchanged while 87% rotated in a clockwise direction.

Group IV (non-cleft group): Throughout the period studied the maxillary nerve was aligned in a clockwise position. Forty-seven percent of the group underwent a clockwise rotation, while 27% underwent a counterclockwise adjustment.

Gonial Angle

Group I (net mandibular retrusive effect): The gonial angle in 52% of the group closed. At age 3, 87% had a severe (---) clockwise alignment. By age 12, only 43% had the same alignment. Twenty-two percent of the group underwent a counterclockwise adjustment by age 12.

Group II (net mandibular protrusive effect): At age 3, 94% had a severe clockwise alignment. Thirty-nine percent of the group between age 3 and 12 underwent a counterclockwise rotation of the gonial angle. Fifty-six percent, though, remained unchanged. By age 12, 17% the group, though, still possessed a severely obtuse gonial angle alignment.

Group III (net neutral effect): At age 3, 85% of the group had a severe clockwise (---) alignment. By age 12, 62% of the group was still similarly affected. Thirty-nine percent of the group rotated in a counterclockwise direction.

Group IV (non-cleft group): At age 3, 87% of this group had a clockwise alignment. By age 6, 40% had assumed a counterclockwise alignment. By age 12, 60% had rotated to have a counterclockwise alignment.

The remaining twelve anatomic characteristics will be examined in a more generalized manner. Where significant findings are encountered the scope of the description will be adjusted to the need.

Aggregate Cranial/Floor / Maxillary and Ramus / Corpus Horizontal Dimensions At A And B Points

In Group I at age 3, 83% of the group possessed a mandibular retrusive alignment. By age 9, only 44% still showed a retrusive effect. At age 12, 52% of the group had assumed a mandibular protrusive effect. In Group II, at age 3, 72% of the group demonstrated a mandibular retrusive relationship. At age 9, only 44% still demonstrated this same relationship. This remained unchanged to the end of the period studied. In Group III, at age 3, 39% of the group possessed a mandibular retrusive effect and 31% had a protrusive mandibular relationship. At age 6, 62% of the group had a mandibular retrusive tendency. By age 9, though, this tendency had reverted to the original situation and the tendency continued unchanged through the 12 year old sample. At age 6 the non-cleft group, Group IV, demonstrated a tendency towards a mandibular protrusive relationship. By age 12, this tendency had increased so that 60% of the group had a mandibular protrusive effect.

Aggregate Cranial/floor / Maxilla and Ramus / Corpus Horizontal Dimensions At Spr and Ipr

In Groups I, II, and III the cases at age 3 showed a mandibular retrusive effect. By age 12, the groups still demonstrated a strong mandibular retrusive effect, but there was a tendency for the groups to become more mandibular protrusive. Group IV in contrast began with a strong mandibular retrusive tendency and remained unchanged through the period studied.

Maxillary / Mandibular Arches, Skeletal Dimensions, A Point Compared To B Point

Groups I, II, III and IV all displayed a relatively uniform distribution of protrusive and retrusive effects. Throughout the age period studied there were no appreciable changes observed.

Maxillary / Mandibular Arches, Skeletal Dimensions, Spr Compared To Ipr

At age 3, 52% of the individuals in Group I displayed a mandibular retrusive effect. Throughout the period studied the tendency remained unchanged. In Group II there was a tendency for the group to acquire a mandibular protrusive effect (62%) by age 12. In Group III there was no clear trend but at age 12, 54% of the group had a mandibular retrusive effect compared to 23% that were protrusive. In the non-cleft group, Group IV, at age 3 53% of the group showed a mandibular retrusive effect. At age 12, 60% showed this same relationship.

Corpus / Occlusal Alignment

All four groups at age 3 demonstrated a strong tendency toward a mandibular retrusive effect. By age 12, though, Group I had changed so that there was an equal distribution of protrusive and retrusive effects. Group II which had shown a very strong mandibular protrusive tendency at age 3 (89%) had rotated so significantly that by age 12 66% of the group had a mandibular retrusive effect. In Group III there was no net rotation of the corpus occlusal comparison. In Group IV, between the ages of 3 and 6 years the corpus/occlusal dimension changed from a mandibular protrusive (73%) effect to a mandibular retrusive effect 73%). By age 12, 87% of the group demonstrated a mandibular retrusive effect.

Curve of Spee

In all 4 groups there was a strong tendency for the incisors to be above the FOP at age 3. By age 12, this effect had increased even more.

Inferior Maxillary Plan

In all 4 groups the net effect was the same. All began with a strong clockwise alignment. By age 9, all of the groups had rotated to a counterclockwise relationship.

Ramus / MCF Horizontal Dimensions, Dental

Groups I and IV at age 3 showed no tendency towards a retrusive or protrusive effect. Group II and III, though, possessed strong mandibular protrusive effects. Groups I, II and IV exhibited the same tendency throughout the period of the study. Group III underwent a change such that by age 9 there was an equal tendency for either a protrusive or retrusive effect.

Molar Position

All of the groups except Group II showed a strong tendency for a mandibular retrusive alignment. Group II initially exhibited this tendency but by age 9 only. Thirty-nine percent of the group still exhibited the retrusive effect. This tendency continued through the 12 year group.

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

Groups I, II and III all exhibited strong mandibular retrusive tendencies at age 3. Group IV initially showed no tendency for either a retrusive or protrusive effect. In Group II, III and IV the tendencies remained the same throughout the period studied. Group I, though, from age 3 to 6 demonstrated an increase in the mandibular retrusive tendency so that by age 6, 83% of the group had a mandibular retrusive tendency. By age 12, though, this had changed so that there was an equal distribution of retrusive and protrusive effects.

Maxillary / Mandibular Arches, Dental Dimensions, Spr Compared To Ipr

All 4 groups exhibited a strong tendency for a mandibular retrusive effect. This affect remained essentially the same throughout the period studied.

Anterior Vertical Plane

All four groups demonstrated an extremely strong negative value. This remained essentially unchanged throughout the study.

DISCUSSION

The purpose of the present investigation was to examine the effects clefting of the lip and/or palate has on the contiguous structures of the craniofacial complex. It was also hoped that a differential system of classification could be formed for the cleft palate population. It was hoped that by utilizing the Counterpart Analysis, patterns or tendencies for specific anatomic characteristics could be identified that would serve to classify the cleft group in a manner other than by the type of cleft or its extent.

In an attempt to attain the latter goal the sample population was grouped according to their morphologic expression of seven key anatomic characteristics. These measurements were selected because they examined the craniofacial complex in both the horizontal and vertical dimensions. Included also, were other measurements that represented the anatomic relationship of the palatal area and nasomaxillary complex.

The cleft population was classified by utilizing the initial radiograph for each individual. The result of this was that three groups could be identified; those with a net mandibular retrusive effect, those with a net mandibular protrusive effect or those that possessed a neutral effect at age 3 years. These three groups were developed hypothetically to identify the possible presentations of the anatomic characteristics in the cleft population. Such a classification system enables the examiner to taxonomically categorize the population studied and extend these findings to compare and contrast these groups with other individuals from a wider population base. This is of value if one is to more accurately identify the cleft population and attempt to understand how the clefting phenomenon effects the inherent variabilities found in all populations of individuals. In using such a classification scheme it can easily be appreciated that there is a great deal of variability in the morphologic makeup of the cleft palate group in this study.

Cleft lip and/or palate has been associated with several causal agents. Genetics (Cohen, 1978, Gorlin et al. 1971) teratogens (Fell, 1956; Lorente and Miller 1978) and spontaneous mutations (Krogman 1979) have all been associated with the occurance of cleft lip and/or palate. Disturbances in the timing of the growth process (Krogman, 1979; Watson, 1980), head form (Trasler, 1979) and tissue deficiencies (Coupe & Subtelney, 1960) have also been implicated as possible factors in the multifactorial process that causes clefting (Fogh-Andersen, 1942; Fraser, 1971). In a great number of cases the cause of the cleft can not accurately be identified (Rosenstein, 1985). It has been suggested that the cleft phenomenon is associated with an anomaly complex (Coccaro & Pruzansky 1965) or as a yet fully identified cleft syndrome (Rosenstein, 1975).

If the cleft phenomenon is associated with any of the previous causal methods, it must occur in association with the primary genetic and epigenetic factors involved in the individual. The presence of the net mandibular retrusive, protrusive and neutral effects seen in the present study lead credence to the belief that the effect the clefting process has on the craniofacial complex is adjunctive in nature. Craniofacial development is affected by the cleft process. At age 3 years there are discernable differences between the cleft and non-cleft group in the present study. Though there is a great deal of variability in the seven key measurements, the aggregate relationships for the cleft group versus the non-cleft group demonstrated that the cleft group is greatly affected in an anteroposterior (net mandibular retrusive effect) and vertical (both long and short PM vertical) dimension. The gonial angle relationships are also greatly affected in the cleft group. The gonial angle is much more obtuse in the cleft sample.

Bishara et al. (1979a), Nakamura et al. (1972) and Berkowitz (1978) have stated that there are significant differences between male and female cleft individuals. They have advocated that the two should be handled as separate entities. The results of the present study show that based on the categorization scheme utilized in this study it is not necessary to separate the groups according to sex.

These same authors have also advocated that due to the different etiologic mechanisms it is inappropriate to pool different cleft types. The results of the present study, though, demonstrate that by using a method that is concerned with the interdependency of the various anatomic components of the craniofacial complex this may not be necessary. The results indicate that there are no identifiable differences between cleft types when analyzed according to the methods of the present study. The different types of clefts were distributed throughout the groups that were identified utilizing the counterpart principles.

It appears that even though there are different etiologic causes for the clefting process the resultant effect is such thay there is no great difference between individuals effected with different cleft disorders. Thus it is possible and perhaps more useful to group the cleft population with regard to anatomic characteristics rather than the cleft type. such a method would serve to reliably and qualitatively classify the cleft individual. This would no doubt be beneficial for improved treatment results as it would classify an individual according to their overall craniofacial profile and not simply the disorder present. Knowing how the cleft process has effected the craniofacial complex and the subsequent changes one would expect to see with growth is much more important from a treatment standpoint than labeling the individual by the type of cleft.

The counterpart analysis offers a unique approach to viewing the cleft lip and/or palate individual. It enables the identification of how a growth pattern was formed. Once this pattern has been identified it is then possible to follow this growth pattern through the individual's development (Enlow _et al_., 1971a).

By examining the groups identified in this study several interesting composite relationships may be identified. While the net expression of the three groups is different at age three years there are similarities that emerge under closer scrutiny.

In all three groups the middle cranial fossa (MCF) alignment initially assumed a forward and downward position. As this anatomic characteristic was serially followed it undertook a more backward and upward position. This is in contrast to the non-cleft group that remained relatively stable throughout the period studied. Krogman _et al_. (1975) reported that in their study the sellar angle decreased during the period of their study. They felt that basion and foramen magnum were key sites of adjustment in the cleft individual and that there were genetic underpinnings to this. Dahl (1970) reported that in adults the cranial base was flatter especially in a lateral dimension than the non-cleft group in his study. Whitney _et al_. (1984), though, reported that in children under nine years of age the MCF alignment realigned itself in a downward and forward direction so as to assume a relationship that more closely matched a non-cleft group. The backward alignment change seen in the present study identified an effect reported in other studies (Bishara, 1973; Hayashi _et al_., 1976): The backward alignment occured in association with the nasomaxillary complex being positioned in a more posterior position in the craniofacial complex.

In all three groups the vertical dimension of the nasomaxillary complex is "long" relative to the vertical dimensions of the ramus and middle cranial fossa. Though the net mandibular protrusive group, Group II, at age 3 had a strong tendency for a "short" PM vertical, by age 6 it had increased so as to conform with the other two cleft groups. The PM vertical measurement in Group II was very important in the net effect of the group possessing a net mandibular protrusive effect. Without this initial short PM vertical measurement the cleft groups would more closely resemble one another. This and a strong counterclockwise alignment of the palatal plane helped separate this group from the other two cleft groups. In Group II these two anatomic characteristics served to help give the group a net mandibular protrusive alignment. Group I and III had long PM vertical alignments and no clear alignment tendency for the palatal plane.

A long nasomaxillary complex was also reported by Whitney et al. (1984) as well as most other researchers who concluded that the maxillary complex was hypoplastic in the cleft population (Ross, 1965; Vargervik, 1982; Maue-Dickson, 1979; Berkowitz, 1977). Though measuring other parameters, others have reported variations in the proportions of the midface in cleft palate subjects. Horowitz et al. (1976) in a study of children with repaired clefts of the lip and palate found the anterior midface to be long and the posterior midface to be shorter than the normal. Due to the part counterpart comparison principle what may be considered as "long" is only considered so in relation to its specific anatomic counterpart. Hayashi et al. (1976) and Vora and Joshi (1979) reported poor vertical growth of the ramus in their studies of cleft individuals.

The net effect of this "long" PM vertical dimension resulted in a posteroinferior rotation of the mandible. This offset the mandibular protrusive effects caused by the backward MCF alignment and as will be seen later, the ramus alignment and horizontal dimensions of the arches.

In Groups II and III the ramus alignment initially showed no tendency to be aligned in a clockwise or counterclockwise direction. By age 12, though, all three groups demonstrated a backward alignment of the ramus. Group I at age 3 displayed a strong tendency towards a backward aligned ramus. This effect was very important in initially identifying the mandibular retrusive group. The backward rotation of the ramus alignment acts in a reciprocal manner with the backward alignment of the MCF. It does, though, have a synergistic effect with the "long" PM vertical relationship mentioned earlier.

The horizontal width of the ramus as measured by the RM/MCF (Skel.) comparison shows variable effects among the cleft groups. In the mandibular retrusive group (Group I) there was a slight tendency for the group to adjust to a mandibular retrusive effect. In Groups II and III the retrusive adjustment observed was much more pronounced. By age 12, there was a directional tendency for all of the cleft groups to acquire a "narrower" ramus width. In the initially neutral (Group III) group there still remained a slight tendency for a protrusive mandibular effect. These adjustments can be associated with the backward rotations of the MCF alignment and the ramus alignment. The ramus serves as a key area of adjustment in the developing craniofacial complex (Enlow, et al. 1971). From the present study it can thus be shown that the ramus seems to compensate for developmental changes associated with clefts of the lip and/or palate.

Dahl (1970), and Aduss (1971) have reported an obtuse gonial angle in their studies of individuals with clefts of the palate. In the present study the gonial angle for all these groups was extremely obtuse. When the measurement was examined serially, though, it was seen that the angle did close in a counterclockwise direction. In a number of individuals the gonial angle remained obtuse, in others it closed to a sufficient enough degree to develop a mandibular retrusive effect. This may be considered a reaction to the increasing mandibular retrusive effect of the PM vertical measurement and a backward rotational alignment of the ramus. The net effect of this counterclockwise rotation is to lessen the mandibular protrusive effects seen throughout the craniofacial complex as these individuals matured.

An examination of the maxillary and mandibular arches revealed that there are only small differences in their horizontal dimensions. By age 12, both the mandibular protrusive and retrusive groups have acquired a mild tendency for a mandibular protrusive effect. The protrusive group (Group I) had been retrusive at age 3 years. The neutral group remained essentially in a balanced relationship. Other reports on the association between maxillary length and clefting are not all in agreement. Some studies report a decreased maxillary length (Ross, 1965; Graber, 1954; Krogman et al., 1975; Jolleys, 1954) while others suggest that there are no differences in maxillary length between cleft and non-cleft individuals (Fish, 1973; Grabb and Foster, 1977). Bishara (1973) reported that even though the maxilla is retropositioned in the craniofacial complex the two arches are related to one another in an acceptable manner. The findings of the present study suggest that the length of the mandible is greater than the maxilla. This is no doubt a comparison between a structurally damaged anatomic component, the maxilla, and an undamaged mandible. Because of the nature of the counterpart analysis it matters not if the mandible is of "normal" size only its relationship to its counterpart, the skeletal maxilla. Due to the other regional adaptions occuring in the cleft face, notably the long PM vertical and backward aligned MCF, the mandibular protrusive relationship of the mandible to the maxilla seems to counteract changes seen elsewhere in the craniofacial complex.

The palatal plane in the non-cleft group rotated in a counterclockwise direction from age 3 to 12 years. In the cleft groups different results are found for each group. In Groups I and III there was no tendency for the palatal plane to rotate in either direction. In the mandibular protrusive Group II the palatal plane rotated in a counterclockwise direction. These findings are contrary to those reported by Whitney <u>et al</u>. (1984). They reported initially a high incidence of a clockwise alignment of the palatal plane in young cleft children. They also found a high incidence of counterclockwise aligned palates in the young non-cleft group. By late childhood, opposite rotational changes had occured so that similar palatal alignments existed for both the cleft and non-cleft group. In the present study, by age 12 the non-cleft group had acquired a strong counterclockwise alignment while the cleft group had rotated so that they were uniformly aligned. The differences observed between the two studies seem to be associated with individual variances in the non-cleft group in the present study and not differences in the cleft groups.

The status of aggregate balance or imbalance may change through time by correcting, or aggrevating, early dimensional and alignment relationships among the various parts and counterparts (Enlow, 1982). In the present study the initial aggregate balance or imbalance made it possible to identify three groups of individuals that possessed different sets of anatomic characteristics. As the subjects in the present study matured it was seen that the aggregate relationships of the various components changed so that all three cleft groups came to possess a facial complex that was greatly different from the original presentation.

While the primary site of the cleft phenomenon is centered in the nasomaxillary complex it was evident that the contiguous structures of the craniofacial complex were affected by the presence of a cleft. The clefting process resulted in a more posteriorly positioned maxilla. This caused the various other anatomic components of the craniofacial complex to adjust to this disturbance in maxillary growth. The net effect of this was that by age 12 years the aggregate relationship of the craniofacial complex for all these groups showed a profile that was no longer excessively mandibular retrusive but mildly protrusive. All of these changes appear to be the result of an attenuation of the growth potential of the nasomaxillary process. It appears to have a diminished ability to grow in an anteroposterior manner yet there is a disproportionate increase in its vertical dimension.

The concern of those involved with guiding the craniofacial complex to its most functionally stable and esthetic relationship has been to discern what effect the cleft phenomenon has on growth of the various components of the craniofacial complex. The major thrust of most of the research on the developing cleft child has dealt with trying to identify the habilitative regimen that would best facilitate the development of a healthy, well adjusted, attractive individual.

The surgical repair of congenital cleft of the lip and/or palate has been associated with severe disturbances in the craniofacial complex though (Graber, 1949; Snodgrasse, 1954; Slaughter & Brodie, 1949). It has been said that the iatrogenic procedures involved in correcting congenital clefts of the lip and/or palate result in disturbances in the viability of the growth centers of the maxilla. Others have refuted this belief and have reported that with judicious, non-invasive surgical techniques the cleft patient could undergo satisfactory habilitation and still attain a facial profile that was not greatly different from the non-cleft group (Atherton, 1974; Rosenstein & Jacobson, 1967; Nakamura _et al_. 1972; Cronin & Hunter, 1980; Smahel, 1984a,b). In the few studies available that studied untreated individuals, the craniofacial complex was reported not to be greatly different from the non-cleft population (Bishara _et al_., 1976; Ortiz-Monasterio, 1959).

In the present study the effect of the clefting process and the subsequent surgical repairs have caused a posterior positioning of the maxilla in the craniofacial complex. But due to the adjustive mechanisms inherent in the craniofacial complex the regional components have adjusted to produce, at age 12, a craniofacial pattern that is different from that found at age 3 and also different from that found in the non-cleft group.

The potential for growth of the maxilla in a horizontal anteroposterior dimension has been reported by some to be impaired by the clefting process (Narula & Ross, 1969; Osbourne, 1966). The resultant of this is relative greater vertical growth versus growth anteroposteriorly. Similar findings were found in the present study. Ross (1969) reported that the cleft child between ages 6 and 12 years of age had apparent adequate midfacial development. But with the onset of the adolescent growth spurt, the differential rates of growth caused by the damage to the nasomaxillary area, he believed, would cause a severe midfacial deficiency to become apparent. Unfortunately the present study did not include late adolescent children or adults. It would have been interesting to test this conjecture. Sufficient records past the age of 14 years of age were not available.

It would be extremely interesting to extend this study beyond the 12 year age group to see what effect the clefting process and the subsequent surgical repair had on the craniofacial complex of the late adolescent or adult cleft lip and/or palate individual. It would also be beneficial to repeat this study with a different population of cleft subjects to see if the groups formulated in this study are reproducible in other populations.

SUMMARY

The purpose of this study was to identify and evaluate the morphologic components of the craniofacial complex in the growing individual with congenital cleft lip and/or palate. It was attempted to ascertain if the clefting phenomenon had a consistant effect on the anatomic components of the craniofacial complex. Enlow's counterpart analysis was utilized to identify particular anatomic characteristics in the craniofacial complex.

The study involved 54 individuals with congenital clefts of the lip and palate (bilateral and unilateral) and isolated clefts of the palate (provided from the longitudinal records of the Lancaster Cleft Palate Clinic, Lancaster, PA.). A non-cleft group of fifteen individuals was also examined in the study (provided from the records of the Bolton Study, C.W.R.U., Cleveland, OH). Each individual in this study was examined via lateral cephalometric evaluation at age 3, 6, 9 and 12 years. Similar surgical procedures were carried out for each cleft individual and all primary surgeries were performed by the same surgeon.

The sample of cleft individuals was divided into three groups based on the initial presentation of the individuals at age 3 years. Seven measurements were used to classify the sample. These measurements were : middle cranial fossa (MCF) alignment, ramus (RM) alignment, RM/MCF horizontal skeletal dimension, posterior maxillary (PM) vertical relationship; palatal plane alignment, gonial angle alignment and maxillary nerve alignment.

The classification scheme was such that 43% of the cleft sample (Group I) had a net mandibular retrusive effect based on the seven anatomic characteristics. Thirty-three percent of the sample (Group II) had a net mandibular protrusive effect. Twenty-four percent of the sample (Group III) had a net neutral effect at age 3. The non-cleft group (Group IV) consisted of class I individuals. This was determined by examination of headfilms for an ANB angle less than 4.5° and a class I molar relationship.

Anatomic counterparts were compared relative to one another serially and among the different groups. The planes and angles used in this analysis are designed to coincide specifically with major fields and sites of growth and remodeling.

The findings lead to the following conclusions:

1. At age 3 years, three distinct groups could be identified in the cleft group. Though two of the groups (Group I & II) presented an aggregate mandibular retrusive profile there were significant differences in the two groups to consider them different. PM vertical relationship, width of the ramus compared to the MCF and palatal plane alignment all served to differentiate between the two groups. Group III at age 3 years presented with a more balanced facial profile.

2. The middle cranial fossa alignment changed considerably in the cleft group. The MCF rotated upward and backward in all three cleft groups. It remained unchanged in the non-cleft group. This resulted in a mandibular protrusive effect in the cleft sample. This was associated with the maxilla being positioned more posteriorly in the craniofacial complex.

3. In all 4 groups the ramus alignment rotated in a downward and backward direction. This rotation counteracted mandibular protrusive effects seen elsewhere in the craniofacial complex.

10. It is possible to classify the cleft population according to anatomic characteristics without regard for cleft type or sex of the individual. There was no correlation between cleft type and sex of the individual and the presentation of specific morphologic characteristics in the sample population.

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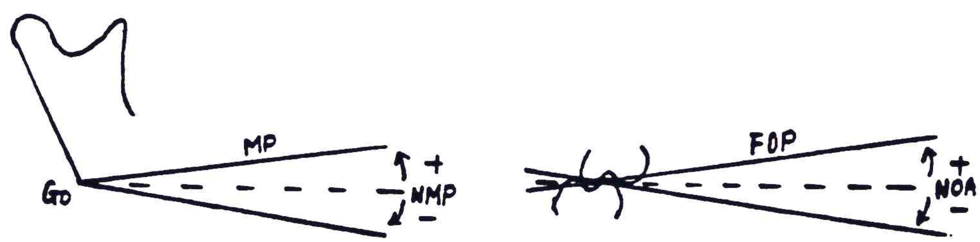
APPENDIX I
DETERMINATION OF SIGN CONVENTION

Rotation

(1) Ar Articulare) registered measurements:
measurements using Ar as a registration point.

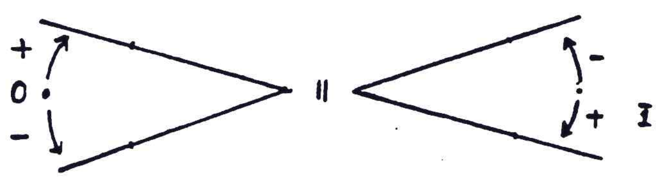
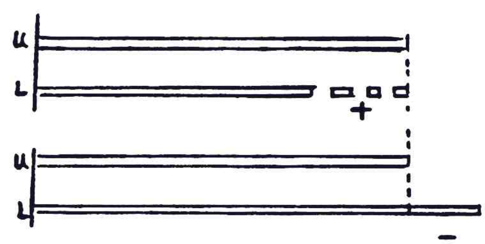
Sign = "+" -- clockwise rotation
"0" -- neutral effect
"-" -- counterclockwise rotation

(2) Non-Ar registered measurements:
measurements not using Ar as a registration point.



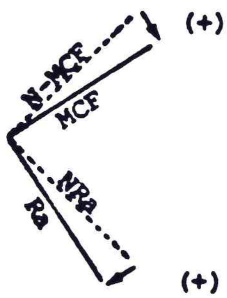
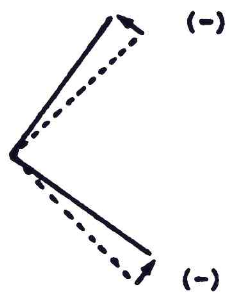
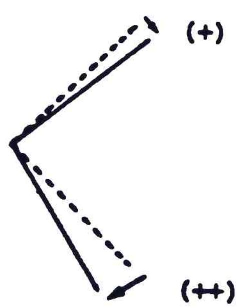
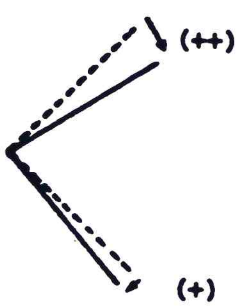
Sign = "+" -- counterclockwise rotation
"0" -- neutral effect
"-" -- clockwise rotation

APPENDIX I (CONT.)

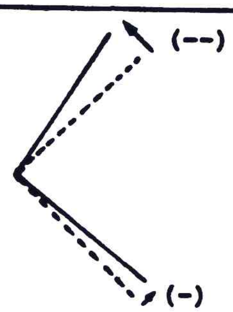
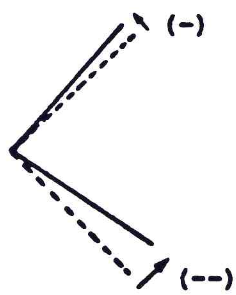
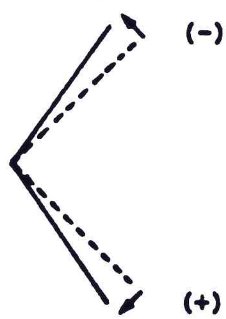
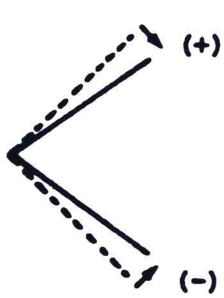
Rotation
(3) Measurements relate to one (anatomic) point  Sign = "+" -- counterclockwise rotation "0" -- neutral effect "-" -- clockwise rotation
Horizontal Dimension
 Sign = upper measurement-lower measurement "+" -- mandibular retrusion "0" -- neutral effect "-" -- mandibular protrusion

APPENDIX II

DETERMINATION 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 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.

APPENDIX II (CONT.)

	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.