A LONGITUDINAL MORPHOMETRIC ANALYSIS AND CLASSIFICATION OF THE CLASS II INDIVIDUAL

by

DAVID JAMES WHITNEY

Submitted in partial fulfillment of the requirements

for the Degree of Master of Science in Dentistry

Department of Orthodontics

CASE WESTERN RESERVE UNIVERSITY

May 1983

A LONGITUDINAL MORPHOMETRIC ANALYSIS AND CLASSIFICATION OF THE CLASS II INDIVIDUAL

Abstract

by

DAVID JAMES WHITNEY

In an effort to improve the evaluation of a Class II individual, a more precise delineation of Class II types was developed by considering the morphological expression and growth of a Class II sample population. The facial patterns within each group were analyzed serially in an attempt to establish some predictive trends of anatomical development. The Angle Classification of malocclusion is essentially subjective, and offers little with which to address the biologic nature of morphological imbalances.

Enlow's counterpart analysis was used to differentiate the anatomical expressions of the individuals. This analysis is intended to compare the individual to himself, the most biologically accurate "norm", using planes representing key fields and naturally occurring sites of growth and remodeling. These horizontal and vertical counterpart relationships are compared for size, rotation, and displacement effect, resulting in a unique facial composite pattern. Comparisons were made for each individual using the counterpart analysis at 5 different ages.

This study involved 40 subjects divided into two sample groups:

1. An untreated control group consisting of Class I dentitions of individuals with good arch development and occlusion.

2. An untreated group consisting of Class II dentitions of individuals with good arch development.

The results lead to the following conclusions:

1. Though the anatomic expressions in both groups displayed both Class II and Class III effects, the Class II group indicated a much greater polarity toward Class II tendencies overall.

2. The 20 Class II individuals were morphologically categorized into 8 recognizable groups, each with unique distinguishing features. Though the groups reflected a vast array of skeletal variation and severity of anatomic expression, a distinct Class II effect was constant.

3. The subjectivity of Angle's "Class II molar relationship" was evident as a multitude of etiological factors were responsible for establishing the molar relationship.

4. Serial trends in the developing Class II individual worsened with age when left untreated as the existing facial imbalances were not only left unchecked, but allowed to compound--the Class II individuals got more Class II with time. The most noticeable anatomic effects were the bony maxillary arch compared to the mandibular corpus, PM vertical, ramus alignment, gonial angle, and MCF/ramus horizontal dimension.

5. No viable prediction patterns were developed due to the myriad of facial effects and serial variability leading to the Class II expression, demonstrated with the counterpart measures utilized in this study. A clinician must question the bias in computer based prediction schemes that do not reflect this variability.

6. It is imperative that a diagnosis reflect the biologic complexity of the malocclusion in order to effect the most purposeful treatment plan.

ACKNOWLEDGEMENTS

The completion of a study of this kind depends upon the assistance and cooperation of many persons. The author is deeply appreciative of the generous guidance received from Dr. Rolf Behrents, who as his advisor, offered limitless patience and encouragement throughout the preparation of this thesis. The many hours together will be remembered and may Dr. Behrents never again determine estimation of error on a Florida beach.

The writer is also grateful to Dr. Donald H. Enlow, for his suggestions and sincere concern. His interpretive skills and knowledge of facial growth and development were instrumental in this writing.

He wishes to thank Dr. Sanford Neuger for his criticism and interest, and Dr. B. Holly Broadbent, Jr., for making available the facilities of the Bolton Study where the experimental data was obtained.

A thanks to Mrs. Linda Nicholl for her typing skills and patience which aided immeasurably in the completion of this thesis.

And finally, a special acknowledgement to his Clinical Faculty, Staff, and the very best of classmates. They are responsible for making the last two years a most valuable experience.

DEDICATED

TO

My wife, Elaine,
whose love and inspiration have been
everpresent throughout my education

My parents,
for their unselfish devotion and love
for which I will always be thankful

TABLE OF CONTENTS

	Page
ABSTRACT	ii
ACKNOWLEDGEMENTS	iv
DEDICATION	v
LIST OF TABLES	vii
LIST OF ILLUSTRATIONS	x
INTRODUCTION	1
REVIEW OF THE LITERATURE	3
STATEMENT OF THESIS	16
METHODS AND MATERIALS	17
COMPARATIVE FINDINGS	29
DISCUSSION	91
SUMMARY AND CONCLUSIONS	98
APPENDIX I	100
LITERATURE CITED	137

LIST OF TABLES

		Page
I.	Definition of Anatomic Landmarks	26
II.	Definition of Cephalometric Planes	28
III.	Analysis of Class II Individuals	30
IV.	Morphological Expression of Group #1	32
V.	Morphological Expression of Group #2	33
VI.	Morphological Expression of Group #3	35
VII.	Morphological Expression of Group #4	36
VIII.	Morphological Expression of Group #5	37
IX.	Morphological Expression of Group #6	39
X.	Morphological Expression of Group #7	40
XI.	Morphological Expression of Group #8	41
XII.	Synergic/Reciprocal Effects of Group #1	44
XIII.	Synergic/Reciprocal Effects of Group #2	46
XIV.	Synergic/Reciprocal Effects of Group #3	48
XV.	Synergic/Reciprocal Effects of Group #4	50
XVI.	Synergic/Reciprocal Effects of Group #5	52
XVII.	Synergic/Reciprocal Effects of Group #6	54
XVIII.	Synergic/Reciprocal Effects of Group #7	56
XIX.	Synergic/Reciprocal Effects of Group #8	58

LIST OF TABLES continued

		Page
XX.	Serial Frequency Distribution for Class II Individuals: Middle Cranial Fossa (MCF) Relative Alignment	61
XXI.	Serial Frequency Distribution for Class II Individuals: PM as Compared with Ramus/ MCF Vertical Dimensions	62
XXII.	Serial Frequency Distribution for Class II Individuals: Ramus Alignment	64
XXIII.	Serial Frequency Distribution for Class II Individuals: Maxillary/Mandibular Arches, Skeletal Dimensions, A Point Compared with B Point.	65
XXIV.	Serial Frequency Distribution for Class II Individuals: Ramus/MCF Horizontal Dimensions (Skeletal)	66
XXV.	Serial Frequency Distribution for Class II Individuals: Gonial Angle Alignment.	68
XXVI.	Serial Frequency Distribution for Class II Individuals: Curve of Spee	69
XXVII.	Frequency Distribution for: Aggregate cranial floor/maxilla and ramus/corpus horizontal dimensions at A and B Point.	74
XXVIII.	Frequency Distribution for: Aggregate cranial floor/maxilla and ramus/corpus horizontal dimensions at SPr and IPr	75
XXIX.	Frequency Distribution for: Middle cranial fossa (MCF) relative alignment	76
XXX.	Frequency Distribution for: Ramus alignment	77
XXXI.	Frequency Distribution for: Ramus/ MCF horizontal dimensions (skeletal)	78

LIST OF TABLES continued

		Page
XXXII.	Frequency Distribution for: Ramus/ MCF horizontal dimensions (dental)	79
XXXIII.	Frequency Distribution for: Molar positions (composite)	80
XXXIV.	Frequency Distribution for: Maxillary/ mandibular arches, skeletal dimensions, A point compared with B point	81
XXXV.	Frequency Distribution for: Maxillary/ mandibular arches, dental dimensions, A point compared with B point	82
XXXVI.	Frequency Distribution for: Maxillary/ mandibular arches, skeletal dimensions, SPr compared with IPr	83
XXXVII.	Frequency Distribution for: Maxillary/ mandibular arches, dental dimensions, SPr compared with IPr	84
XXXVIII.	Frequency Distribution for: PM as compared with ramus/MCF vertical dimensions	85
XXXIX.	Frequency Distribution for: Corpus-occlusal alignment	86
XL.	Frequency Distribution for: Mandibular plane alignment	87
XLI.	Frequency Distribution for: Gonial angle alignment	88
XLII.	Frequency Distribution for: Occlusal plane alignment	89
XLIII.	Frequency Distribution for: Curve of Spee . .	90

LIST OF ILLUSTRATIONS

Figure		Page
1.	Explanation of anatomic effects related to maxillary protrusion	23
2.	Explanation of anatomic effects related to maxillary retrusion	25

INTRODUCTION

As facial balance is a primary objective in orthodontics, clinicians are constantly seeking more efficient methods for analyzing the complexities of craniofacial growth. With the Class II malocclusion representing the greatest number of treatment challenges clinically, it has become apparent that Angle's definition of Class II is inadequate.

Since Broadbent first introduced cephalometrics as a practical and useable diagnostic aid, a multitude of analyses have been developed based upon population norms to better understand anatomical aberrations such as the Class II malocclusion. Moyers (1980) and McNamara (1979) have objectively attempted to classify the Class II malocclusion not only according to its anatomical traits, but also the frequency of these traits' appearance, both taxonomically and quantitatively. Recently, however, researchers have begun to analyze cephalometrically the individual in comparison to himself, the most biologically accurate "norm". This may help explain at least a portion of the clinician's frustration over the past decades, as treatment regimens have not always addressed the biologic nature of the morphological imbalances the patient may present with.

An "anatomic" means for craniofacial evaluation was provided with Enlow's counterpart analysis (1971). The craniofacial

complex is analyzed with cephalometric planes and angles designed to coincide with key fields and regions of growth and remodeling. The individual is compared to his own anatomical features through the use of various horizontal and vertical collateral or counterpart relationships. It has been shown that a functionally balanced craniofacial complex (considering the interrelationship of the various counterparts) clinically represents a "Class I" type of individual. In this individual, the anatomical morphology with relation to the size, rotation, and the displacement of the aforementioned counterparts would be proprotionally nearly equal, or any regional imbalances compensated for by adjustments among the counterparts.

The counterpart analysis will also locate any craniofacial imbalances as determined by relative protrusions or retrusions of any of the counterparts. Without equivalent intrinsic compensations (Enlow, 1971 b), a morphological aberration will modify the overall expression of the individual, thereby deviating from a proportionally harmonious form and pattern. It seems correct to assume that the counterpart analysis will lend itself to a more proper typing of the Class II individual, and from this a more meaningful treatment regimen might be developed, one which addresses the true developmental etiology of the malocclusion.

REVIEW OF THE LITERATURE

Facial balance is of utmost concern to health specialists, not only because of the many vital organs concentrated in a circumscribed area, but also because of the social value of the face. Orthodontists, employing cephalometric techniques, have investigated the relationship between dental occlusion and skeletal balance of the face (Sassouni et al., 1964). At its beginning, cephalometrics use was principally focused on growth studies of the skull. Cephalometrics did not become popular until it was adopted to routine clinical practice as an aid in diagnosis and treatment planning. Through it, a description and communication of the nature of the orthodontic problem became possible (Ricketts, 1955).

Broadbent (1931) was the first to develop an accurate technique for morphological growth studies on the living. As need for standardization was apparent, he simplified the techniques for head and apparatus alignment, lending cephalometric study to reproducibility, consistency, and accuracy (Horvath, 1979).

Later, Broadbent (1937) developed the "Bolton triangle" and "registration point" as a means for comparing lateral headplates utilizing a stable reference. He provided, also, an understanding as to why a cranial headplate should be used as an

adjunct to dental casts and other diagnostic materials. His findings showed quantitatively in the form of superimposition tracings from age one month to adulthood of "normal children", that the "growth of the face is not the complex process that it seems to be by similar superimposition of tracings from craniostatic drawing of dead children" (1937).

Brodie (1941), using a Broadbent cephalometer, serially examined 21 headplates of males from ages 5 months to 8 years. He analyzed the craniofacial complex by considering four regional entities: the brain case, the nasal region, the upper alveolus, and the mandible. Each part was examined independently of the other three through regional superimpositions, with particular attention to angular measurements. He concluded that growth displays great "constancy of pattern," and that morphogenetic pattern is established by the age of three months and remains essentially stable thereafter. His findings paralleled those of Broadbent, in that growth displays consistency in a downward and forward pattern. The implications were that facial form is maintained as the same growth pattern continues on a proportional scale (Ricketts, 1960).

Later, Brodie (1951) assessed serial roentgenograms from the Bolton study of patients between 8 and 17 years of age. Even though his conclusions were somewhat more liberal in recognizing variation in these older patients, he still maintained that

consistency in growth pattern was an overriding factor. He adhered to his description of "original proportionality" although he did note some compensatory variations. Also he proposed that an individual should not be judged against a statistical yardstick derived from a group. Brodie (1955) used the Na-S plane as a stable reference to measure incremental growth of the cranial base and the relative contributions made by each part of the cranial base to the whole. He determined these contributions to be virtually stable from ages three to 18 years, though he noted periods of acceleration, deceleration, and plateaus of incremental cranial base growth.

First Broadbent and then Brodie, by different approaches, pointed out what has been termed "the constancy of the facial pattern" during the growth process from birth to adulthood. Based upon averages drawn from serial longitudinal study of a number of persons, neither investigator reported individual variations. Many have interpreted their findings to mean that the growth of the face is a proportional enlargement with all the skeletal parts maintaining a constant relationship. In light of more recent studies, maturational and sex differences in the facial pattern, this interpretation must be modified.

Bjork (1947) utilized metallic implants as radiographic markers to study craniofacial growth in 322 boys at 12 years of age, and 281 male conscripts between 21 and 23 years. He con-

cluded that prognathism increases with age in both the maxilla and mandible, with the mandible expressing the greater extent of morphologic variation. As no alteration in the shape of the cranial base was detected, the increase in prognathism was attributed to an altering relation betweem the cranial base and jaw length.

In a later study, Bjork (1955) looked longitudinally at the lateral headplates of 243 males, ages 12 and 20 years. The cross-sectional analysis that followed displayed a range of facial proportions, with more individual growth variations. He maintained that the rate of growth of the brain case diminishes and the growth of the brain itself is complete by ages 10 to 12 years. Nonetheless, the facial structures and mandible continue developing until approximately 20 years of age.

Lande (1952) quantitatively studied the growth behavior of the human bony facial profile, using serial headplates of 39 males. He determined that the mandible becomes more prognathic in relation to the brain case during growth, generally after 7 years of age, with very little change in the maxilla. Associated with this is a decrease in inclination of the lower border of the mandible. Accordingly, his conclusion was that the convexity of the face nearly always decreases.

Downs (1948) also recognized variability in facial development, as well as the need for a better diagnostic evaluation of

an individual. He sought a means for describing facial form and denture relationship. His premise that harmony and balance of the component parts of the face, namely the skeletal framework, denture, and overlying musculature, led to his "Downs Analysis". His analysis of 10 comparisons considers 5 skeletal and 5 dental interrelationships. He found that "there is a facial pattern that represents a mean or average form for individuals possessing excellent occlusion" with however, "a notable deviation on both sides of the mean". The interrelation of the 10 components and their correlation with type, function, and esthetics has offered the orthodontist a much utilized diagnostic tool.

Moore (1959) also felt that variation rather than consistancy characterized craniofacial growth. Not only variations associated with the facial form of different persons, but also those that occur within any given individual. He held that the concept of "constancy of the facial pattern" should receive broader interpretation, and relates only to the general conformation of a face.

Nonetheless, it is only natural to strive to maximize the effectiveness of a treatment regimen and to seek out additional diagnostic information as a supplement (Harris et al., 1975). Thus, population "norms" or "standards" of dentofacial morphology and growth have been considered as potentially relevant additions to the patient's own record as a means for identifying a developmental problem. Harris went on to say that:

> In our heterogenous society, however, the use of standards computed as simple averages from large samples of individuals of varying ethnic, socioeconomic, and genetic backgrounds is obviously of questionable utility.

Overall, the greatest limitation in modern day orthodontics is not so much the integrity of the variables themselves in the measurements used but, rather, that the individual patients' growth potential may easily depart considerably from existing population norms.

Class II Classifications

Orthodontists are becoming more cognizant of the need for basic understanding of the biological complexities of the growth process. The various studies on the subject of Class II, Division 1 malocclusion are in themselves testimony to the fact that there is still much to be learned about the basis for its development and classification.

Angle (1907) spoke merely of one type of Class II, Division 1 malocclusion, where simply the mandible was distally positioned and relatively underdeveloped. Since the advent of cephalometry, studies have been carried out to better recognize areas of growth aberrations in the craniofacial complex in the person with a malocclusion, and to more effectively classify various types of Class II, Division 1 malocclusion. It is quite apparent that orthodontists now need a more complete and discriminating classification for this type of malocclusion than the pioneer system presented by Angle.

Kane (1978) maintains that:

> Most clinicians are aware of this intragroup variability, as evidenced by the array of differential analyses, multiplicity of treatment plans, and ever expanding mechanotherapy that these situations require.

His observations, based on these various studies, were that most authors agree that mandibular retrusion, in absolute size or relative position, is an important factor together with maxillary dental protrusion and excess facial height.

Henry (1957) used dental casts and lateral head roentgenograms to attempt to find a more germaine classification system for the Class II, Division 1 malocclusion. He based his criteria for selecting a Class II, Division 1 population sample on Angle's method for relating the positions of the maxillary and mandibular first molars. Using 27 mixed dentition and 76 permanent dentition patients, he categorized four separate groups of this malocclusion as follows: (1) maxillary alveolar protrusion, (2) maxillary basal protrusion, (3) micromandible, and (4) mandibular retrusion.

Later, McNamara (1979) examined a clinical population of Class II malocclusion patients to determine the nature and frequency of occurrence of specific contributing components. The significance is that the mean values are not as important as the variability seen cross-sectionally among the individuals. McNamara evaluated 277 children from 8 to 10 years old according to four horizontal and one vertical relationships: (1) maxillary skeletal, (2) maxillary dental, (3) mandibular dental, (4) mandibular skeletal, and (5) vertical development.

To determine the frequency of appearance of various combinations, he selected arbitrary neutral values bounding a range of normal variability for each of the five components. Values less than the neutral range indicated a retrusive position for the horizontal component or a deficient vertical development. Likewise, values greater than the neutral range relate to a protrusive position horizontally or excessive vertical development. This reduced each value to a trichotomy into which all subjects could be classified according to their facial morphology.

Out of his five trichotomies and 243 possible combinations of components, McNamara only had 77 different combinations actually appear. Only one combination represented even 10% (28 out of 277 individuals) of his Class II population. The number of members in the balance of the combinations or subsets dropped off immediately, with the next highest group having only 12 members, or less than 5% of those studied. He concluded that the Class II malocclusion is not a single entity and can result from numerous combinations of skeletal and dental developments, with mandibular skeletal retrusion being the most common single characteristic.

Hirschfeld and his colleagues (1975) used cluster analytic (numerical taxonomy) methods for study of selected facial measurements obtained from 308 North American caucasion children. The objective was to develop categories of facial skeletal

types. Traditionally, defining and labeling subgroups of a population have been carried out by methods essentially subjective, and therefore unable to deal with an entire set of variables adequately. Five categories were obtained, and three of them appeared to be subgroups, previously undetected, of Angle Class II malocclusion. The groupings were derived completely objectively by the clustering techniques employed, and were based on natural relationships existing among the subjects.

Intrigued by the possibility of more accurately typing Class II malocclusions, Moyers (1980) assessed 57 untreated Class II cases from the University of Michigan's longitudinal data base, as well as 640 individual patients from other sources. He was able to segregate the sample population into 6 horizontal and 5 vertical groups. By using a procedure of aborization, he developed 15 subtypes of Class II malocclusions. Analyses of the subtypes showed that the skeletal characteristics of each group were remarkably persistent through the period of growth and development for each individual. A few subjects were grouped into their classification however, merely due to their dental features. He concluded that midface prognathism made up only 20% of the population sample, whereas over 50% displayed mandibular retrusion with little or no maxillary protrusion. From these conclusions, Moyers recognized the desirability of treating the Class II malocclusion more with functional jaw orthopedic appli-

ances, in lieu of extraoral traction which is much more widely used in America today.

Moyers (1978) now advocates "diphasic orthodontic therapy, with skeletal correction at an early age followed by alignment of the teeth later, when skeletal correction has been achieved and stabilized". More precise classification of subtypes of the Class II malocclusion such as Moyers (1980) has given us, will allow for a treatment regimen to be more individualized according to the patient's own morphologic requirements. This new knowledge of Class II malocclusion subtypes, rather than the loose "Class II" assemblage, provides an improved base for further research and more efficient treatment delivery.

The Counterpart Analysis

Enlow (1971a) developed a cephalometric "analysis" with procedures unlike other established system of diagnosis and head film appraisal. Measurements, as such, are not utilized, and comparisons of individuals with populations means or standards are not made. Its purpose is to account for the individuality of anatomical and developmental characteristics that have produced the craniofacial composite pattern in a given person.

Enlow (1971a) states that:

> Most bones do not ordinarily grow as isolated, unrelated, independent units. When a given anatomical part enlarges, some other specific, collateral or geometrically comparable part or parts must also enlarge or become displaced in the same direction and to an equivalent,

> parallel extent if the same anatomical pattern and form balance is to be retained.

It follows that a direct appraisal of the actual anatomical effects of bones' respective sizes and angular relationships can be made, assessing the influences of both cortical remodeling and displacement (Enlow, 1971).

Enlow has clarified the misconception of growth constancy as he has shown that the many bones of the craniofacial complex "do not simply grow anteriorly and inferiorly, as is suggested in a conventional superimposition of serial headfilm tracings registered on the cranial base". His findings instead quantify the facial "downward and forward" ultimate result as a:

> summation of the individual, multidirectional growth and displacement changes of the maxilla, ethmoid, frontal, sphenoid, temporal, occipital, lacrimal, vomer and all other such elements within the craniofacial composite together with their related soft tissues (Enlow, 1971a).

The intent of this analysis is that the only "norm" or "standard" used is the patient compared to himself. In this way, the specific combinations of structure and growth responsible for the overall anatomical morphologic result can be analyzed. The cephalometric planes used (Enlow, 1975, 1982) correspond to the major sites of craniofacial growth and remodeling, and thereby become valid biological criteria for studying an individual's craniofacial growth and development.

The regional sites used are:

1. the maxillary tuberosity
2. the mandibular condyle
3. the junction of the ramus and corpus
4. the anterior border of the ramus
5. the posterior border of the ramus
6. the anterior surface of the maxillary bony arch
7. the anterior surface of the mandibular bony arch
8. the occlusal plane
9. the middle cranial fossa

The posterior maxillary plane is a key component in this analysis. It forms a natural anatomic boundary between the sets of counterparts or collateral anatomic regions, thus offering a reference for other comparisons to be made. The (1) anterior cranial fossa, maxilla, and mandibular corpus, and (2) the middle cranial fossa, pharyngeal space, and ramus serve this analysis as two sets of mutual horizontal counterparts anterior to and posterior to the PM plane, respectively. Equal incremental growth between each part and its respective counterpart will maintain a constant morphological pattern.

Any existing growth differentials will be expressed as a protrusive or retrusive variation in that structural pattern. These local anatomic expressions can be identified precisely, and the composite of all of them then evaluated to determine the

underlying etiology for any individual's craniofacial variations and any malocclusion present. This approach represents a "form and pattern" evaluation rather than a conventional cephalometric appraisal in which the individual is compared to a statistical base of values (Enlow, 1971).

STATEMENT OF THESIS

The objective of this investigation is to identify morphologic categories of untreated Class II malocclusions as determined by particular combinations of anatomic characteristics in the craniofacial complex. Enlow's counterpart analysis is utilized in the distinguishing of the groups.

Once the malocclusion is objectively classified, an evaluation of longitudinal morphogenic relationships for each category will be made. An attempt will be made to identify significant growth trends and develop a viable prediction scheme for the early recognition of a malocclusion.

METHODS AND MATERIALS

Source

The lateral cephalograms analyzed in this study were obtained from the files of the Bolton-Brush Study Center at Case Western Reserve University. The control (Class I) cases were a portion of the sample used to develop the Bolton Standards.

The study casts utilized were also part of the Bolton-Brush Collection.

Sample

Group I

A sample of 20 control subjects consisting of Class I cases with good arch development and occlusion was studied. These cases were selected at random, and without regard to the sex of the individual. The following criteria were met in each instance:

1. no orthodontic therapy prior to the ages studied;
2. Angle Class I molar relationship bilaterally with the mesiobuccal cusps of the maxillary first molars occluding in the buccal grooves of the mandibular first molars;
3. the molar relationships were verified in the permanent dentition (the 12 to 16 year age group);
4. each control case had lateral cephalograms at four age periods: (1) birth to 6 years, (2) 6 to 12 years, (3) 12 to 16 years, and (4) older than 16 years.

The average age for the first cephalogram in the youngest age group was 5 years, 5 months, with a range of 3

years, 11 months to 6 years, 0 months. For the second group, the average age was 9 years, 0 months, with a range from 7 years, 11 months to 10 years, 11 months. For the third group, the average age was 14 years, 1 month with a range from 13 years, 11 months to 15 years, 3 months. For the fourth group, the average age was 17 years, 5 months with a range from 16 years, 0 months to 18 years, 5 months.

In addition, if lateral cephalograms were available, a very young and/or an adult age level were also utilized. Additional young-age lateral cephalograms were available for 13 cases, with an average age of 3 years, 1 month and with a range from 2 years, 0 months to 4 years, 11 months. Adult cephalograms were available for 4 cases, with an average age of 48 years, 8 months and a range from 40 years, 6 months to 55 years, 0 months (Behrents, 1983).

Group II

A sample of 20 Class II malocclusion cases were studied. All were selected at random and without regard to sex. The following criteria were met in each instance:

1. no orthodontic therapy prior to the ages studied;
2. Angle Class II molar relationship bilaterally with the mesiobuccal cusps of the maxillary first molars occluding mesial to the buccal grooves of the mandibular first molars;
3. the molar relationships were verified in the permanent dentition (the 12 to 16 year age group);

4. each Class II malocclusion case had lateral cephalograms present at the same four time periods as in the control group.

The average age for the first cephalogram of the earliest age group was 5 years, 3 months, and the range was 4 years, 5 months to 6 years, 0 months. For the second group, the average age was 9 years, 3 months, with a range from 7 years, 11 months to 10 years, 0 months. For the third group, the average age was 13 years, 11 months, with a range from 12 years, 11 months to 14 years, 10 months. For the fourth group, the average age was 17 years, 3 months with a range from 16 years, 0 months to 20 years, 0 months.

In addition, if lateral cephalograms were available, a very young age and/or an adult age level were also utilized.

Additional young age lateral cephalograms were available for 17 cases, with an average age of 3 years, 4 months, and a range from 2 years, 11 months, to 4 years, 0 months. Adult lateral cephalograms were available for 2 cases, with an average age of 53 years, 0 months, and a range from 49 years, 10 months, to 56 years, 2 months (Behrents, 1983).

Technical Details

The lateral cephalograms of both the untreated Angle Class I and untreated Angle Class II malocclusions selected from the Bolton-Brush Collection were produced with a Broadbent cephalometer.

Tracings were completed on 0.003" acetate using an England Berol Turquoise 10 pencil with 2H drawing leads. The linear and angular measurements were made using a Dome protractor.

Measurements

All points and planes required by the counterpart analysis were drawn by one observer. Seventeen anatomic variables were compared for each tracing and recorded as a maxillary protrusive effect (+), a neutral effect (0), or a mandibular protrusive effect (-). If the measurement of each effect was greater than 2.5 mm, it was recorded as (++) or (--), respectively.

An explanation of measurement procedures can be found in the Appendix. The 17 variables examined are as follows:

1. Aggregate cranial floor/maxilla and ramus/corpus horizontal dimensions at A and B Point.
2. Aggregate cranial floor/maxilla and ramus/corpus horizontal dimensions at SPr and IPr.
3. Middle cranial fossa (MCF) 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. Mandibular plane alignment.

15. Gonial angle alignment.

16. Occlusal plane alignment.

17. Curve of Spee.

The following analyses were utilized in this study:

1. Control cases--Frequency distribution of all variables for each age group was tabulated.

2. Class II cases--Frequency distribution of all variables for each age group was tabulated.

3. Cross-tabulations were performed on the Class II cases to determine whether a synergic or reciprocal relationship exists between different variables.

4. Anatomic expressions were analyzed serially for the Class II individuals to determine whether growth trends exist.

Figure 1. A forward inclination of the middle cranial fossa (a) has a maxillary protrusive (+) effect (b). Because the maxilla is lowered relative to the condyle, the ramus is rotated dowward and backward (c) producing a retrusive effect on the mandibular corpus (d). A long vertical dimension along the posterior part of the maxilla (e) has a similar retrusive effect on the mandible. If the effects of both a vertical middle cranial fossa orientation and long vertical maxilla are combined, the rotational result on the mandible is compounded. The breadth of the pharynx (f) is established by the middle cranial fossa and bridged by the ramus, which is an architectural counterpart of the middle cranial fossa (Enlow, 1982).

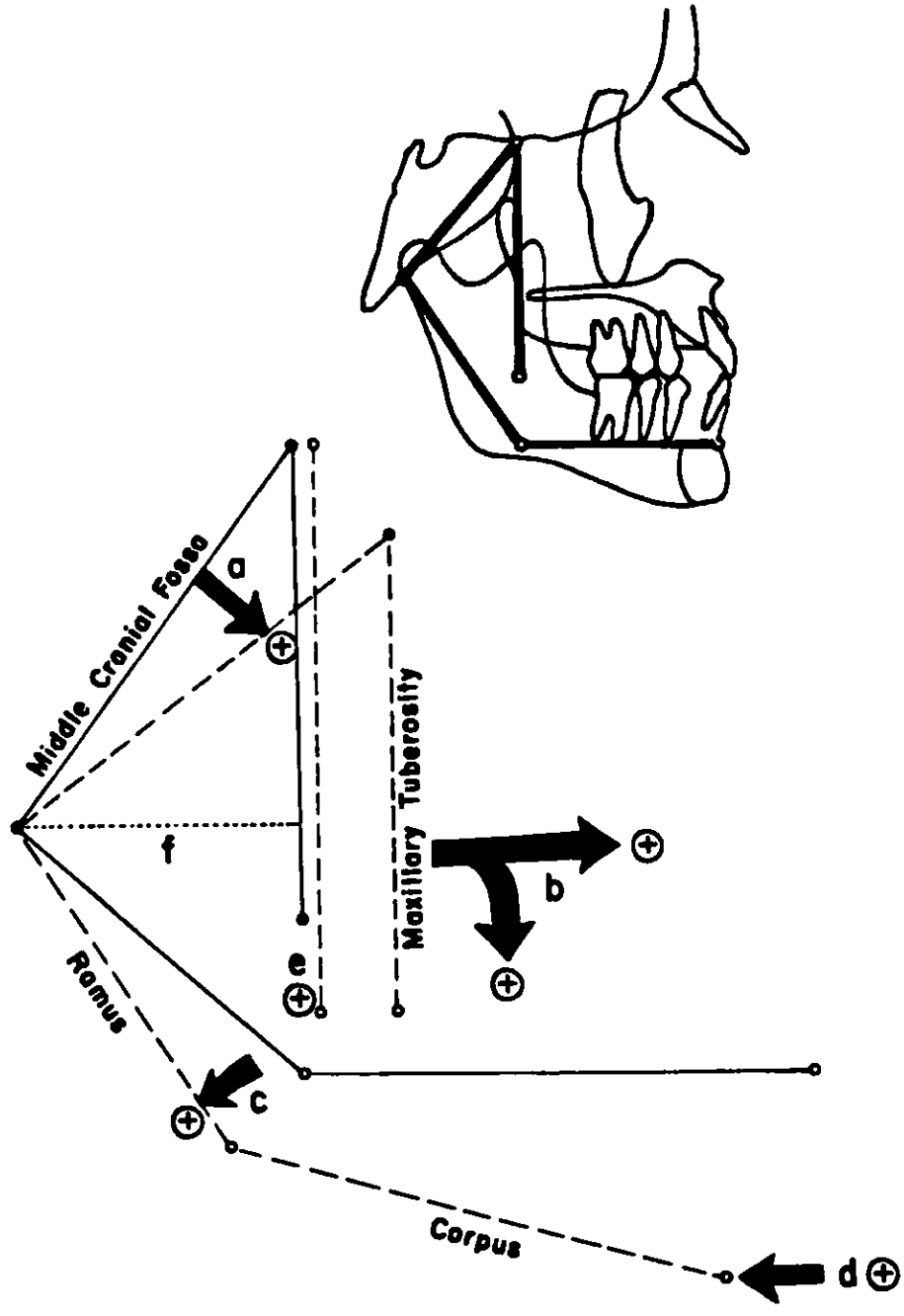
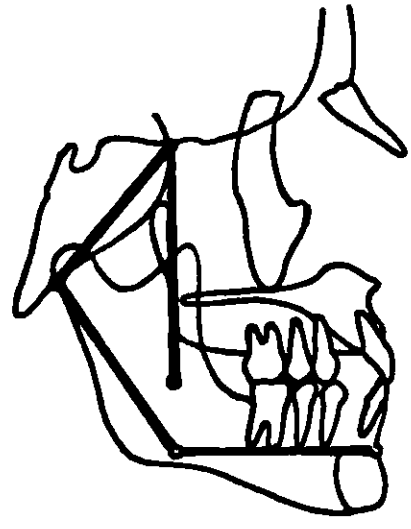

Middle Cranial Fossa
a
f
Maxillary Tuberosity
b
e
Ramus
c
Corpus
d

Figure 2. A vertical, upright orientation of the middle cranial fossa (g) has a maxillary retrusive (-) effect (h). The maxilla is raised relative to the condyle, so the ramus rotates upward and forward (j), with a protrusive effect on the mandibular corpus (k). A short vertical dimension along the posterior part of the maxilla (m) also has a protrusive effect on the mandible (Enlow, 1982).



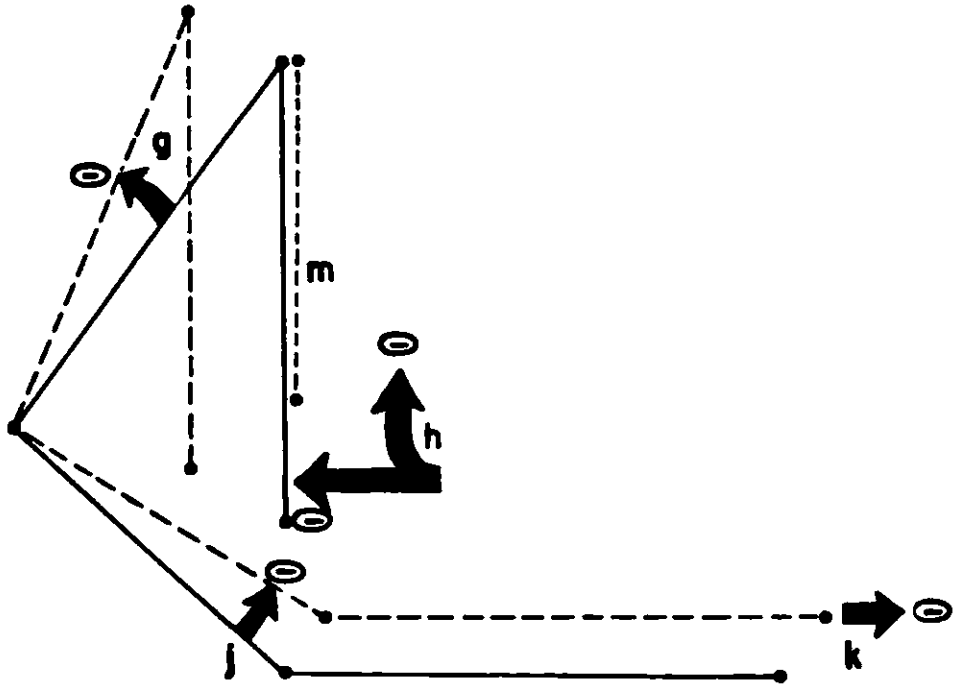

g
m
h
j
k

TABLE I

DEFINITIONS OF ANATOMIC LANDMARKS

Points	Definition
A	A point, the most posterior point on the premaxilla between anterior nasal spine and superior prosthion.
ANS	Anterior nasal spine, the forward most tip of the floor of the nose at the bimaxillary suture.
Ar	Articulare, the point at which the inferior surface of the cranial base intersects the posterior margin of the condylar neck.
ARa	Anterior ramus, the point at which the functional occlusal plane intersects the anterior margin of the ramus.
B	B point, the most posterior point on the anterior surface of the mandibular alveolar process of the central incisors.
IPr	Inferior prosthion, the point of contact of the alveolar process between the mandibular central incisors.
Go	Gonion, the intersection of the mandibular plane and a line tangent to the posterior border of the ramus.
Go (Bolton)	Gonion (Bolton), the point at which the angle of the mandible intersects a line drawn from the intersection of the mandibular plane and a line tangent to the posterior border of the ramus from articulare.
Me	Menton, the most inferior point of the symphysis of the mandible.
O	Occipital point, the inferior most point on the endocranial surface of the occpitial fossa.
Or	Orbitale, the lowest point on the inferior margin of the orbit.

TABLE I continued

Points	Definition
PNS	Posterior nasal spine, the posterior most tip of the posterior spine of the palatine bone.
PRa	Posterior ramus, the point at which the functional occlusal plane intersects the posterior margin of the ramus.
SE	Sphenoethmoidal junction, the point at which the floor of the anterior cranial fossa intersects the averaged image of the great wings of the sphenoid bone.
SPr	Superior prosthion, the point of contact of the alveolar process between the maxillary central incisors.

TABLE II

DEFINITIONS OF CEPHALOMETRIC PLANES

Points	Description
Ar to Go	The alignment of the ramus is demonstrated by the line connecting the articulare with constructed gonion.
ARa	Anterior ramus plane, demonstrated by 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, demonstrated by a straight line (disregarding any dentoalveolar curve which may be present) drawn from the most anterior maxillary-mandibular premolar contact to the most posterior maxillary-mandibular molar contact.
MCF	Middle cranial fossa, demonstrated by a line from SE to Ar.
NOA	Neutral occlusal axis, demonstrated by a dashed line drawn perpendicular to PM through the most posterior maxillary-mandibular molar contact of the last fully eruped molars.
NRa	Neutral ramus, demonstrated by a dashed line drawn from Ar to a point midway between Ar and the neutral PM line at the level of gonion.
PM	PM vertical, demonstrated by a line from SE through the averaged inferior most point of the pterygo-maxillary fissure.
PRa	Posterior ramus plane, demonstrated by the line from Ar to the intersection of FOP with the posterior border of the ramus.
REF	Reference line, demonstrated by the line from Ar parallel to FOP.

COMPARATIVE FINDINGS

Class II Classification Breakdown

The results of the counterpart analysis of the Class II untreated sample population lead to the recognition of eight groups within this general malocclusion type, as summarized in Table III. This classification system was based upon a cross-sectional evaluation of the rotational position of the middle cranial fossae, the PM vertical relationship of the nasomaxillary complex, and ramus alignment. In addition, the following anatomical measures were found to be informative in their expression for individuals within each group: maxillary and mandibular bony arch relative lengths (skeletal), A point compared with B point; the ramus/MCF horizontal dimensional (skeletal) relationship; gonial angle alignment; and the Curve of Spee measurement.

An analysis of the distribution of maxillary and mandibular protrusion effects follow in sequence for the eight groups and the individual members of each group, so as to better interpret the anatomical expression of its Class II development. Lastly, the effects of synergic or reciprocal regional compensations was appraised. The composite of these determinations led to a comprehensive accounting of the key anatomic features throughout the craniofacial complex, thereby providing an understanding of the morphologic and morphogenic roles of the various local and regional components.

TABLE III

ANALYSIS OF CLASS II INDIVIDUALS

Group	Individual	Sex	MCF/PM Alignment	PM/Ramus-MCF Relative Vertical Dimension	Ramus Alignment
1	1204	M	+	+	++
	1894	F	+	+	+
	1895	F	+	+	++
	110	F	+	+	+
2	2274	M	+	0	++
3	113	M	++	--	+
	3706	M	++	--	++
	2553	M	+	-	+
	2207	M	+	-	+
4	1051	M	+	-	0
5	2816	M	+	--	-
6	1916	F	--	++	++
	1908	F	--	++	+
	1238	M	--	++	++
	1948	M	-	+	+
	1168	M	-	+	++
	259	M	--	++	+
7	1269	F	--	+	--
8	2147	F	-	--	--
	2686	M	-	-	--

Maxillary protrusion effects are indicated by a (+), and mandibular protrusion effects are indicated by a (-). Effects that exceed 2.5 mm are represented by a (++) or (--). A neutral effect is indicated by a (0).

Group #1

The craniofacial complex of this group is characterized by a forward rotation of the cranial floor, a "long" PM vertical, and a backward rotated ramus, all features contributing to underlying Class II tendencies. The patient population comprising this group was mixed with regard to maxillary and mandibular protrusive effects for both the bony maxillary-mandibular arches and the counterpart relationship between the skeletal ramus and the middle cranial fossa. The gonial angle was closed in all but one person, thereby adding to the composite Class II effect. The nature of the Curve of Spee also reflected a maxillary protrusive effect throughout the group (Table IV).

Group #2

This group exhibited a forward flexure of the middle cranial fossa and a backward rotation of the ramus, both thus having a maxillary protrusive effect. The PM vertical expressed a neutral relationship, thereby having no effect on the aforementioned Class II characteristics. The bony maxillary arch as compared to the mandibular corpus, the gonial angle, and the Curve of Spee all added to the underlying maxillary protrusiveness of this group. The ramus-MCF (skeletal) relationship, conversely, displayed a mandibular protrusive effect (Table V).

TABLE IV

MORPHOLOGICAL EXPRESSION

GROUP #1

	Anatomical Effect	Protrusion Effect
Cranial Floor Alignment	Forward Rotation	+
PM Vertical	"Long" Vertical	+
Ramus Alignment	Backward Rotation	+
Mx-Md A/B sk		++ ++ -- -
Ramus-MCF sk		-- -- ++ +
Gonial Angle Alignment		++ + ++ 0
Curve of Spee		+ + + +

Sample Size: 4

Maxillary protrusion effects are indicated by a (+), and mandibular protrusion effects are indicated by a (-). Effects that exceed 2.5 mm are represented by a (++) or (--). A neutral effect is indicated by a (0).

TABLE V

MORPHOLOGICAL EXPRESSION

GROUP #2

	Anatomical Effect	Protrusion Effect
Cranial Floor Alignment	Forward Roatation	+
PM Vertical	"Neutral" Vertical	0
Ramus Alignment	Backward Rotation	+
Mx-Md A/B sk		+
Ramus-MCF sk		--
Gonial Angle Alignment		++
Curve of Spee		++

Sample Size: 1

Maxillary protrusion effects are indicated by a (+), and mandibular protrusion effects are indicated by a (-). Effects that exceed 2.5 mm are represented by a (++) or (--). A neutral effect is indicated by a (0).

Group #3

This group displayed a forward rotation of the middle cranial fossa and backward rotation of the ramus, both maxillary prognathic features. This was nullified somewhat by the occurrence of a "short" PM vertical relationship which is a mandibular protrusive expression. The gonial angle tended toward closure and the Curve of Spee extended above the functional plane of occlusion, both demonstrations of Class II effects. The bony maxillary and mandibular arches, when compared to the ramus-MCF measures offset each other morphologically with Class II and Class III tendencies in a reciprocal fashion (Table VI).

Group #4

This Class II facial group expressed a forward flexure of the cranial base and a "short" PM vertical, thus representing maxillary and mandibular features, respectively. The ramus-MCF (skeletal), gonial angle, and Curve of Spee displayed maxillary protrusiveness, while the bony maxillary-mandibular skeletal relationship was morphologically opposite in its effect, having a mandibular protrusive pattern (Table VII).

Group #5

This group possessed a "short" PM vertical and a forward rotation of the ramus, both mandibular protrusive expressions. Conversely, the flexure of the middle cranial fossa displayed a

TABLE VI

MORPHOLOGICAL EXPRESSION
GROUP #3

	Anatomical Effect	Protrusion Effect
Cranial Floor Alignment	Forward Rotation	+
PM Vertical	"Short" Vertical	-
Ramus Alignment	Backward Rotation	+
Mx-Md A/B sk		++ + -- -
Ramus-MCF sk		- - ++ 0
Gonial Angle Alignment		++ ++ + ++
Curve of Spee		+ + ++ ++

Sample Size: 4

Maxillary protrusion effects are indicated by a (+), and mandibular protrusion effects are indicated by a (-). Effects that exceed 2.5 mm are represented by a (++) or (--). A neutral effect is indicated by a (0).

TABLE VII

MORPHOLOGICAL EXPRESSION

GROUP #4

	Anatomical Effect	Protrusion Effect
Cranial Floor Alignment	Forward Rotation	+
PM Vertical	"Short" Vertical	-
Ramus Alignment	No Rotation	0
Mx-Md A/B sk		-
Ramus-MCF sk		++
Gonial Angle Alignment		++
Curve of Spee		++

Sample Size: 1

Maxillary protrusion effects are indicated by a (+), and mandibular protrusion effects are indicated by a (-). Effects that exceed 2.5 mm are represented by a (++) or (--). A neutral effect is indicated by a (0).

TABLE VIII

MORPHOLOGICAL EXPRESSION

GROUP #5

	Anatomical Effect	Protrusion Effect
Cranial Floor Alignment	Forward Rotation	+
PM Vertical	"Short" Vertical	-
Ramus Alignment	Forward Rotation	-
Mx-Md A/B sk		-
Ramus-MCF sk		++
Gonial Angle Alignment		++
Curve of Spee		++

Sample Size: 1

Maxillary protrusion effects are indicated by a (+), and mandibular protrusion effects are indicated by a (-). Effects that exceed 2.5 mm are represented by a (++) or (--). A neutral effect is indicated by a (0).

forward rotation. The balance of the measures gave a composite Class II tendency except for the relationship between the bony maxillary arch and the mandibular corpus, which showed mandibular prognathism (Table VIII).

Group #6

The craniofacial morphology in this group is characterized by an overall composite of regionally excessive maxillary protrusive effects, with minor reciprocal expressions. These anatomical expressions include a mandibular protrusive nature (upward flexure) of the middle cranial fossa, and in two individuals, a long mandibular arch measure. In one individual, a wide ramus relationship was demonstrated. The remaining four relationships exclusively displayed maxillary prognathism (Table IX).

Group #7

This group has five of the seven comparisons having a maxillary protrusive effect. However, the flexure of the middle cranial fossa was a Class III expression (upward and backward), and the ramus alignment forward. These two features consequently tend to offset the other effects subduing the overall Class II morphology of the face (Table X).

Group #8

The craniofacial combination in this group displays mandibular protrusive effects through an upward and backward

TABLE IX

MORPHOLOGICAL EXPRESSION

Group #6

	Anatomical Effect	Protrusion Effect
Cranial Floor Alignment	Backward Rotation	-
PM Vertical	"Long" Vertical	+
Ramus Alignment	Backward Rotation	+
Mx-Md A/B sk		++ + ++ ++ - -
Ramus-MCF sk		+ + ++ - ++ ++
Gonial Angle Alignment		++ ++ ++ ++ + ++
Curve of Spee		+ + ++ ++ ++ ++

Sample Size: 6

Maxillary protrusion effects are indicated by a (+), and mandibular protrusion effects are indicated by a (-). Effects that exceed 2.5 mm are represented by a (++) or (--). A neutral effect is indicated by a (0).

TABLE X

MORPHOLOGICAL EXPRESSION

Group #7

	Anatomical Effect	Protrusion Effect
Cranial Floor Alignment	Backward Rotation	-
PM Vertical	"Long" Vertical	+
Ramus Alignment	Forward Rotation	-
Mx-Md A/B sk		++
Ramus-MCF sk		+
Gonial Angle Alignment		++
Curve of Spee		++

Sample Size: 1

Maxillary protrusion effects are indicated by a (+), and mandibular protrusion effects are indicated by a (-). Effects that exceed 2.5 mm are represented by a (++) or (--). A neutral effect is indicated by a (0).

TABLE XI

MORPHOLOGICAL EXPRESSION

Group #8

	Anatomical Effect	Protrusion Effect
Cranial Floor Alignment	Backward Rotation	-
PM Vertical	"Short" Vertical	-
Ramus Alignment	Forward Rotation	-
Mx-Md A/B sk		++ +
Ramus-MCF sk		++ +
Gonial Angle Alignment		++ --
Curve of Spee		++ +

Sample Size: 2

Maxillary protrusion effects are indicated by a (+), and mandibular protrusion effects are indicated by a (-). Effects that exceed 2.5 mm are represented by a (++) or (--). A neutral effect is indicated by a (0).

cranial base flexure, a "short" PM vertical, and a forward rotation of the ramus. The balance of the anatomical measures analyzed were expressions of maxillary prognathism. The only exception to this was an open gonial angle in one individual (Table XI).

Tables XII through XIX display the synergic or reciprocal effects that any one given anatomical expression may have on another (Enlow et al., 1971). As the nature and severity of an anatomic composite is not only influenced by the independent measures, the intrinsic offsetting ("compensating") effects are important in understanding the cumulative pattern of regional protrusive effects to derive the "total picture". Of the 17 relationships studied, four demonstrated significance when compared cross-sectionally among the 8 Class II groups in that a definite pattern was established. These were:

MCF Alignment/PM Vertical Dimension

Five of the groups displayed a reciprocal effect when comparing the anatomic effects between middle cranial fossa flexure and the PM vertical dimension. In essence, these combinations tended to neutralize all or in part, any structural direction toward maxillary or mandibular protrusiveness.

MCF Alignment/Curve of Spee

Five of the Class II groups demonstrated a synergic

maxillary protrusive effect. Anatomically, this means that the cranial base flexure occurred in a forward manner while the Curve of Spee placed the mandibular incisors superior to the functional occlusal plane. As both of these morphological characteristics relate to maxillary prognathism, their overall expression was cumulative.

Ramus Alignment/Curve of Spee

In this relationship, five groups displayed a maxillary protrusive synergic effect. The ramus has rotated in a clockwise manner expressing a consequent mandibular retrusive effect. Likewise, the Curve of Spee demonstrated a Class II tendency, therefore exhibiting another cumulative mandibular retrusive relationship.

PM Vertical Dimension/Curve of Spee

This analysis shows that five groups displayed a reciprocal neutralizing effect resulting in a composite, compensatory anatomical result. This expression neither leads to or detracts from a Class II morphological facial pattern.

As four of the seven anatomical relationships were individualized for the patient population (Tables IV-XI), many of the synergic/reciprocal effects were mixed, yielding an overall protrusive result for each individual summarixed in Tables XII through XIX. A "neutral effect" or "NE" relates to a comparison in which

TABLE XII

SYNERGIC/RECIPROCAL EFFECTS

GROUP #1

Anatomical Relationship	Synergic/Reciprocal	Protrusion Effect
MCF Alignment/Ramus Alignment	Synergic	+
MCF Alignment/Ramus-MCF Dimensions, Skeletal	Mix	0 0 + +
MCF Alignment/A-B Skeletal Arch Dimension	Synergic	+ + 0 0
MCF Alignment/PM Vertical Dimension	Synergic	+
Ramus-MCF Skeletal Dimension/Ramus Alignment	Mix	0 0 + +
Ramus Alignment/A-B Skeletal Arch Dimension	Mix	+ + 0 0
Ramus Alignment/PM Vertical Dimension	Synergic	+
Ramus-MCF Skeletal Dimension/PM Vertical Dimension	Mix	0 0 + +
A-B Skeletal Arch Dimensions/PM Vertical Dimension	Mix	+ + 0 0
MCF Alignment/ Curve of Spee	Synergic	+
Ramus Alignment/ Curve of Spee	Synergic	+
A-B Skeletal Arch Dimension/Curve of Spee	Mix	+ + 0 0

TABLE XII continued

Anatomical Relationship	Synergic/Reciprocal	Protrusion Effect
PM Vertical Dimension/ Curve of Spee	Synergic	+
MCF Alignment/ Gonial Angle Alignment	Mix	+ + + NE
Ramus Alignment/ Gonial Angle Alignment	Mix	+ + + NE
A-B Skeletal Arch Dimension/Gonial Angle Alignment	Mix	+ + 0 NE
PM Vertical Dimension/ Gonial Angle Alignment	Mix	+ + + NE

Maxillary protrusion effects are indicated by a (+), and mandibular protrusion effects are indicated by a (-). Neutral effects are indicated by a (0). A neutral effect, where one or both of the measures were neutral, is indicated by a (NE). A synergic effect is one which augments an expression and a reciprocal effect is one which neutralizes an expression. A combination of both synergic and reciprocal effects is indicated by a (MIX).

TABLE XIII

SYNERGIC/RECIPROCAL EFFECTS

GROUP #2

Anatomical Relationship	Synergic/Reciprocal	Protrusion Effect
MCF Alignment/Ramus Alignment	Synergic	+
MCF Alignment/Ramus-MCF Dimensions, Skeletal	Reciprocal	0
MCF Alignment/A-B Skeletal Arch Dimension	Synergic	+
MCF Alignment/PM Vertical Dimension	Neutral Effect	NE
Ramus-MCF Skeletal Dimension/Ramus Alignment	Reciprocal	0
Ramus Alignment/A-B Skeletal Arch Dimension	Synergic	+
Ramus Alignment/PM Vertical Dimension	Neutral Effect	NE
Ramus-MCF Skeletal Dimension/PM Vertical Dimension	Neutral Effect	NE
A-B Skeletal Arch Dimensions/PM Vertical Dimension	Neutral Effect	NE
MCF Alignment/ Curve of Spee	Synergic	+
Ramus Alignment/ Curve of Spee	Synergic	+
A-B Skeletal Arch Dimension/Curve of Spee	Synergic	+

TABLE XIII continued

Anatomical Relationship	Synergic/Reciprocal	Protrusion Effect
PM Vertical Dimension/ Curve of Spee	Neutral Effect	NE
MCF Alignment/ Gonial Angle Alignment	Synergic	+
Ramus Alignment/ Gonial Angle Alignment	Synergic	+
A-B Skeletal Arch Dimension/Gonial Angle Alignment	Synergic	+
PM Vertical Dimension/ Gonial Angle Alignment	Neutral Effect	NE

Maxillary protrusion effects are indicated by a (+), and mandibular protrusion effects are indicated by a (-). Neutral effects are indicated by a (0). A neutral effect, where one or both of the measures were neutral, is indicated by a (NE). A synergic effect is one which augments an expression and a reciprocal effect is one which neutralizes an expression. A combination of both synergic and reciprocal effects is indicated by a (MIX).

TABLE XIV

SYNERGIC/RECIPROCAL EFFECTS

GROUP #3

Anatomical Relationship	Synergic/Reciprocal	Protrusion Effect
MCF Alignment/Ramus Alignment	Synergic	+
MCF Alignment/Ramus-MCF Dimensions, Skeletal	Mix	0 0 + NE
MCF Alignment/A-B Skeletal Arch Dimension	Mix	+ + 0 0
MCF Alignment/PM Vertical Dimension	Reciprocal	0
Ramus-MCF Skeletal Dimension/Ramus Alignment	Mix	0 0 + NE
Ramus Alignment/A-B Skeletal Arch Dimension	Mix	+ + 0 0
Ramus Alignment/PM Vertical Dimension	Reciprocal	0
Ramus-MCF Skeletal Dimension/PM Vertical Dimension	Mix	- - 0 NE
A-B Skeletal Arch Dimensions/PM Vertical Dimension	Mix	0 0 - -
MCF Alignment/ Curve of Spee	Synergic	+
Ramus Alignment/ Curve of Spee	Synergic	+
A-B Skeletal Arch Dimension/Curve of Spee	Mix	+ + 0 0

TABLE XIV continued

Anatomical Relationship	Synergic/Reciprocal	Protrusion Effect
PM Vertical Dimension/ Curve of Spee	Reciprocal	0 0 0 0
MCF Alignment/ Gonial Angle Alignment	Synergic	+
Ramus Alignment/ Gonial Angle Alignment	Synergic	+
A-B Skeletal Arch Dimension/Gonial Angle Alignment	Mix	+ + 0 0
PM Vertical Dimension/ Gonial Angle Alignment	Reciprocal	0

Maxillary protrusion effects are indicated by a (+), and mandibular protrusion effects are indicated by a (-). Neutral effects are indicated by a (0). A neutral effect, where one or both of the measures were neutral, is indicated by a (NE). A synergic effect is one which augments an expression and a reciprocal effect is one which neutralizes an expression. A combination of both synergic and reciprocal effects is indicated by a (MIX).

TABLE XV

SYNERGIC/RECIPROCAL EFFECTS

GROUP #4

Anatomical Relationship	Synergic/Reciprocal	Protrusion Effect
MCF Alignment/Ramus Alignment	Neutral Effect	NE
MCF Alignment/Ramus-MCF Dimensions, Skeletal	Synergic	+
MCF Alignment/A-B Skeletal Arch Dimension	Reciprocal	0
MCF Alignment/PM Vertical Dimension	Reciprocal	0
Ramus-MCF Skeletal Dimension/Ramus Alignment	Neutral Effect	NE
Ramus Alignment/A-B Skeletal Arch Dimension	Neutral Effect	NE
Ramus Alignment/PM Vertical Dimension	Neutral Effect	NE
Ramus-MCF Skeletal Dimension/PM Vertical Dimension	Reciprocal	0
A-B Skeletal Arch Dimensions/PM Vertical Dimension	Synergic	-
MCF Alignment/ Curve of Spee	Synergic	+
Ramus Alignment/ Curve of Spee	Neutral Effect	NE
A-B Skeletal Arch Dimension/Curve of Spee	Reciprocal	0

TABLE XV continued

Anatomical Relationship	Synergic/Reciprocal	Protrusion Effect
PM Vertical Dimension/ Curve of Spee	Reciprocal	0
MCF Alignment/ Gonial Angle Alignment	Synergic	+
Ramus Alignment/ Gonial Angle Alignment	Neutral Effect	NE
A-B Skeletal Arch Dimension/Gonial Angle Alignment	Reciprocal	0
PM Vertical Dimension/ Gonial Angle Alignment	Reciprocal	0

Maxillary protrusion effects are indicated by a (+), and mandibular protrusion effects are indicated by a (-). Neutral effects are indicated by a (0). A neutral effect, where one or both of the measures were neutral, is indicated by a (NE). A synergic effect is one which augments an expression and a reciprocal effect is one which neutralizes an expression. A combination of both synergic and reciprocal effects is indicated by a (MIX).

TABLE XVI

SYNERGIC/RECIPROCAL EFFECTS

GROUP #5

Anatomical Relationship	Synergic/Reciprocal	Protrusion Effect
MCF Alignment/Ramus Alignment	Reciprocal	0
MCF Alignment/Ramus-MCF Dimensions, Skeletal	Synergic	+
MCF Alignment/A-B Skeletal Arch Dimension	Reciprocal	0
MCF Alignment/PM Vertical Dimension	Reciprocal	0
Ramus-MCF Skeletal Dimension/Ramus Alignment	Reciprocal	0
Ramus Alignment/A-B Skeletal Arch Dimension	Synergic	-
Ramus Alignment/PM Vertical Dimension	Synergic	-
Ramus-MCF Skeletal Dimension/PM Vertical Dimension	Reciprocal	0
A-B Skeletal Arch Dimensions/PM Vertical Dimension	Synergic	-
MCF Alignment/ Curve of Spee	Synergic	+
Ramus Alignment/ Curve of Spee	Reciprocal	0
A-B Skeletal Arch Dimension/Curve of Spee	Reciprocal	0

TABLE XVI continued

Anatomical Relationship	Synergic/Reciprocal	Protrusion Effect
PM Vertical Dimension/ Curve of Spee	Reciprocal	0
MCF Alignment/ Gonial Angle Alignment	Synergic	+
Ramus Alignment/ Gonial Angle Alignment	Reciprocal	0
A-B Skeletal Arch Dimension/Gonial Angle Alignment	Reciprocal	0
PM Vertical Dimension/ Gonial Angle Alignment	Reciprocal	0

Maxillary protrusion effects are indicated by a (+), and mandibular protrusion effects are indicated by a (-). Neutral effects are indicated by a (0). A neutral effect, where one or both of the measures were neutral, is indicated by a (NE). A synergic effect is one which augments an expression and a reciprocal effect is one which neutralizes an expression. A combination of both synergic and reciprocal effects is indicated by a (MIX).

TABLE XVII

SYNERGIC/RECIPROCAL EFFECTS

Group #6

Anatomical Relationship	Synergic/Reciprocal	Protrusion Effect
MCF Alignment/Ramus Alignment	Reciprocal	0
MCF Alignment/Ramus-MCF Dimensions, Skeletal	Mix	0 0 0 - 0 0
MCF Alignment/A-B Skeletal Arch Dimension	Mix	0 0 0 0 - -
MCF Alignment/PM Vertical Dimension	Reciprocal	0
Ramus-MCF Skeletal Dimension/Ramus Alignment	Mix	+ + + 0 + +
Ramus Alignment/A-B Skeletal Arch Dimension	Mix	+ + + + 0 0
Ramus Alignment/PM Vertical Dimension	Synergic	+
Ramus-MCF Skeletal Dimension/PM Vertical Dimension	Mix	+ + + 0 + +
A-B Skeletal Arch Dimensions/PM Vertical Dimension	Mix	+ + + + 0 0
MCF Alignment/ Curve of Spee	Reciprocal	0
Ramus Alignment/ Curve of Spee	Synergic	+
A-B Skeletal Arch Dimension/Curve of Spee	Mix	+ + + + 0 0

TABLE XVII continued

Anatomical Relationship	Synergic/Reciprocal	Protrusion Effect
PM Vertical Dimension/ Curve of Spee	Synergic	+
MCF Alignment/ Gonial Angle Alignment	Reciprocal	0
Ramus Alignment/ Gonial Angle Alignment	Synergic	+
A-B Skeletal Arch Dimension/Gonial Angle Alignment	Mix	+ + + + 0 0
PM Vertical Dimension/ Gonial Angle Alignment	Synergic	+

Maxillary protrusion effects are indicated by a (+), and mandibular protrusion effects are indicated by a (-). Neutral effects are indicated by a (0). A neutral effect, where one or both of the measures were neutral, is indicated by a (NE). A synergic effect is one which augments an expression and a reciprocal effect is one which neutralizes an expression. A combination of both synergic and reciprocal effects is indicated by a (MIX).

TABLE XVIII

SYNERGIC/RECIPROCAL EFFECTS

Group #7

Anatomical Relationship	Synergic/Reciprocal	Protrusion Effect
MCF Alignment/Ramus Alignment	Synergic	-
MCF Alignment/Ramus-MCF Dimensions, Skeletal	Reciprocal	0
MCF Alignment/A-B Skeletal Arch Dimension	Reciprocal	0
MCF Alignment/PM Vertical Dimension	Reciprocal	0
Ramus-MCF Skeletal Dimension/Ramus Alignment	Reciprocal	0
Ramus Alignment/A-B Skeletal Arch Dimension	Reciprocal	0
Ramus Alignment/PM Vertical Dimension	Reciprocal	0
Ramus-MCF Skeletal Dimension/PM Vertical Dimension	Synergic	+
A-B Skeletal Arch Dimensions/PM Vertical Dimension	Synergic	+
MCF Alignment/ Curve of Spee	Reciprocal	0
Ramus Alignment/ Curve of Spee	Reciprocal	0
A-B Skeletal Arch Dimension/Curve of Spee	Synergic	+

TABLE XVIII continued

Anatomical Relationship	Synergic/Reciprocal	Protrusion Effect
PM Vertical Dimension/ Curve of Spee	Synergic	+
MCF Alignment/ Gonial Angle Alignment	Reciprocal	0
Ramus Alignment/ Gonial Angle Alignment	Reciprocal	0
A-B Skeletal Arch Dimension/Gonial Angle Alignment	Synergic	+
PM Vertical Dimension/ Gonial Angle Alignment	Synergic	+

Maxillary protrusion effects are indicated by a (+), and mandibular protrusion effects are indicated by a (-). Neutral effects are indicated by a (0). A neutral effect, where one or both of the measures were neutral, is indicated by a (NE). A synergic effect is one which augments an expression and a reciprocal effect is one which neutralizes an expression. A combination of both synergic and reciprocal effects is indicated by a (MIX).

TABLE XIX

SYNERGIC/RECIPROCAL EFFECTS

Group #8

Anatomical Relationship	Synergic/Reciprocal	Protrusion Effect
MCF Alignment/Ramus Alignment	Synergic	-
MCF Alignment/Ramus-MCF Dimensions, Skeletal	Reciprocal	0
MCF Alignment/A-B Skeletal Arch Dimension	Reciprocal	0
MCF Alignment/PM Vertical Dimension	Synergic	-
Ramus-MCF Skeletal Dimension/Ramus Alignment	Reciprocal	0
Ramus Alignment/A-B Skeletal Arch Dimension	Reciprocal	0
Ramus Alignment/PM Vertical Dimension	Synergic	-
Ramus-MCF Skeletal Dimension/PM Vertical Dimension	Reciprocal	0
A-B Skeletal Arch Dimensions/PM Vertical Dimension	Reciprocal	0
MCF Alignment/ Curve of Spee	Reciprocal	0
Ramus Alignment/ Curve of Spee	Reciprocal	0
A-B Skeletal Arch Dimension/Curve of Spee	Synergic	+

TABLE XIX continued

Anatomical Relationship	Synergic/Reciprocal	Protrusion Effect
PM Vertical Dimension/ Curve of Spee	Reciprocal	0
MCF Alignment/ Gonial Angle Alignment	Mix	0 -
Ramus Alignment/ Gonial Angle Alignment	Mix	0 -
A-B Skeletal Arch Dimension/Gonial Angle Alignment	Mix	+ 0
PM Vertical Dimension/ Gonial Angle Alignment	Mix	0 -

Maxillary protrusion effects are indicated by a (+), and mandibular protrusion effects are indicated by a (-). Neutral effects are indicated by a (0). A neutral effect, where one or both of the measures were neutral, is indicated by a (NE). A synergic effect is one which augments an expression and a reciprocal effect is one which neutralizes an expression. A combination of both synergic and reciprocal effects is indicated by a (MIX).

one or both of the measurements had a neutral (0) measure itself. Consequently, it would have no effect, when related to another part or counterpart, on the morphological expression of anatomic features.

Frequency Distributions for Anatomical Relationships

Just as a classification system was used to group more meaningfully the Class II population, the same system was used to study the Class II individual serially. The incidence and distribution of maxillary and mandibular protrusive effects for these individuals is summarized in Tables XX through XXVI.

Middle Cranial Floor Alignment

The nature of the flexure of the middle cranial fossa was a fairly constant relationship serially. There was a forward flexure in most of the cases (52.9%) at age 3, again at age 6-12 (52.6%), and over 16 years old (52.3%). There was a lesser maxillary protrusive effect at age 6 (38.1%) and greater incidence of Class II rotation at age 12-16 (71.4%) (Table XX).

PM Compared with Ramus/MCF Vertical Relationship

In this relationship, there was an overall increase in maxillary prognathism serially, though the PM vertical was "short" until the age group greater than 16. There is a marked increase from age 3 (23.6%) to age 6 (42.9%) in the PM vertical effective measure. By age 6-12 however, the maxillary protrusive effect

TABLE XX

MIDDLE CRANIAL FOSSA (MCF) RELATIVE ALIGNMENT

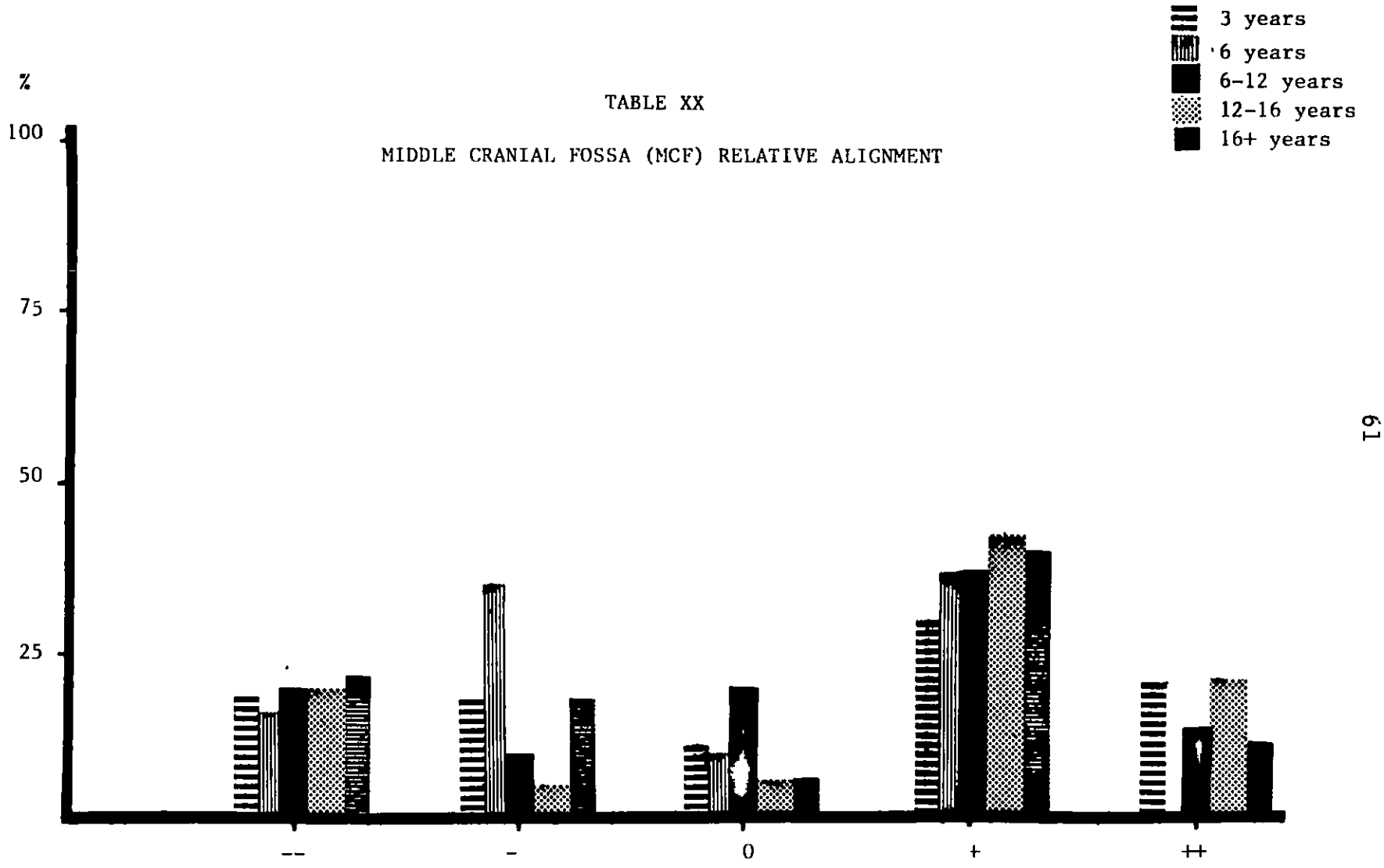
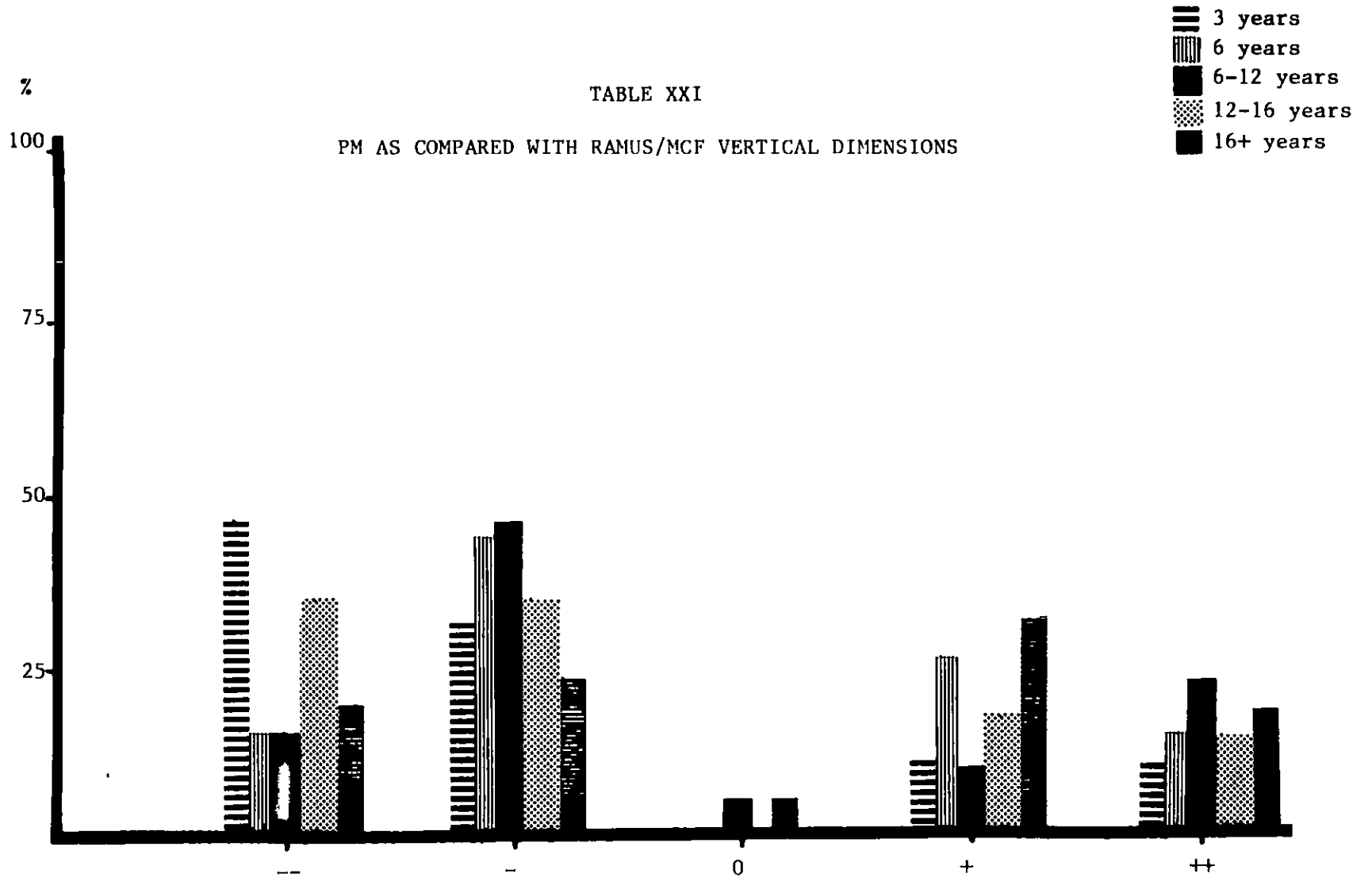


TABLE XXI

PM AS COMPARED WITH RAMUS/MCF VERTICAL DIMENSIONS



drops to 33% but then again increases in incidence. This would be expected in normal midfacial growth and relates well with the serial effects of the ramal alignment (Table XXI).

Ramal Alignment

A backward rotation of the ramus contributing to a maxillary protrusive effect increased serially except for a drop from age 6-12 (76.2%) to age 12-16 (66.7%). By age 16, the backward rotation of the ramus was again 76.2%. This uprighting of the ramus would be expected to exist in a serial study as a partial compensation for the increasing vertical expression of the naso-maxillary complex, alveolar tissue, and eruption of permanent teeth. The increase at age 6 correlates with an increase in PM vertical at the same age (Table XXII).

Maxillary/Mandibular Arches, Skeletal, A Point Compared with B Point

The highest incidence is at age 6 (66.7%) where an increase in effective horizontal length would be expected with the eruption of the first molars. Though it drops at age 6-12 (52.5%), every other serial comparison shows an increase in the extent of the maxillary prognathic effect longitudinally (Table XXIII).

Ramus/MCF Horizontal Dimension (Skeletal) Relationship

This analysis shows a somewhat steady increase in a Class

TABLE XXII

RAMUS ALIGNMENT

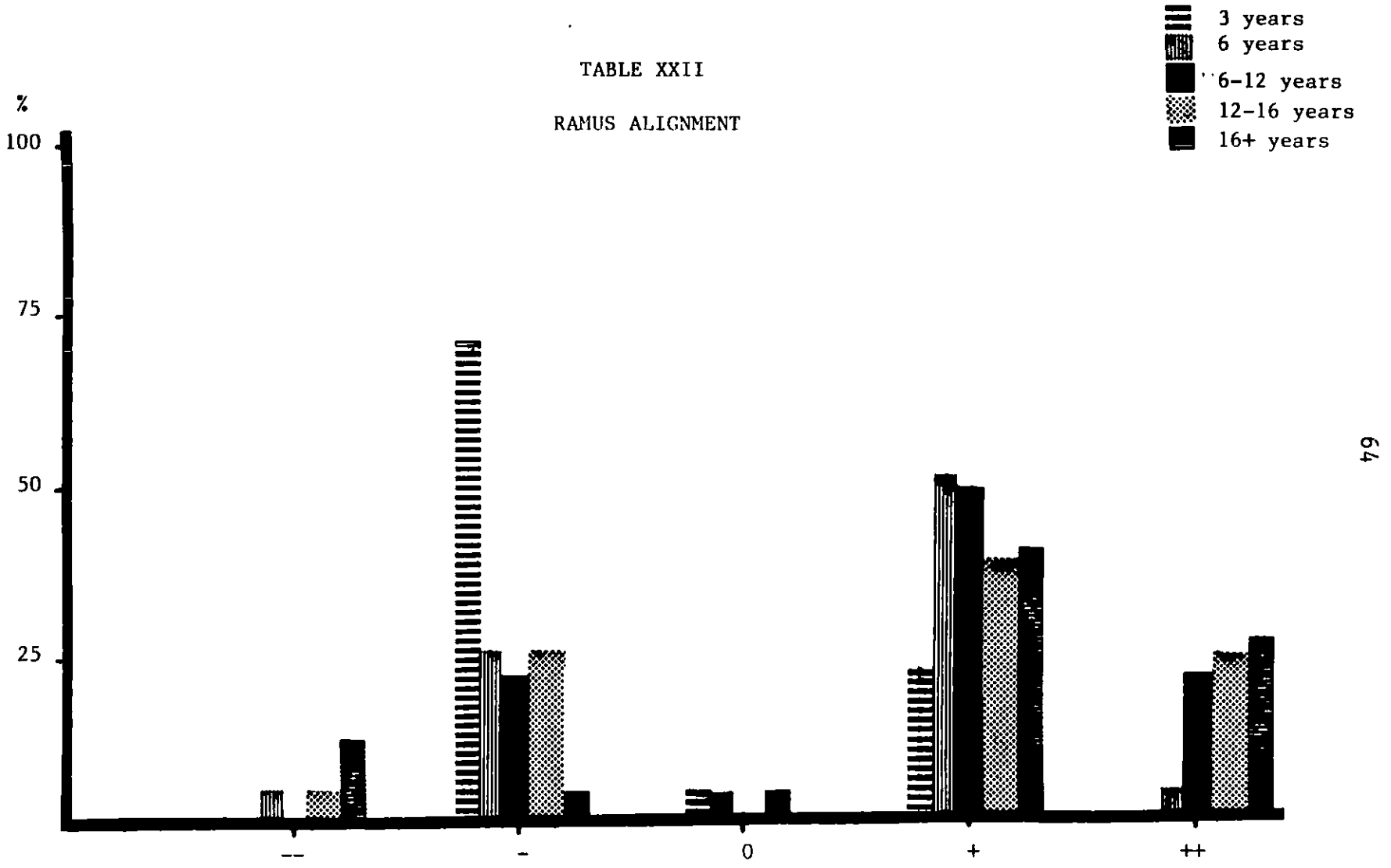


TABLE XXIII

MAXILLARY/MANDIBULAR ARCHES, SKELETAL DIMENSIONS,

A POINT COMPARED WITH B POINT

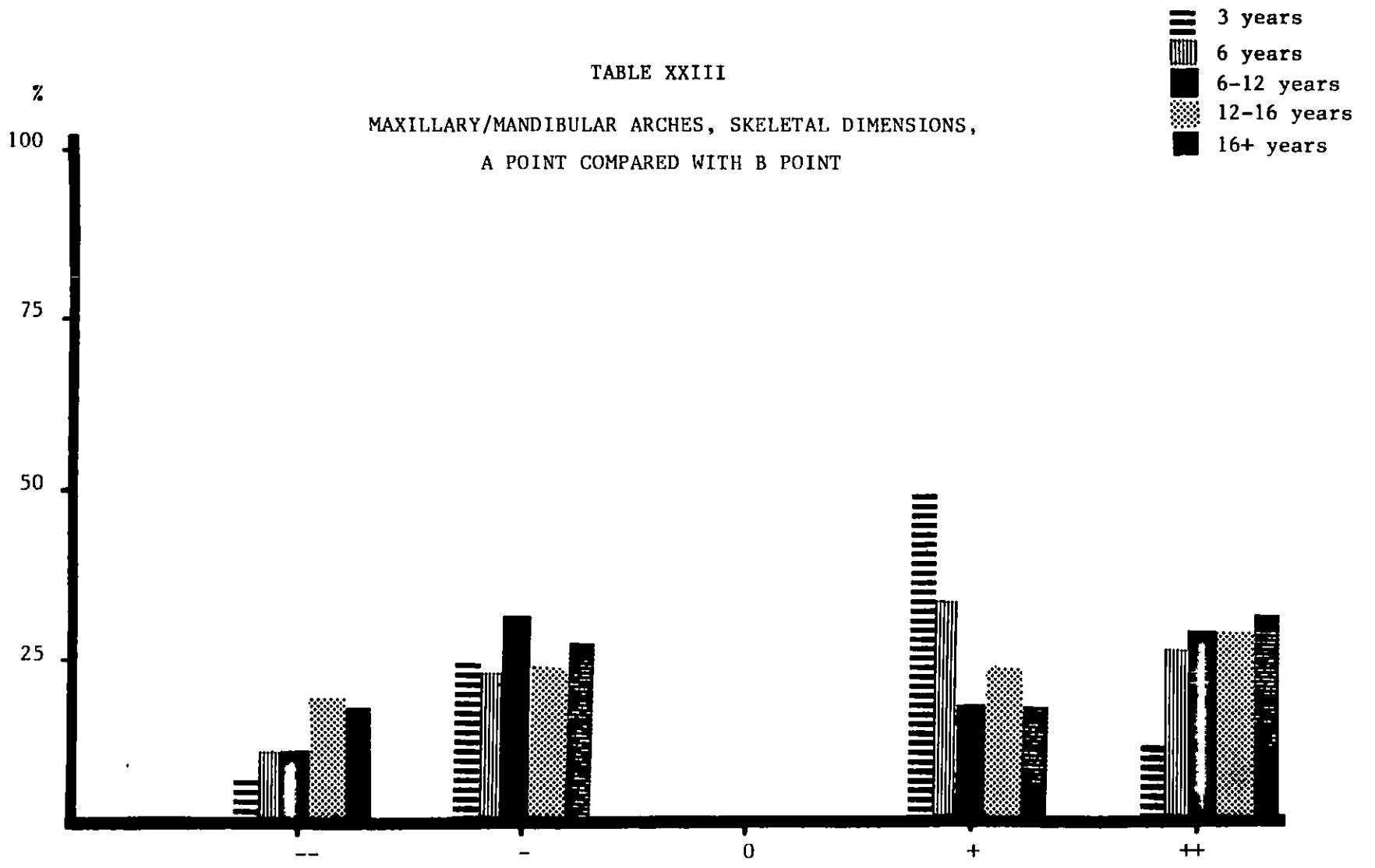
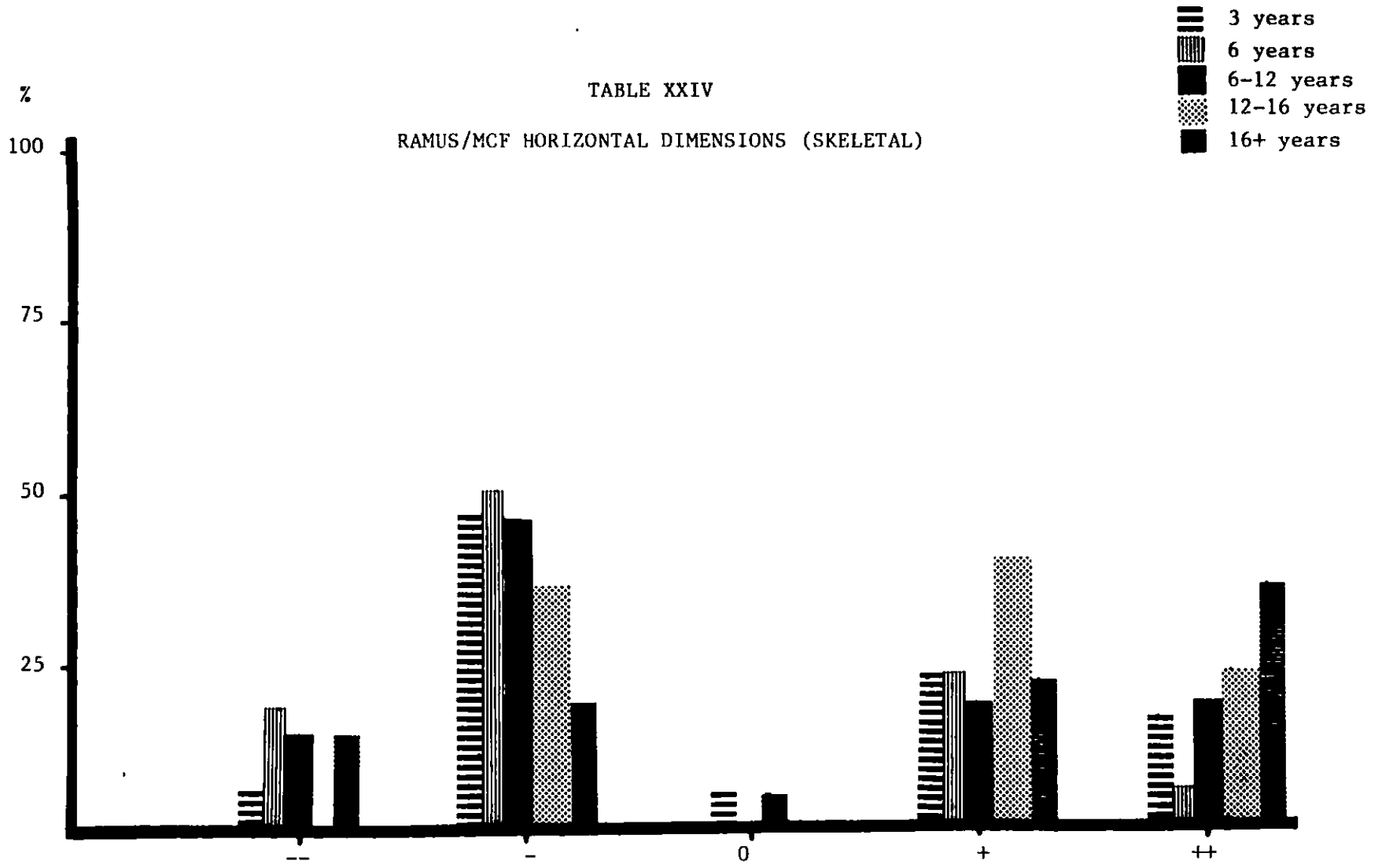


TABLE XXIV

RAMUS/MCF HORIZONTAL DIMENSIONS (SKELETAL)



II morphological tendency serially, but with a major drop in the incidence of a maxillary protrusive effect from age 3 (41.1%) to age 6 (28.7%). There is another minor drop from age 12-16 (66.8%) to the age above 16 (62.0%). Nonetheless, a protrusive nature exists with the horizontal skeletal dimension of the middle cranial floor being greater than its counterpart, the skeletal ramus. Possibly, the increase in mandibular prognathism at age 6 is related to the bony maxillary arch growth spurt in a reciprocal fashion to help offset the facial imbalances already existing (Table XXIV).

Gonial Angle Alignment

The gonial angle alignment analyzes the angle formed at the junction of the ramus and the corpus of the mandible. As Enlow (1971) stated, the gonial angle normally decreases in conjunction with the uprighting of the ramus. This was well documented in the sample population with the mandibular retrusive nature (superior rotation) increasing steadily from age 3 (58.8%) to 90.4% by age 16. There was a slight drop at age 12-16, but the incidence of a mandibular retrusive effect still remained evident at 66.9% (Table XXV).

Curve of Spee

The Curve of Spee expresses a positional relationship between the mandibular anterior teeth and the functional occlusal

TABLE XXV

GONIAL ANGLE ALIGNMENT

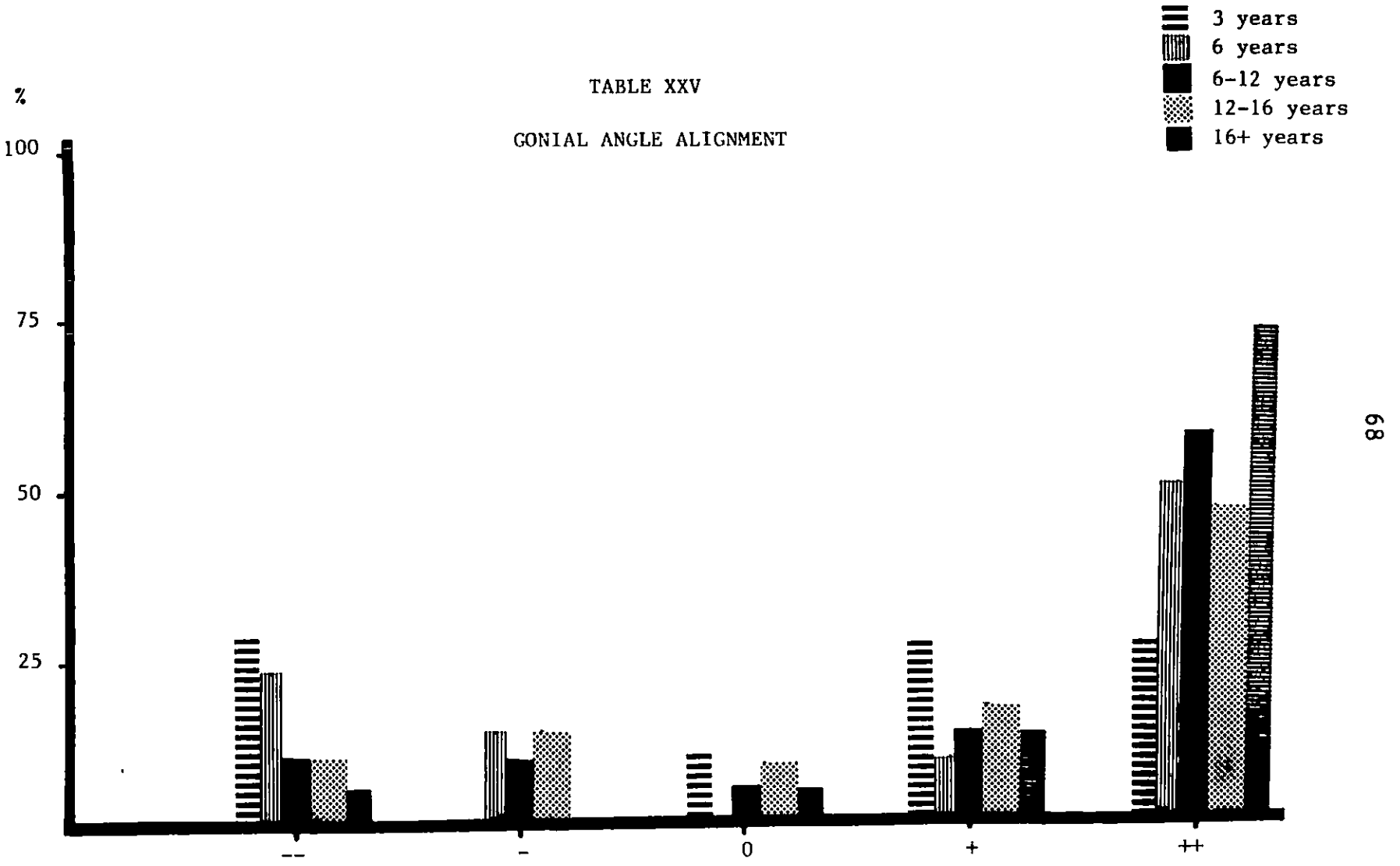
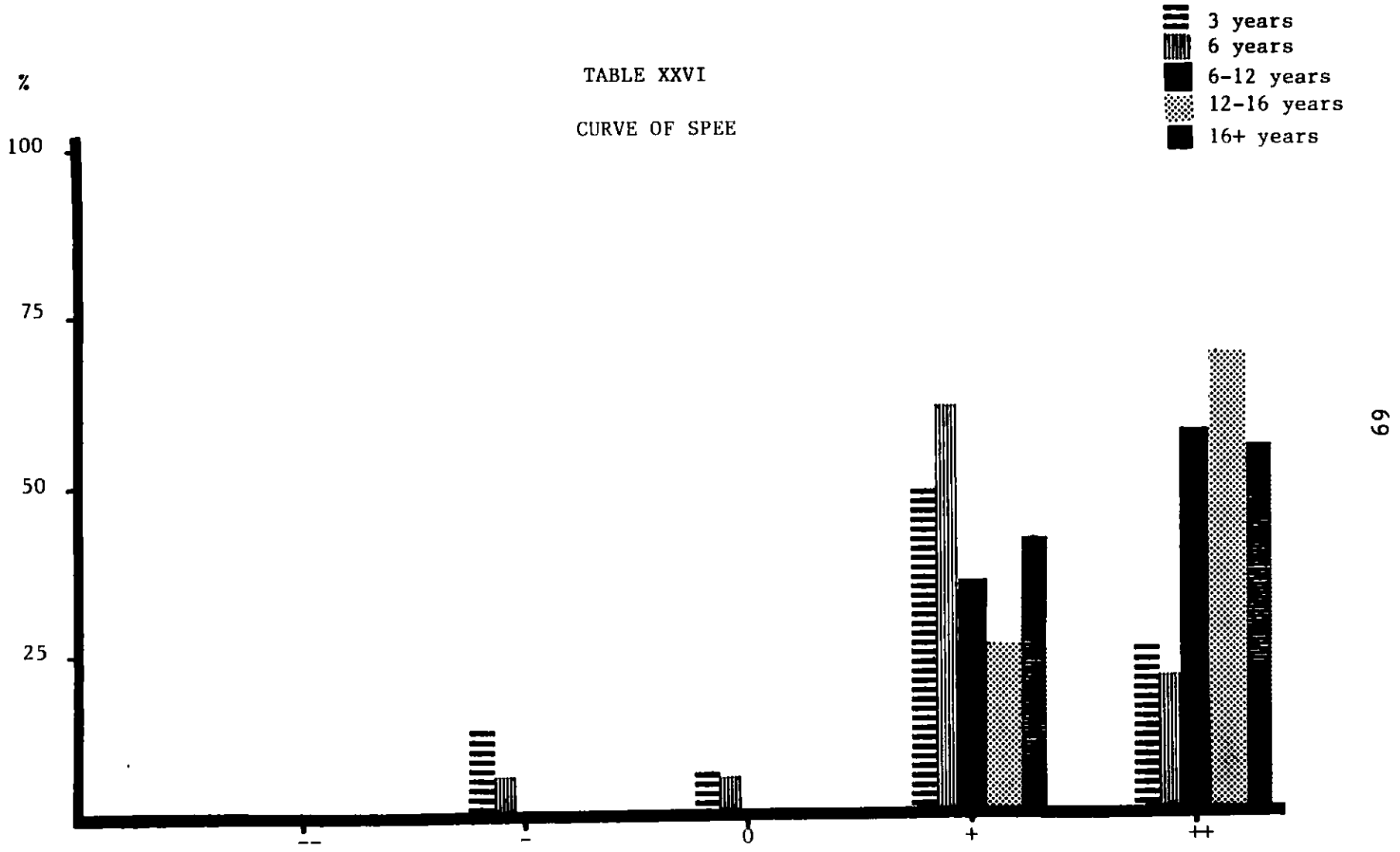


TABLE XXVI

CURVE OF SPEE



plane. In all five age groups, the great majority of the sample population exhibited a mandibular retrusive type of relationship, with the mandibular incisors being superior to that reference plane. The lowest incidence (82.4%) of the maxillary protrusive effect existed at age 3 but quickly increased and stabilized at 100% by age 6-12. This marked Class II tendency combines in a cumulative synergic relationship along with other Class II tendencies, such as a forward middle cranial fossa flexure and a backward aligned ramus. The deepening Curve of Spee provides a dental compensation that precludes the development of an anterior open bite (Enlow et al., 1982) (Table XXVI).

Development of a Prediction Pattern

The frequency distributions just described showed a predilection toward greater mandibular retrusion (Class II effect) serially with age. For an anatomically more specific prediction scheme, the 20 individuals comprising the 8 Class II groups were serially analyzed for combinations of each person's 7 measurements. This avoided the need for the use of population histograms and allowed more personalized trends to be recognized. The trends that were identified were as follows:

1. A maxillary protrusive (+) trend is one in which the measurements indicate a greater maxillary prognathic (or mandibular retrusive) expression with age.

2. A maxillary retrusive (or mandibular protrusive) (-) trend is one in which the measurements indicate a greater mandibular prognathic expression with age.

The middle cranial floor flexure analysis demonstrated a maxillary protrusive (+) trend for four individuals and a mandibular protrusive (-) trend for four individuals. The PM vertical dimension was more significant with 5 individuals expressing a maxillary protrusive (+) trend and one individual the converse. The ramus alignment was quite interesting with 14 individuals displaying a (+) response serially and two a (-) response. The maxillary-mandibular skeletal comparisons at A and B points demonstrated a maxillary protrusive (+) trend in 7 individuals and mandibular protrusive (-) trend in four individuals.

The MCF/ramus horizontal dimension relationship (skeletal) seemed pertinent in that there were 12 (+) trends and four (-) trends established. Lastly, the gonial angle alignment developed into a maxillary protrusive (+) trend for 11 individuals and a mandibular protrusive (-) trend for one person. Any difference from the number of trends found and the total sample size (20) was due to the fact that the remainder of the patients were either so mixed (having both maxillary and mandibular protrusive effects), or so stable that no significant serial change in prognathism could be established in either direction.

When comparing the 7 frequency distributions of anatomic features between the Class II and Class III sample populations (Pfister, 1983), however, the trends previously discussed were found to have little value for purposes of prediction. With this

data, an estimation of error was developed for each of the anatomical measurements, with the following results:

Maxillary/mandibular arches, skeletal, A point compared with B point--23%

Gonial angle alignment--24%

Ramus alignment--28%

Curve of Spee--29%

Middle cranial floor alignment--40%

PM compared with ramus/MCF vertical dimension--46%

Ramus/MCF horizontal dimension relationship (skeletal)--49%.

Therefore, the skeletal measurements used were quite adequate for describing subsets of the Class II malocclusion morphogically, as they represented the best geometrical expressions of the craniofacial complex. They could not, however, be utilized singly as a means for predicting a malocclusion. In order to become a tool of great predictive efficacy, more study is now needed to find a better discriminating combination of variables between the Class II and Class III person.

Frequency Distribution for Anatomical Relationships

As a means for verifying the Class II tendency (overall mandibular retrusion) in this sample population, a comparison using frequency distributions was made for a control Class I population. Data was also gathered from a similar study of Class III individuals (Pfister, 1983), as it became evident that a greater

anatomical diversification in measure and expression was necessary to develop an accurate prediction-scheme. The incidence and distribution of maxillary and mandibular protrusive effects for the 3 malocclusions in the 16 year old individuals is summarized in Tables XXVII-XLIII).

Considering the relevance of the frequency distributions to this study, it will suffice to say that most measures have morphological expression indicative of the malocclusion of the individuals being represented. It is very apparent once again (Enlow, 1971), that the Class I malocclusion is more a composite of various Class II and Class III balances with some neutralizing effects, rather than a separate category of malocclusion.

The particular measurements that call for comment are the PM vertical relationships and the corpus/occlusal alignments. These frequency distributions vary somewhat from expectations for Class II and Class III delineations, yet are representative of the population samples used in these studies.

TABLE XXVII

AGGREGATE CRANIAL FLOOR/MAXILLA AND RAMUS/CORPUS

HORIZONTAL DIMENSIONS AT A AND B POINT

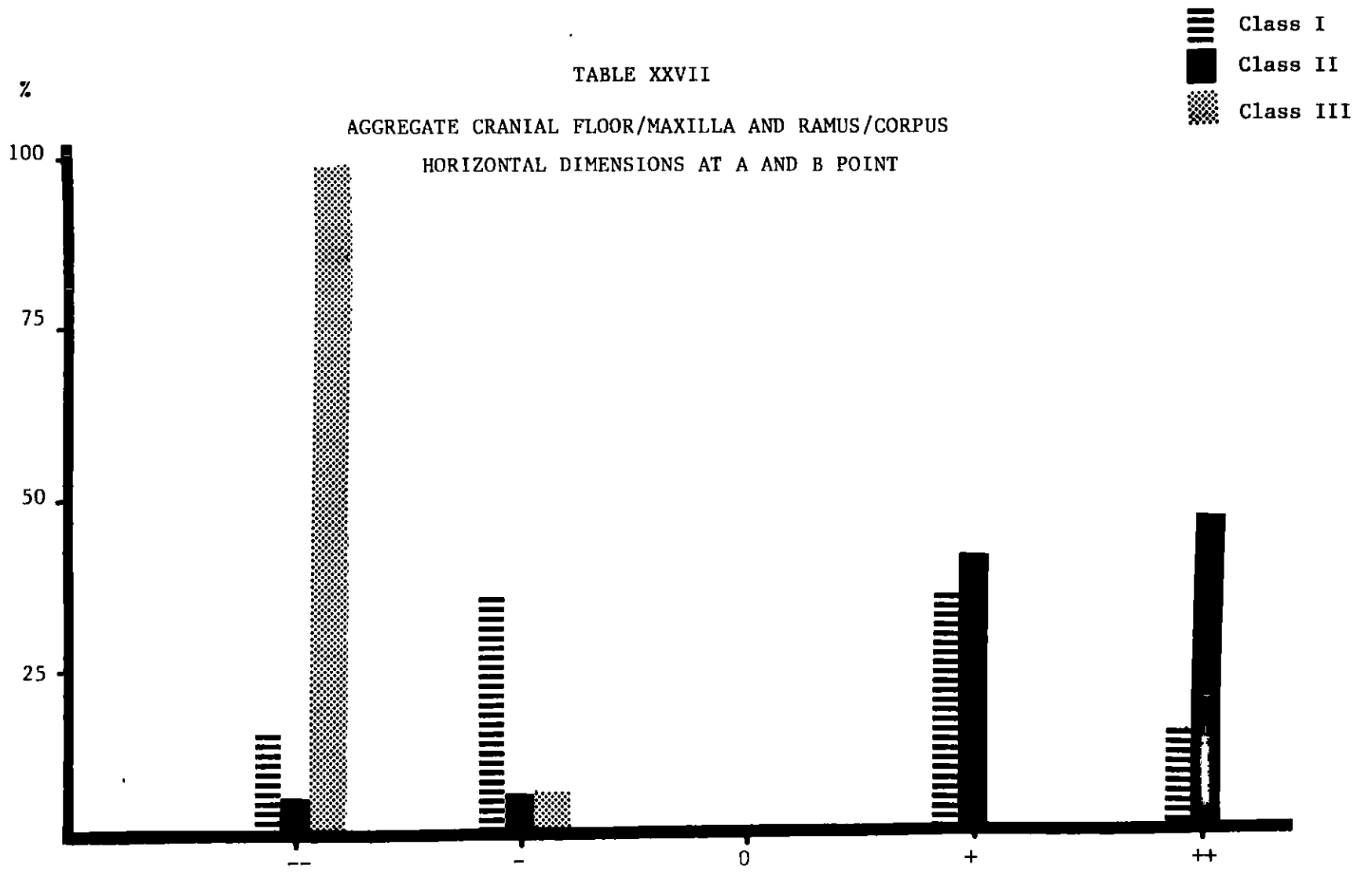


TABLE XXVIII

AGGREGATE CRANIAL FLOOR/MAXILLA AND RAMUS/CORPUS HORIZONTAL DIMENSIONS AT SPr and IPr

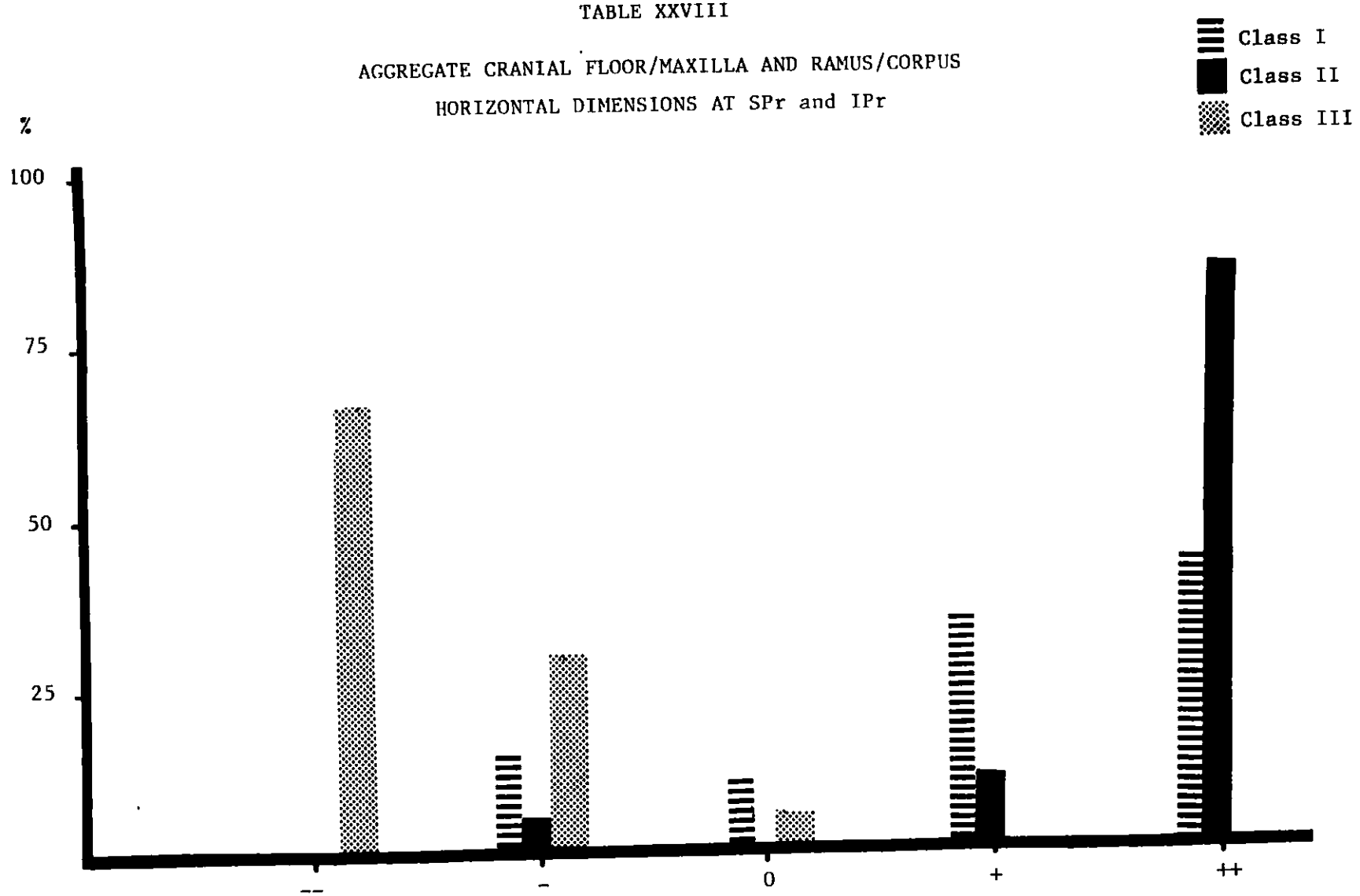


TABLE XXIX

MIDDLE CRANIAL FOSSA (MCF) RELATIVE ALIGNMENT

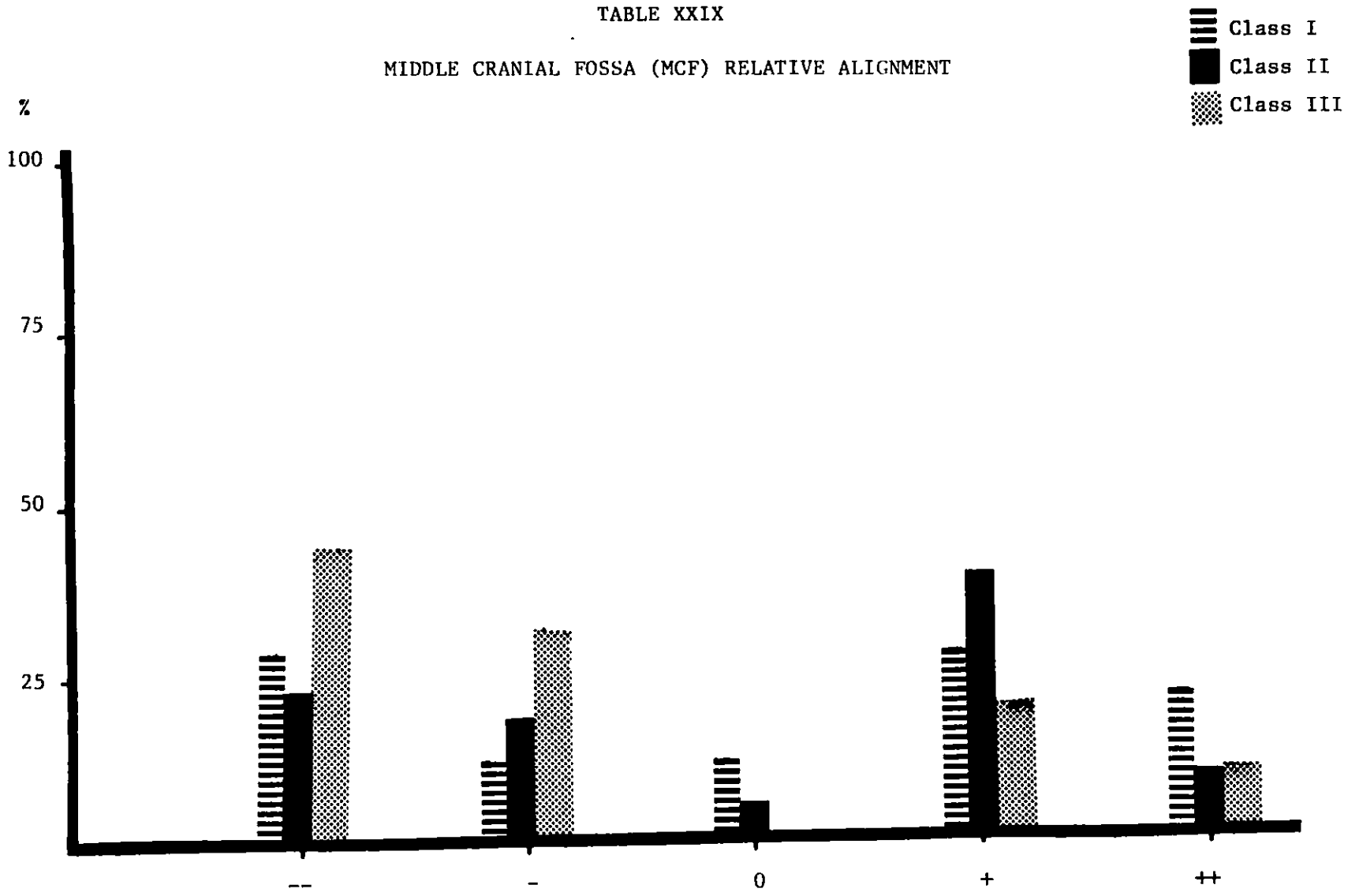


TABLE XXX

RAMUS ALIGNMENT

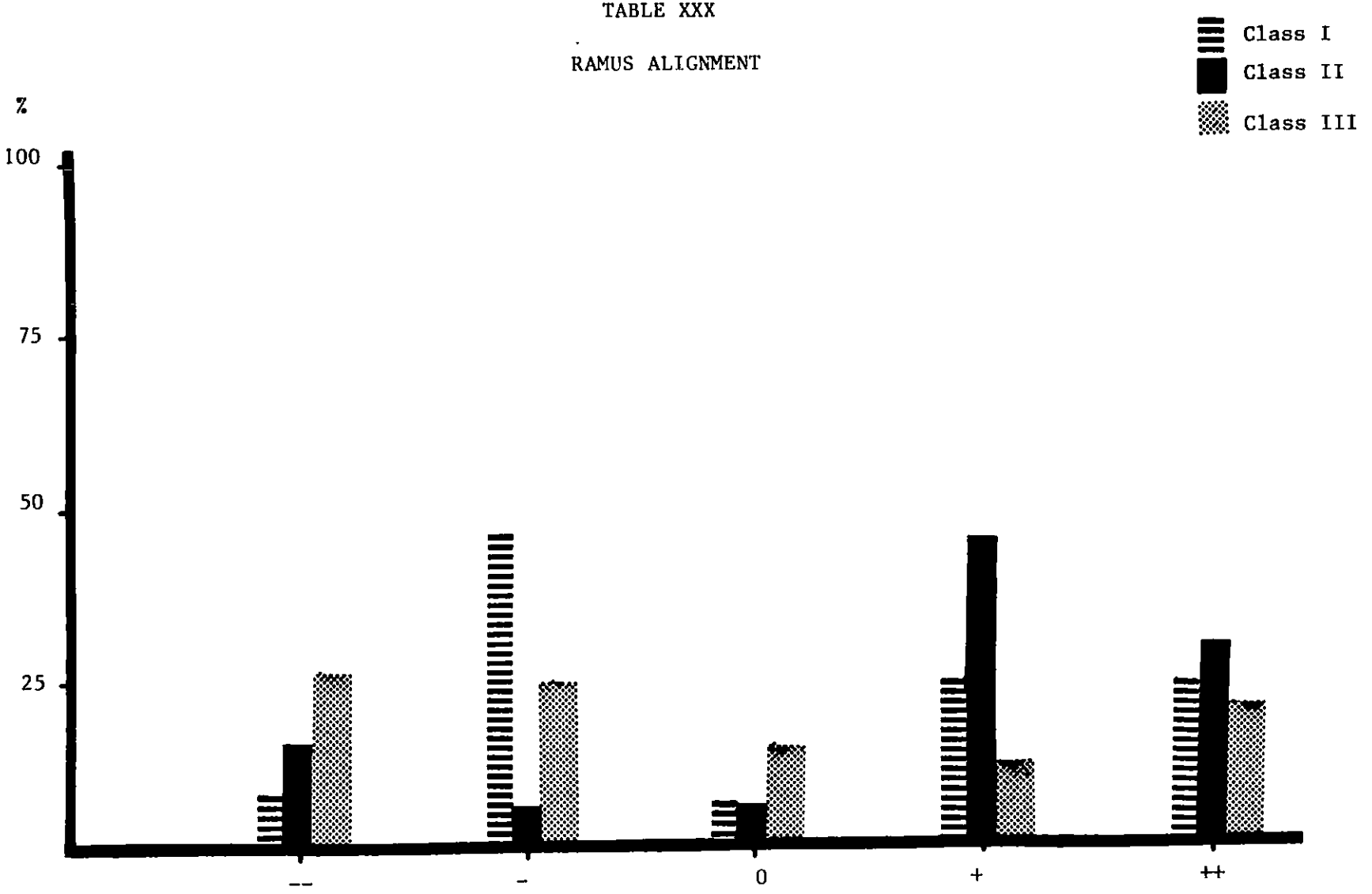


TABLE XXXI

RAMUS/MCF HORIZONTAL DIMENSIONS (SKELETAL)

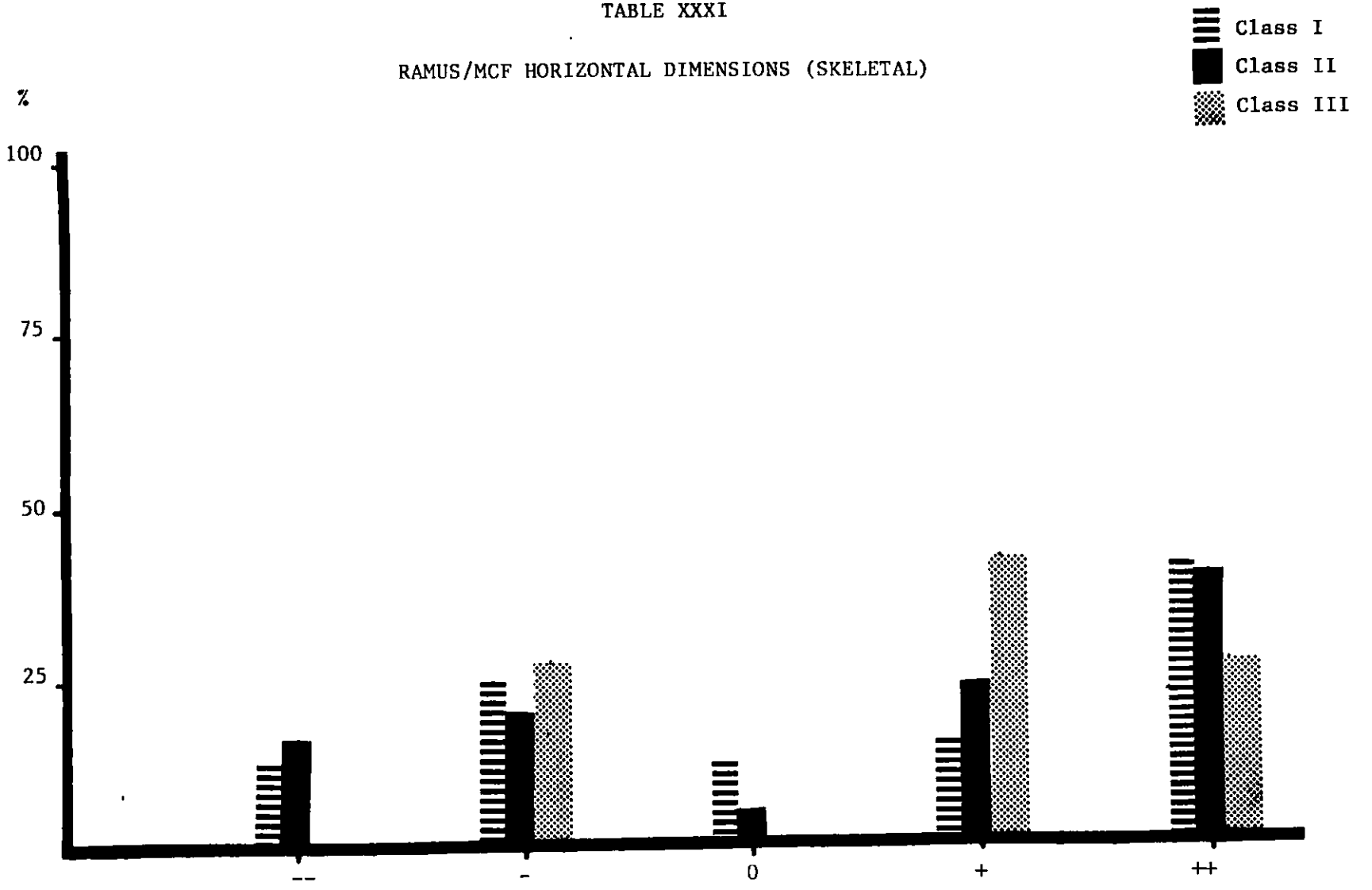


TABLE XXXII

RAMUS/MCF HORIZONTAL DIMENSIONS (DENTAL)

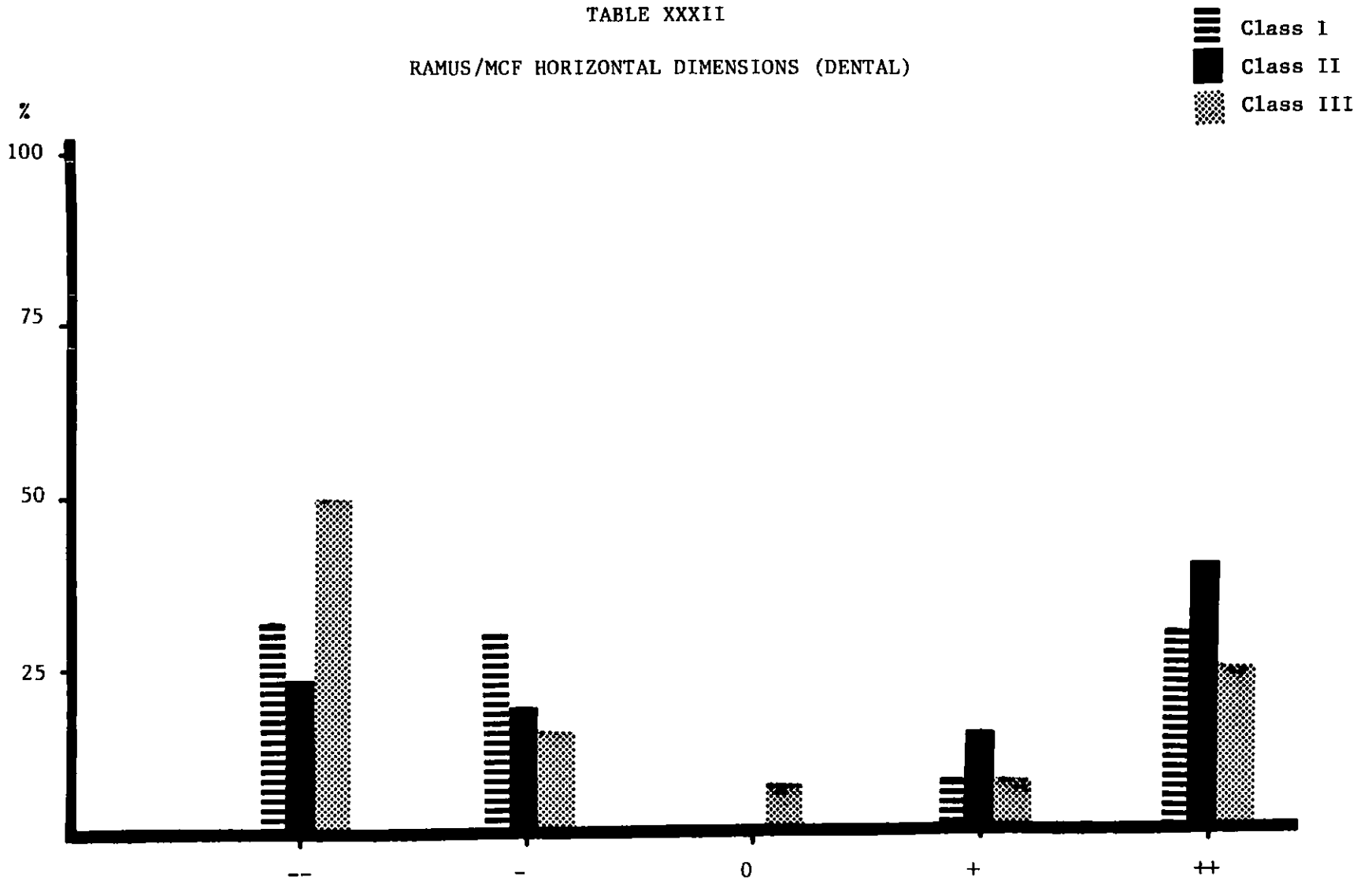


TABLE XXXIII

MOLAR POSITIONS (COMPOSITE)

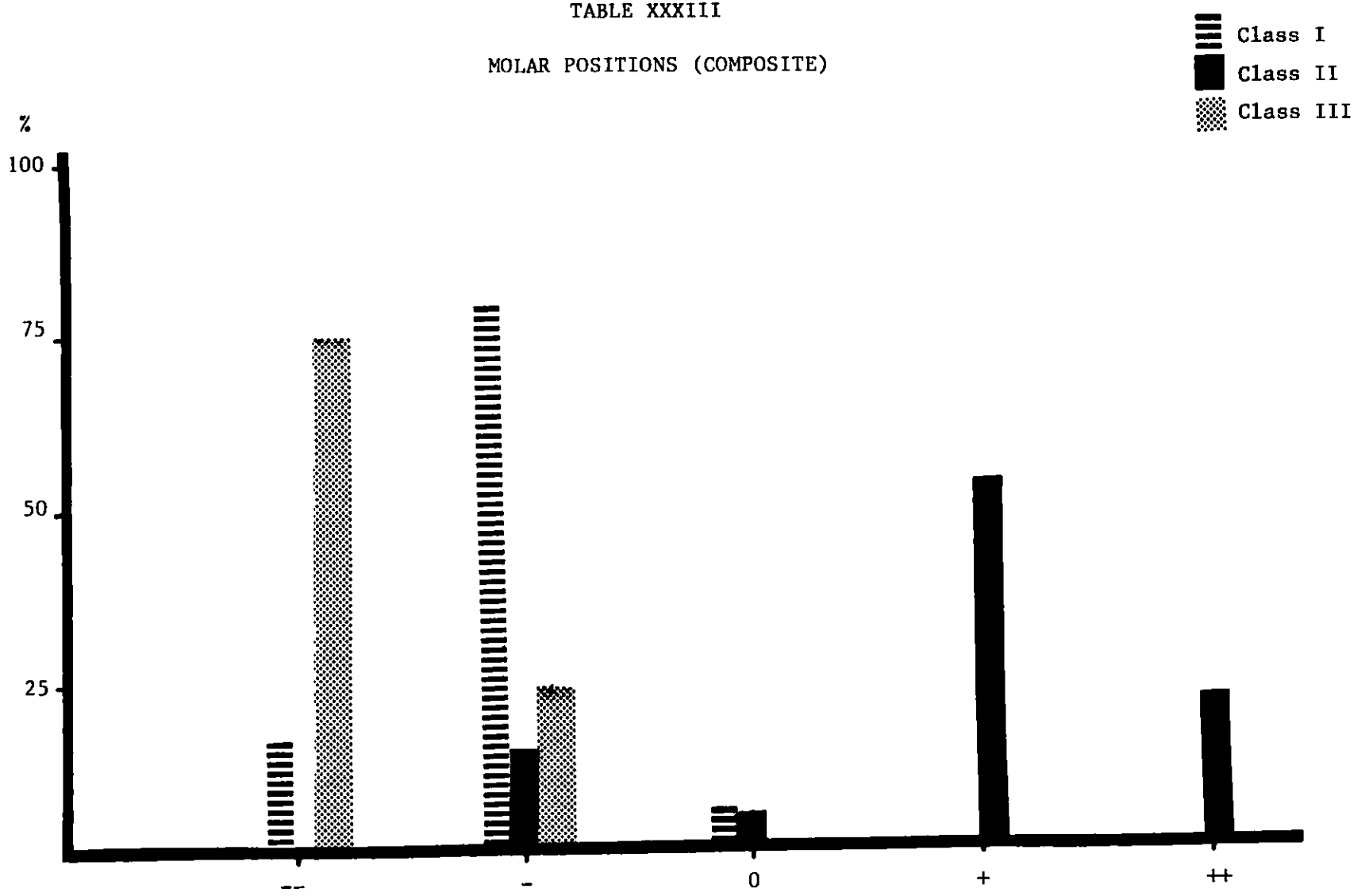


TABLE XXXIV

MAXILLARY/MANDIBULAR ARCHES, SKELETAL DIMENSIONS,

A POINT COMPARED WITH B POINT

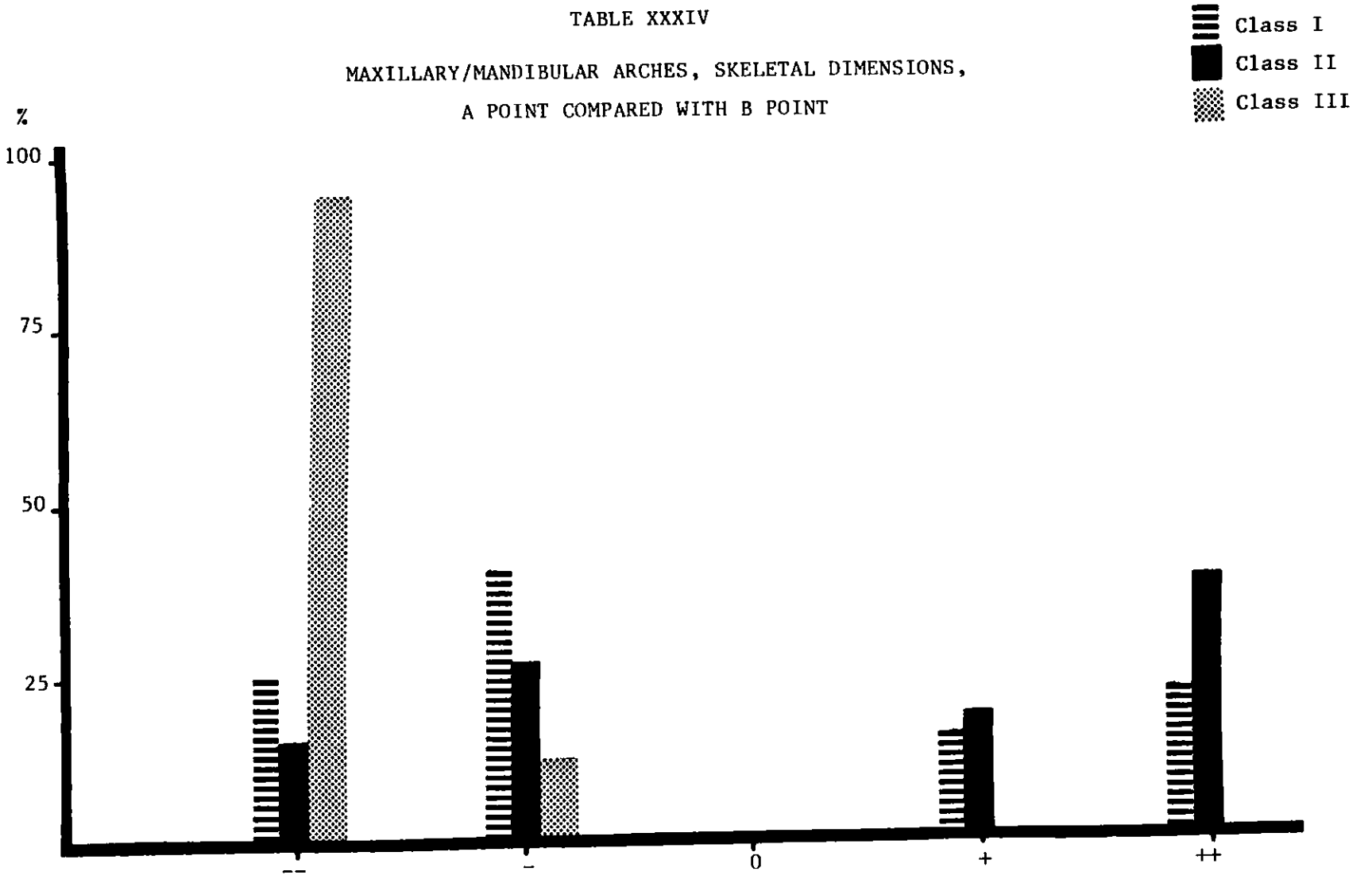


TABLE XXXV

MAXILLARY/MANDIBULAR ARCHES, DENTAL DIMENSIONS,

A POINT COMPARED WITH B POINT

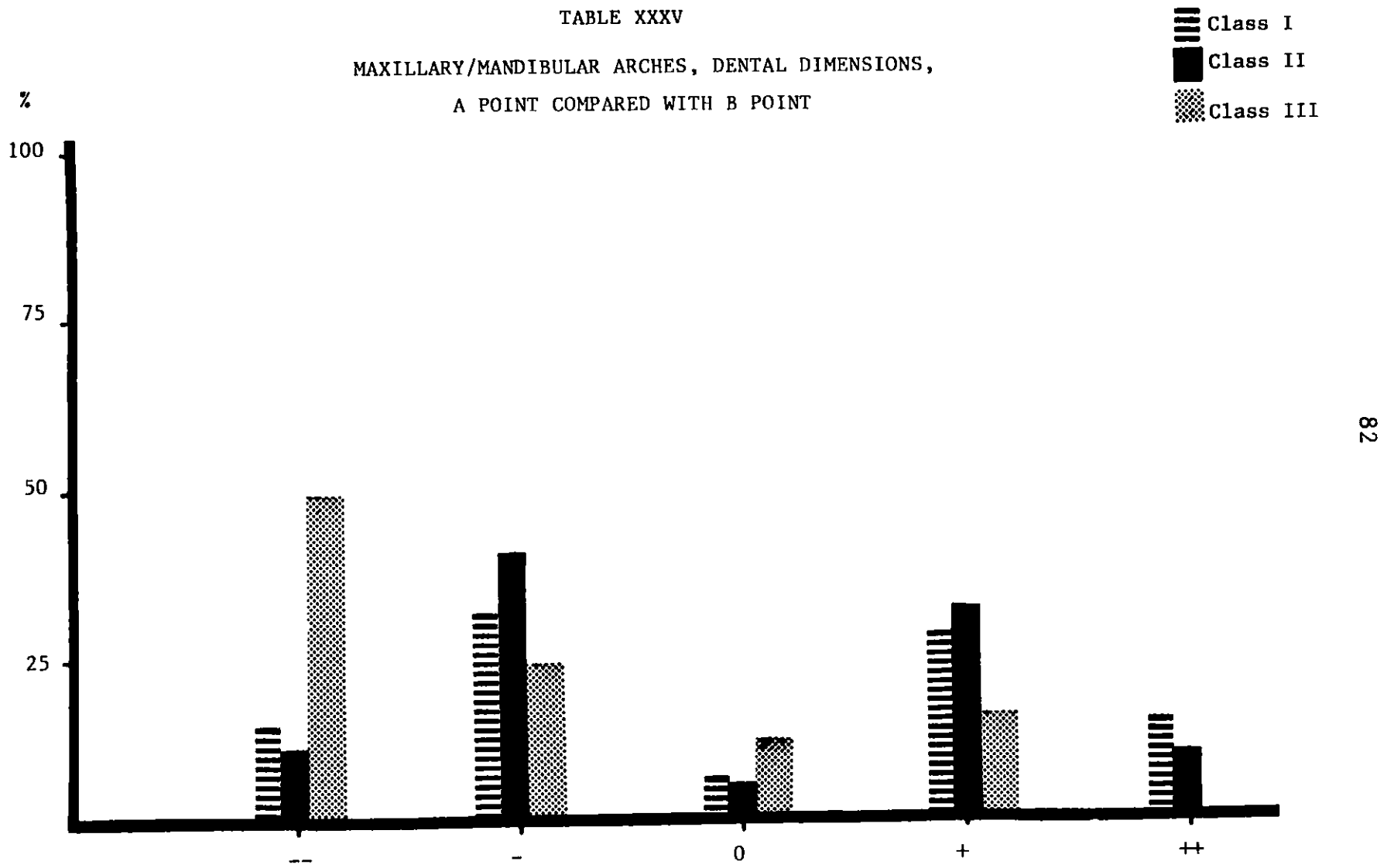


TABLE XXXVI

MAXILLARY/MANDIBULAR ARCHES, SKELETAL DIMENSIONS,
SPr COMPARED WITH IPr

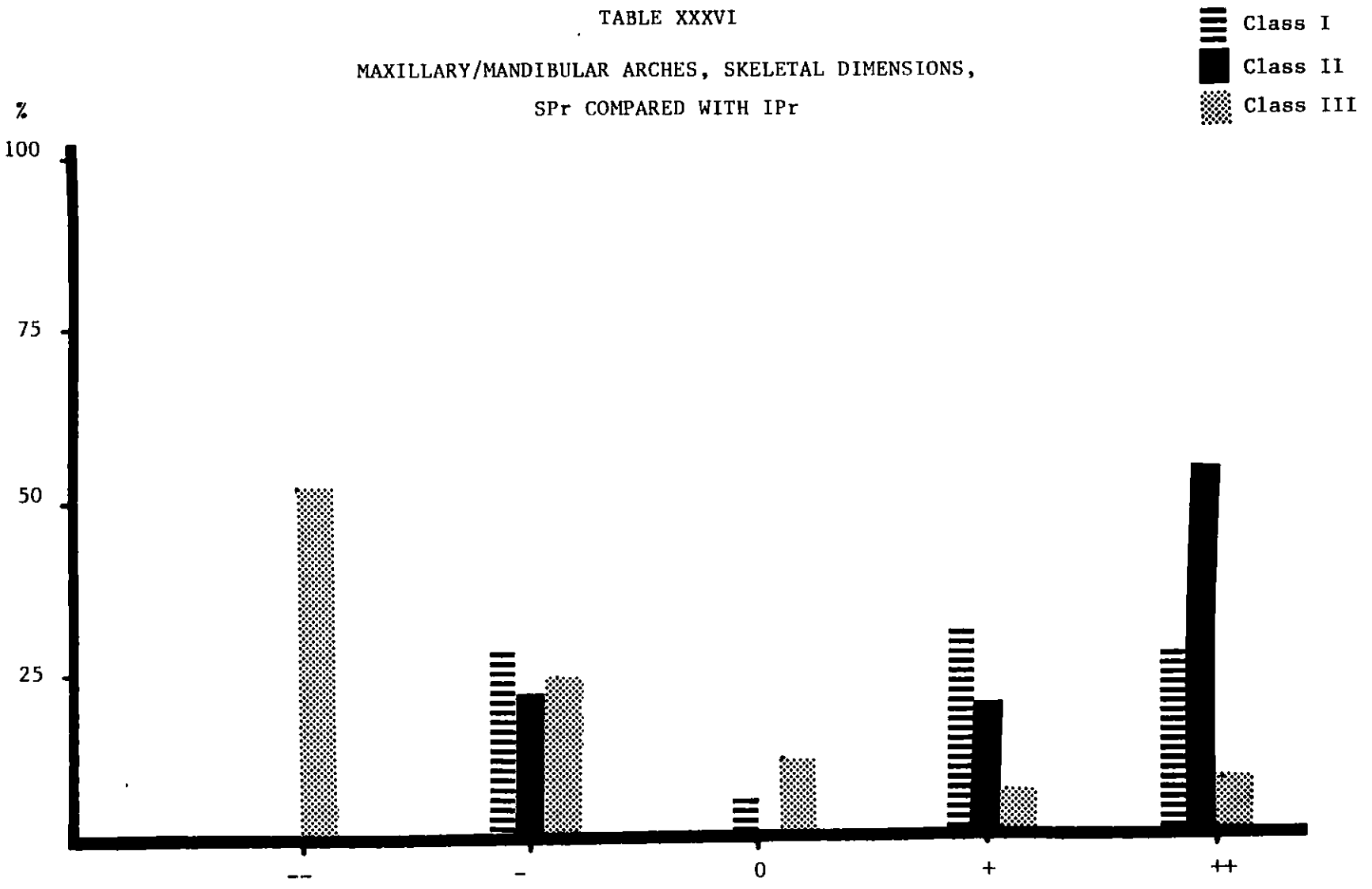


TABLE XXXVII

MAXILLARY/MANDIBULAR ARCHES, DENTAL DIMENSIONS,
SPr COMPARED WITH IPr

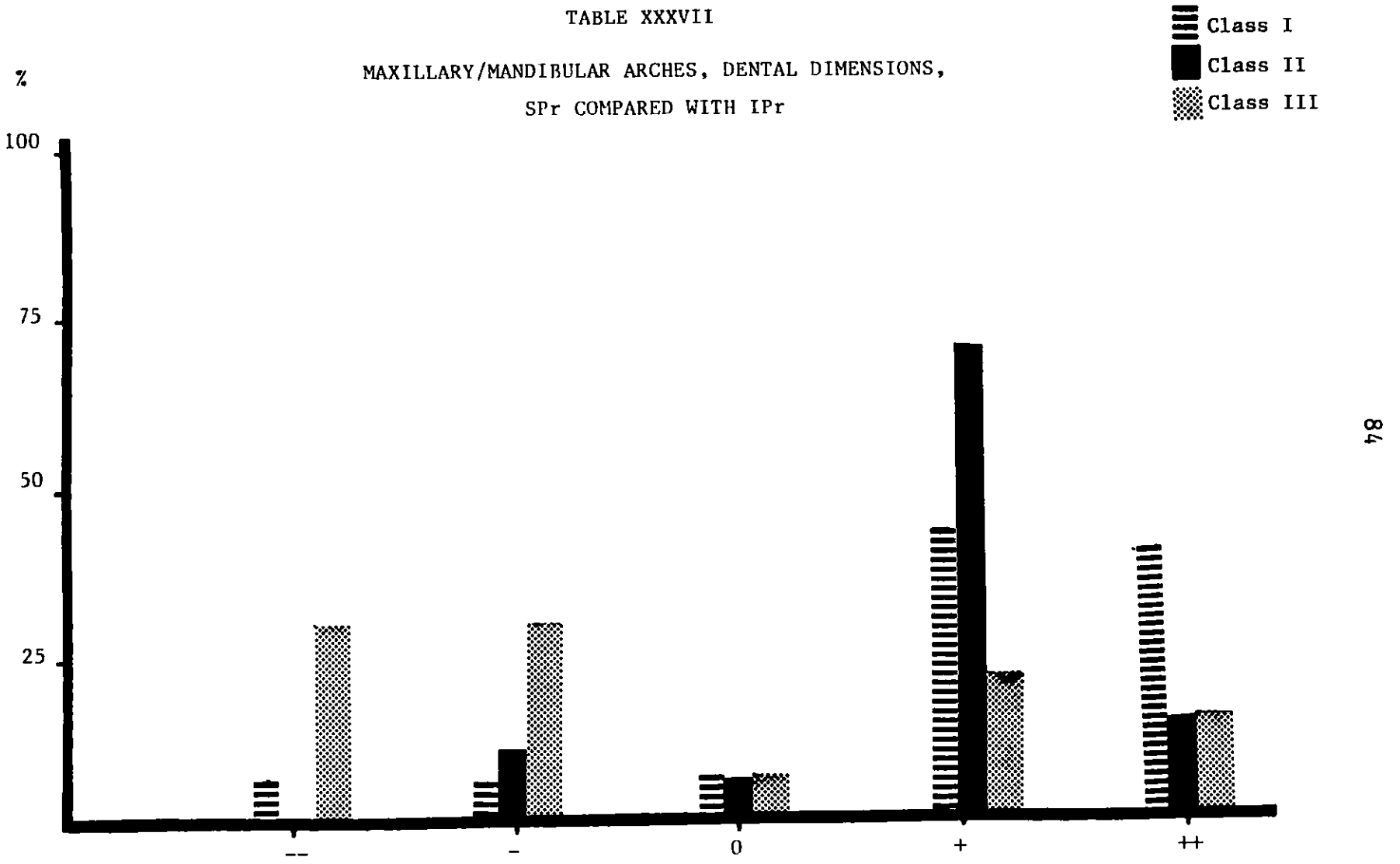


TABLE XXXVIII

PM COMPARED WITH RAMUS/MCF VERTICAL DIMENSIONS

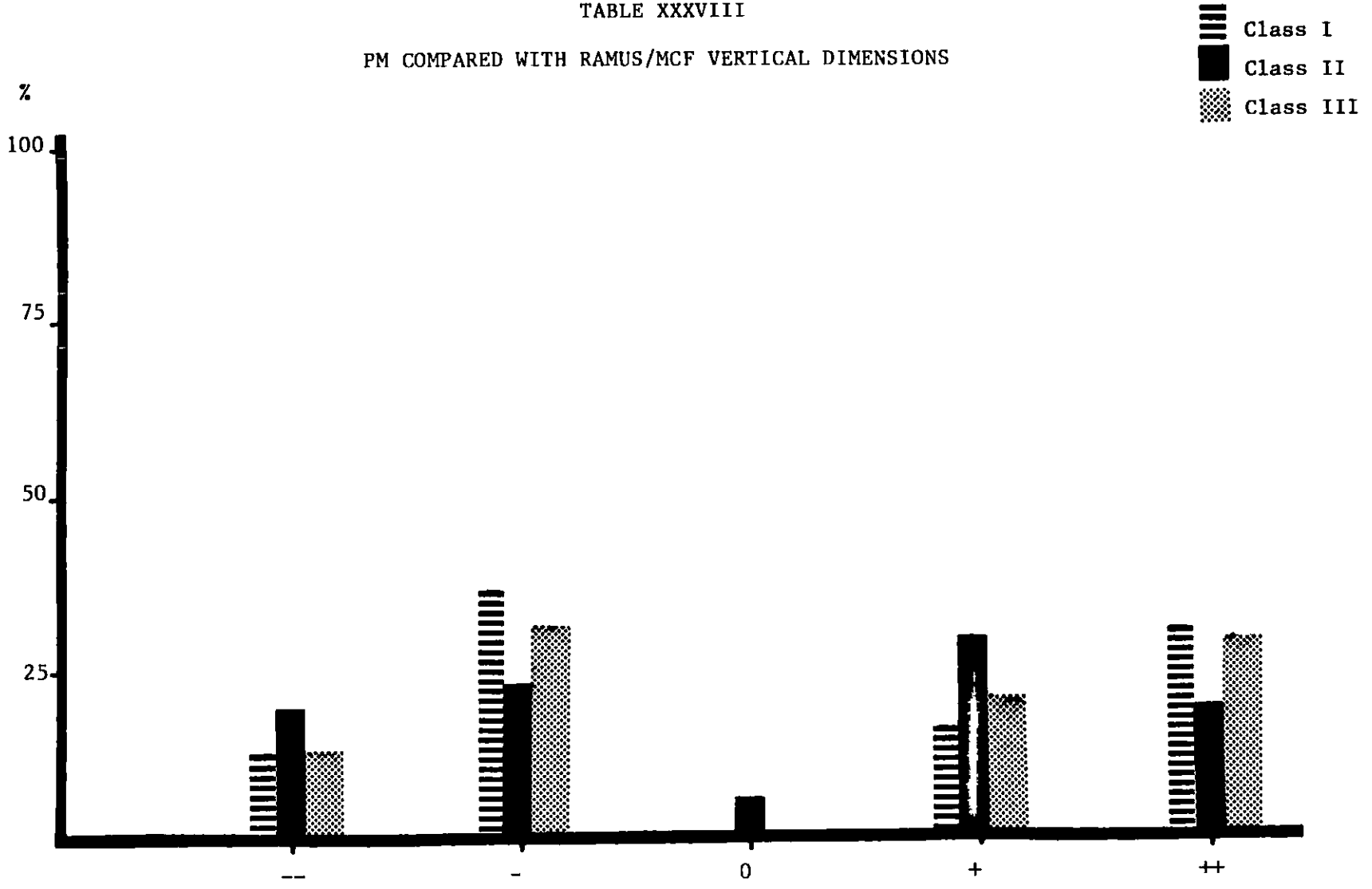


TABLE XXXIX

CORPUS/OCCLUSAL ALIGNMENT

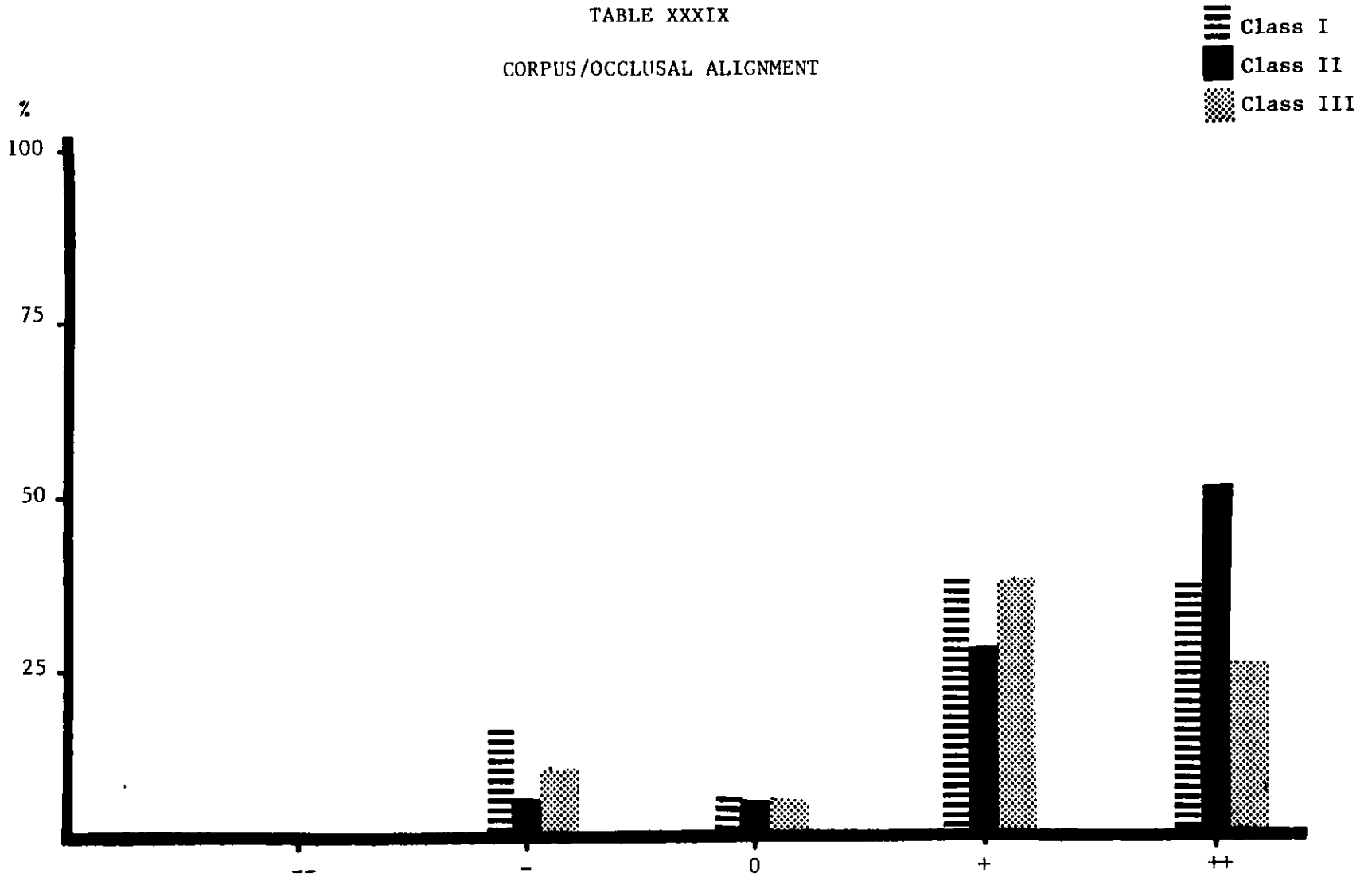


TABLE XL

MANDIBULAR PLANE ALIGNMENT

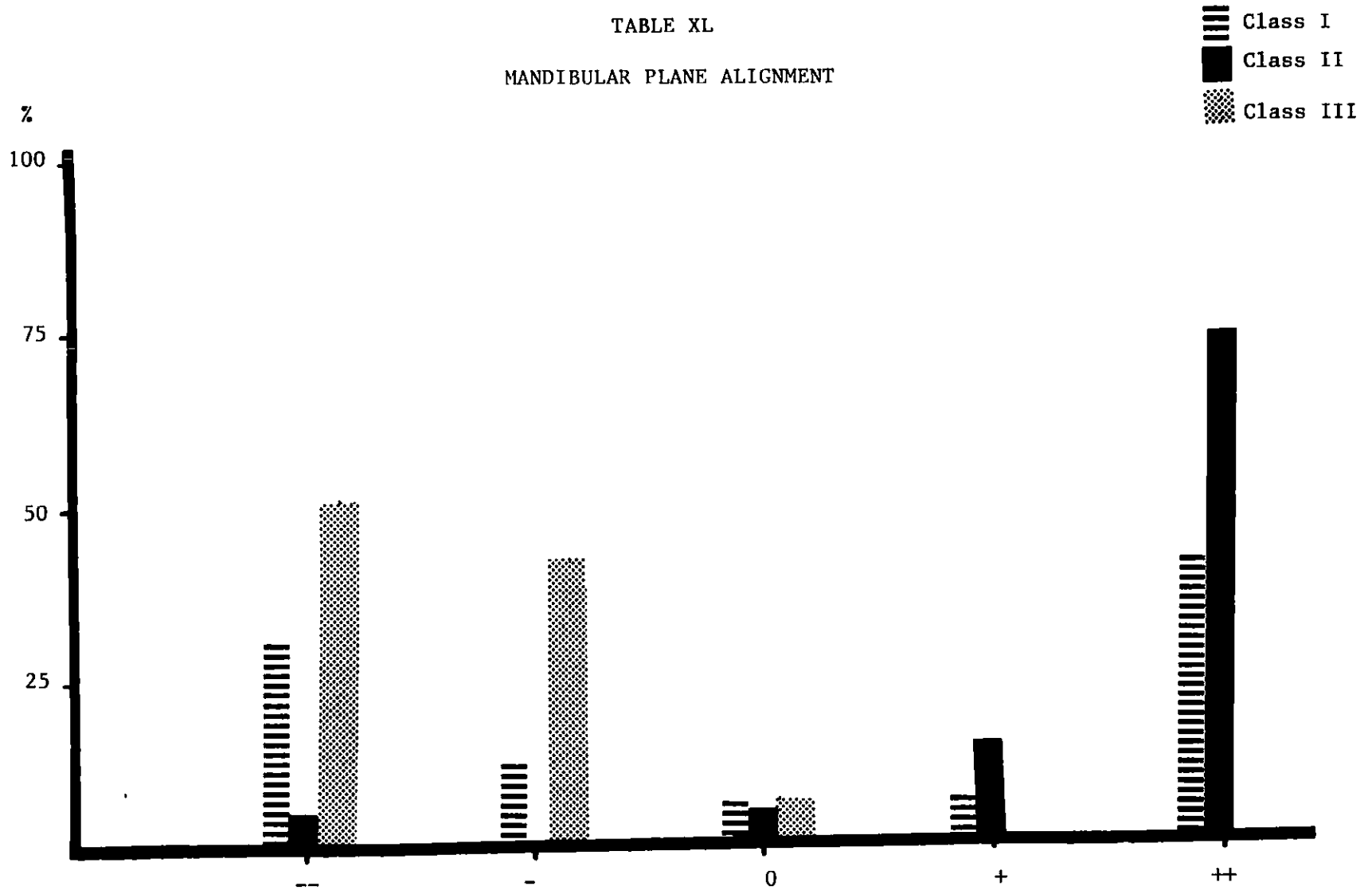


TABLE XLI

GONIAL ANGLE ALIGNMENT

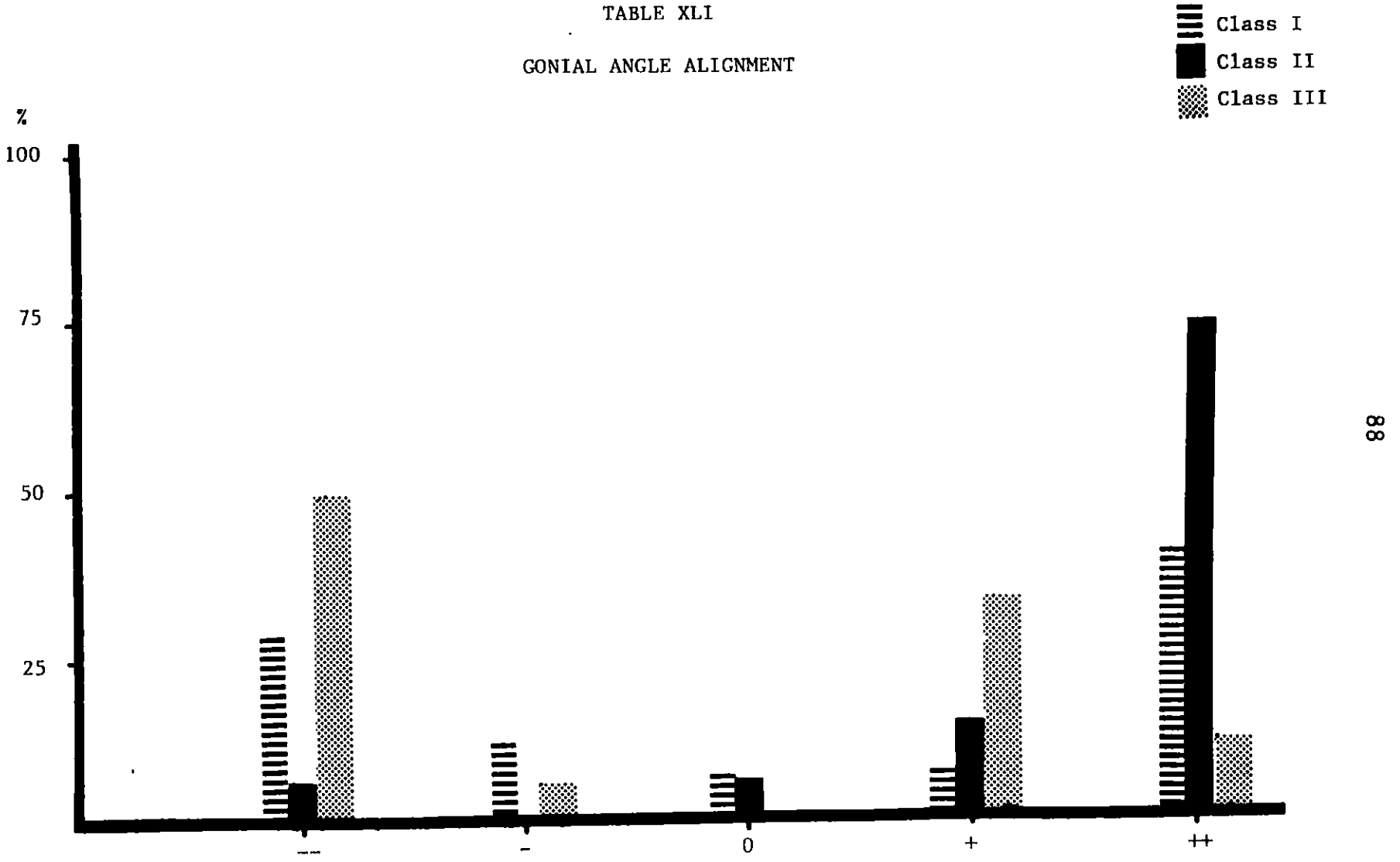


TABLE XLII

OCCLUSAL PLANE ALIGNMENT

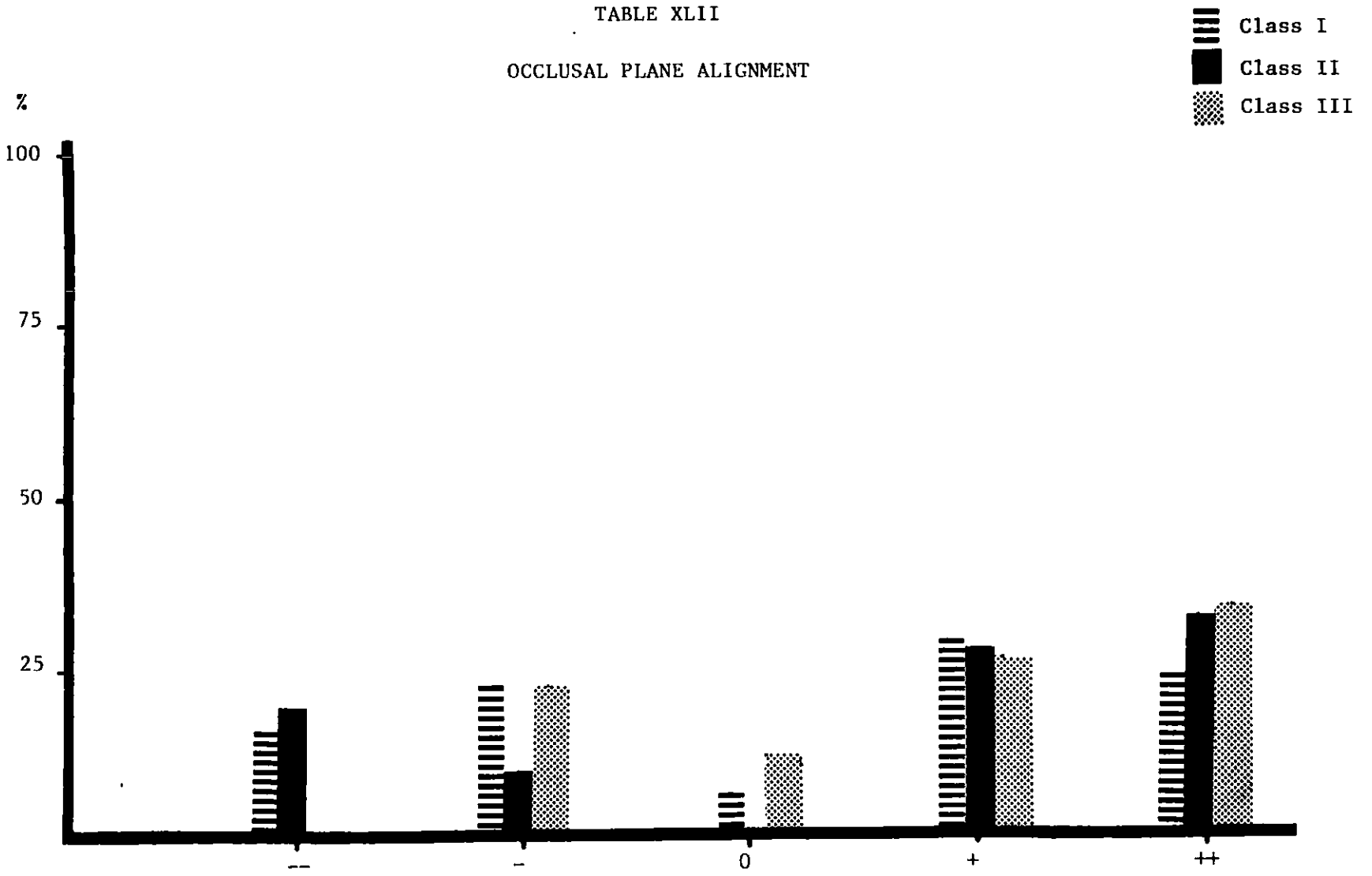
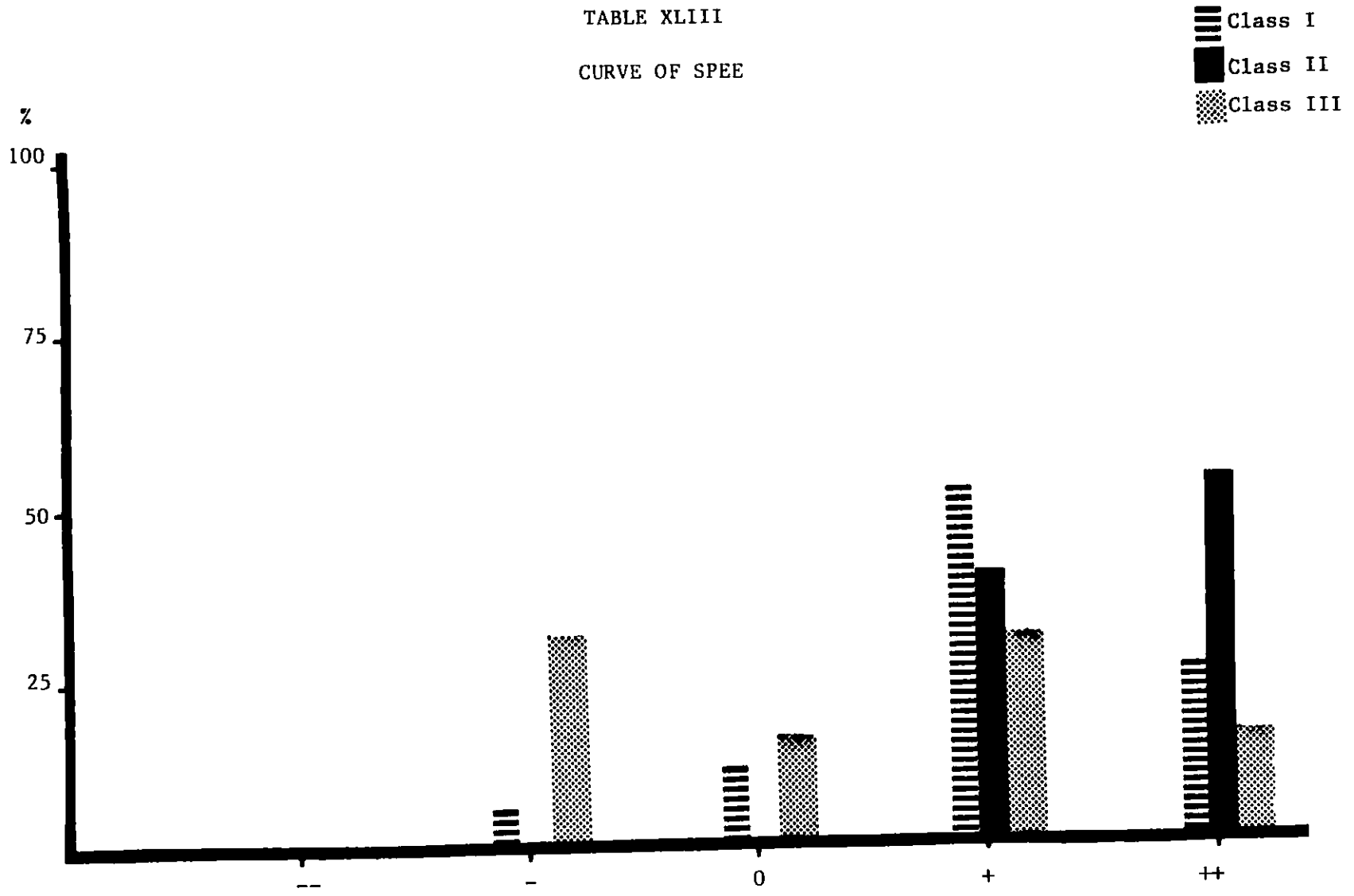


TABLE XLIII

CURVE OF SPEE



DISCUSSION

Examination of the Class II sample population using the counterpart analysis (Enlow, 1971) established 8 recognizable groups, each with its own unique morphological expression. Although 17 measures were initially evaluated, only 7 were ultimately used. Three of the measures, cranial floor alignment, PM vertical, and the ramus alignment, were utilized as the basis for the groupings. Four other measures, bony maxillary and mandibular arches, ramus/MCF horizontal dimension relationship, gonial angle alignment, and the curve of Spee added anatomical specificity by addressing individual combinations within the groups formed. These 7 anatomical relationships offer the best geometrical expression of the facial pattern, and likewise, a most relevant morphologic typing within a malocclusion.

In two of the groups, one of the major anatomical discriminators displayed a neutral (0) positioning. Considering the possibilities of tracing error, lack of film clarity, and asymmetries, it must be suspect that these groups could well have joined another, already existing group by displaying even the slightest maxillary or mandibular protrusive effect. This would further reduce the number of Class II groups.

The groups displayed a vast array of skeletal variations and severity of protrusive/retrusive anatomical expressions.

Though this diversification was constant throughout the sample, overall there was a distinct composite mandibular retrusive effect.

This study showed that the malocclusion typified by Angle's "Class II molar relationship" is indeed one of many morphological patterns. The molar relationship is a consequence of a multitude of developmental factors. All planes of the face must be considered in developing a comprehensive diagnosis--horizontal, vertical, and transverse. This has been emphasized in various studies (Kane, 1978; Henry, 1957; McNamara, 1979; Hirschfeld, 1973; Moyers, 1980), and without doing so, the intricacies of the Class II facial pattern will be camouflaged. It is apparent just how subjective the Angle Classification really is, and although it serves to provide easily determined patient comparisons, one should not lose an awareness of this subjectivity.

To further appreciate the morphology of Class II composite facial patterns, an evaluation was made for synergic and reciprocal effects (Enlow, 1971). Of the 17 relationships analyzed, four displayed quantitative significance in a cross-sectional comparison. The middle cranial fossa flexure/PM vertical dimension demonstrated a reciprocal neutral effect in 5 of the 9 groups. In these groups, the cumulative result is a partly or wholly offsetting combination of regional imbalances, which are thereby compensatory in nature.

Both the middle cranial fossa flexure and ramus alignment, when compared to the curve of Spee, expressed synergic maxillary protrusive (+) effects. Consequently, their impact is cumulative, increasing mandibular retrusion. This was typical of 5 groups.

The PM vertical dimension/curve of Spee relationship for 5 groups showed a reciprocal relationship, again serving to partly neutralize their effects.

Some of the measures had a neutral (0) effect. As these measures offer no impact on the developing facial balance, they could in turn have no synergic or reciprocal basis upon any other anatomical expression.

In order to establish growth trends that may be present, the Class II sample population was investigated both serially, using cross-sectional frequency distributions for anatomic relationships at different age levels, and by comparing the individuals progressively to themselves. Both maxillary protrusive (+) and maxillary retrusive (-) effective trends were found. The frequency distributions were adequate for a general comparison, but analyzing each individual serially produced more sensitive information.

From the frequency distributions, the alignment of the middle cranial fossa displayed a fairly constant serial relationship. Though the PM vertical was "short" until age 16, it increased

serially, experiencing only minor deviations from this pattern. The ramal alignment constantly demonstrated a maxillary protrusive tendency (backward alignment). The uprighting of the skeletal ramus correlated well with maxillary protrusive trends for both the closing of the gonial angle and increasing of the curve of Spee. These are "normal" occurrences (Enlow, 1975), and though their effect is cumulative toward mandibular retrusion, this synergic effect contributes to the establishment of a sustained overbite. The maxillary bony arch was consistently longer than the mandibular corpus, and this differential increased with age. There was a significant protrusive growth spurt at age 6 years to accomodate other growth changes, such as the accomodation of the maxillary first molars.

In comparing the middle cranial fossa with the mandibular ramus, the MCF horizontal measure suggests predominance of mandibular retrusiveness that increases longitudinally. There was a sharp drop at age 6 (28.7%), however, which is a reciprocal expression to the bony maxillary arch horizontal increase. This contributes to maintenance of the craniofacial composite in a somewhat balanced state. The data demonstrated that the mandibular retrusive facial expressions worsened with age if left untreated, and were overall more severe expressions than for the Class I individuals.

In comparing the individuals serially, trends expressing both mandibular retrusiveness (+) and protrusiveness (-) were established for the sample population. All 7 criteria utilized for establishing the groups were analyzed. To be a valid trend, the measurements had to increase serially either in a (+) or (-) direction, indicative of an increase of facial imbalance severity. Individuals were not acceptable for this purpose when anatomic measurements were stable during growth or too vacillating to establish an accurate trend of development.

The most significant trends found were a mandibular retrusive effect for the PM vertical in 5 individuals, and a similar effect in 14 individuals for the ramus alignment (a backward alignment). The incremental horizontal growth of the bony maxillary arch as compared to the mandibular corpus showed increased relative length serially, thereby accentuating the mandibular retrusiveness in 7 individuals. Another trend found was that the MCF/ramus horizontal dimension relationship in 12 individuals showed an increase in the middle cranial base incrementally, further retruding the mandible. The gonial angle alignment also was typical of a mandibular retrusive trend as it consistently became more acute with age in 11 persons.

Even though these trends were somewhat sporatic, they demonstrated that many of the maxillary protrusive effects may worsen with age if left unattended by compounding the existing

facial disharmonies. In a study addressing craniofacial compensations involved with the aging process (Behrents, 1983), lateral cephalograms for a portion of this study's sample population were made available at a much older age. Though this is not a total representation of the group, the implications are that growth does continue well on into adulthood and the existing craniofacial spectrum will maintain in a fairly uniform manner with only minor variations.

A viable prediction pattern for classification was unable to be developed in this study. As a myriad of etiological components serve to mold the ultimate facial composite of the Class II, this same complexity leaves prediction capability questionable at best. The 7 counterpart measures found to be the most informative geometrical expressions for the face, categorized the Class II individuals into 8 subgroups. However, when these same measures were used in an attempt to develop prediction patterns, large estimations of error were present. Prediction patterns are not germaine to the intent of the counterpart analysis, yet this study's results certainly left one with a feeling that facial imbalances are destined to worsen with age. It is due to the ability of the counterpart analysis in allowing a closer examination of individual growth fields, that more valid serial comparisons can be made. In an expanded study, a more discriminating combination of counterpart variables taken from data of Class II and

Class III individual comparisons should aid in determining more accurate growth predictions.

The Class I malocclusion is merely characterized by an effective balance between offsetting maxillary and mandibular protrusive effects.

As has been established, the complexity of the underlying craniofacial composite in the Class II individual makes an accurate classification system difficult to develop. The subjective Angle "Class II molar relationship" offers ease in communication of a standard. Nonetheless, it is apparent that categorizing individuals by this method is morphologically quite superficial.

Using the counterpart analysis, some meaningful correlations have been made. Groups within the Class II malocclusion were established using the most accurate of all norms, the individual himself. Of paramount importance is that the diagnosis reflects the composite structural complexity of the malocclusion. Only in consideration of an individual's particular combination of morphologic features can a proper therapeutic plan be developed to specifically address the nature of underlying factors that predisposed a malocclusion in that individual.

SUMMARY AND CONCLUSIONS

The purpose of this study was to develop a more precise delineation of Class II types by considering the morphological expression and growth of the individual. As facial balance is of major concern to the orthodontist, a more objective anatomical classification than Angle's "Class II molar relationship" is needed. This would allow more individualized treatment modifications which would address the biologic nature of morphological imbalances. The facial patterns within each group were analyzed serially in an attempt to establish some predictive trends of anatomical development.

Enlow's counterpart analysis was used to differentiate the anatomical expressions of the individuals. This analysis is intended to compare the individual to himself, the most biologically accurate "norm", using planes representing key fields and naturally occurring sites of growth and remodeling. These horizontal and vertical counterpart relationships are compared for size, rotation, and displacement effect, resulting in a unique facial composite pattern. Comparisons were made for each individual using the counterpart analysis at 5 different ages.

This study involved 40 subjects divided into two sample groups:

1. An untreated control group consisting of Class I dentitions of individuals with good arch development and occlusion.

2. An untreated group consisting of Class II dentitions of individuals with good arch development.

The results lead to the following conclusions:

1. Though the anatomic expressions in both groups displayed both Class II and Class III effects, the Class II group indicated a much greater polarity toward Class II tendencies overall.

2. The 20 Class II individuals were morphologically categorized into 8 recognizable groups, each with unique distinguishing features. Though the groups reflected a vast array of skeletal variation and severity of anatomic expression, a distinct Class II effect was constant.

3. The subjectivity of Angle's "Class II molar relationship" was evident as a multitude of etiological factors were responsible for establishing the molar relationship.

4. Serial trends in the developing Class II individual worsened with age when left untreated as the existing facial imbalances were not only left unchecked, but allowed to compound--the Class II individuals got more Class II with time. The most noticeable anatomic effects were the bony maxillary arch compared to the mandibular corpus, PM vertical, ramus alignment, gonial angle, and MCF/ramus horizontal dimension.

5. No viable prediction patterns were developed due to the myriad of facial effects and serial variability leading to the Class II expression, demonstrated with counterpart measures utilized in this study. A clinician must question the bias in computer based prediction schemes that do not reflect this variability.

6. It is imperative that a diagnosis reflect the biologic complexity of the malocclusion in order to effect the most purposeful treatment plan.

APPENDIX I

Figure 3. All the points and planes used in the counterpart analysis are demonstrated in this diagram. The solid lines represent the subject's own relationships while the dashed lines represent neutral positions. This diagram includes additions to the original construct and procedure presented by Enlow (1971).

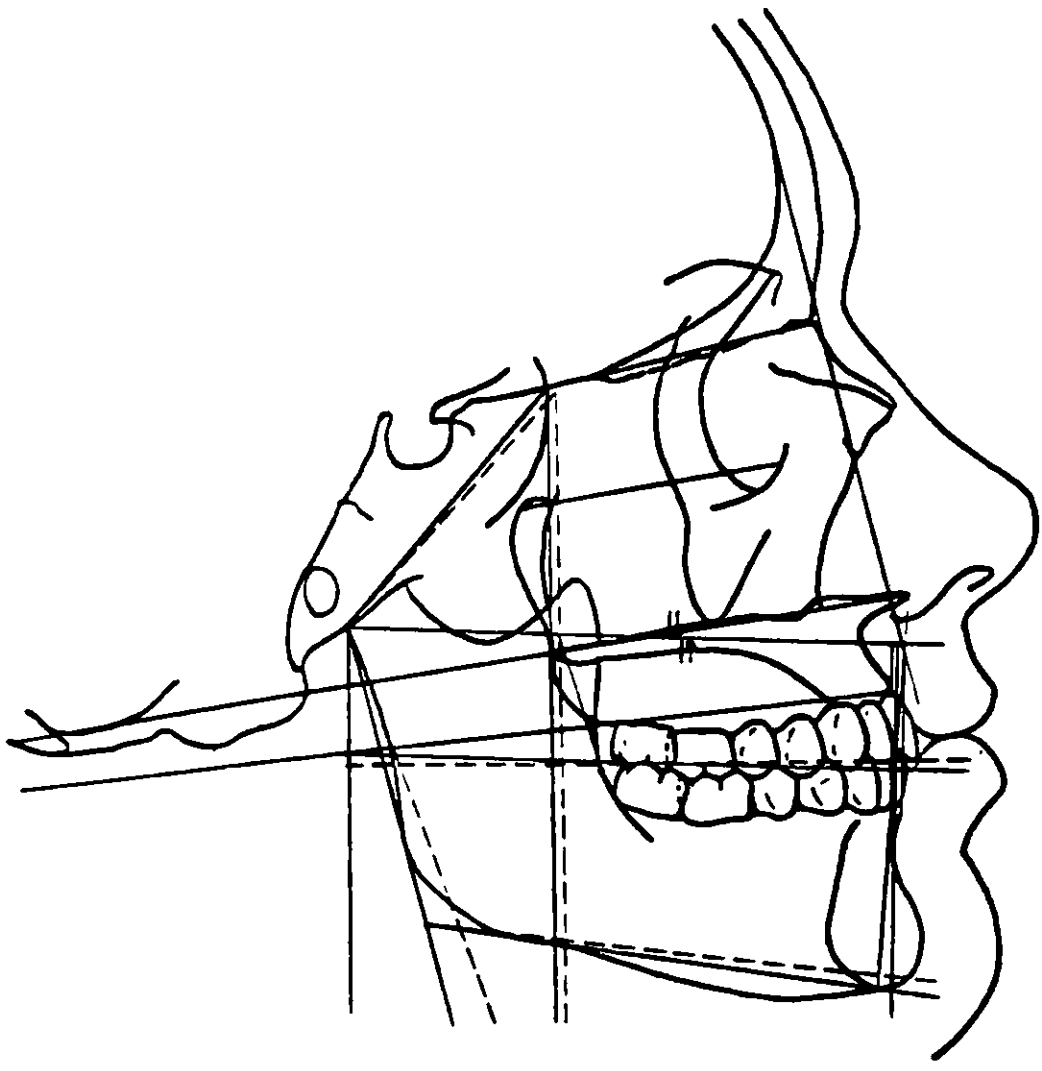


Figure 4. Aggregate cranial floor/maxilla and ramus/corpus horizontal dimensions at A and B points. This diagram demonstrates the comparison of lengths from Ar to A point and Ar to B point. The measurements are made in millimeters along REF. The lines from A point to REF and B point to REF are drawn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

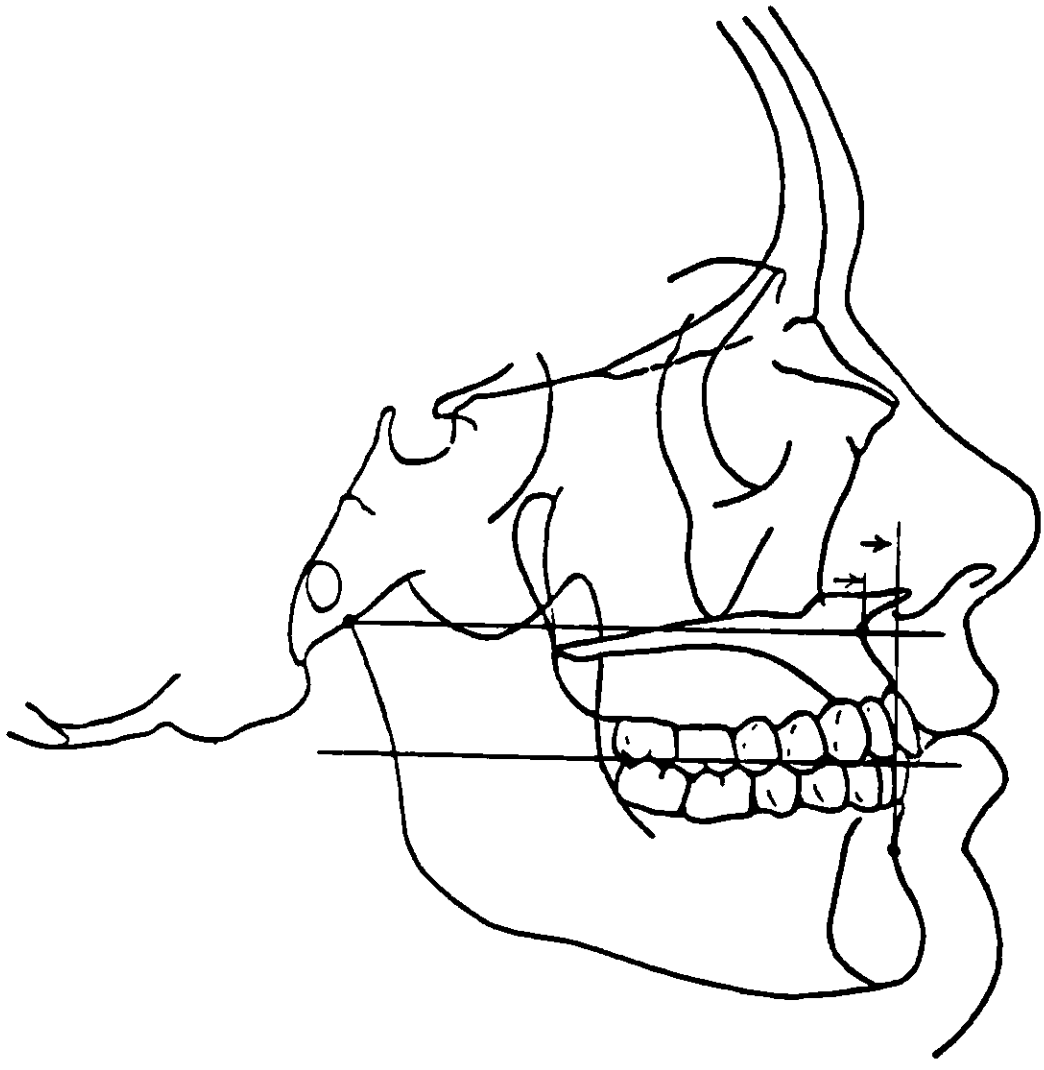


Figure 5. Aggregate cranial floor/maxilla and ramus/corpus horizontal dimensions at SPr and IPr. This diagram demonstrates the comparison of lengths from Ar to SPr and Ar to IPr. The measurements are made in millimeters along REF. The lines from SPr to REF and IPr to REF are drawn perpendicular to REF.

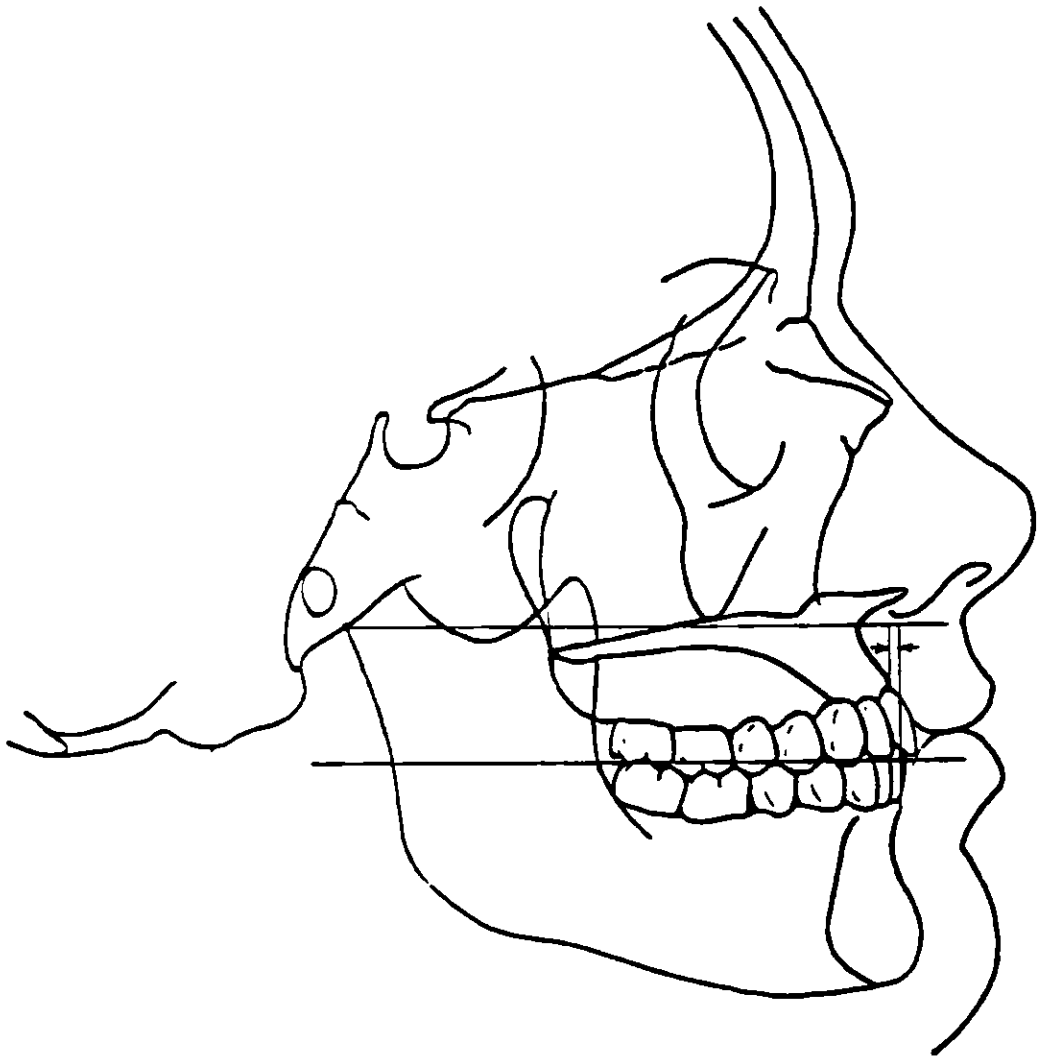


Figure 6. Middle cranial fossa (MCF) and posterior maxillary (PM) relative alignment. This diagram compares the neutral MCF/PM alignment (dashed line), which has an internal angle of 40.3° to the patient's MCF/PM alignment. The neutral MCF/PM alignment is drawn using a preconstructed template which has 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 PM parallel to each other. (4) Draw the neutral MCF/PM alignment with a dashed line on the tracing. The distance between the neutral PM and the subject's PM vertical can now be measured along REF in millimeters. When the PM vertical lies behind the neutral PM it is recorded as a negative number. When it is in front of the neutral PM it is a positive number. This measurement determines the effects of anterior/posterior directions of middle cranial fossa alignment on corresponding retrusive/protrusive placement of the maxilla and mandible.

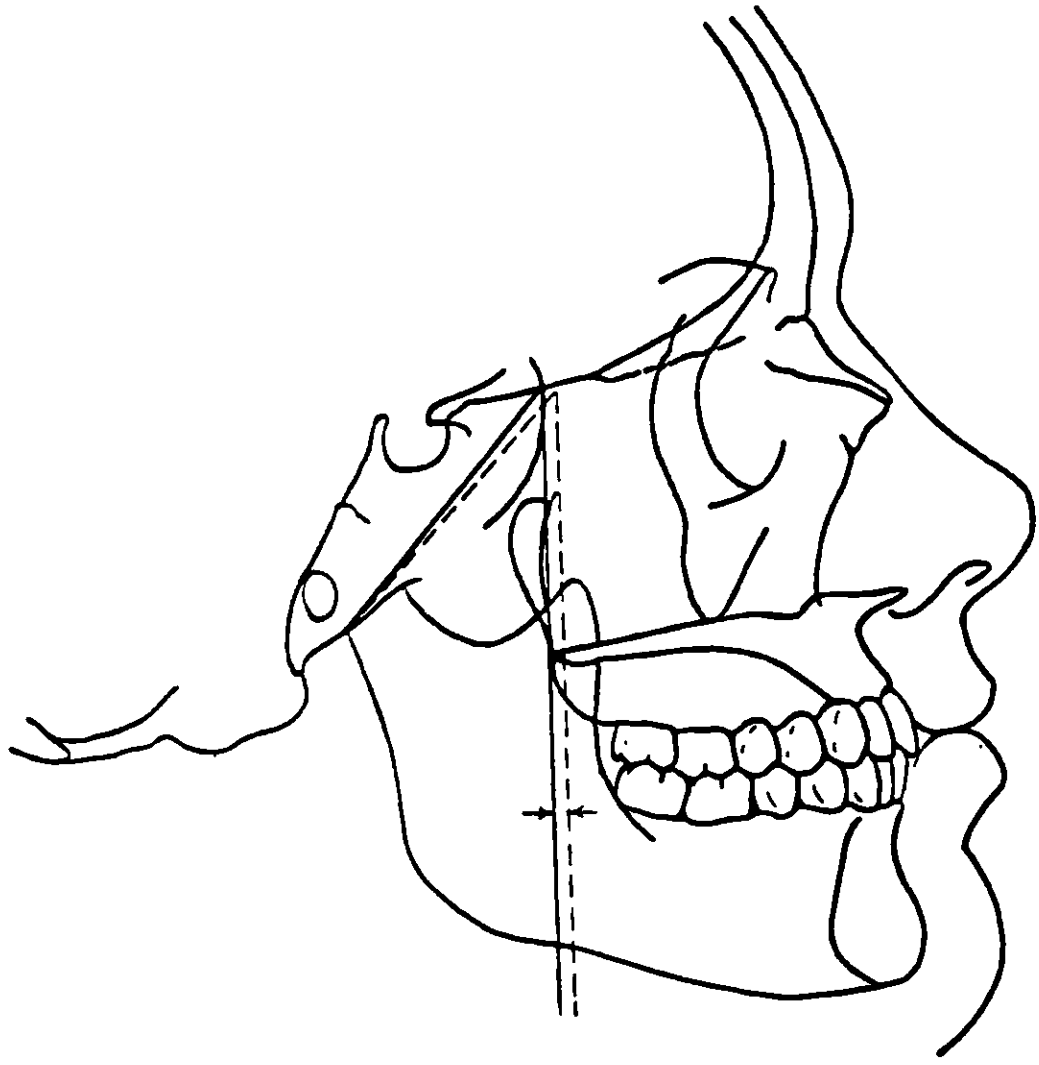


Figure 7. Ramus alignment. This diagram demonstrates the alignment of the subject's ramus plane and its relationship to the neutral ramus plane. A line from Ar to Go represents the individual's ramus plane. The neutral ramus plane is represented by a line from Ar to the midpoint between Ar and the neutral 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.

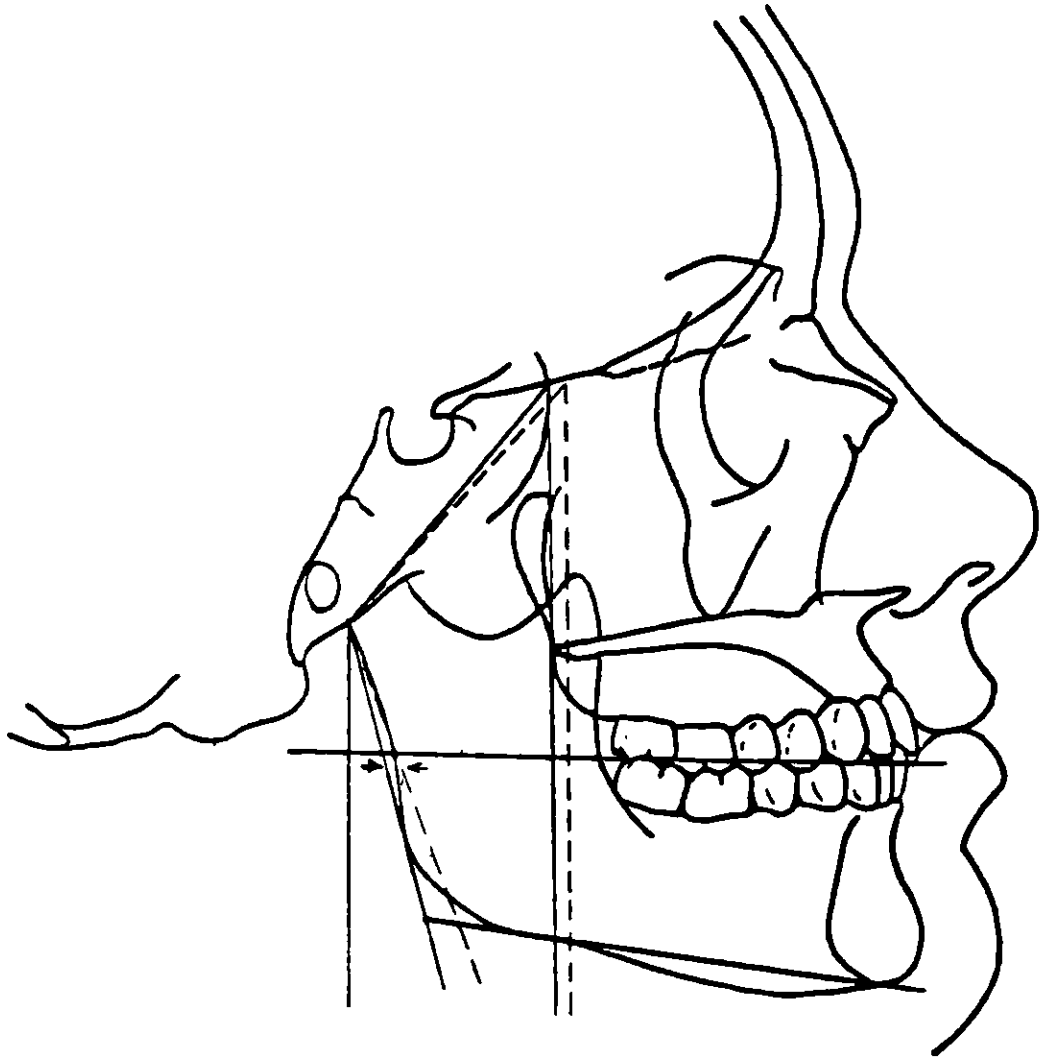


Figure 8. Ramus/MCF horizontal dimensions (skeletal). This diagram demonstrates the comparison of the horizontal dimensions of the middle cranial fossa (Ar to PM neutral) with the width of the ramus (Ar to ARa), and resultant effect on retrusive/protrusive placement of the maxilla and mandible. This measurement is made along REF in millimeters. The line PRa is drawn from Ar to FOP where it intersects the posterior border of the ramus. A line parallel to PRa is drawn from the anterior border of the ramus where it intersects FOP up to REF. The line indicates ARa. The distance from AR to ARa and Ar to PM neutral are now measured along REF.

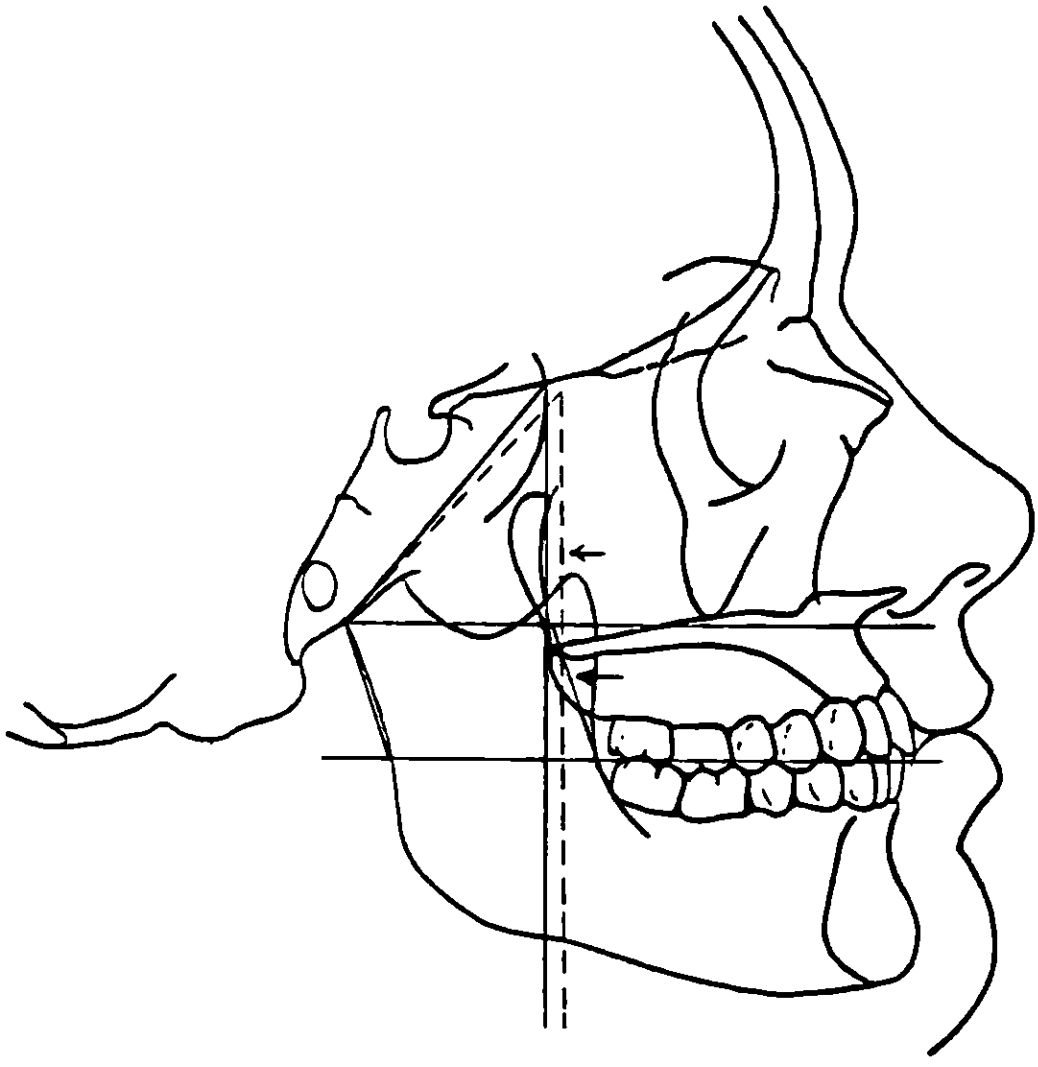


Figure 9. Ramus/MCF horizontal dimension (dental). The neutral positions of the molars are demonstrated with this measurement. The distal surfaces of the maxillary and mandibular first molars are indicated on REF by short vertical lines. The maxillary molar is corrected to its neutral position by adding 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.

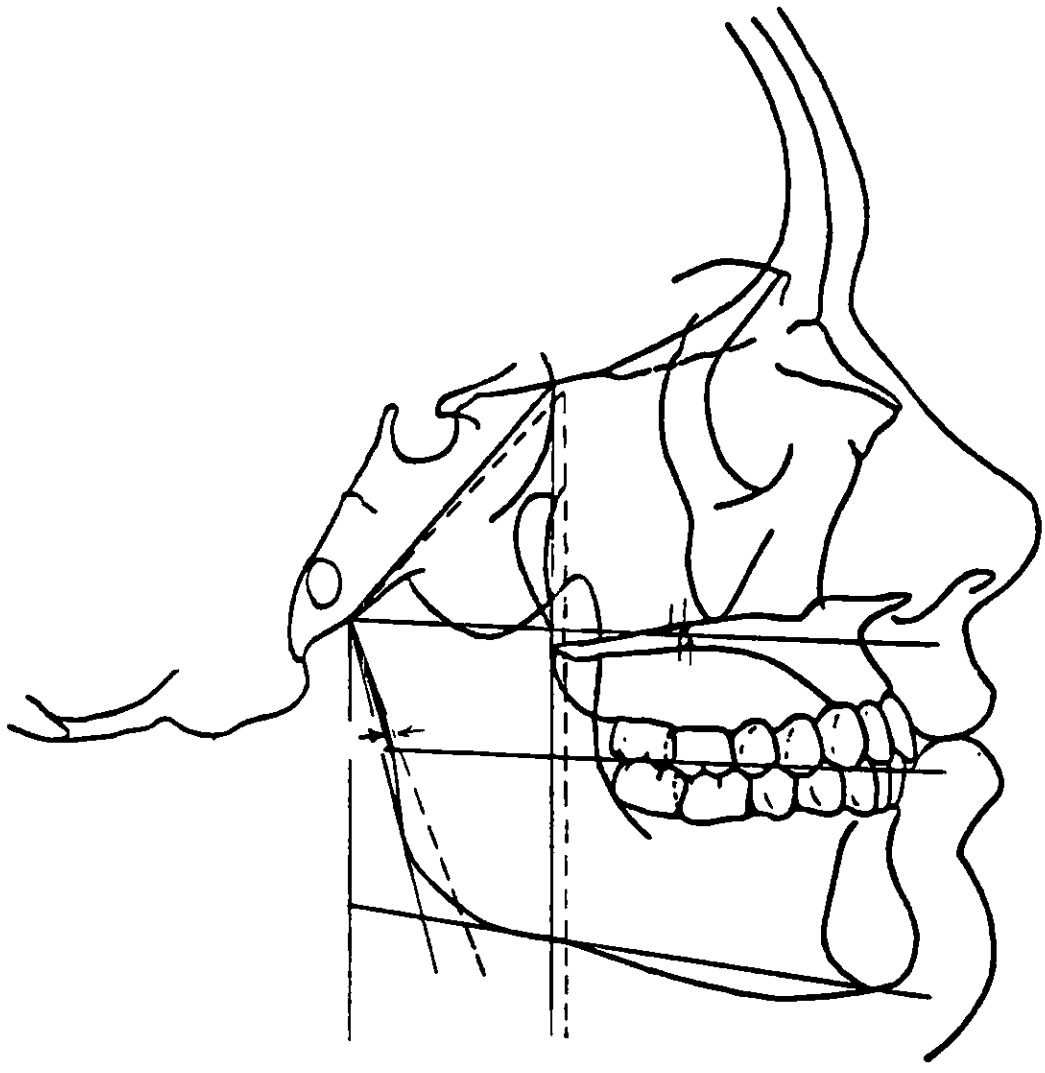


Figure 10. Molar positions (composite). Short vertical lines along REF indicate the distal surfaces of the maxillary and mandibular first molars. The measurement is made in millimeters along REF from Ar to the short vertical lines.

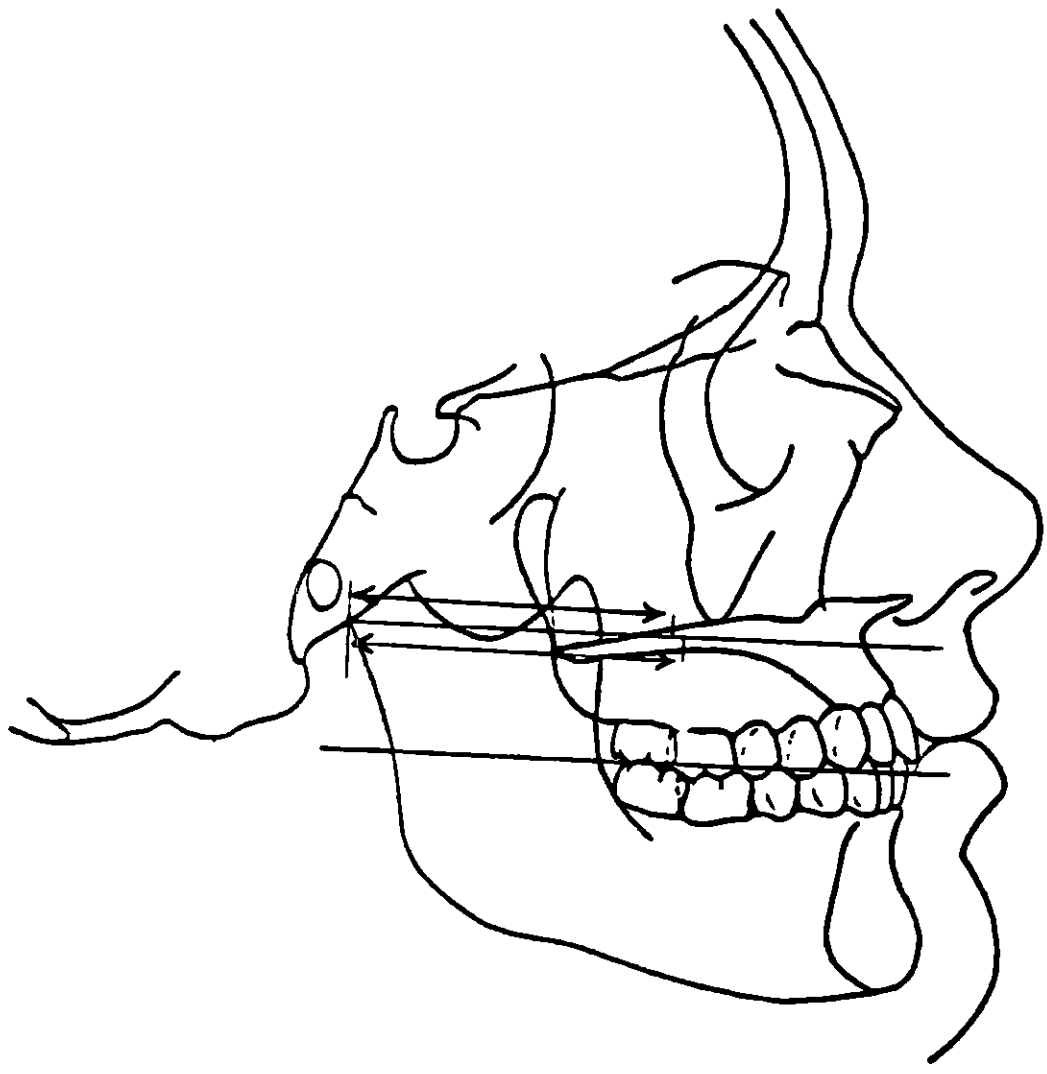


Figure 11. Maxillary/mandibular arches, skeletal dimensions, A point compared with B point. This diagram compares the length of the maxillary skeletal arch with the length of the mandibular skeletal arch. The maxillary skeletal arch is measured in millimeters from PM (solid line) along REF to A point. The mandibular skeletal arch is measured in millimeters from ARa where it intersects REF to B point along REF.

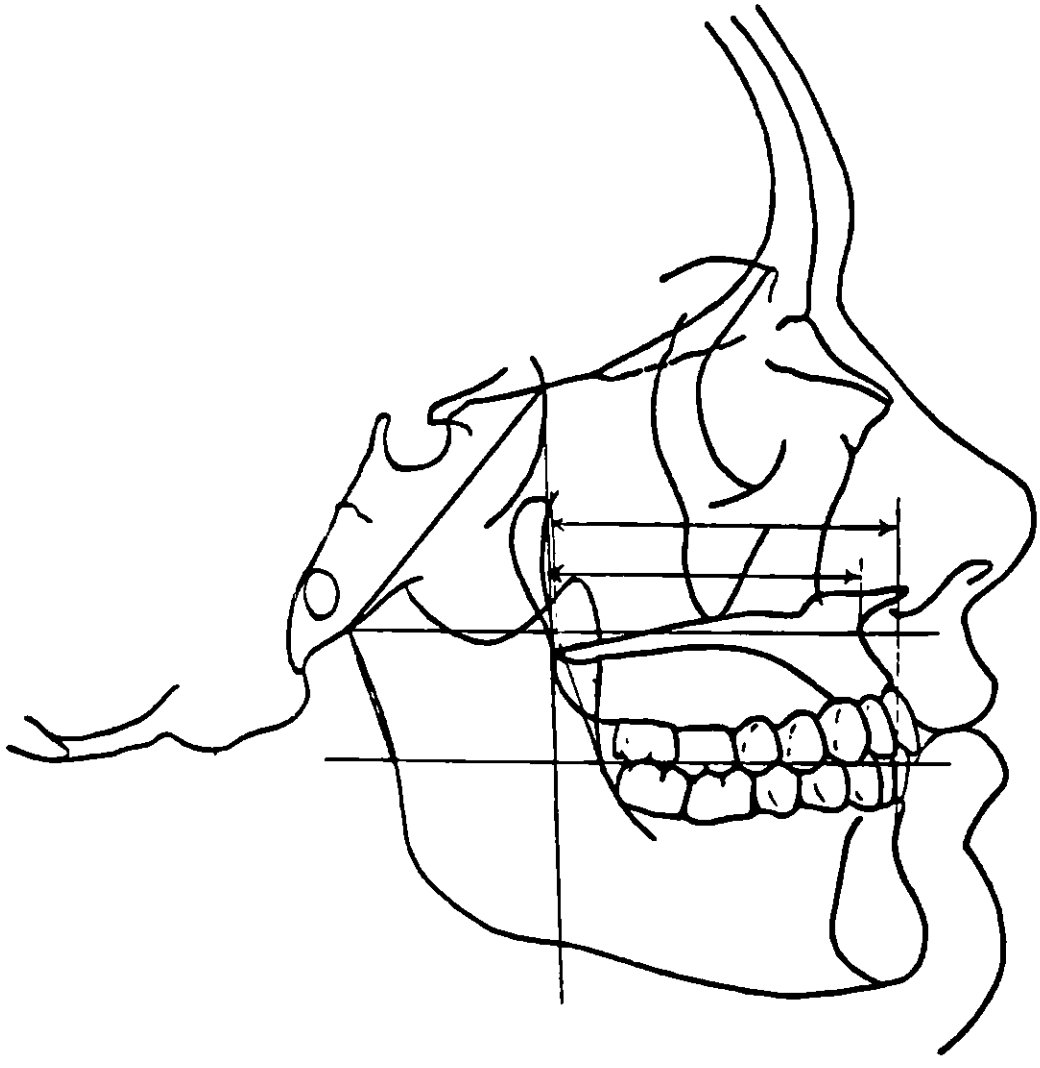


Figure 12. Maxillary/mandibular arches, dental dimensions, A point compared with B point. This is similar to the previous measurement except that the distances are measured to the distal surfaces of the first molars.

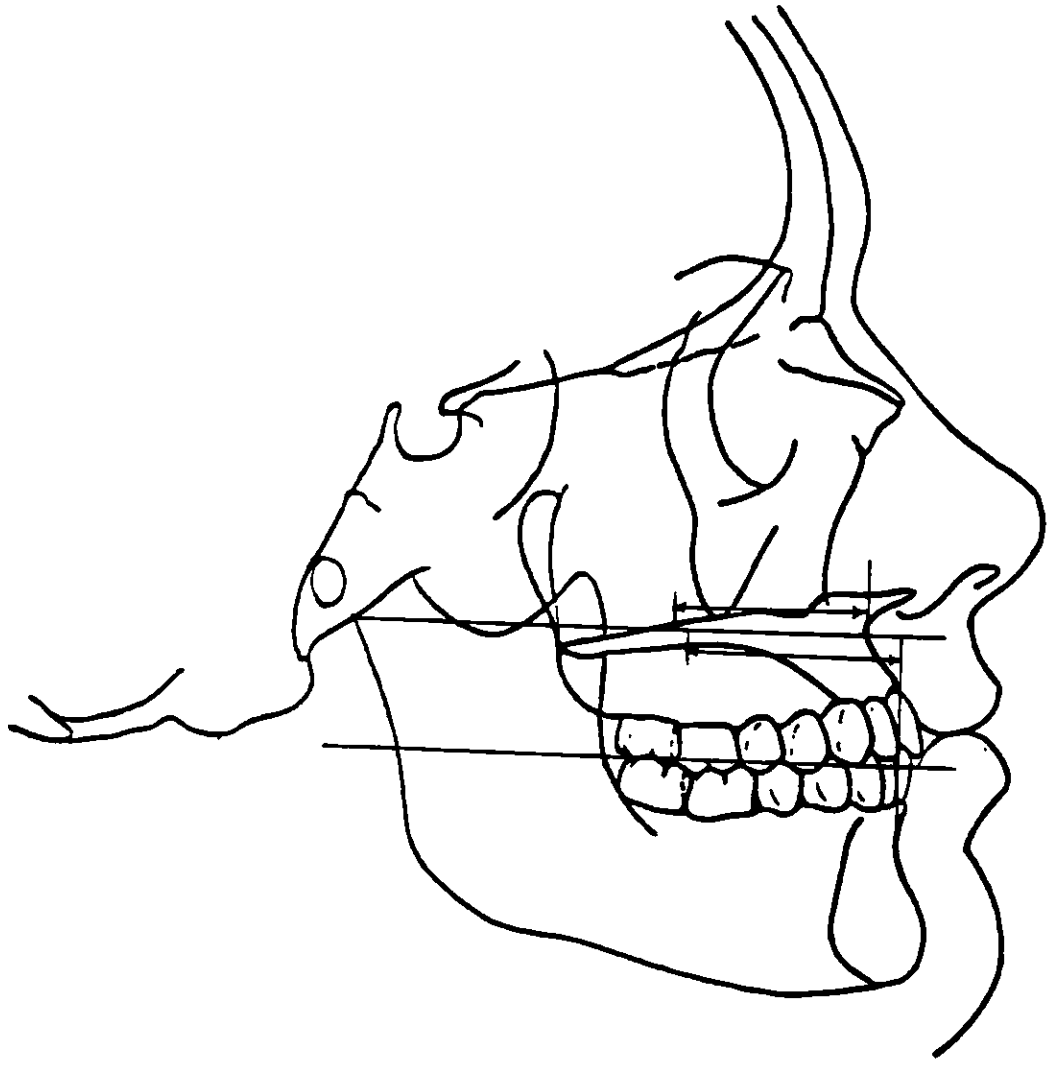


Figure 13. Maxillary/mandibular arches, skeletal dimensions, SPr compared with IPr. This comparison is identical to Figure 11 except that PM is measured to SPr and ARa is measured to IPr.

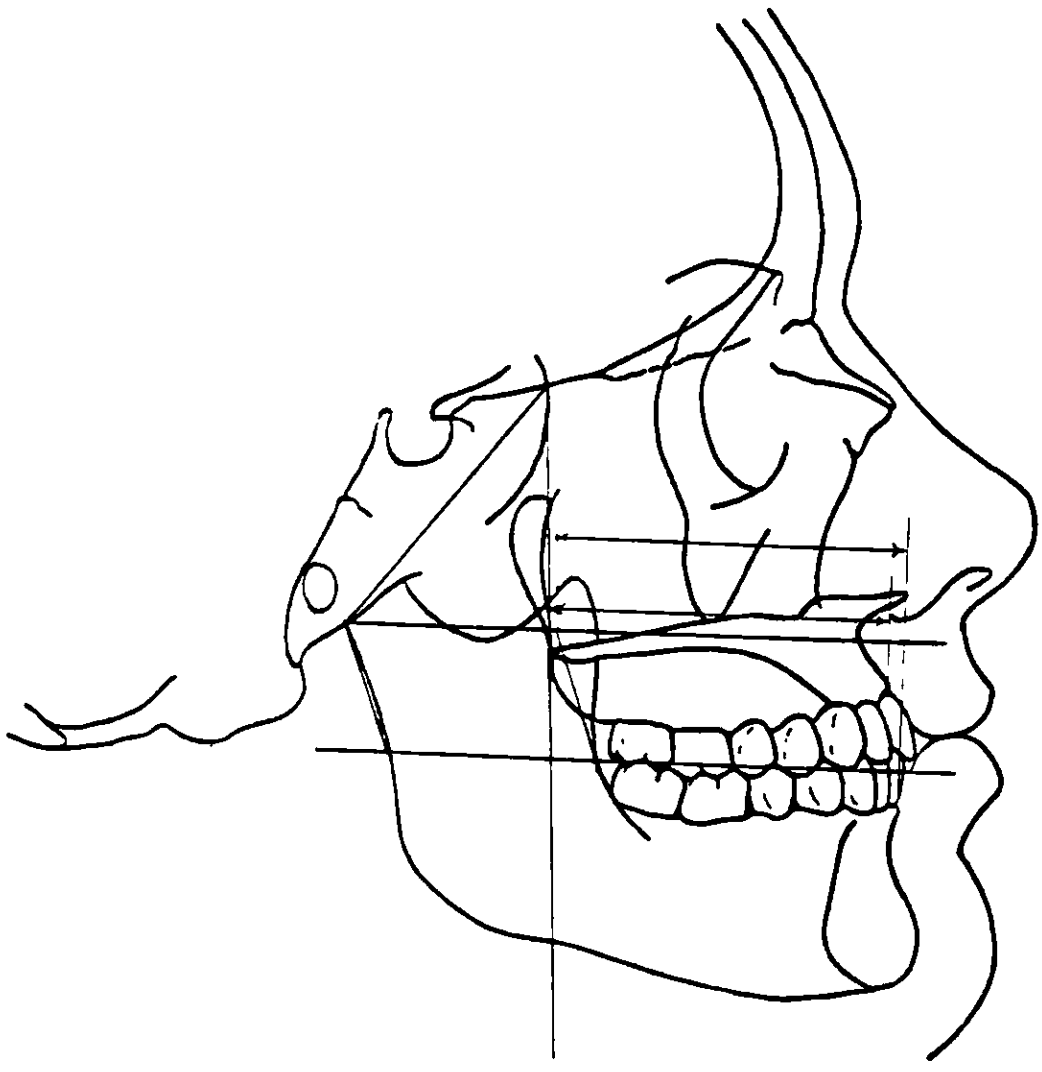


Figure 14. Maxillary/mandibular arches, dental dimensions, SPr compared with IPr. This measurement is identical to that in Figure 12 except that the distal of the maxillary first molar is measured to SPr and the distal of the mandibular first molar is measured to IPr.

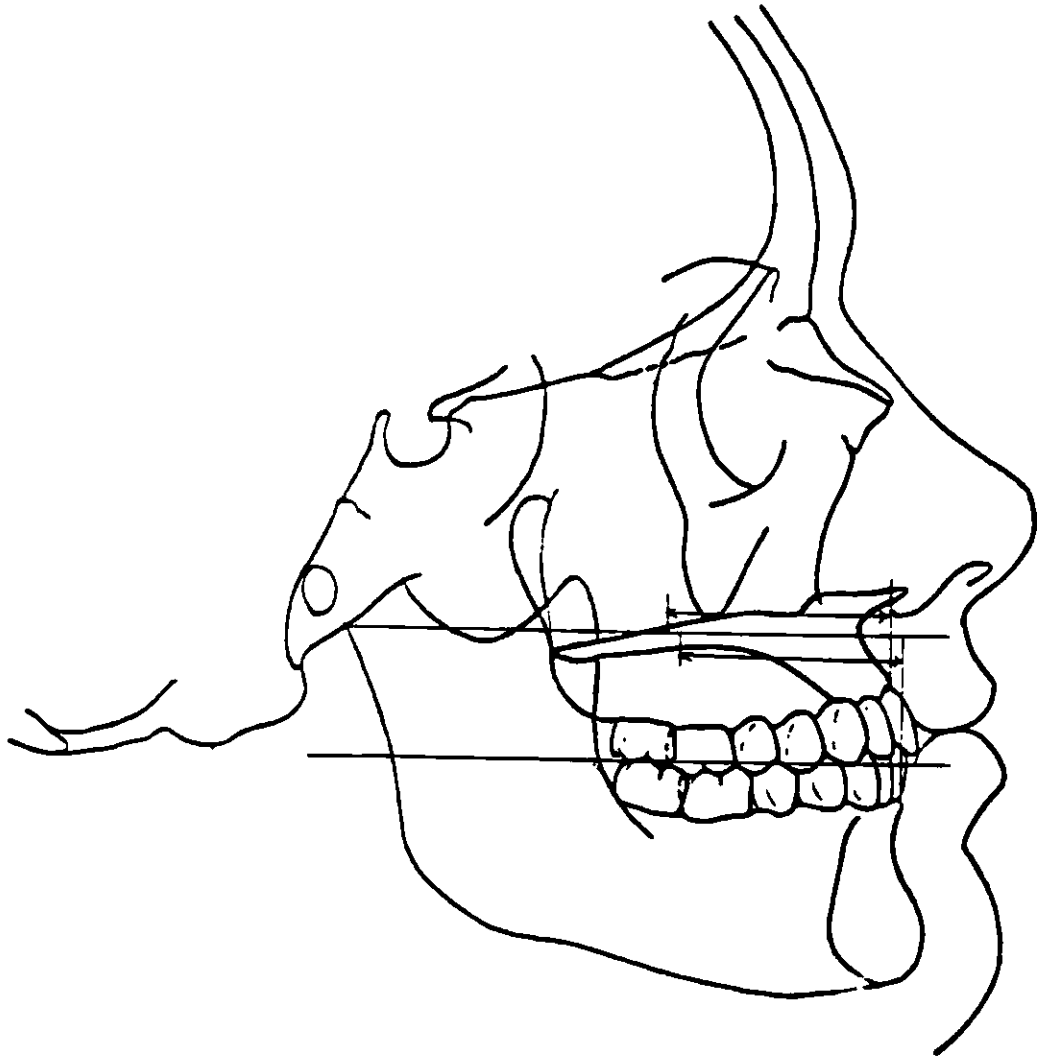


Figure 15. PM as compared with ramus/MCF vertical dimensions. The individual's relative posterior vertical nasomaxillary height is determined by this measurement. When the MCF rotates forward or backward, and the ramus rotates the same amount in the corresponding direction, no vertical disproportion in PM dimension has occurred relative to the composite vertical dimension of the middle cranial fossa and the ramus. The MCF rotation is determined by measuring the difference between PM and neutral PM along FOP. If PM is ahead of neutral PM, the MCF has a downward and forward rotation and is recorded as a positive value. If the PM is behind the neutral PM, the MCF has an upward and backward rotation and is recorded as a negative value. The ramus rotation is determined by measuring the difference between PRa and NRa along FOP. If PRa is ahead of NRa then the ramus has a forward rotation and is recorded as a negative value. If PRa is behind NRa then the ramus has a backwards rotation and is recorded as a positive value. Positive rotations of the MCF and the ramus will cause a "long" PM to occur. Negative rotations will cause a "short" PM to occur. (Ethnic variations and populations tendencies were not considered in this study.)

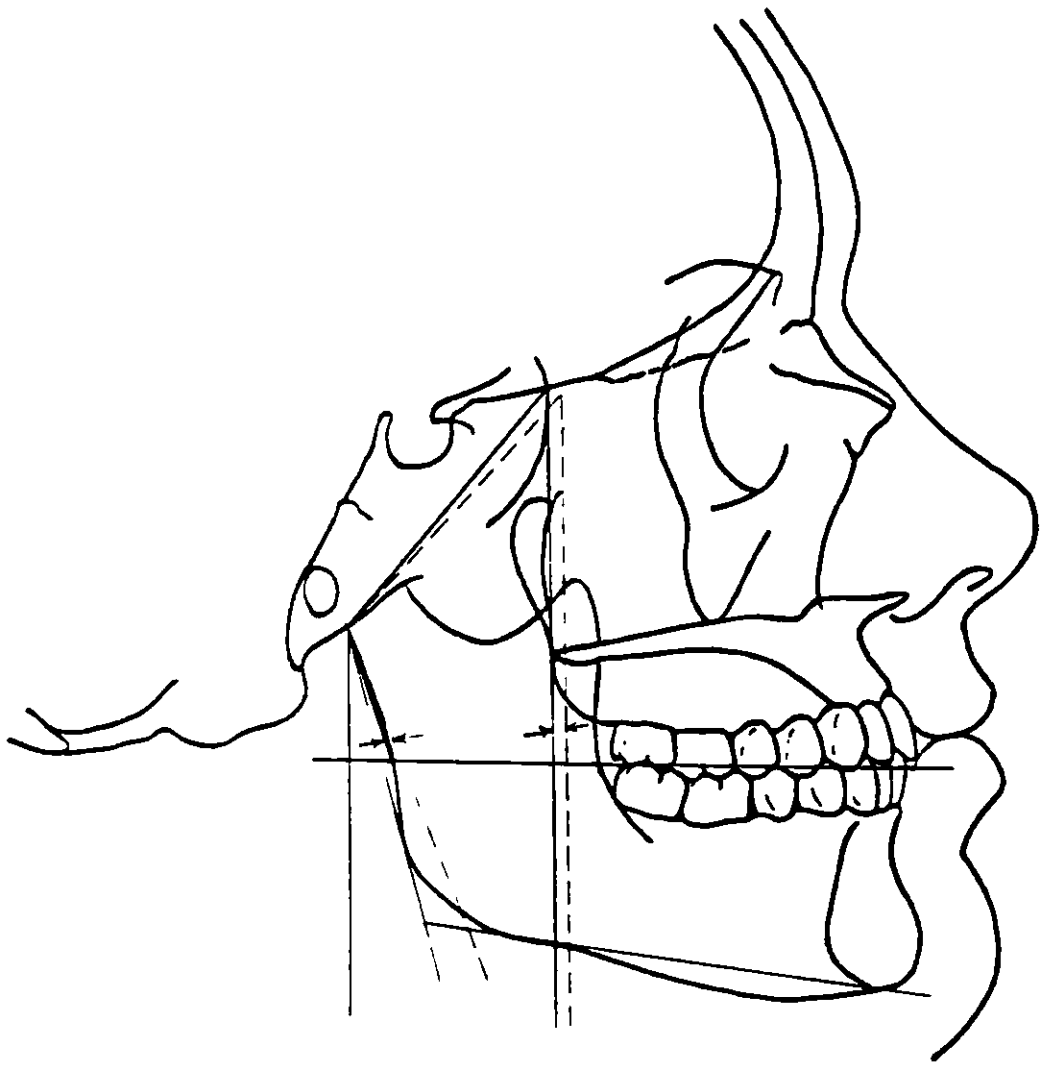


Figure 16. Corpus-occlusal alignment. This diagram demonstrates the extent of occlusal rotation as compared to the extent of ramus rotation. NOA acts as a reference line to determine the amount and direction of the occlusal rotation. NRa acts as a reference line to determine the amount of ramus rotation. Two arcs are drawn in this diagram. The radius of both arcs are equal in length. The length of the radius is determined by measuring the distance from the last occlusal contact point of the last fully erupted maxillary and mandibular molar to the point where the perpendicular from B point to REF crosses FOP along FOP. One arc is drawn from Ar, as the vertex, crossing the lines Ar to Go and NRa. The other arc is made from the last molar contact point, as the vertex crossing NOA and FOP. The distance between Ar to Go and NRa is measured at the points of intersection with the arc. If Ar to Go is behind NRa it is a positive number, if in front it is a negative number. The distance between FOP and NOA is measured at the point of intersection with the arc. If FOP is above NOA it is a positive number, if below it is a negative number. If FOP and Ar to Go have rotated equally in the same direction, the occlusal/corpus rotation is neutral. Any differential between them which involves an upward rotation of the corpus/occlusal plane relative to the ramus rotation results in a maxillary protrusive effect, and a downward corpus/occlusal rotation relative to the ramus rotation produces a mandibular protrusive effect.

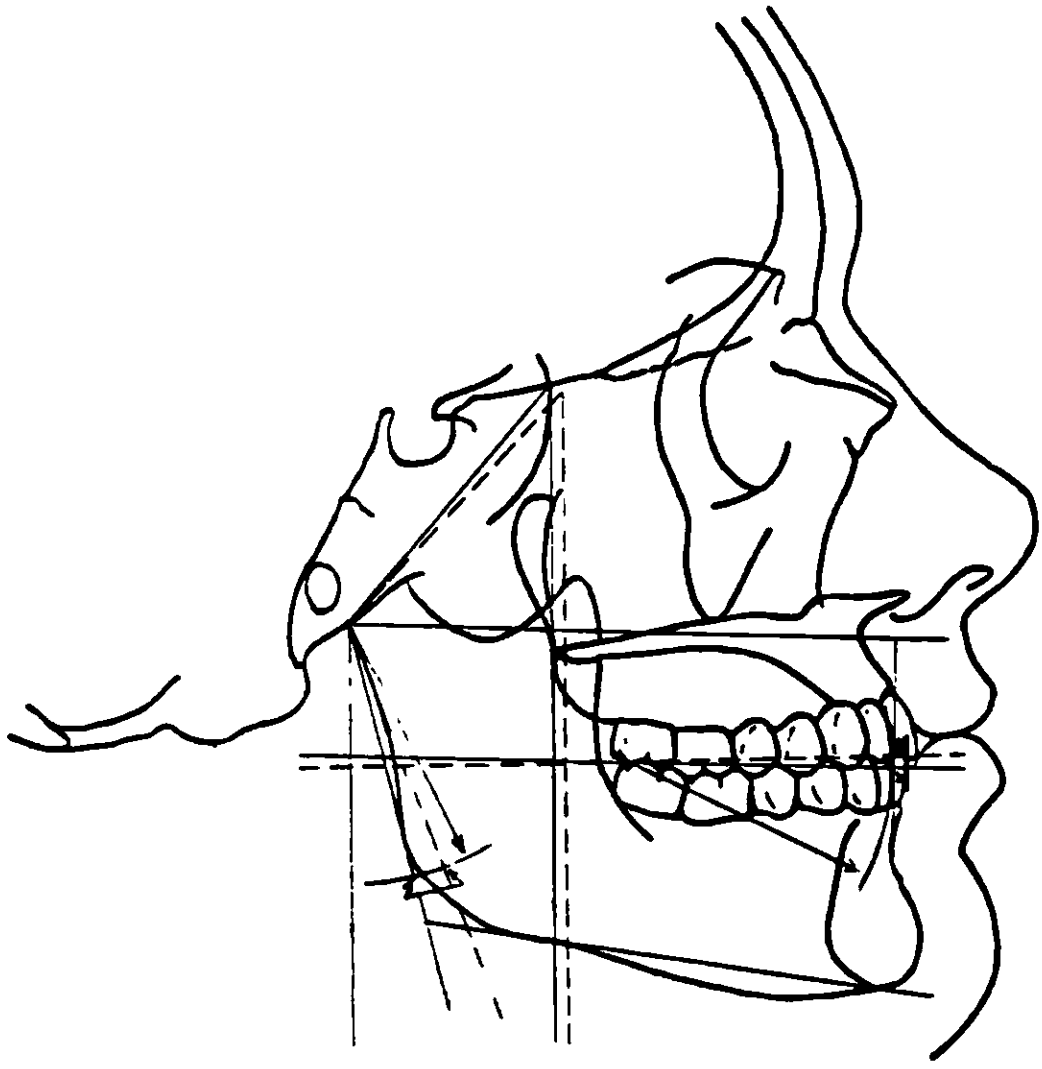


Figure 17. Mandibular plane alignment. The dashed line represents the neutral gonial angle as determined from the Bolton Standards Broadbent et al., 1975). The subject's mandibular plane is indicated by the line Me to Go (Bolton). The distance between the neutral mandibular plane and the subject's mandibular plane is measured along the line through B point perpendicular to REF. If Me to Go (Bolton) is above the neutral mandibular plane, it is positive, if below, it is negative.

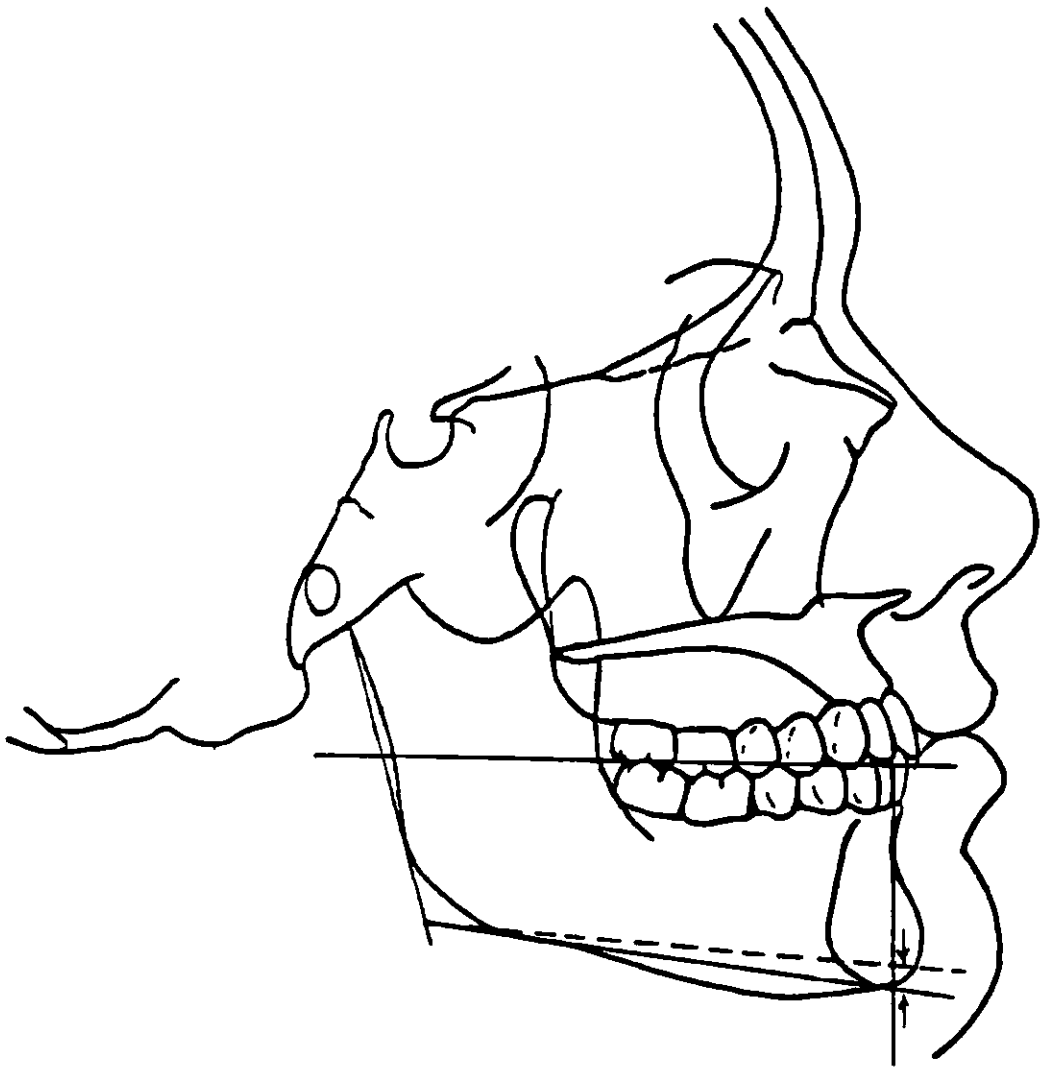


Figure 18. Gonial angle alignment. This diagram is similar to that in Figure 17. However, the measurement here is of two angles made in degrees. The neutral gonial angle and Ar to Go (Bolton) to Me.

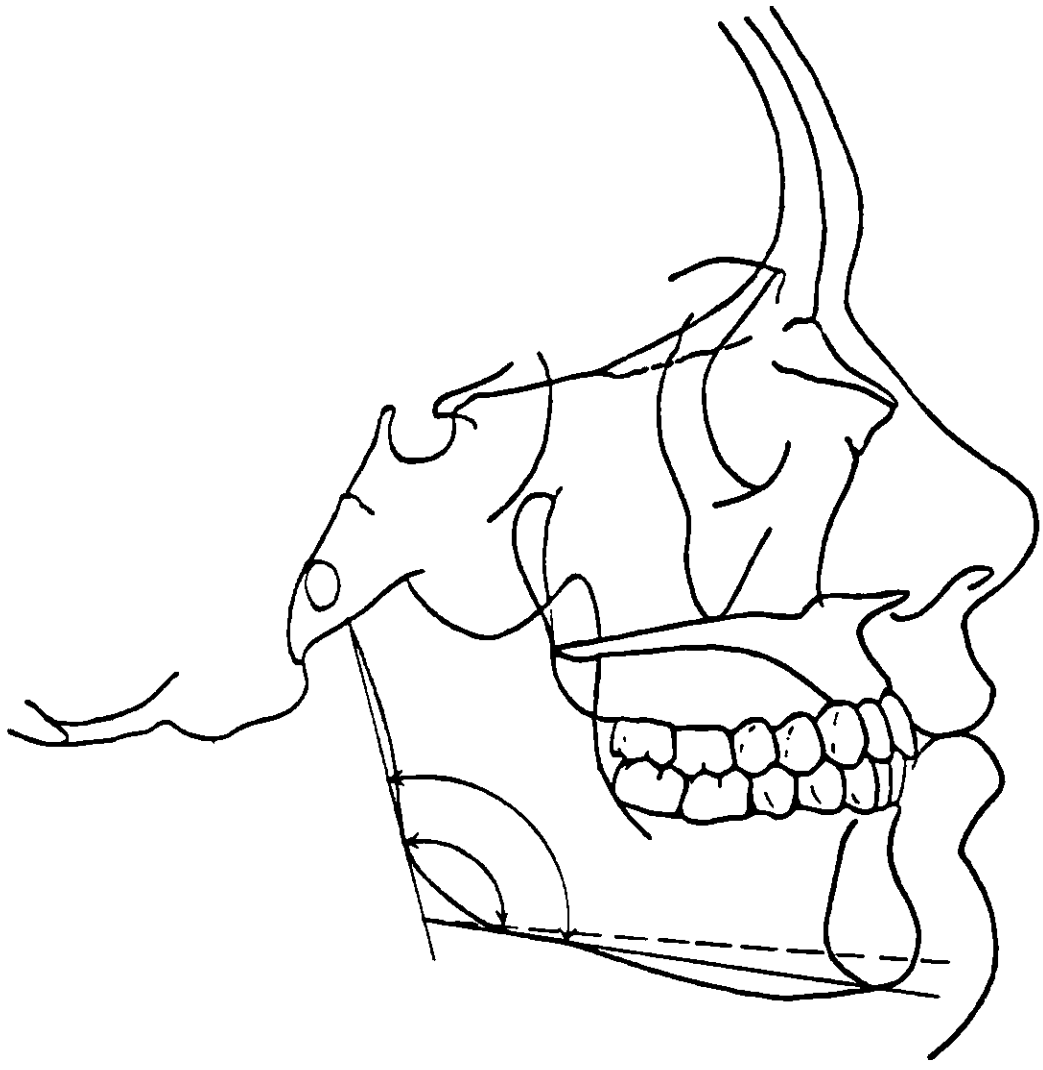


Figure 19. Occlusal plane alignment. This diagram demonstrates the direction and amount of occlusal plane and rotation. The measuremet is made between FOP and NOA along a perpendicular from IPr to FOP. If FOP is above NOA it is a positive number, if below NOA it is a negative number. Positive and negative values indicate counterclockwise and clockwise rotations, respectively.

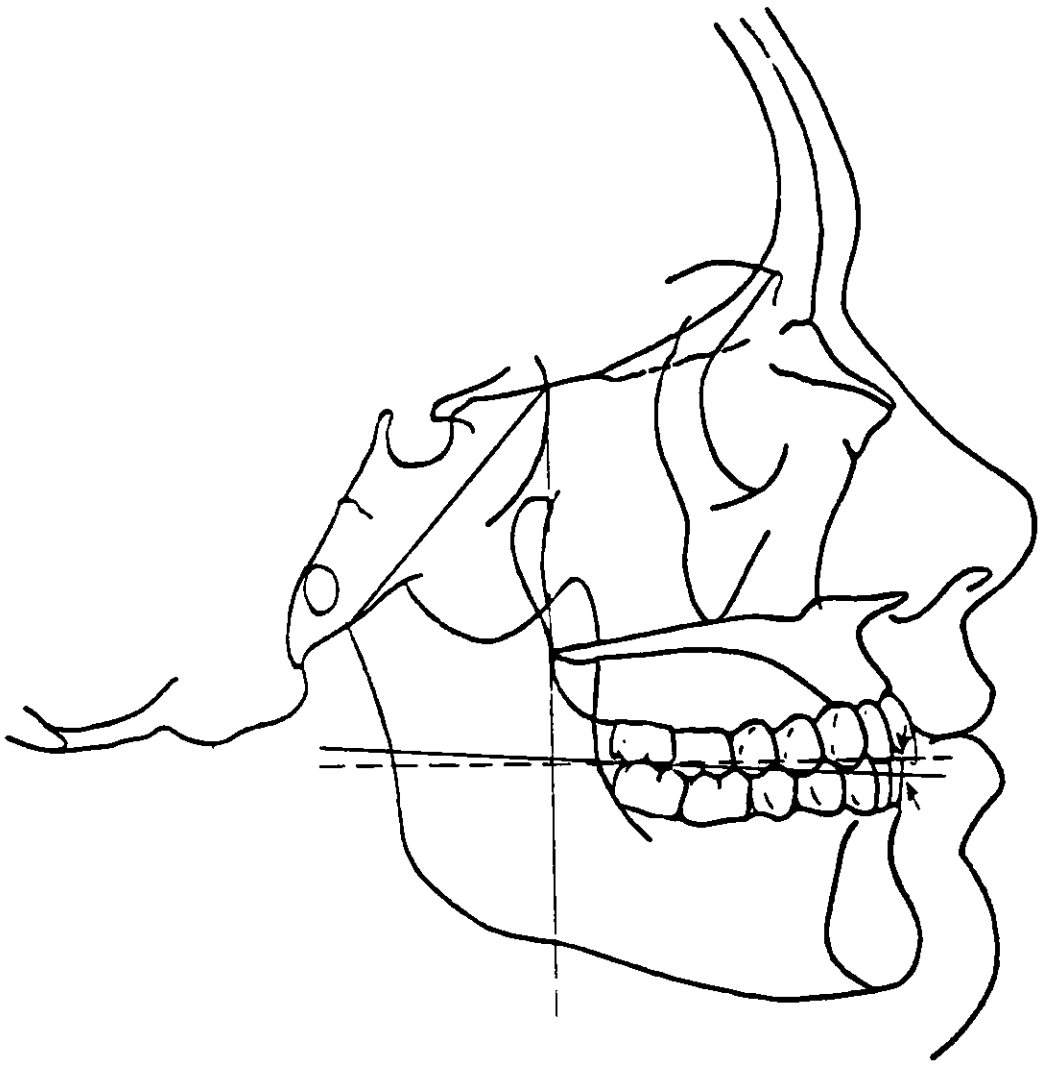
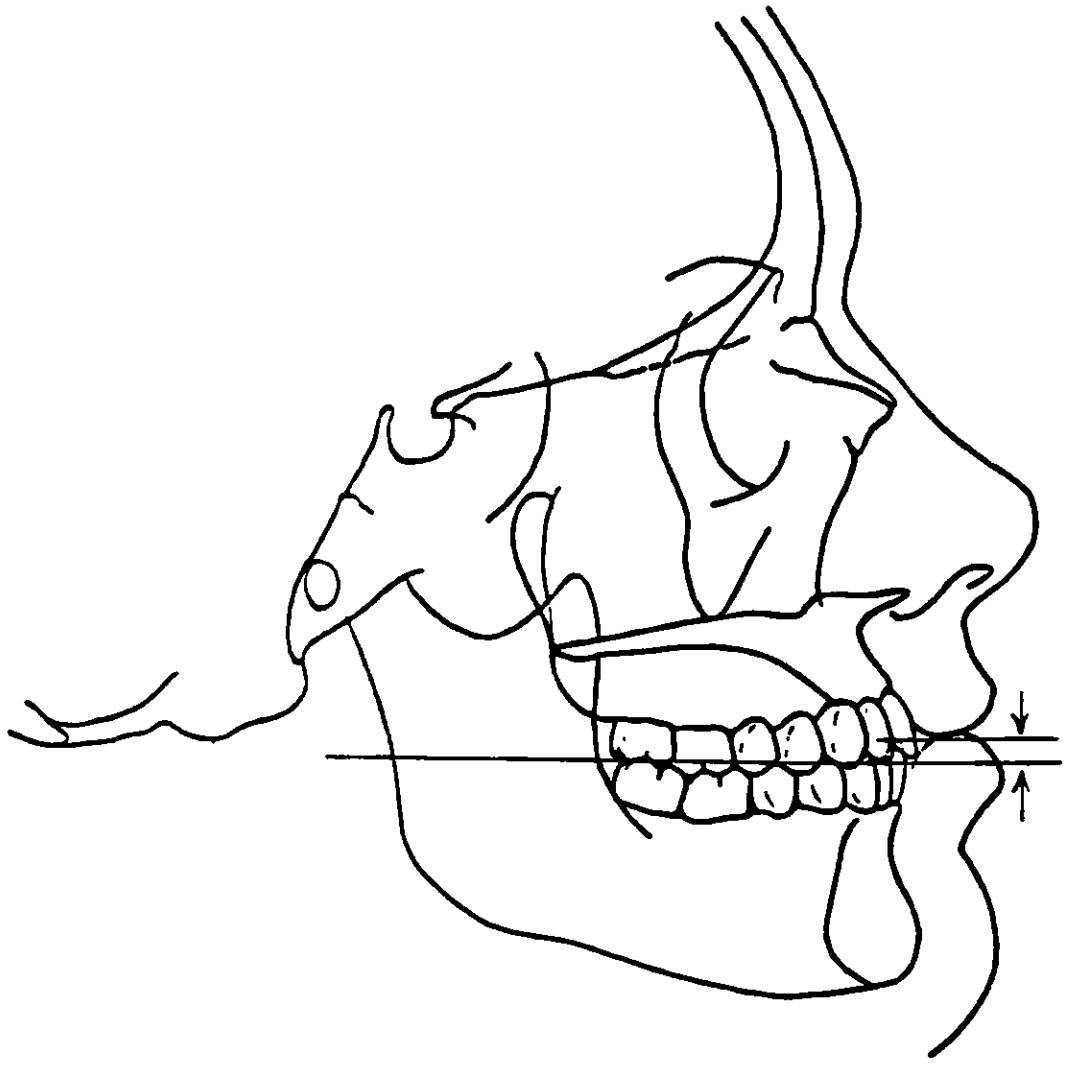


Figure 20. Curve of Spee. This is demonstrated by measuring the distance between the incisal edge of the mandibular central incisors and FOP. If the central incisors are above FOP it is a positive number, if below FOP it is a negative number.



LITERATURE CITED

Angle, E.H.: Treatment of Malocclusion of the Teeth. 7th ed. S.S. White Co., Philadelphia, 1907.

Behrents, R.: The effects of aging on the craniofacial complex. Unpublished Ph.D. thesis, The University of Michigan, Ann Arbor, Michigan. 1983. In Progress.

Bjork, A.: The face in profile. Svensk Tandl. Tidskrift, 40 (Suppl. 5B), Lund, 1947.

Bjork, A.: Cranial base development: A follow-up x-ray study of the individual variation in growth occurring between the ages of 12 and 20 years and its relation to brain case and face development. Am. J. Orthod., 41: 198-225, 1955.

Broadbent, B.H.: A new x-ray technique and its application to orthodontics. Angle Orthod., 1: 45-66, 1931.

Broadbent, B.H.: The face of the normal child. Angle Orthod., 7: 183-208, 1937.

Broadbent, B.H.: Bolton standards and technique in orthodontic practice. Angle Orthod., 7: 209-233, 1937.

Broadbent, B.H., Sr., B.H. Broadbent, Jr., and W.H. Golden: Bolton Standards of Dentofacial Developmental Growth. C.V. Mosby Co., St. Louis, 1975.

Brodie, A.G.: On the growth pattern of the human head from the third month to the eighth year of life. Am. J. Anat., 68: 209-262, 1941.

Brodie, A.G.: Late growth changes in the human face. Angle Orthod., 23: 146-157, 1953.

Brodie, A.G.: The behavior of the cranial base and its components as revealed by serial cephalometric roentgenograms. Angle Orthod., 25: 148-160, 1955.

Downs, W.: Variation in facial relationships: their significance in treatment and prognosis. Am. J. Orthod., 34: 812-840, 1948.

Enlow, D., C. Pfister, E. Richardson, and T. Kuroda: An analysis of Black and Caucasian Craniofacial Patterns. Angle Orthod., 52: 279-287, 1982.

Enlow, D., T. Kuroda, and A. Lewis: The morphological and morphogenic basis for craniofacial form and pattern. Angle Orthod., 41: 161-188, 1971.

Enlow, D.H., T. Kuroda, and A.B. Lewis: Intrinsic craniofacial compensations. Angle Orthod., 41: 271-285, 1971.

Enlow, D., and R. Moyers: Growth and architecture of the face. J.A.D.A., 82: 763-774, 1971.

Enlow, D.: Handbook of Facial Growth. W.B. Saunders Co., Philadelphia, 1975.

Enlow, D.: "Rotations of the mandible during growth," in Determinants of Mandibular Form and Growth, J. McNamara (Center for Human Growth and Development, Ann Arbor, Michigan, 1975), pp. 65-76.

Enlow, D.: Handbook of Facial Growth. W.B. Saunders Co., Philadelphia, 1982.

Harris, J.E., C. Kowalski, and S. Walker: Intrafamilial dentofacial associations for Class II, Division 1 probands. Am. J. Orthod., 67: 563-569, 1975.

Henry, R.G.: A classification of Class II, Division 1 malocclusion. Angle Orthod., 27: 83-92, 1957.

Hirschfeld, W.J., R.E. Moyers, and D.H. Enlow: A method of deriving subgroups of a population: A study of craniofacial taxonomy. Am. J. Phys. Anthropol., 39: 279-290, 1973.

Horvath, L.M.: A comparison of craniofacial compensation effects in treated and untreated cases. Unpublished M.S. thesis, Case Western Reserve University, Cleveland, Ohio. 1979.

Kane, E.G.: Dentoalveolar rotation in correction of Class II malocclusion. Am. J. Orthod., 73: 634-646, 1978.

Lande, J.L.: Growth behavior of the human bony facial profile as revealed by serial cephalometric roentgenology. Angle Orthod., 22: 78-90, 1952.

McNamara, J.A.: Components of Class II malocclusion in children 8-10 years of age. Angle Orthod., 51: 177-202, 1981.

McNamara, J., and R. Behrents: Standards for Cephalometric Evaluations. The University of Michigan, 1981.

Moore, A.: Orthodontic treatment factors in Class II malocclusion. Am. J. Orthod., 45: 323-352, 1959.

Moyers, R.E., F.L. Bookstein, and K.E. Guire: The concept of pattern in craniofacial growth. Am. J. Orthod., 76: 136-148, 1979.

Moyers, R.E., M. Riolo, K. Guire, R. Wainright, F. Bookstein: Differential diagnosis of Class II malocclusions. Part I. Facial types associated with Class II malocclusions. Am. J. Orthod., 78: 477-494, 1980.

Pfister, C.: A morphometric analysis of the mandibular prognathic individual. Unpublished Masters thesis, Case Western Reserve University, Cleveland, Ohio. 1983.

Ricketts, R.M.: Planning treatment on the basis of the facial pattern and an estimate of its growth. Angle Orthod., 27: 14-37, 1957.

Ricketts, R.: The influence of orthodontic treatment on facial growth and development. Angle Orthod., 30: 103-133, 1960.

Sassouni, V., and S. Nanda: Analysis of dentofacial vertical proportions. Am. J. Orthod., 50: 801-823, 1964.

83 31 81CS2 0,104 7 TH Pu 6166