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A LONGITUDINAL MORPHOMETRIC ANALYSIS AND CLASSIFICATION OF THE CLASS III INDIVIDUAL UTILIZING THE COUNTERPART ANALYSIS

by

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Abstract

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Numerous theories attempting to account for the skeletal pattern involved in the Class III individual have been proposed. Each has looked at a possible primary contributor to the prognathic profile. However, there is ample reason to assume that more than one skeletal imbalance, in different areas of the craniofacial complex, are contributing to the Class III skeletal pattern.

The purpose of this study is to longitudinally evaluate the various anatomic counterparts and their interrelationships, within the Class III craniofacial complex and to determine which of these contributes earliest and to the greatest degree to the prognathic profile. Also studied was the longitudinal stability of various combinations of these anatomic parts and relationships. This information will aid in the ability to predict a Class III skeletal pattern early in development and allow treatment to be initiated accordingly. Using Enlow's counterpart analysis, hypothetical groups were formed based on random combinations of these primary and secondary anatomic parts and relationships.

The results of this study may be summarized:

1. The 20 Class III 16 year old sample consisted of 3 different craniofacial compositions with 3 subtypes of Type III^3, all demonstrating a prognathic mandible with a Class III malocclusion. The 20 Class I 16+ year old sample consisted of 4 different craniofacial compositions with 2 subtypes of Type I^3 and 2 subtypes of Type I^4, all demonstrating a Class I occlusion.

2. The most stable Class III anatomic parts and relationships are the middle cranial fossa alignment and the mandibular corpus length relative to the maxilla. The most variable Class III anatomic relationships are the ramus alignment and horizontal width of the ramus relative to the MCF dimension. The Class I subjects are similar to the Class III, in variability of the anatomic relationships, varying only 10-15% in all but two areas. The Class III sample has 25% more backward positioned MCF than the Class I and 90% of the Class III subjects, from 9 years of age, had a mandibular corpus longer than the maxillary corpus, compared to only 70% of the Class I.

3. The Class III sample exhibited a steady decrease in the number of different craniofacial compositions, from 6 to 16+ years of age. In contrast, the Class I sample maintained a high level of different craniofacial compositions, throughout the same time period. However, both groups did express a pubertal growth spurt, reflected in the significant increase in variability among the anatomical relationships, between the age levels of 9 and 14.

4. In the Class III group, the combination of anatomic relationships which included; middle cranial fossa alignment, mandibular corpus length relative to maxilla, ramus horizontal width relative to MCF and the gonial angle, exhibited a pattern stability of 78% at the 9 year level and a 90% stability at the 14 year level. The Class I anatomic combinations were too variable to predict better than 50%. These levels of prediction confidence are for this sample; further research is needed to determine confidence levels in other samples.

Information from Whitney (1983) on a sample of 20 skeletal Class II analyzed in a similar manner, was compared to the Class

III and Class I data from this study.

The results of this comparison may be summarized:

1. The Class II 16+ year old sample consisted of 6 different craniofacial compositions with 4 different subtypes, demonstrating a Class II malocclusion.

2. The middle cranial fossa alignment and mandibular corpus length relative to the maxilla, which was very stable in the Class III sample, is extremely variable in the Class II pattern.

3. The Class II sample exhibited a steady increase in the number of different craniofacial compositions, even after the 14 year age level. This is contrary to the Class III sample, which showed a steady decrease in the number of compositions, especially after the 14 year level. The Class I sample did not fluctuate but rather, maintained a significant number of different craniofacial compositions.

The overall results from this study and the Class II comparison may be summarized:

1. The Class III craniofacial complex exhibits a large amount of change early in development and maintains it partly through puberty. The craniofacial pattern then appears to only undergo refinements, not total architectual turn over.

2. The Class II craniofacial complex showed less change early in development, but significant increases in the number of changes from before puberty to late adolescence. Many portions of the Class II craniofacial pattern appear to be changing at all age levels, as reflected by the large number of individual counterpart changes for each age level.

3. The Caucasoid Class I sample showed Class II tendencies in some anatomic parts and relationships and Class III in others. It appears from this study that Class I individuals are not a separate dental classification but rather, a craniofacial composition that has balanced or compensated for the various maxillary and mandibular protrusive tendencies, within their present craniofacial complex.

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DEDICATED

TO

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TABLE OF CONTENTS

	Page
ABSTRACT	ii
ACKNOWLEDGEMENTS	v
DEDICATION	vi
LIST OF TABLES	ix
LIST OF ILLUSTRATIONS	x
INTRODUCTION	1
REVIEW OF THE LITERATURE	4
STATEMENT OF THESIS	16
METHODS AND MATERIALS	17
RESULTS	42
DISCUSSION	77
SUMMARY AND CONCLUSIONS	98
LITERATURE CITED	101

LIST OF TABLES

		Page
I.	Definitions of Anatomic Landmarks	21
II.	Definitions of Cephalometric Planes	23
III.	Analysis of Class III Subtypes	44
IV.	Analysis of Class I Subtypes	46
V.	Distribution Percentages of Class I and Class III Individuals in the Various Types, Based on a Sample of 20 Individuals Per Class	47
VI.	Class III Craniofacial Compositions	49
VII.	Class I Craniofacial Compositions	50
VIII.	Changes Found in the Class III Anatomic Relationships During the Time Intervals Studied	51
IX.	Changes Found in the Class I Anatomic Relationships During the Time Intervals Studied	52
X.	Class II Craniofacial Compositions	53
XI.	Changes Found in the Class II Anatomic Relationships During the Time Intervals Studied	54

LIST OF ILLUSTRATIONS

Figure		Page
1.	Middle cranial fossa (MCF) and posterior maxillary (PM) relative alignment	25
2.	Ramus alignment	27
3.	Ramus/MCF horizontal dimensions (skeletal)	29
4.	Maxillary/mandibular arches, skeletal dimensions, A point compared with B point	31
5.	PM as compared with ramus/MCF vertical dimensions	33
6.	Gonial angle alignment	35
7.	Curve of Spee	37
8.	Mandibular protrusive relationship	39
9.	Maxillary protrusive relationship	41
10.	Type III^{1} composite	56
11.	Type III^{2*} composite	58
12.	Type III^{2**} composite	60
13.	Type III^{2***} composite	62
14.	Type III^{3} composite	64
15.	Type I^{1} composite	66
16.	Type I^{2} composite	68
17.	Type I^{3*} composite	70
18.	Type I^{3**} composite	72
19.	Type I^{4*} composite	74
20.	Type I^{4**} composite	76

INTRODUCTION

The cause and developmental nature of the Class III prognathic skeletal pattern has been a subject of much debate through the years. Numerous theories attempting to account for the skeletal pattern involved have been proposed. These have focused primarily on possible underlying skeletal imbalances, heredity, and functional dysplasias. Treatment has usually been directed at a particular area, thought by the clinician to be the most important cause of the problem.

In a treatment procedure involving a Class III malocclusion, the age of the patient and the timing for appliance placement are significant factors if growth is to be affected. If a constrained maxilla represents the true underlying problem, then growth in this morphologic region must be released as soon as possible so that normal nasomaxillary growth and development can proceed. If, however, an abnormal mandible is involved, the objectives of an orthopaedic treatment procedure can be utilized, and the objective is to restrain all possible horizontal mandibular growth, or at least to redirect it in a more vertical vector. Thus, the initiation time for treatment, becomes crucial to treatment success. However, early prediction and then diagnosis of a true skeletal Class III, has not been consistently successful using present-day methods. The various procedures for conventional

cephalometric analyses have necessarily been based almost entirely on population means and standards. These normative based analyses yield very little biologic interpretation, because their constructs do not coincide or have any direct relation to actual fields and sites of growth and remodeling.

An analysis that evaluates an individual based on the individual's own existing composition of anatomic parts and relationships, and which shows how each growth change in size, rotation, configuration, and displacement, would allow a far more informative assessment of the biologic nature of the skeletal aberrations involved. The individual, therefore, would be evaluated using his own set of "natural" standards determined by his or her existing combinations of relationships of actual anatomic parts. The counterpart method represents an attempt at such an analysis. It is a method by which certain craniofacial parts and counterparts are compared to determine their expression and final fit. This method can describe, for a specific individual, how a growth pattern has occurred by accounting for the biological activities that occurred at the actual sites and fields of growth and development. Being able to determine the developmental path of the Class III craniofacial complex is important in determining which particular relationships, once establishing mandibular protrusion at some stage in childhood, remain so until childhood. If these relationships can be known, then the opportunity to predict

the eventual individualized adult skeletal characteristics of a given person can be made more accurately.

Mandibular prognathism is a multifactorial result of many regional morphogenic combinations involving disproportionately growing sizes and rotations of anatomic counterparts. Heredity and functional conditions must be taken into consideration as potential contributors in establishing the circumstances that lead to these composite Class III features. Nonetheless, treatment procedures should ideally be designed to address the particular, underlying combination of anatomic characteristics in any given patient. A long face, open bite Class III, for example, should not be treated in a manner similar to a short face, deep bite just because both are "Class III". Therefore, the clinician must consider the entire craniofacial complex, not just a superficial dental classification, when alternative treatment procedures are considered. The positioning of teeth represent a final anatomic expression of a balanced or imbalanced craniofacial skeletal complex.

LITERATURE REVIEW

Since the introduction of cephalometric roentgenology by Broadbent (1931) and Hofrath (1931), researchers and clinical orthodontists have sought to develop an analysis that can provide a meaningful anatomic and developmental evaluation of an individual's craniofacial pattern as determined from lateral cephalograms.

Through the years, the approaches to cephalometric studies have changed, but the results have always been derived from normative-based analyses. Tweed (1946) and later Downs (1948) developed analytic procedures that were very effective for treatment planning and diagnosis but which still considered only the final facial pattern, rather than a developmental pattern analysis. To more completely understand the entire craniofacial complex and its development, an analysis was needed that could evaluate the developmental effects of the major sites of growth, remodeling, and displacement of the key components of the craniofacial complex.

The Counterpart Analysis

Enlow (1971) developed a "counterpart" analysis to account for the individualized combinations of anatomical and developmental characteristics that were involved in the craniofacial composite pattern of any given individual.

The cephalometric planes utilized by Enlow, in contrast to most conventional planes and angles, correspond to actual fields and sites of growth, remodeling, and displacement. As explained below, this makes it possible for a given individual to provide his own built-in and morphologically natural set of "standards", with no need for comparisons with population norms.

The posterior maxillary (PM) plane is a key plane in this analysis. The PM plane forms a natural vertical anatomic boundary between the various sets of anterior and posterior horizontal counterparts. The anterior counterparts include the anterior cranial fossae, the corpus of each maxillary and mandibular halves, the palate, and the superior parts of the nasal region. The posterior counterparts include the middle cranial fossae, the pharyngeal space, and the mandibular rami. In the vertical dimension the ramus/middle cranial fossae is a counterpart to the vertical, posterior segment of the nasomaxillary complex which in turn is a counterpart with the anterior-vertical portion of the ethmomaxillary region.

If a precise match exists between or among specific counterparts, they are in "structural" balance and have a neutral anatomic effect. If one or the other is dimensionally long or short, a mandibular or maxillary protrusive effect exists for that regional anatomic relationship, and this contributes to the multifactional basis for a malocclusion or some other morphologic variation.

If any two of a given individual's counterparts do not either rotate or enlarge during growth to an equivalent extent or direction, relative to the other, a dimensional offset is established, and with it a corresponding morphologic form or pattern variation is created. This offset contributes to a protrusive or retrusive effect in that regional part of the craniofacial complex. In this way, specific combinations of structure and growth patterns, and thus combinations of them that establish the overall anatomical pattern in any particular person, can be accounted for and explained. Up until now, this type of information could only be derived by studies utilizing microscopic tissue examination, vital staining, or implant markers.

Mandibular Prognathism

Edward Angle (1907) was the first to use a systematic, dentally-based rationale for classifying different types of malocclusions. With regard to mandibular protrusion, Angle states:

> The Class III is characterized by mesial occlusion in both lateral halves of the dental arches. The extent, to which the mesial occlusion must exist in order to place the case in this class, is slightly more than one-half the width of a single cusp of a maxillary first molar distal to the mesial buccal groove of a mandibular first molar on each side.

Angle went on to say that these cases are always progressive, and the severity of mesial occlusion can become progressively greater, even to the extent of a full molar width or more.

Mandibular prognathism related to anteroposterior skeletal imbalances have been based on various components of the craniofacial complex. Dewey (1919) considered that the deformity in some cases results from an underdeveloped premaxillae, while Goddard (1900) and Lischer (1912) felt that an overdeveloped ramus is more at fault. Sicher and Krosa (1921) compared Class III to Class I crania and concluded that prognathism occurs primarily because of variations in the size of the mandible.

Bjork (1947), studying 281 Swedish adults, found a smaller saddle angle (N-S-Art) in the Class III sample as compared to a Class I mean. Bjork theorized that this was a reflection of a more anteriorly placed temporomandibular joint. This he felt was a contributing factor in causing pronounced mandibular prognathism.

Classification of Mandibular Prognathism

Steegman (1948) was one of the first to classify the Class III malocclusion into two separate groups, true skeletal and pseudo-functional Class III malocclusion. He determined that the pseudo Class III was the result of a positional or functional placement of the mandible, rather than a true skeletal dysplasia. He further divided the true Class III malocclusion into a maxillary or mandibular skeletal dysplasia, or a combination of the two.

A more recent study involving classification was carried out by Jacobson (1974). In distinguishing between pseudo and

true skeletal Class III, he identified five variables which were felt to provide a basis for subtyping. The first two variables involve a large mandible or small maxillae. The next three variables he utilized represent the first attempt at looking beyond actual horizontal jaw lengths. They include retropositioning of the maxillae, forward mandibular positioning, and rotations of the mandible relative to the neurocranium. He classified two basic morphologic patterns of Class III, which are the divergent and convergent types. Typically, characteristic features of the divergent Class III pattern include variations of the palatal, occlusal, and mandibular planes, an obtuse gonial angle and, in extreme cases, an anterior open-bite. The convergent type of Class III has planes which tend toward parallelism, an acute gonial angle, and a deep anterior overbite. Jacobson also found that sexual dimorphism was mainly reflected in the relatively larger male Class III mandible. Although the craniofacial proportions of the male and female Class III cases were similar, the females tended toward a slightly more divergent type of pattern.

Horowitz (1969) found the Class III and Class I mandibular body lengths to be quite similar. This he felt demonstrated that mandibular prognathism is not primarily a matter of size discrepancy but rather a result of complex disturbances among multiple craniofacial relationships. He also found that mandibular form and position, rather than mandibular size or maxillary varia-

tions, represent the most significant contribution to the mandibular prognathic individual.

Incidence and Heredity

The frequency of mandibular prognathism and Class III malocclusion is relatively low in the general North American or Western European population. Seipel (1946) found 4% of 140 Swedes over 21 years of age having Class III malocclusions. In a literative survey, Jacobson (1973) reported a frequency from 1.6 to 12.2%, with a mean slightly below 5%.

Suzuki (1961) surveyed 1,362 individuals from 243 Japanese families. In families with a history of prognathism, 34.3% of the family members demonstrated the trait, whereas in families with no history of prognathism only 7.5% had the trait. For five families, in which both parents were prognathic, 40% of the children were affected. If one parent was affected, 20.2% of the children were prognathic; if neither parent was affected only 11.2% of the children were prognathic.

Gorlin et al. (1965) reported prognathism associated with certain X chromosome aneuploidal conditions. He stated that the probability of both maxillary and mandibular prognathism is increased with the addition of each X chromosome, from the XO to XXXXY syndromes. He also found that the mandible is more frequently affected.

Whenever genetic transmission of a certain trait is examined, the experiment of design, is to test monozygotic, pure genetic transmission, and dizygotic, more complex gene transmission, twins. These experiments yield information that provides a basis for evaluating the frequency and nature of the influence of heredity in the development of that trait. Markovic (1970) found of 15 monozygotic twins, 14 (93.37%) of these were concordant and 1 (6.7%) discordant for Class III malocclusion. Of the 15 dizygotic twins, 5 (33.3%) were concordant and 10 (66.6%) were discordant. These results strongly suggest that genetic factors play some predominant role in the etiology of Class III malocclusions.

Litton et al. (1970) compiled a very extensive study on the mode of transmission of mandibular prognathism. Due to incomplete penetrance and irregular pattern of expression, he quite clearly showed that simple autosomal dominant or recessive transmission were not involved in the inheritance of mandibular prognathism. Litton proposed a polygenic model with a threshold for expression as the most probable mode of genetic transmission for this trait. This model explains the familial distribution and relative prevalence within the general population and in siblings of affected persons. Litton found no evidence to suggest that the trait is sex linked. The possibility that different modes of transmission exist in different families or different populations was not ruled out.

Functional Basis for Mandibular Prognathism

Moyers (1949), in studies involving muscle contraction patterns in Class II, division 1 cases, concluded that abnormal muscle patterns may be of etiologic significance in the development of malocclusions.

Ahlgren (1971), in electromyographic studies on chewing and incising actions in Class III individuals, derived results similar to those of Moyers. His study was structured for analyzing the coordination and magnitude of masticatory muscle action patterns and how these related to the form of the Class III mandible. Ahlgren found the Class III gonial angle to be on an average, 10° larger than the Class I norm. During incising, the reduced electromyographic activity indicated that the masseter muscles were strongly inhibited, rather than the temporalis muscles as seen in Class I. During chewing, a similar observation was made: reduced electromyographic activity was found to be a result of inhibited masseteric action rather than temporalis inhibition. Ahlgren concluded that inhibition of muscle activity during both chewing and incising makes the angular process (insertion of the masseter muscle) less massive resulting in a more obtuse gonial angle. He also felt that a posterior rotation of the mandible, as described by Bjork (1969), may also be accentuated by hypofunction of the mandible.

Role of Dental Compensation in Mandibular Prognathism

Robinson et al. (1972) noted the presence of several anteroposterior dental compensations in untreated Class III individuals. These compensations included tendencies toward proclination of maxillary incisors and retroclination of mandibular incisors and a negative overjet.

Robinson (1972) and Geiger (1980), examining Class III untreated cases for gingival recession and functionally mobile teeth, found twice as many mobile teeth and three times the extent of labial gingival recession in Class III than Class I individuals.

It is evident that if a balanced maxillary and mandibular skeletal relationship exists, adjustments of the dentition can provide improved intercuspation and more functional overbite and overjet. However, the occurrence of vertical and/or horizontal skeletal dysplasias increases the need for more extensive dental compensations.

Growth of the Mandible

Brodie (1941) was one of the pioneers in the field of growth pattern determinations for the craniofacial complex. He regarded the facial pattern in an individual as relatively constant and unchanging and an extension of the fetal pattern. Bjork (1968), by means of longitudinal implant studies, however, show-

ed that individual growth changes of the mandible are the rule rather than the exception.

Using histologic methods, Enlow et al. (1964) demonstrated that the mandible grows in several principle, divergent directions simultaneously. Remodeling processes during mandibular growth involve a constant process of "area relocation". As the entire mandible increases in size, its various parts occupy, in sequence, new locations, and the changes involved are produced by regional remodeling alterations. The remodeling and relocation of the ramus in a posterior direction, for example, provides for a lengthening of the corpus. The ramus also undergoes rotational remodeling to produce a more upright ramus to accomodate the vertical enlargement of the nasomaxillary complex and the eruption of the dentition (Enlow, 1975). The corpus is not able to rotate by resorption of bone along its inferior surface. It is the growth and remodeling of the ramus, not the corpus, that largely provides for mandibular arch positioning, and this involves ramus height, breadth, and the development of a more open or closed angular relationship between the ramus and corpus.

In conjunction with the developmental function of the various fields of growth and remodeling throughout all parts of the ramus, the condyle represents a localized adaptive site for ramus and whole mandible growth. The condyle is structured to

provide developmental accomodation for the varied, complex regional directions and magnitudes of growth that characterize different facial types, occlusal patterns and the infinite variety of individual craniofacial patterns.

According to the functional matrix concept Moss (1969), the soft tissue matrix carries the mandible inferiorly and anteriorly. The condyle is simultaneously stimulated to respond by growth in an opposite direction, thereby sustaining its proper anatomic position and articular relationship with the basicranium.

Based on various experiments and longitudinal cephalometric studies, Ricketts (1972) concludes that the path of growth of the mandible conforms to an arcial pattern along a circle from the coronoid process to the center of the symphysis. Ricketts felt that this pattern is congruous with a logarithmic spiral pattern of mandibular growth proposed by Moss (1965). Such a pattern correlates in part with the distribution of fields of resorption and deposition on the surface of the mandible as described by Enlow et al. (1971). An arcial pattern has become Ricketts' basis for a computerized forecasting of mandibular growth. Using this procedure, he has found that Class III mandibles, especially the severe types (ANB-4 or greater), do not conform to a normal pattern in amount or direction.

Prediction of Mandibular Prognathism

Schulhof and Bogha (1975) studied several thousand cephalometric records processed by the Ricketts' forecasting method, in which the actual growth was different from that which was predicted. A particular Class III type emerged, one that grew more in the mandible and less in the cranial base than predicted. The three measurements that most consistently deviated from the predicted values were ramus position, porion location, and cranial deflection. Based on these findings, Ricketts proposed a new "true" skeletal Class III preduction model, which has an abnormally foward porion, a forward ramus position, a downward and forward basion, and a tendency for a Class III molar relationship.

Schulhof (1977), using 14 Japanese skeletal Class III cases with longitudinal records for a period of four years, tested the new Ricketts' Class III forecasting model. These cases were shown to have an average of 93% more growth in the mandible than in the cranial base, with a minimum excess mandibular growth of 63%. The forecast showed 82% accuracy for the cranial base and 73% accuracy for the mandibular growth expected.

Ricketts' result is slightly better than the Johnston grid, which can predict with 70% accuracy, but it still has one major drawback. This involves the additive process of constant growth factors derived from population norms. The method, unfortunately, precludes recognition of individual growth circumstances and combinations.

STATEMENT OF THESIS

The objective of this study is to morphometrically and longitudinally analyze the true Class III skeletal pattern and determine which of the anatomic parts and relationships of the craniofacial complex contribute most to the prognathic profile. Also to be determined, is a what age the Class III pattern first begins to express itself. Once established, these early mandibular protrusive counterparts will be followed to determine their stability through time. This study was primarily concerned with Class III and Class I craniofacial compositions, however, a comparison with Class II data, analyzed in a manner similar to this study, will be presented.

METHODS AND MATERIALS

The lateral cephalograms of the Class I and Class III untreated cases were made available from the Bolton-Brush Collections housed at Case Western Reserve University.

Sample

Group I

A sample of 20 control subjects, without regard to sex, with a Class I occlusion was selected according to the following criteria:

1. No orthodontic treatment was involved prior to or during the ages studied.
2. Each case had serial headfilms available for at least four age levels: under 3 years, 4 to 6 years, 7 to 12 years, 13 to 16 years, and older than 17 years of age.
3. Class I occlusion was present bilaterally, determined by inspection of the casts for molar relationship at 12 years of age.
4. Severe dental crowding was absent.
5. Normal overbite (1-2 mm) and overjet (1 mm) were present.

One lateral cephalogram for each age level was utilized. The average age for the first cephalograms was 2 years, 3 months, with a range from 1 year, 11 months to 3 years. The average age for the second cephalograms was 5 years, 4 months, with a range from 4 years to 6 years. The average age for the

third cephalograms was 9 years, 3 months, with a range from 7 years to 11 years, 11 months. The average age for the fourth cephalograms was 14 years, 2 months, with a range from 12 years, 1 month to 16 years. The average age for the fifth cephalograms was 17 years with a range from 16 years, 1 month to 18 years, 10 months.

Group II

A sample of 20 untreated Class III cases were studied. These cases were selected at random, without regard to sex, according to the following criteria:

1. No orthodontic treatment occurred prior to or during the ages studied.
2. Class III occlusion existed bilaterally as determined by inspection of casts for molar relationship at 16 years of age.
3. Each Class III case had serial headfilms available for at least four age levels: under 3 years, under 6 years, 7-12 years, 13-16 years, older than 16 years of age.
4. Severe dental crowding was absent.

One lateral cephalogram for each age level was utilized. For the under 3 year age level, only 6 cases were available. The average age for the first cephalograms was 2 years, 8 months with a range from 2 years, 2 months to 2 years, 11 months. The average age for the second cephalograms was 5 years, 6 months with a range from 4 years, 2 months to 5 years, 11 months. The average age for the third cephalograms was 9 years, 1 month with

a range from 8 years, 11 months to 11 years, 1 month. The average age for the fourth cephalograms was 14 years, 2 months to 16 years. The average age for the fifth cephalograms was 17 years, 2 months with a range from 16 years, 2 months to 18 years, 5 months.

Technical Details

The cephalograms for both the Class I and Class III cases were taken at the Broadbent-Bolton Center using the Broadbent cephalometer.

Tracings were made by pencil (2H) on 0.003 inch acetate. The linear and angular were made using the millimeter scale and compass of a Baume protractor.

Measurements

All points and planes necessary for the counterpart analysis were drawn by one observer and were rechecked at a later date by the same observer. Seven anatomic variables were compared and analyzed for each tracing. The result of each part-counterpart comparison was recorded as a maxillary protrusive (+), a neutral (0), or a mandibular protrusive (-) effect. If the extent of the protrusive effect was less than or equal to 2.5 mm the symbols (+) or (-), respectively, were used. If the effect was greater than 2.5 mm, a double (++) of (--) was used.

Tables I and II outline and provide definitions for the specific anatomic landmarks and cephalometric planes used. Explanations for measurement procedures accompany each appropriate figure (1-9). Figures 8 and 9 are composites of maxillary and mandibular protrusive relationships, respectively.

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 neurtal 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.

Figure 1. 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.

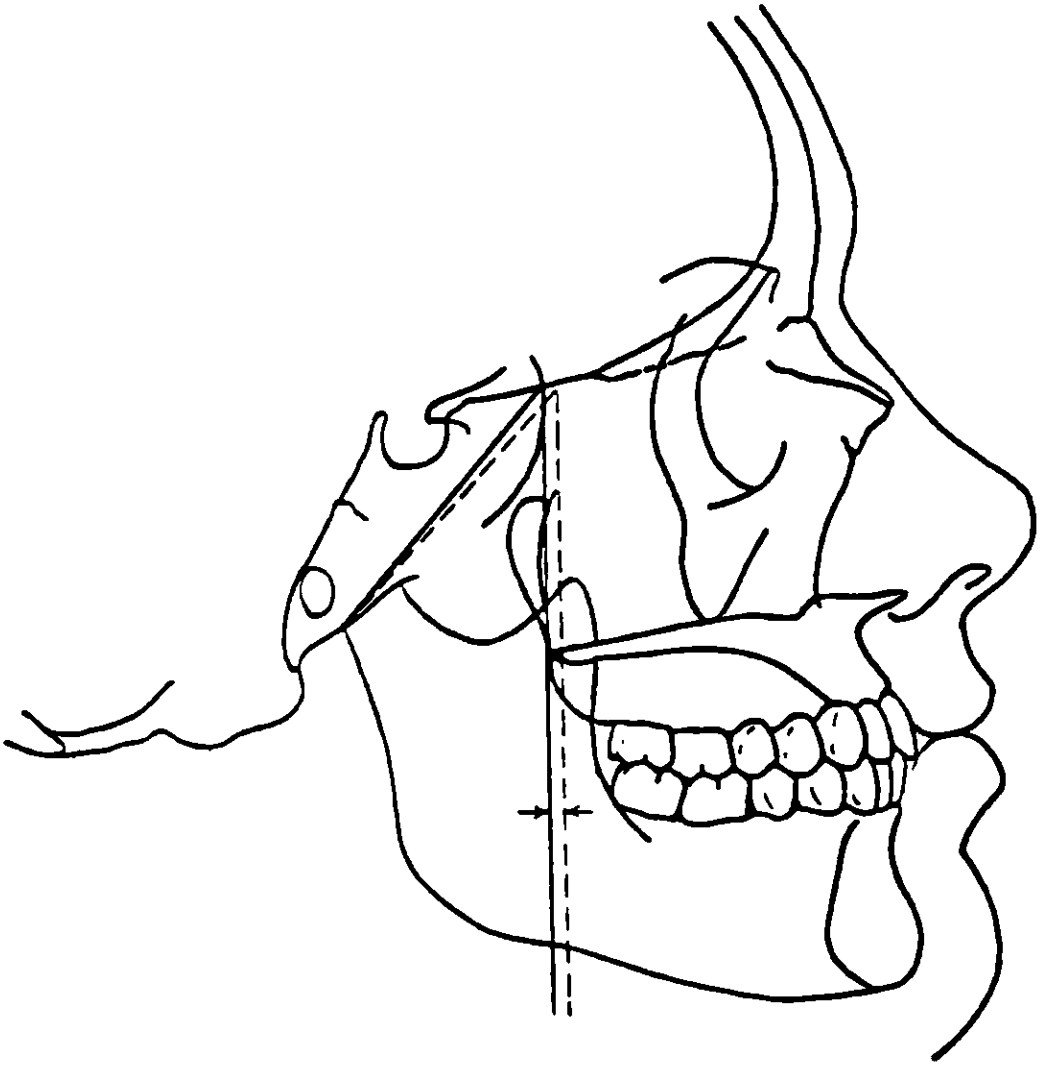


Figure 2. Ramus alignment. This diagram demonstrates the alignment of the subject's ramus plane and its relationship to the neutral ramus plane. A line from Ar to Go represents the individual's ramus plane. The neutral ramus plane is represented by a line from Ar to the midpoint between Ar and the neutral 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.

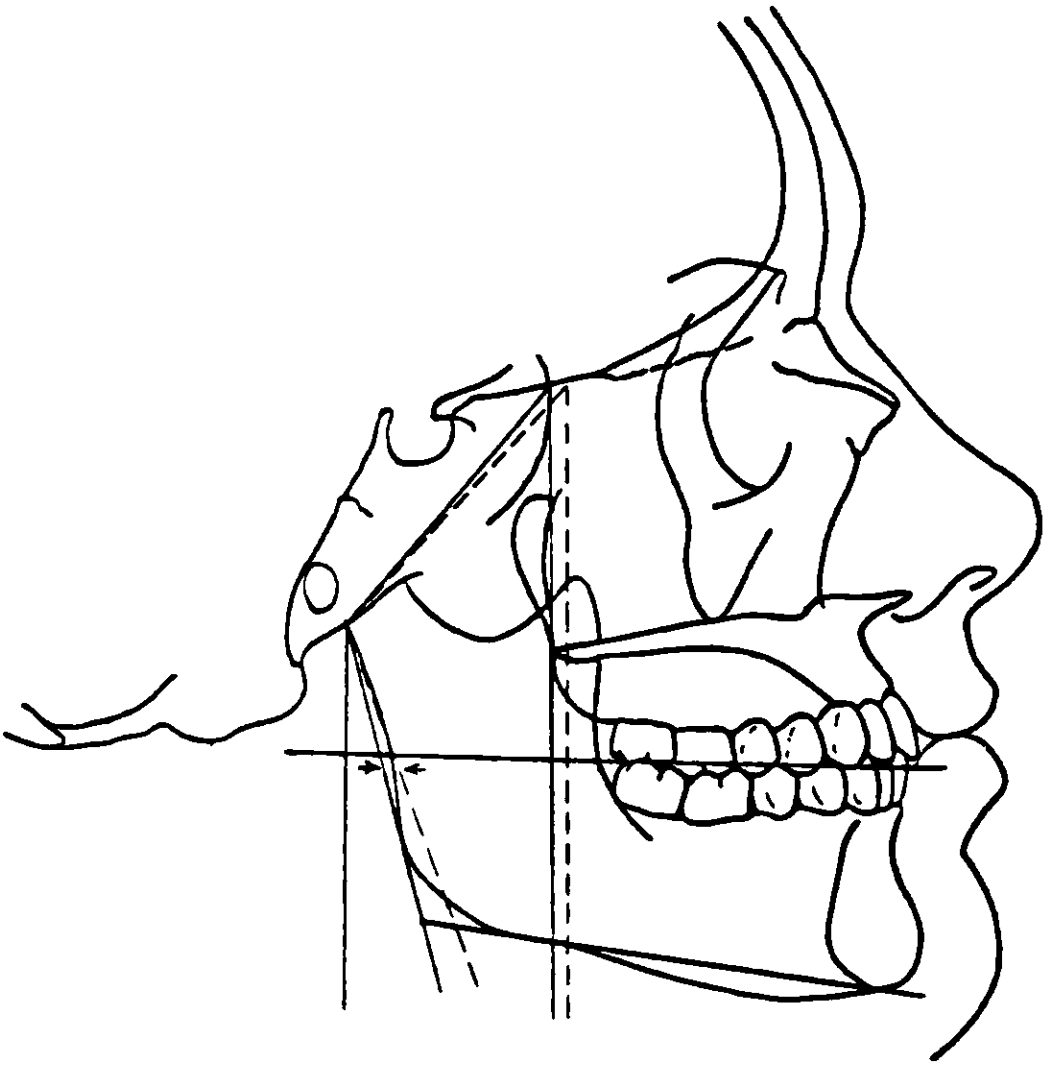


Figure 3. Ramus/MCF horizontal dimensions (skeletal). This diagram demonstrates the comparison of the horizontal dimensions of the middle cranial fossa (Ar to PM neutral) with the width of the ramus (Ar to ARa), and resultant effect on retrusive/protrusive placement of the maxilla and mandible. This 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.

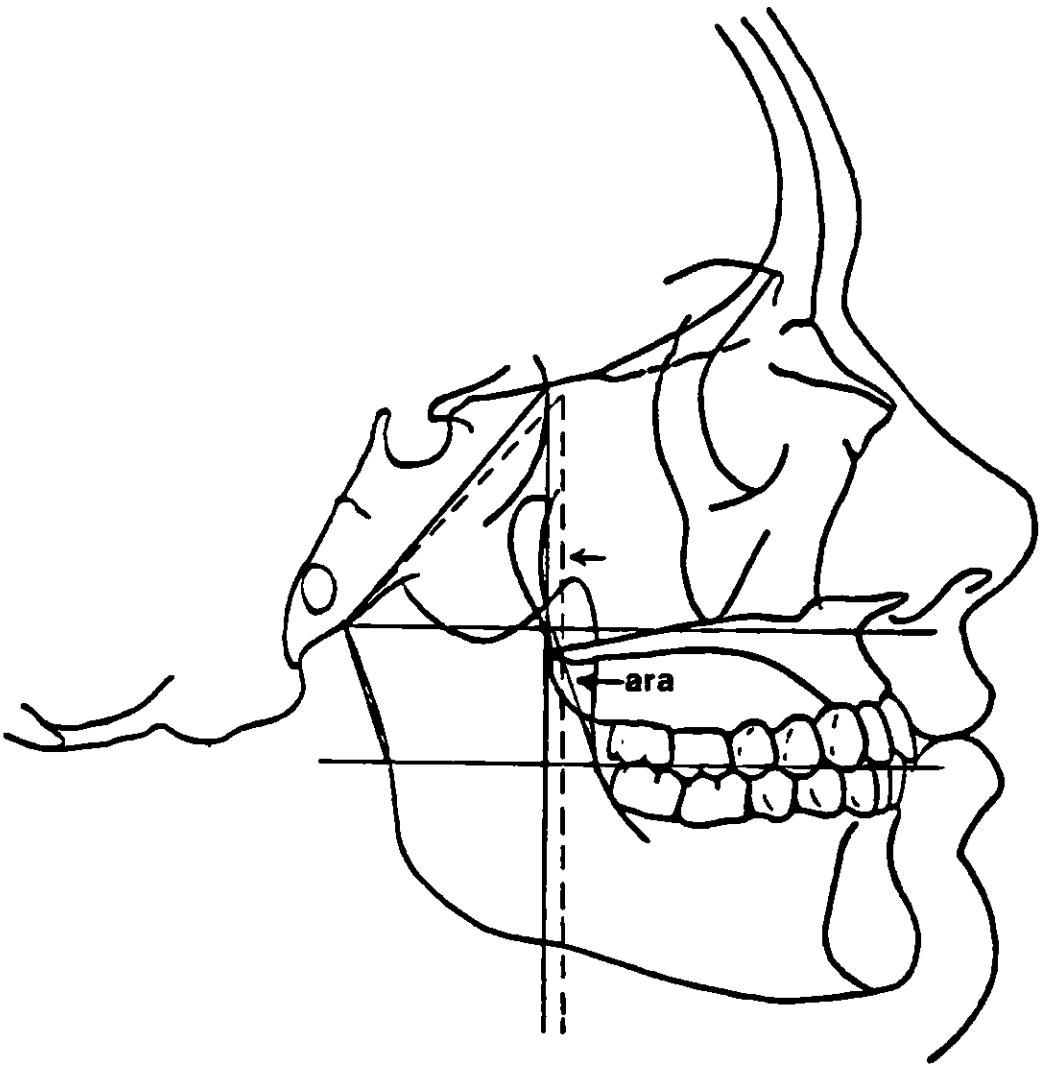

ara

Figure 4. 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.

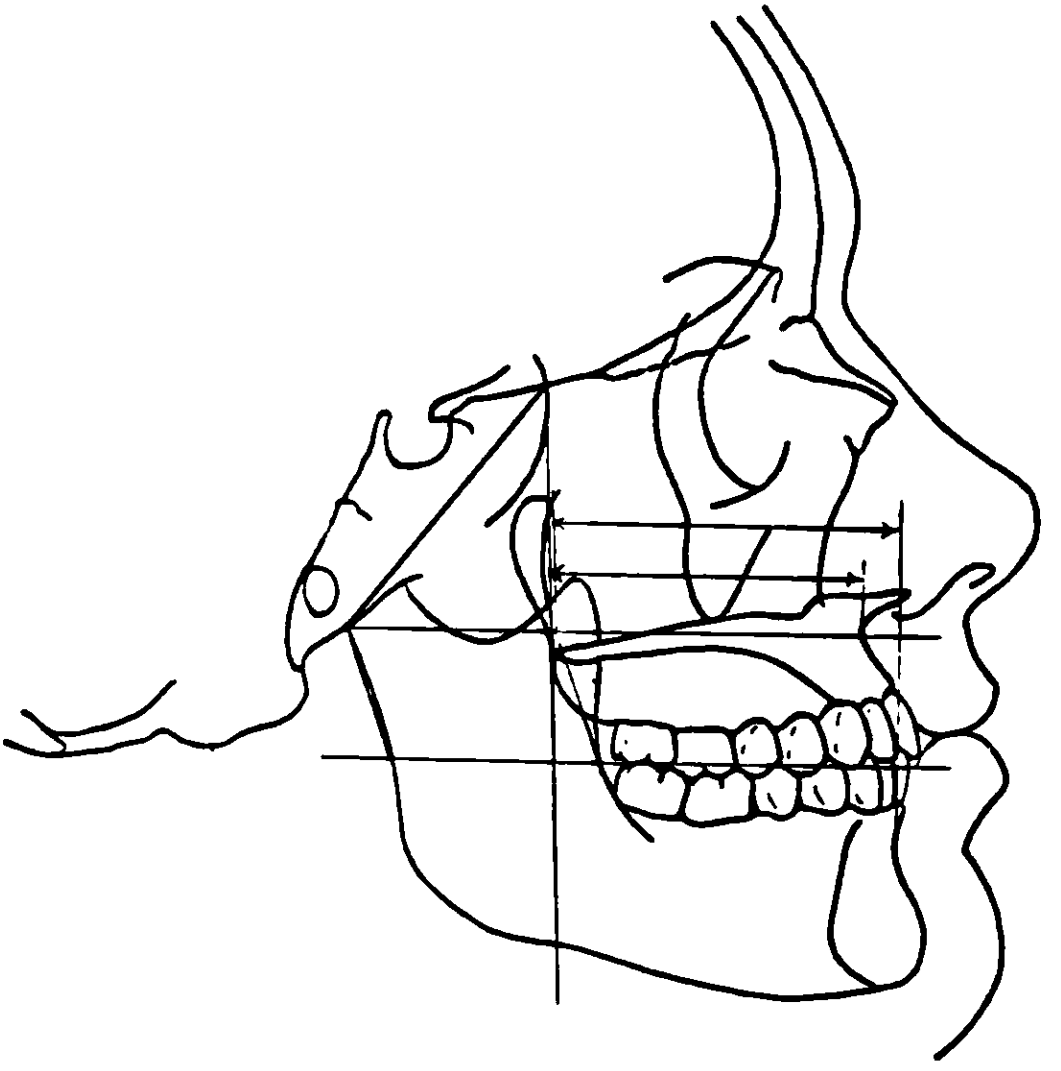


Figure 5. PM as compared with ramus/MCF vertical dimensions. The individual's relative posterior vertical nasomaxillary height is determined by this measurement. When the MCF rotates forward or backward, and the ramus rotates the same amount in the corresponding direction, no vertical disproportion in 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.)

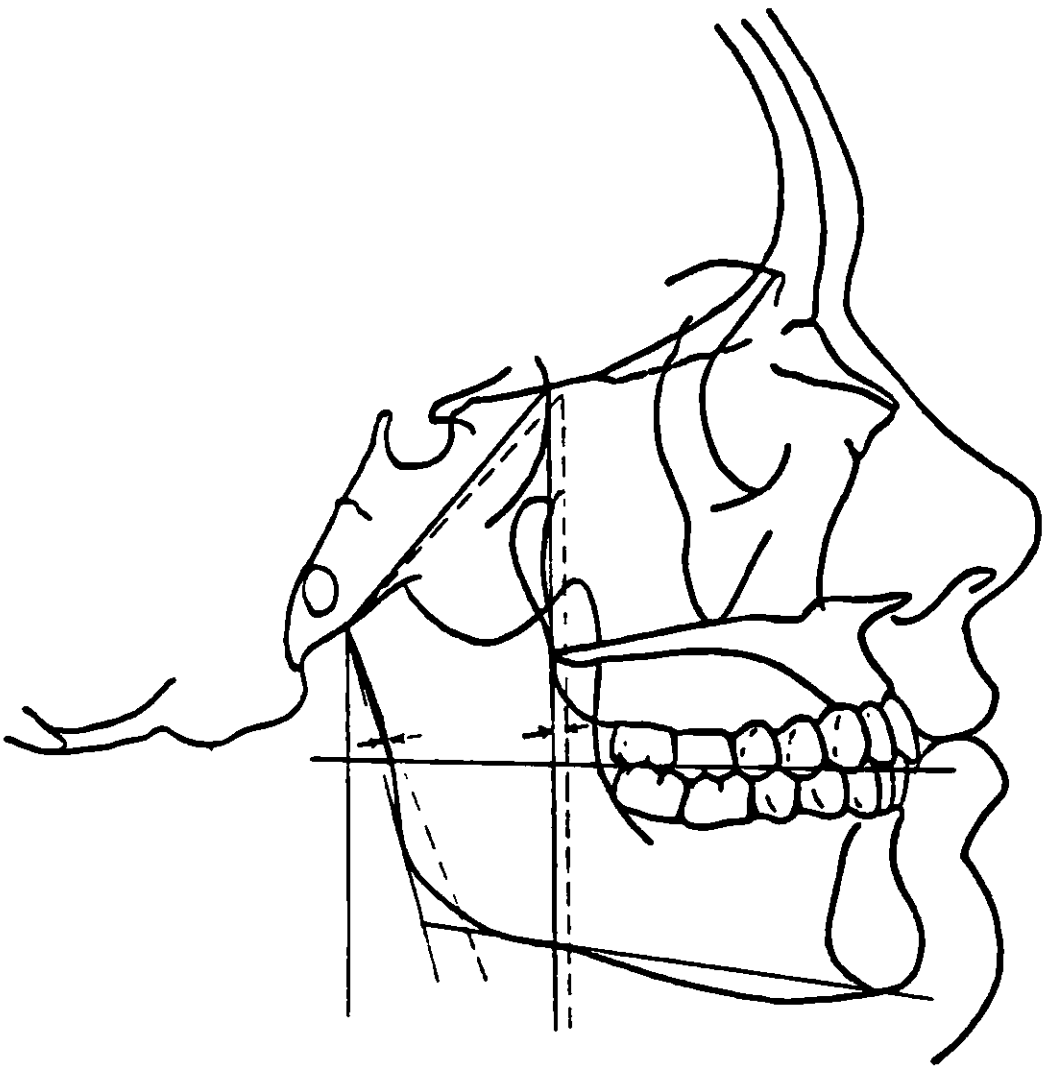


Figure 6. Gonial angle alignment. This diagram is similar to that in Figure 16. However, the measurement here is of two angles made in degrees. The neutral gonial angle and Ar to Go to Me.

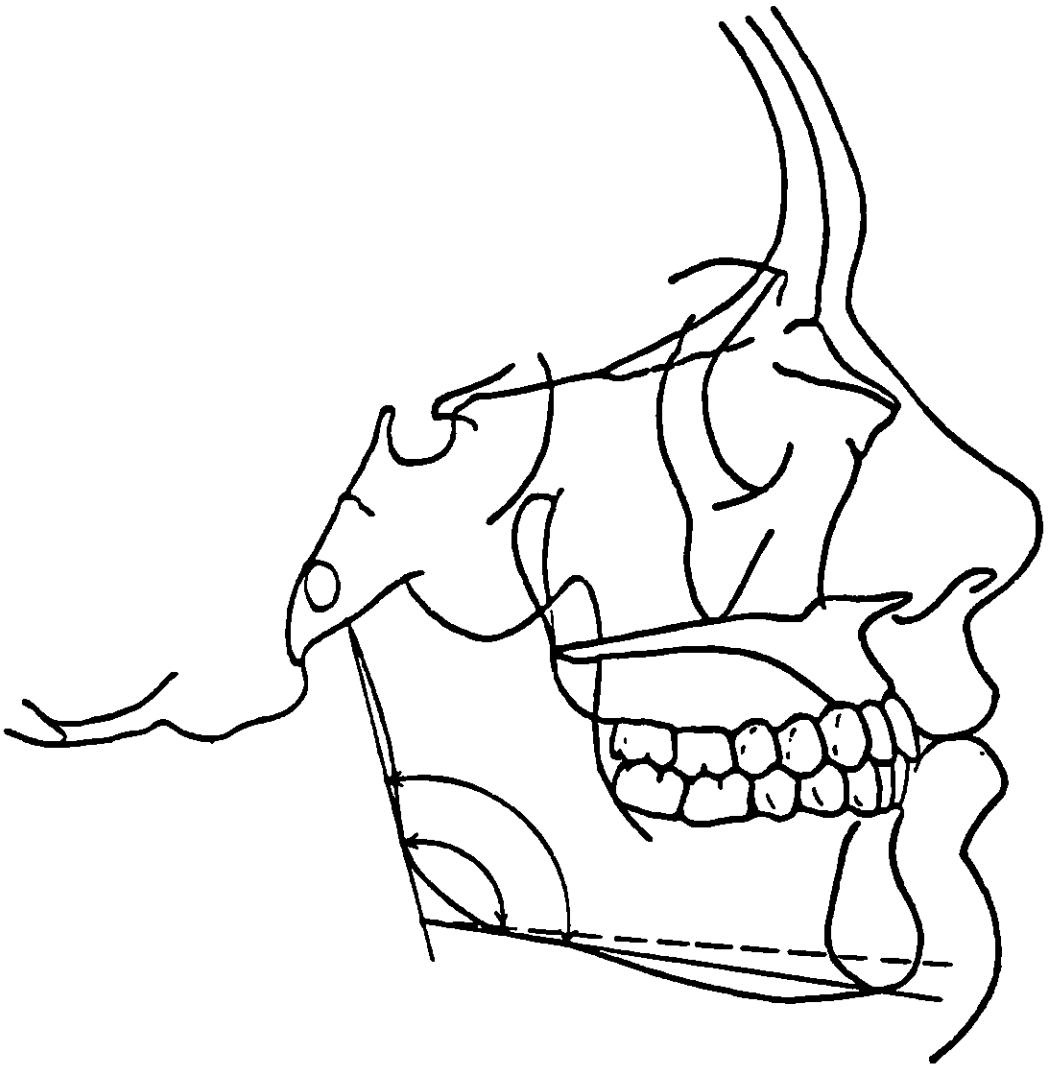


Figure 7. Curve of Spee. This is demonstrated by measuring the distance between the incisal edge of the mandibular central incisors and FOP. If the central incisors are above FOP it is a positive number, if below FOP it is a negative number.

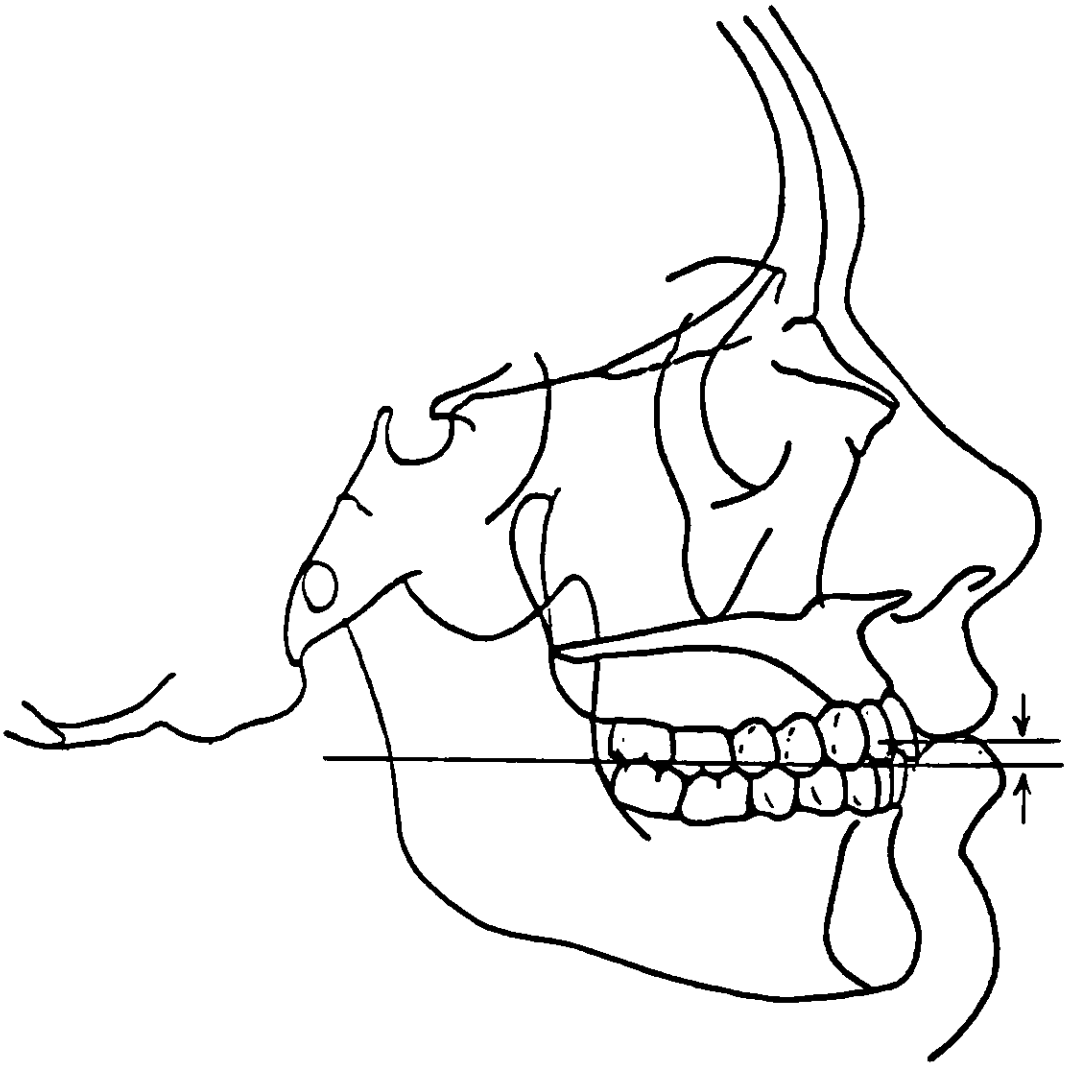
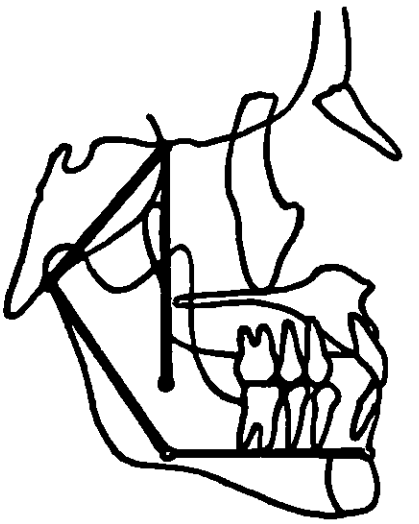


Figure 8. Mandibular protrusive effects. A vertical, upright orientation of the middle cranial fossa (g) has a maxillary retrusive (-) effect (h). The maxilla is raised relative to the condyle, so the ramus rotates upward and forward (j), with a protrusive effect on the mandibular corpus (k). A short vertical dimension along the posterior part of the maxilla (m) also has a protrusive effect on the mandible (Enlow, 1982).



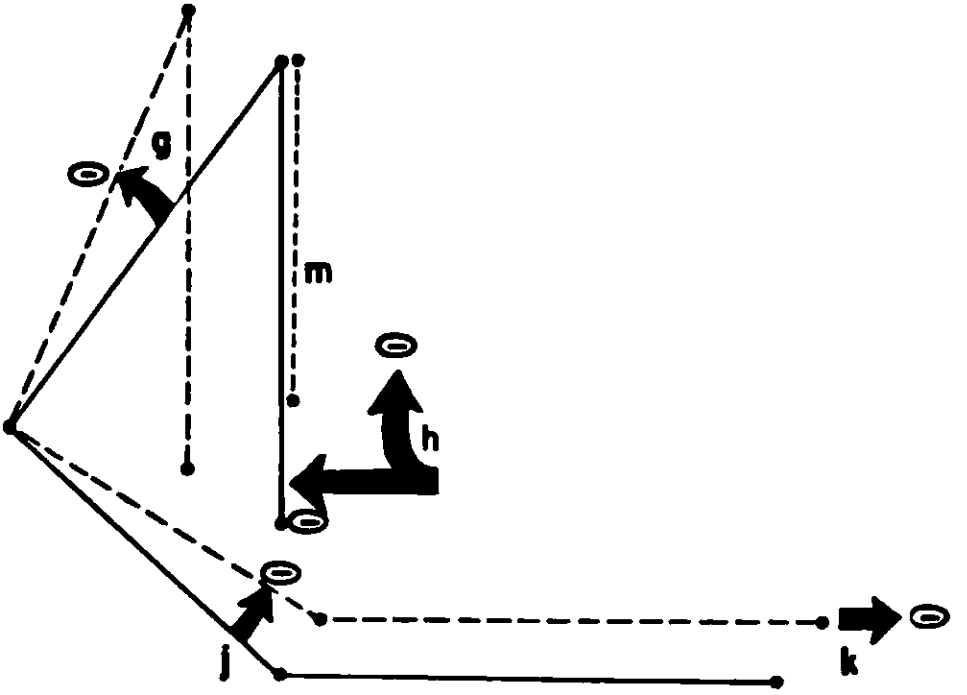
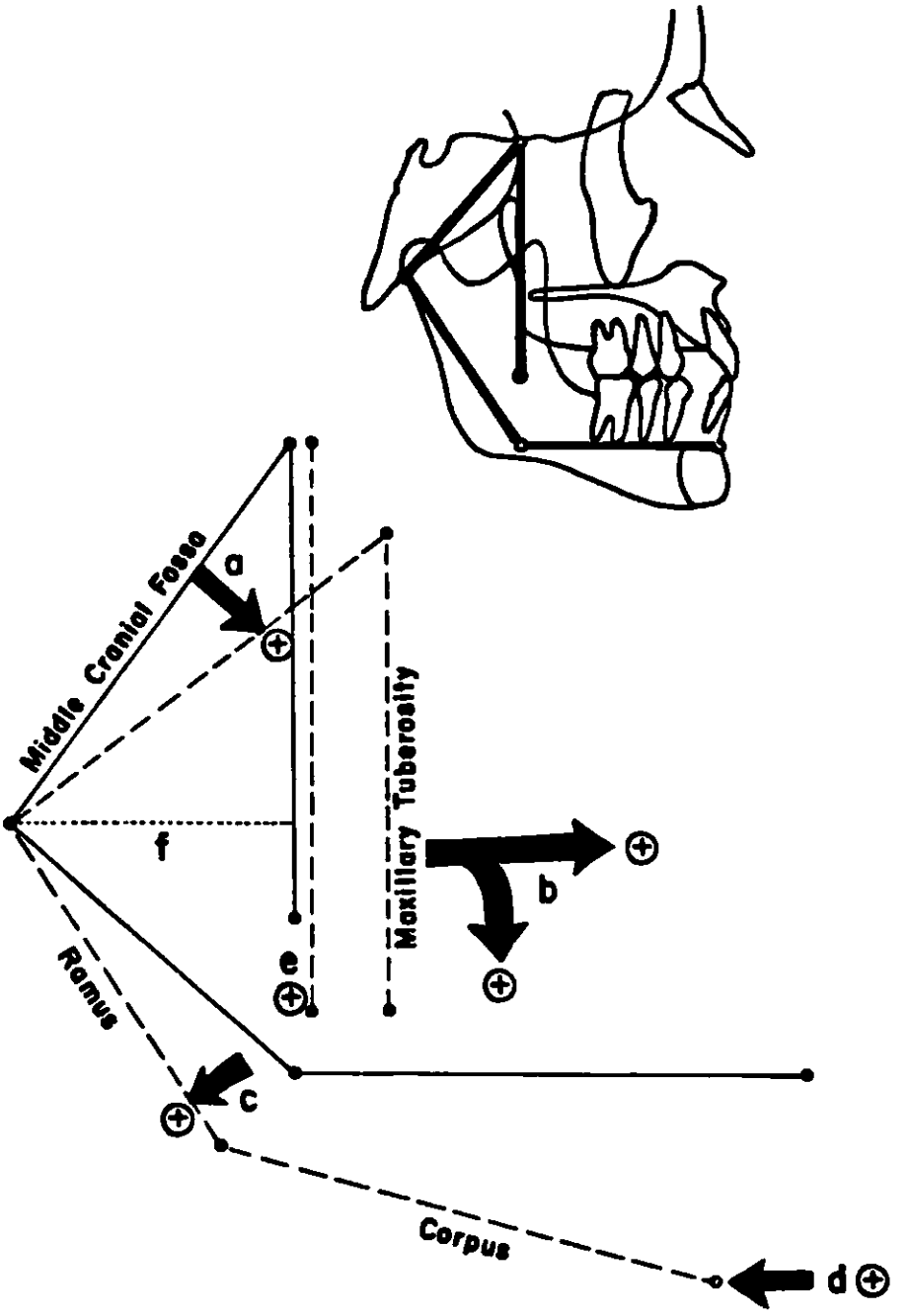

g
m
h
j
k

Figure 9. Maxillary protrusive effects. 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

RESULTS

Tables III to IX and Figures 10 to 20 represent the data from the analysis of the Class III and Class I samples.

TABLE III

ANALYSIS OF CLASS III SUBTYPES

Maxillary protrusive effects are indicated by (+), and mandibular protrusive effects by (-). Neutral effects are represented by a (0). Effects 2.5 mm or greater are represented by a (++) or (--). Vertical columns under each type represent a single 16+ year old individual's composite craniofacial pattern.

TABLE III

ANALYSIS OF CLASS III SUBTYPES

Anatomical Relationships	Type III[1]	Type III[2*]	Type III[2**]	Type III[2***]	Type III[3]
	Number of Individuals				
MCF/PM Alignment	++ ++ + ++ + +	-- - -- - -	- -- --	-- --	- -- -- -
PM/Ramus-MCF Relative Vertical Dimensions	-- - - -- -- -	++ ++ ++ ++ +	+ + +	++ ++	- -- - --
Ramus Alignment	- ++ 0 -- - -	+ + ++ ++ ++	- -- --	0 0	- -- -- --
Maxillary/ Mandibular Arches, Skeletal, A and B Points	-- -- -- -- -- --	-- -- -- - -	-- -- --	-- --	-- -- -- --
MCF/Ramus Horizontal Relative Dimensions, Skeletal	+ - + ++ + ++	+ - ++ - -	- - ++	++ ++	+ ++ + ++
Gonial Angle	+ -- -- + + --	+ -- -- - --	+ ++ +	-- --	+ ++ -- --
Curve of Spee	+ - 0 + ++ 0	+ ++ - + -	0 - +	- -	++ ++ + -

* Subtype of Type III[2]

** Subtype of Type III[2]

*** Subtype of Type III[2]

TABLE IV

ANALYSIS OF CLASS I SUBTYPES

Maxillary protrusive effects are indicated by a (+), and mandibular protrusive effects by a (-). Neutral effects are represented by a (0). Effects 2.5 mm or greater are represented by a (++) or (--). Vertical columns under each type represent a single 16+ year old individual's composite craniofacial pattern.

TABLE IV

ANALYSIS OF CLASS I SUBTYPES

Anatomical Relationships	Type I^1	Type I^2	Type I^{3*}	Type I^{3**}	Type I^{4*}	Type I^{4**}
	Number of Individuals					
MCF/PM Alignment	+	0 0	+ + ++ ++	++ + + +	-- -- -	-- -- -- -- -- -
PM/Ramus-MCF Relative Vertical Dimensions	+	++ ++	- - - -	-- -- - -	++ ++ ++	+ + + ++ - -
Ramus Alignment	++	++ ++	+ + +	- - - 0	++ + +	- - -- - - -
Maxillary/ Mandibular Arches, Skeletal A and B Points	-	++ ++	-- -- -- ++	- - - -	- + +	- -- ++ - -- +
MCF/Ramus Horizontal Relative Dimensions, Skeletal	0	-- 0	- + + -	- - -- -	++ ++ +	++ ++ ++ ++ ++ -
Gonial Angle	0	++ ++	-- -- -- ++	+ -- ++ ++	++ ++ ++	-- - ++ -- -- -

* Subtypes of Type I^3 and Type I^4

** Subtypes of Type I^3 and Type I^4

TABLE V

DISTRIBUTION PERCENTAGES OF CLASS I AND CLASS III INDIVIDUALS IN THE VARIOUS TYPES BASED ON A SAMPLE OF 20 INDIVIDUALS PER CLASS

Type	Class I	Type	Class III
I^{1}	5%	III^{1}	30%
I^{2}	10%	III^{2*}	25%
I^{3*}	20%	III^{2**}	15%
I^{3**}	20%	III^{2***}	10%
I^{4*}	15%	III^{3}	20%
I^{4**}	30%		

Table VI and VII. Each column consists of anatomical relationship combinations present at the mean age for the time period indicates. The groups in each column were first categoried according to MCF alignment, vertical PM, and maxillary and mandibular corpus length. Then, ramus alignment, horizontal width of the ramus, and gonial angle were added to show the complete range of anatomic variables analyzed.

Table VI is for the Class III cases and Table VII for the Class I. The numbers under each combination represent the actual case numbers from the Bolton Study. The lines represent the paths taken by each craniofacial combination through its development. The top of the chart reflects more maxillary protrusive (+) effects, while the bottom more mandibular protrusive (-). (The Class I three year old sample contains only 15 individuals and the Class III only 7. The remaining age groups consist of 20 individuals in both craniofacial types.)

TABLE VI

CLASS III CRANIOFACIAL COMPOSITIONS

Age Levels (years)				
3	6	9	14	16+
+ - 0 - 0 -	+ - 0 + - -	+ 0 - + + -	+ + - + + -	+ - - - + +
1962	2033	2033	3238	109
+ - 0 - - -	+ - - - - +	+ - - - + -	+ + - + - -	108
2579	108	1883	1121	107
- + + + + +	+ - - - - -	+ - - + 0 +	+ - - + + +	+ - - + - -
3238	1883	108	108	2033
- + + - 0 -	0 + - + - -	0 0 - 0 0 +	+ - - - + +	+ - - - + -
3100	947	3238	109	1883
- + 0 + - +	- + + + - 0	- + + + - -	+ - - + - -	+ - - 0 + -
1937	1937	1175	2033	1175
- + 0 - + +	- + + 0 0 -	- + - 0 - -	+ - - + -	- + - - - +
2441	1175	1121	1883	3238
- + 0 - - -	- + + - + 0	- + - + + +	0 - - - 0 +	2579
2138	2138	107	107	- + - + - -
- 0 + - 0 0	- + - + + -	- + - - + +	- + - 0 0 +	947
2419	1155	2138	2579	1937
- 0 - - + 0	2790	- + - + + -	- + - + - -	1121
2033	- + - - + -	1155	947	- + - + + -
	2441	2900	1937	1155
3 Groups	2419	- + - 0 0 -	- + - + + -	- + - 0 + -
	2900	947	1175	2900
	- + - - + +	- + - + - +	1155	- + - + + +
	2579	2579	2900	2603
	- + - 0 - -	- + - + 0 -	- + - - + -	- + - - + +
	2603	2603	1962	2138
	- + - - - -	- + - - - 0	- + + - + +	- + - 0 + -
	1121	1937	2603	2790
	- + 0 - + -	- + - - 0 -	- - - - + +	- - - - + +
	3100	2419	2441	2441
	- 0 - - - 0	- +0 + + +	3100	3100
	3238	109	- - - - + -	- - - - + -
	- 0 0 + - 0	- 0 - - + -	2138	1962
	107	2441	2149	2419
	- - + - + -	- 0 - - 0 0	2790	
	1962	3100		3 Groups
	- - - - - +	- - - - + +	5 Groups	
	109	1962		
		- - - - + -		
	5 Groups	2790		
		6 Groups		

TABLE VII

CLASS I CRANIOFACIAL COMPOSITIONS

Age Levels (years)				
3	6	9	14	16+
+ + + + + +	+ + + + - +	+ + - + - +	+ + + + - +	+ + - + 0 0
2242	134	1212	1212	134
+ + + + 0 -	+ 0 + + - -	+ + - + - -	2242	+ - + + - +
3098	3098	3098	+ + - + + -	105
+ - + + - +	+ 0 + + 0 -	+ - + + - +	945	+ - - + - -
105	945	105	3098	2516
1208	+ - + + - +	+ - + - - -	+ - + + - +	+ - - + + -
+ - - - - +	105	3065	105	945
2516	+ - + - - +	1973	+ - - + + +	3098
+ - - 0 0 -	1973	+ - - + - -	134	+ - - - - - +
945	+ - - + - +	2516	+ - - + - -	131
1973	1212	+ - - - - +	2516	1208
+ - - + - -	+ - - + - -	131	+ - - - + -	1973
134	2516	0 + - + + -	3065	+ - - - - -
- - + - - -	- + + + + +	945	+ - - - - -	1257
3065	2032	- + + 0 + +	131	0 + + + - +
3 Groups	- + + - + +	2540	+ - - - + -	1212
	2540	- + + + - +	2187	0 + + + 0 +
	- + + - - 0	1208	0 + + - + +	2242
	1257	- + + + + +	1257	- + + + + +
	- + + - - -	2032	0 - + - - -	2032
	3065	- + + + 0 +	1973	115
	- + + + - -	2242	- + + - + -	- + + - + +
	2187	- + - + + +	2540	1139
	- + + - + -	4166	- + + + + +	- + - + + +
	114	- + + + - -	2032	4166
	- + 0 + 0 +	2187	- + + - + +	- + - - + -
	2242	- + - - + -	1139	3065
	- + - + + +	115	- + - + + +	2540
	4166	1139	115	114
	- + - - + -	- 0 + + - 0	4166	- - - - + -
	1139	1257	- - + - - +	1123
	- - + - - +	- - + - - -	1208	- - + - - -
	113	1123	- - + - - -	2187
	1208	- - - + -	1123	5 Groups
	- - + + + -	114	- 0 - - + -	
	1123	6 Groups	114	
	0 - 0 - + -		7 Groups	
	115			
	6 Groups			

TABLE VIII

CHANGES FOUND IN THE CLASS III ANATOMIC RELATIONSHIPS DURING THE TIME INTERVALS STUDIED

Mean Age Group	Total # of Changes	MCF	PM/Ramus-MCF	RA Align.	$MX_{/MD}{}^{A}{}_{/B}$	$RA_{/MCF}$	Gonial Angle
6-9	35	2	6	10	2	10	5
9-14	39	4	9	8	2	9	7
14-16+	16	4	3	5	0	2	2

These changes involve a combination of the three possible values. A change in either a maxillary or mandibular protrusion, or a change to a neutral effect.

TABLE IX

CHANGES FOUND IN THE CLASS I ANATOMIC RELATIONSHIPS DURING THE VARIOUS TIME INTERVALS STUDIED

Mean Age Group	Total # of Changes	MCF	PM/Ramus-MCF	RA Align.	$MX_{/MD}{}^{A}{}_{/B}$	$RA_{/MCF}$	Gonial Angle
6-9	27	4	9	5	7	1	1
9-14	31	5	5	7	4	7	3
14-16+	30	7	7	0	9	5	2

These changes involve a combination of the three possible values. A change in either a maxillary or mandibular protrusion, or a change to a neutral effect.

TABLE X

CLASS II CRANIOFACIAL COMPOSITIONS

Age Levels (years)				
3	6	9	14	16+
+ - + + - +	+ - + + - +	+ + - + - +	+ + + + + -	+ + + + - +
1895	1895	110	1895	1894
+ - + - + -	+ - + + - -	+ - + + - +	+ + + + - +	1204
2207	1894	1894	1204	+ + - + + +
1168	2274	1895	+ + - + + +	1895
+ - - + + -	+ - + - - +	113	1168	+ + - + + 0
3706	113	2274	+ - + + - +	110
+ - - + - +	+ - - + - +	+ - + + - -	1894	+ 0 + + - +
1204	110	3706	1948	2274
+ - + 0 - +	+ - - + + -	+ - + - - -	+ - + + + -	+ - + + - +
2274	3706	2207	3706	1204
+ - - - - +	+ - - - + -	2686	+ - + - + -	3706
2816	2147	+ - - + - +	2207	+ - - + 0 +
+ - - - + -	0 - + - + -	1204	2686	2207
2147	2207	+ - - - + +	+ - - + + 0	+ - - + + +
+ - - - - 0	0 - - - - +	2816	110	2553
2553	1051	0 0 - + + +	+ - - + - +	+ - - 0 + +
0 - + - + +	- + + + + -	2553	2274	1051
1948	1168	0 - - - + +	+ - - + + +	+ - - - + +
0 - + - - +	- + + + - +	1051	2553	2816
113	1204	0 - - + - +	+ - - - + +	- + + + + +
- + + + - +	1269	1908	2816	1916
1238	2553	0 - - + + +	1908	1908
- + + - + 0	1916	1948	0 - + + +	1238
259	1908	- + + + - 0	1051	- + + + - +
- + + - - -	- + - + - -	1168	- + + + - +	1948
1894	1238	- + + - + -	1916	- + - + + +
- + - + - +	- + - - + +	2147	- + + - + +	1269
1916	259	- + + + - +	1269	- + - + + +
- - + - + -	- - + - - +	1916	- + - + + +	1168
2686	2816	1269	1238	259
- - - + 0 +	- - + 0 - +	- + - + + +	- + - + + 0	- - + - + +
1908	1948	1238	259	2147
4 Groups	- - + - + -	259	- - + - + +	- - + - + -
	2686	5 Groups	2147	2686
	4 Groups		5 Groups	6 Groups

TABLE XI

CHANGES FOUND IN THE CLASS II ANATOMIC RELATIONSHIPS DURING THE VARIOUS TIME INTERVALS STUDIED ACCORDING TO WHITNEY (1983)

Mean Age Group	Total # of Changes	MCF	PM/ Ramus-MCF	Ramus Alignment	$^{MX}/_{MD}$ $^{A}/_{B}$	Ramus/ MCF	Gonial Angle
6-9	35	8	5	3	7	8	4
9-14	31	4	5	2	5	10	5
14-16+	28	6	5	3	6	4	4

These changes involve a combination of the three possible values; a change in either a maxillary or mandibular protrusion or a change to a neutral effect.

Figure 10. Mixed composite of mandibular and maxillary protrusive relationships characterizing type III[1]. This type exhibits a forward MCF alignment (1) accompanied by a short vertical PM (2). The ramus alignment (3) varies with each individual case from backward, neutral, to a forward positioning. The mandibular corpus (4) is longer relative to the bony maxillary arch. In all but one case analyzed, the ramus is narrow horizontally (5) as compared to neutral MCF horizontal dimension (6). The gonial angle (7) varies with the case, being closed in 50% of the cases. Neutral (non-protrusive or non-retrusive) relationships are shown by the dashed lines.

TYPE III[1]

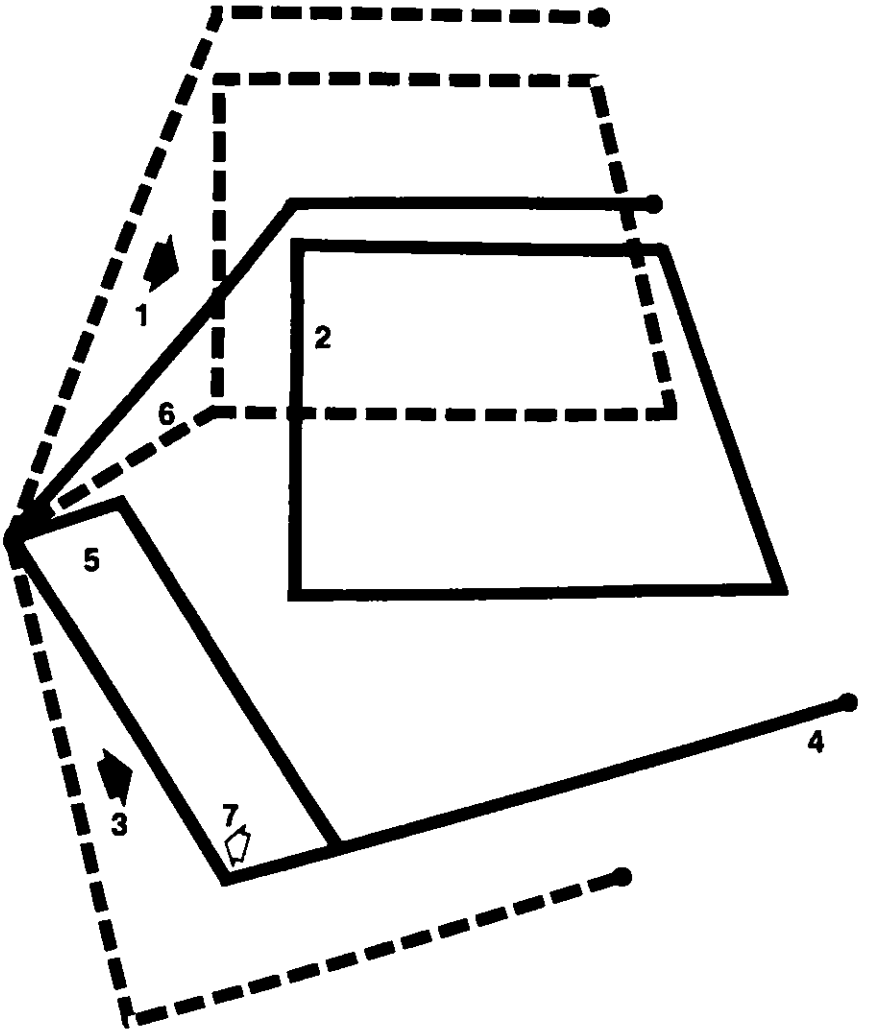


Figure 11. Mixed composite of mandibular and maxillary protrusive relationships characterizing Type III^{2*}. This type has a backward MCF alignment (1) accompanied by a long vertical PM (2). Ramus alignment (3) is aligned posteriorly. The mandibular corpus (4) is long relative to the long maxillary arch. Horizontal ramus width varies from less than (5) to greater than (6), the neutral horizontal dimension of the MCF (7). In all but one case, the gonial angle (8) is open.

TYPE III^{2*}

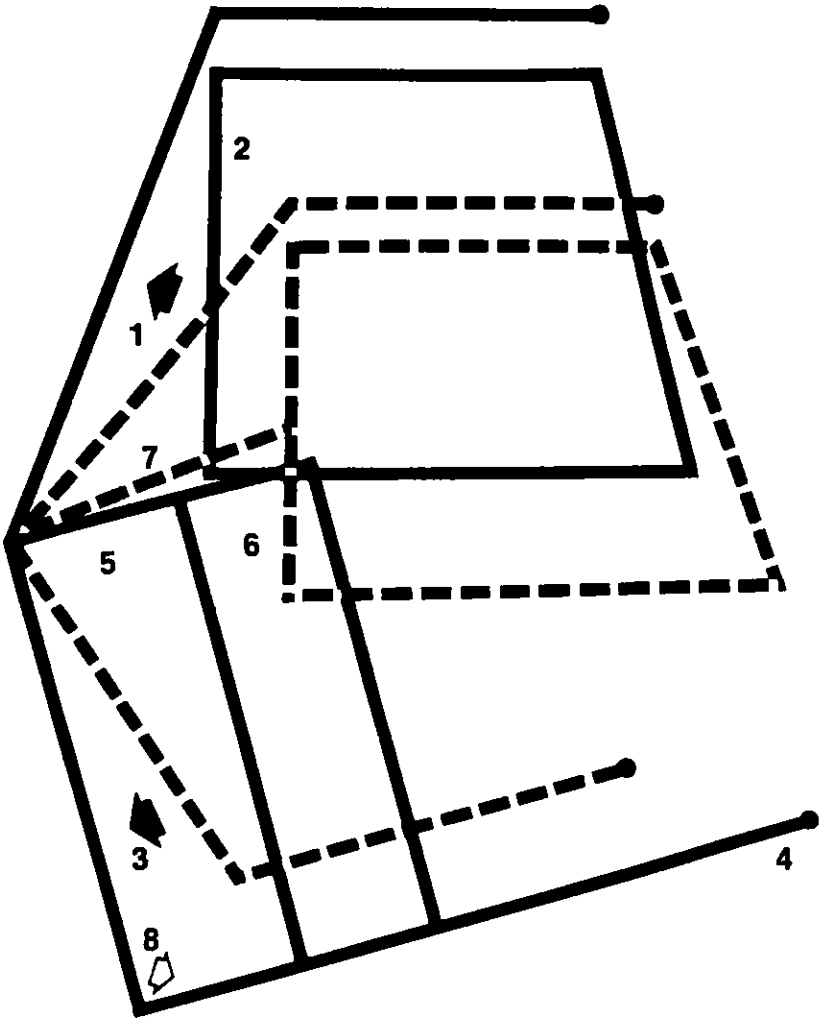


Figure 12. Mixed composite of mandibular and maxillary protrusive relationships characterizing Type III^{2**}. This type has a backward MCF alignment (1) accompanied by a long vertical PM (2). Ramus alignment (3) is aligned anteriorly in every case. The mandibular corpus (4) is longer relative to the bony maxillary arch. The horizontal width of the ramus is greater (5) than the neutral MCF horizontal dimension (6) in 50% of the cases, and less (7) than in 50% of the cases. In all individuals the gonial angle (8) is closed.

TYPE III[2**]

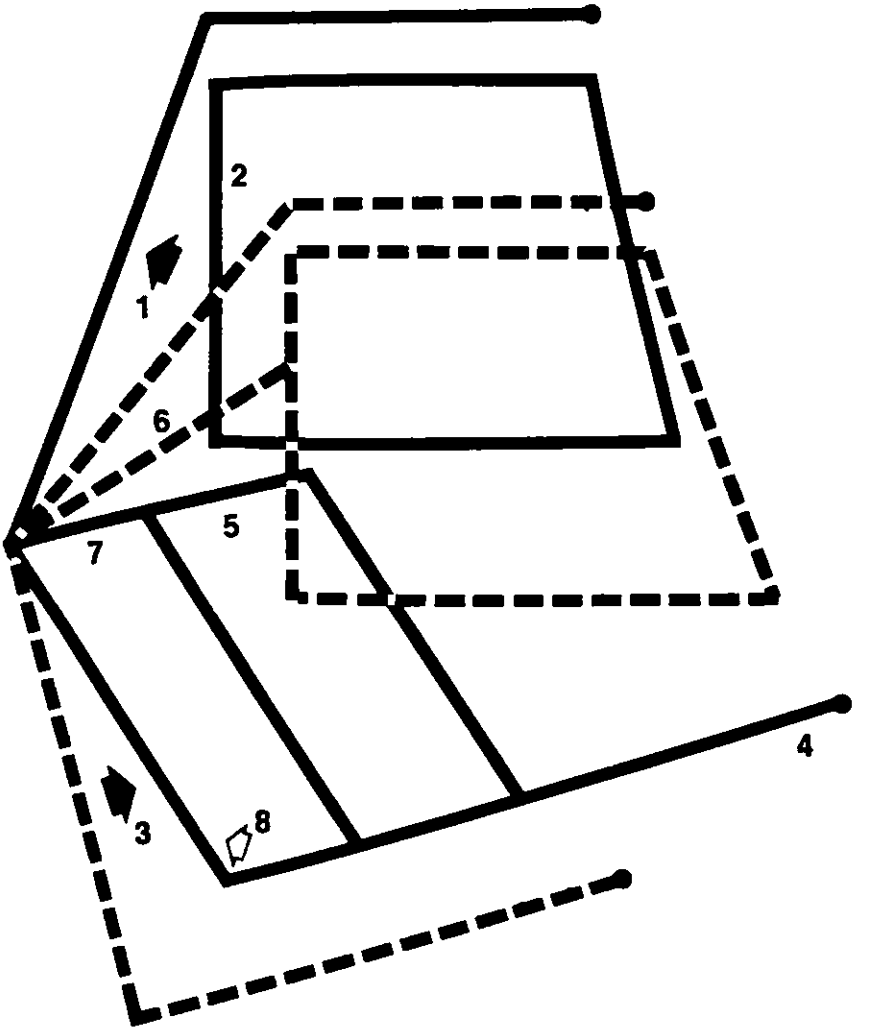


Figure 13. Mixed composite of mandibular and maxillary protrusive relationships characterizing Type III^{2***}. This type has a backward MCF alignment (1) accompanied by a long vertical PM (2). Ramus alignment (3) is neutral in all cases. The mandibular corpus (4) is long relative to the bony maxillary arch. The horizontal width of the ramus (5) is narrow relative to the neutral horizontal dimension of MCF (6). The gonial angle (7) is open in every case.

TYPE III^{2***}

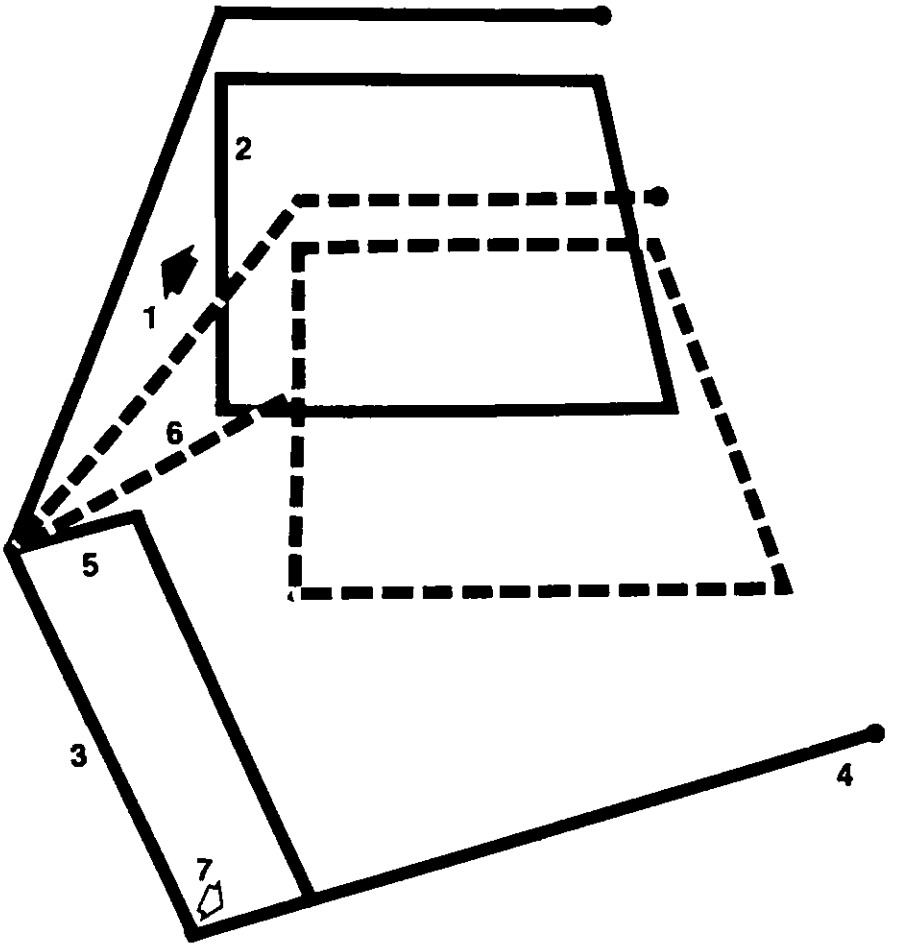


Figure 14. Mixed composite of mandibular and maxillary protrusive relationships characterizing Type III[3]. This type has a backward MCF alignment (1) accompanied by a long vertical PM (2). The ramus (3) has a forward alignment. All cases have a long mandibular corpus (4) relative to the maxillary corpus. Horizontal ramus width (5) is narrower than the neutral horizontal dimension of the MCF (6) in every case. The gonial angle (7) was open in 50% of the cases and closed in 50% of the cases.

TYPE III[3]

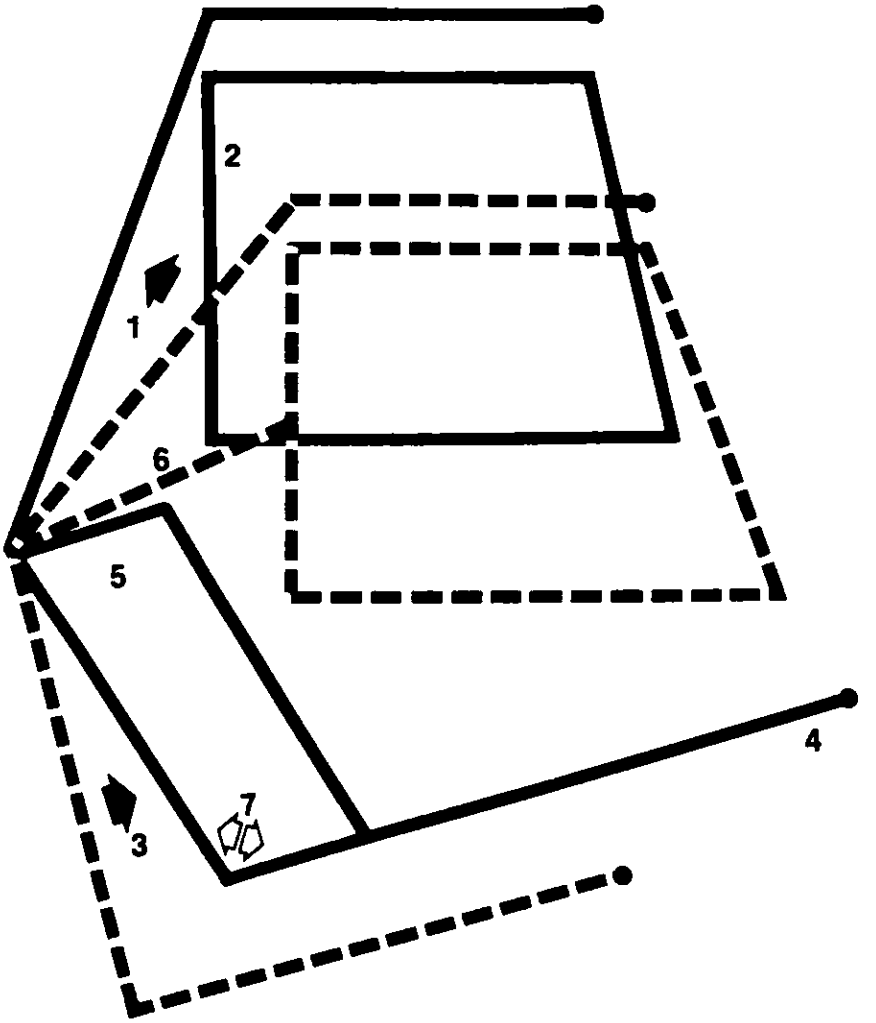


Figure 15. Mixed composite of mandibular and maxillary protrusive relationships characterizing Type I^1. This type has a forward MCF alignment (1). The vertical PM (2) is long in all cases, which contributes to a backward ramus alignment (3). The mandibular corpus (4) is long relative to the bony maxillary arch. The horizontal width of the ramus (5) is equal to the neutral horizontal dimension of the MCF (6). The gonial angle (7) is neutral.

TYPE I[1]

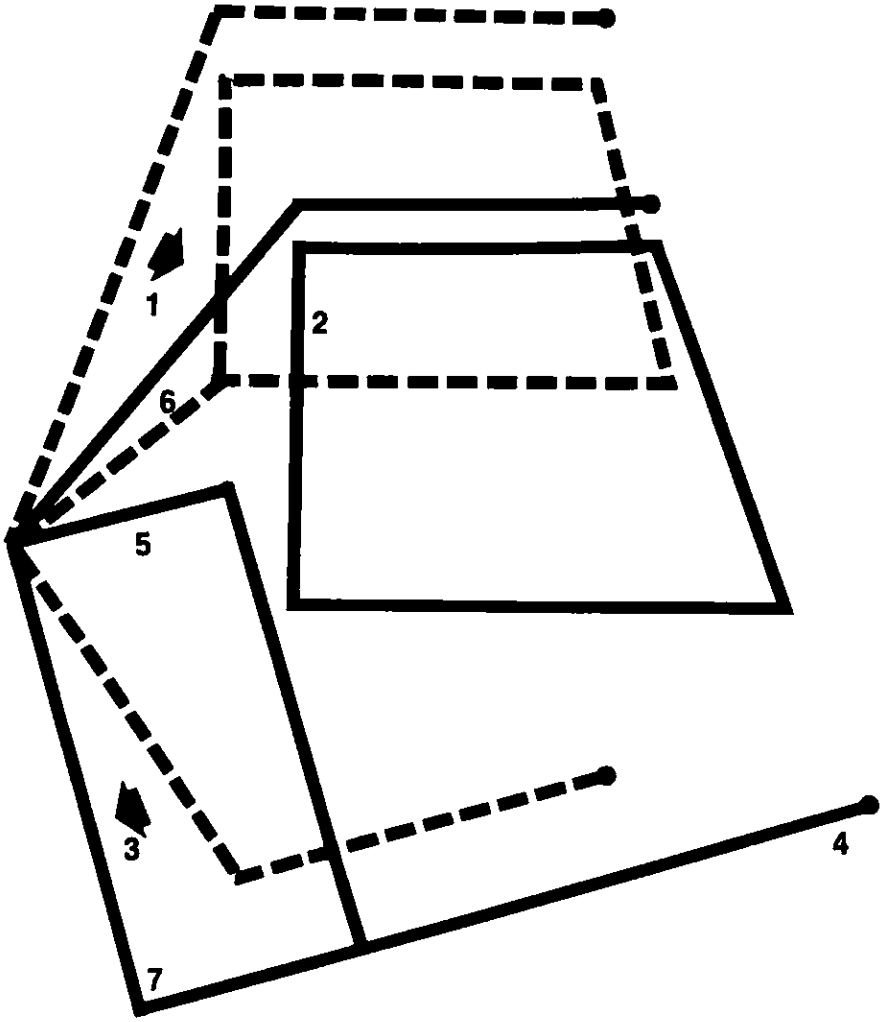


Figure 16. Mixed composite of mandibular and maxillary protrusive relationships characterizing Type I^2. This type has a neutral MCF alignment (1). A long vertical PM (2), which contributes to a backward ramus alignment (3). The mandibular corpus (4) is short relative to the bony maxillary arch. Horizontal ramus width varies with the individual from equal (5) to wider (6) than the neutral horizontal dimension of the MCF (7). The gonial angle (8) is closed in all cases.

TYPE I[2]

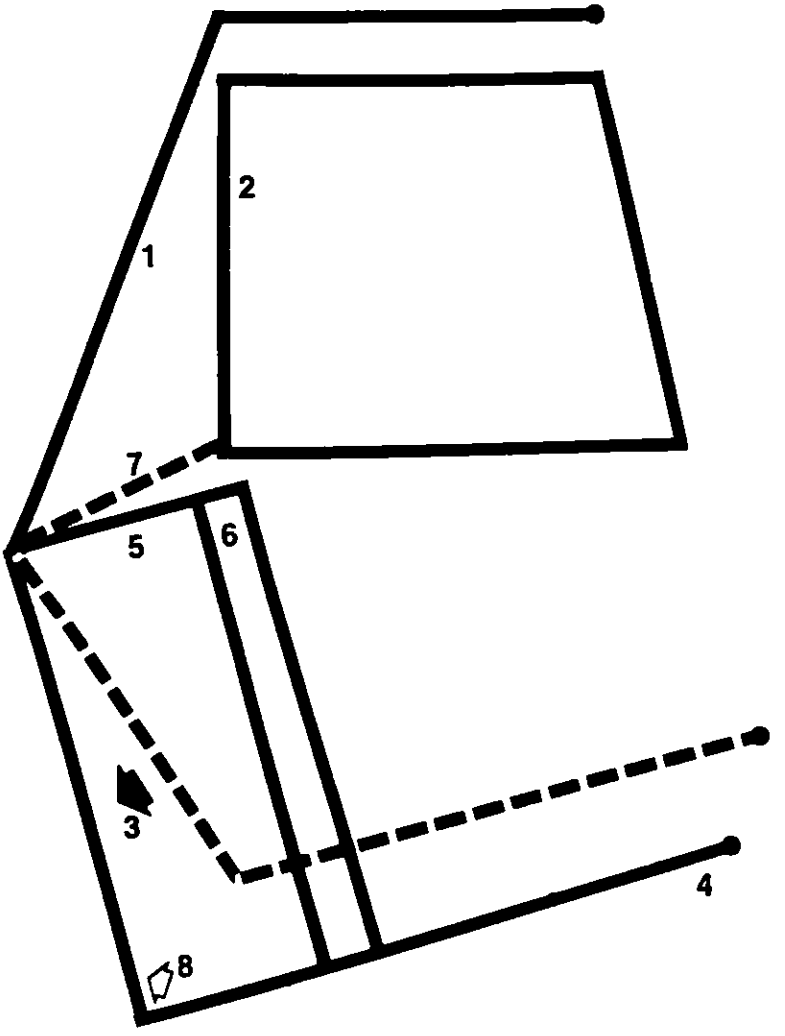


Figure 17. Mixed composite of mandibular and maxillary protrusive relationships characterizing Type I^{3*}. This type has a forward MCF alignment (1) accompanied by a short vertical PM (2). Ramus alignment (3) is aligned backward. In all but one case, the mandibular corpus (4) is long relative to the maxillary corpus. The horizontal width of the ramus varies from narrower (5) to wider (6) than the neutral horizontal dimension of the MCF (7). In all but one case the gonial angle (8) is open.

TYPE I^{3*}

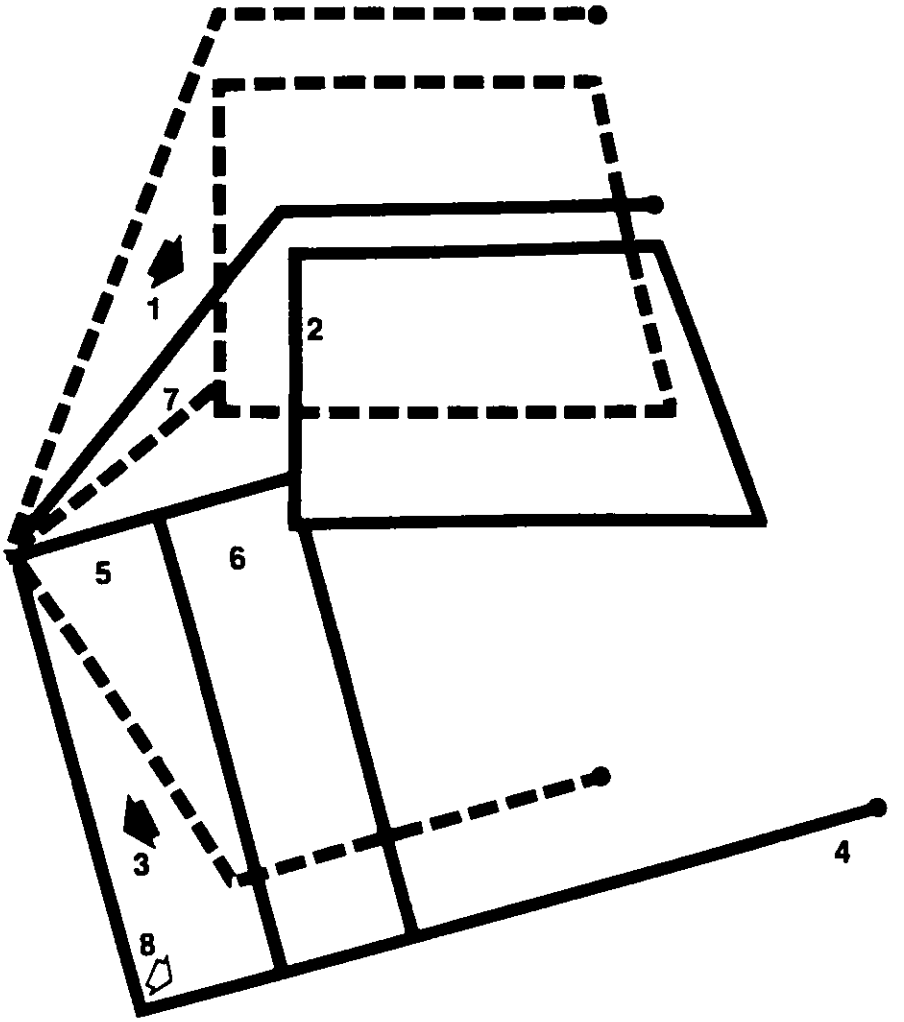


Figure 18. Mixed composite of mandibular and maxillary protrusive relationships characterizing Type I^{3**}. This type has a forward MCF alignment (1) accompanied by a short vertical PM (2). The short vertical PM contributes, in all but one case, to the forward ramus alignment (3). The mandibular corpus (4) is long relative to the maxillary corpus. The horizontal width of the ramus is wider (5) than the neutral horizontal dimension of the MCF (6) in every individual. In all but one case, the gonial angle (7) is closed.

TYPE I^{3**}

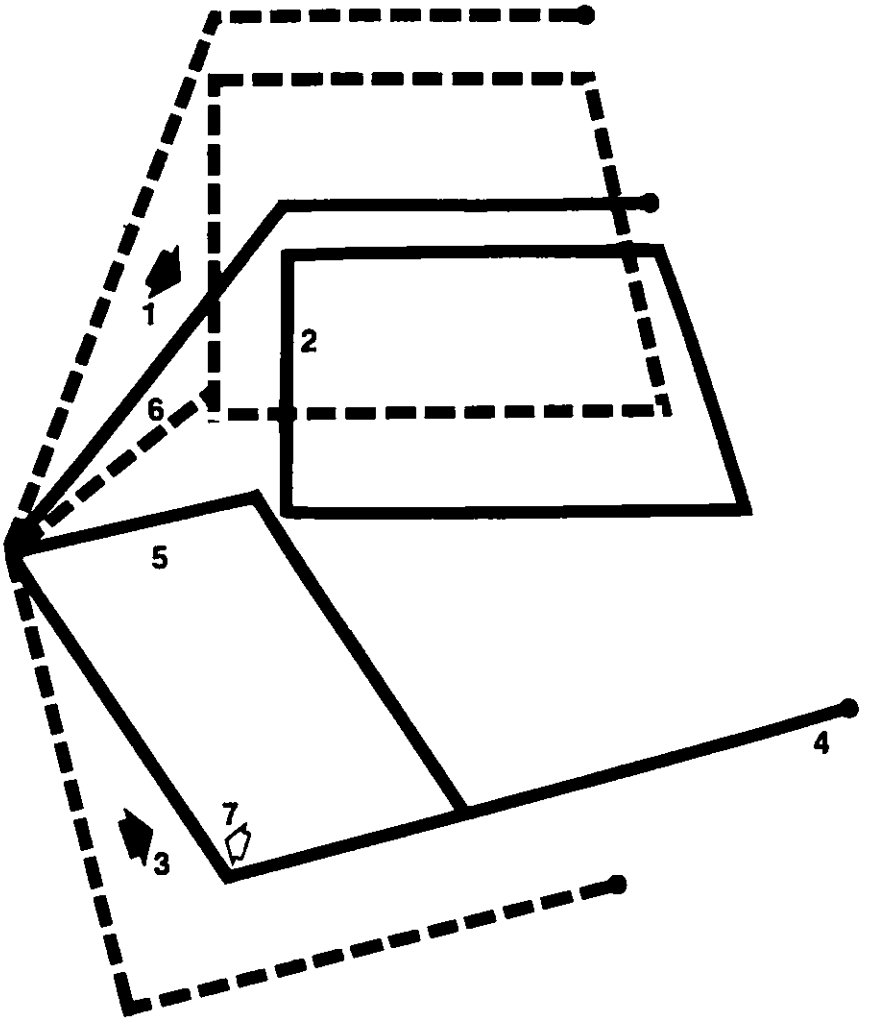


Figure 19. Mixed composite of mandibular and maxillary protrusive relationships characterizing Type I^{4*}. This type has a backward MCF alignment (1) accompanied by a long vertical PM (2). The long vertical PM contributes to the backward ramus alignment (3). In all but one case, the mandibular corpus (4) is long relative to the maxillary corpus. Horizontal ramus width (5) is narrower than the neutral horizontal dimension of the MCF (6) in every case. The gonial angle (7) in every case is closed.

TYPE I4*

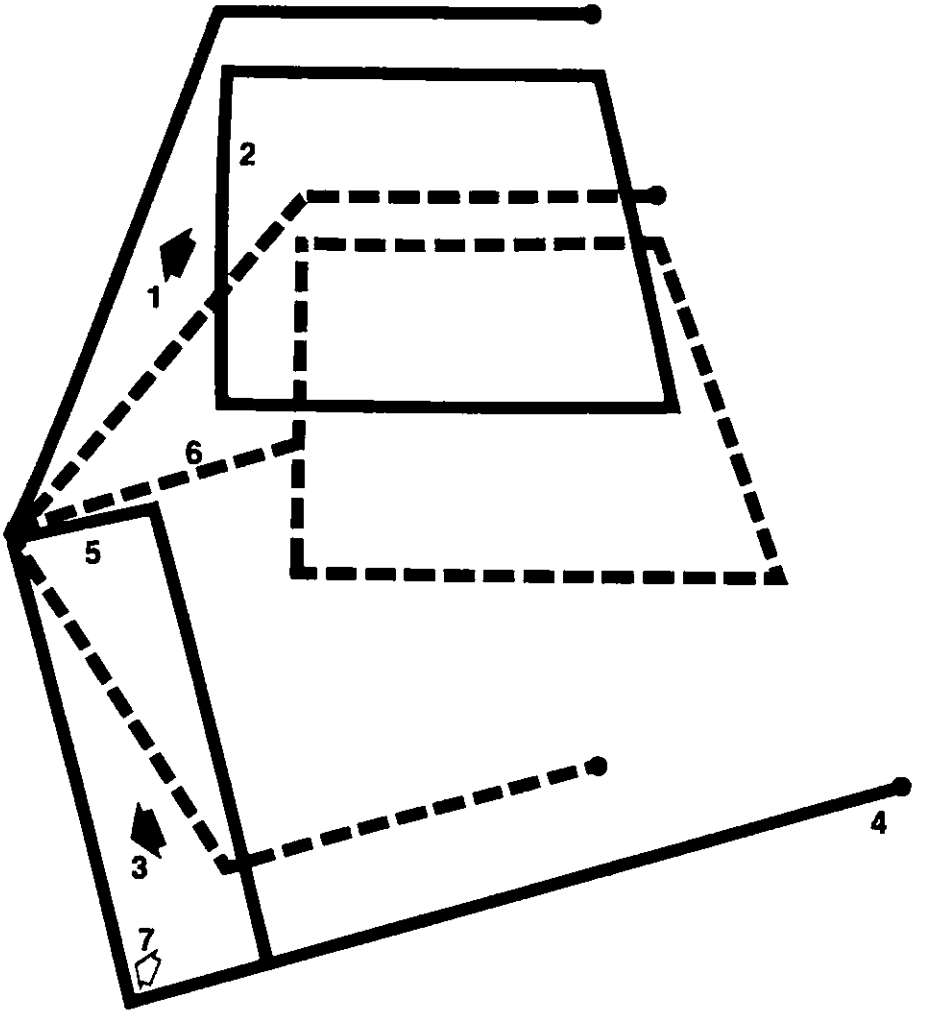
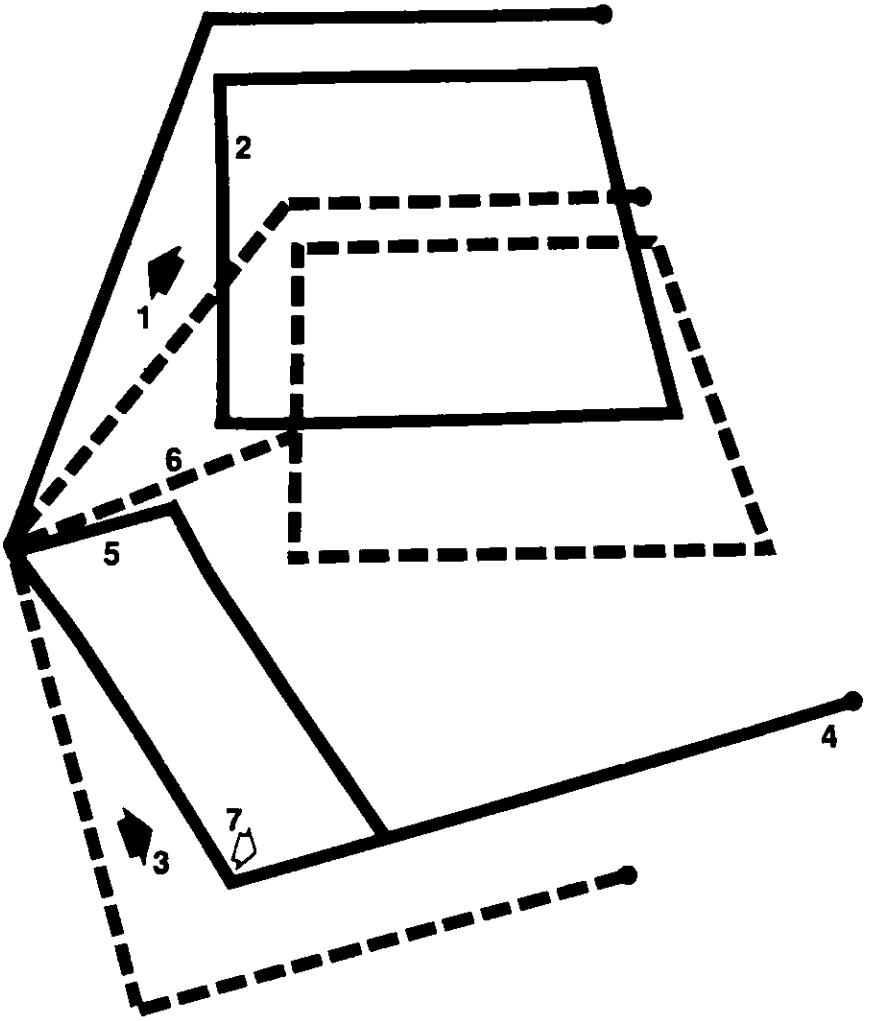


Figure 20. Mixed composite of mandibular and maxillary protrusive relationships characterizing Type I^{4**}. This type has a backward MCF alignment (1) accompanied in all but two cases by a long vertical PM (2). The ramus alignment (3) is aligned forward. In all but two cases, the mandibular corpus (4) is long relative to the maxillary corpus. All but one case, has a horizontal ramus width narrower (5) than the neutral horizontal dimension of the MCF (6). In all but one case the gonial angle (7) is open.

TYPE I^{4**}



DISCUSSION

The basic Class III skeletal pattern comprises a combination of certain sets of regional anatomic parts and counterparts that produce a resultant composite mandibular protrusive effect. Enlow et al. (1971) has shown, using the counterpart analysis, the nature of the specific patterns of regional relationships that are involved. In the present study, a series of hypothetical combinations of these anatomic part and counterpart relationships were formed. The resultant groupings reflect the different possible morphologic types of Class III malocclusions that can occur.

Three particular anatomic relationships that are regarded as fundamental in establishing the basic facial pattern were utilized as the core variables for all groups. These are the alignment of the middle cranial fossa, the vertical PM dimension, and mandibular corpus length relative to the maxilla. In addition, four other key anatomic relationships that act to secondarily complement those just mentioned were included. These are ramus alignment, horizontal width of the ramus relative to the horizontal dimension of MCF, gonial angle, and the Curve of Spee.

The Class III sample of 20 individuals was analyzed using Enlow's Counterpart Analysis according to different hypothetical combinations of anatomical and developmental characteristics.

In the following paragraphs, these various combinations are described, and how the nature of the structural relationships contributes to the overall craniofacial pattern of that type of Class III are evaluated.

The type III^1 group is characterized by a forward (anteriorly aligned) positioning of the middle cranial fossa. This results in a more horizontally elongate expression of both the middle cranial fossae and a more anteriorly positioned anterior cranial fossa. It thereby places the entire nasomaxillary complex in a more protrusive (Class II) position relative to the mandible. The entire nasomaxillary complex is also more inferiorly placed relative to the mandibular condyle. This usually produces a downward and backward rotational alignment of the ramus. In the type III^1 individual, however, a forward rotation of the ramus has occurred, and this is due to the short posterior height of the nasomaxillary complex (short vertical PM). This type's short midface has thus contributed to a positional change in the mandible, as it rotates to a more upward and forward (protrusive) position.

The horizontal length of the mandibular corpus relative to the maxilla is longer in this type, which is also an anatomical factor contributing to the prognathic nature of the face. The gonial angle, in almost all cases, is open, which further increases the protrusive expression of the already horizontally long mandib-

ular corpus. However, the ramus was involved in a developmentally compensatory action, and its narrow nature relative to MCF reduces the extent of horizontal corpus protrusion. The extent, however, has not fully compensated for the Class III condition, although the severity was significantly reduced.

The type III^{2*} has undergone an uprighting of the middle cranial fossa, which results in a backward MCF alignment. This causes a relative retrusion of the nasomaxillary complex and also narrows the posteroanterior dimension of MCF. A more forward relative placement of the entire mandible results. The backward MCF alignment, further, is augmented by a long posterior height of the nasomaxillary complex, (long vertical PM). In contrast to the type III^{1}, this results in a downward and backward ramus alignment. This backward position of the ramus increases the vertical expression of the ramus to accomodate the longer midface. It also offsets the forward placement of the mandible by the MCF alignment. Thus, the mandibular protrusion factors underlying this Class III type lies in the mandible itself.

The primary anatomical basis for this type of mandibular prognathism is the longer mandibular corpus relative to the maxilla. To further increase the horizontal length discrepancy, the majority of the cases, expressed a wide horizontal ramus width relative to the MCF dimension. Along with these two features, the gonial angle, in all but one case, is open and this further increases the mandibular protrusive expression.

The type III^{2**} has undergone a backward positioning of the middle cranial fossa accompanied by a long vertical PM. In contrast to type III^{2*}, this longer vertical PM only partially offsets the posterior-aligned MCF. The ramus thus is still rotated forward, which caused the mandible to be positioned forward relative to the maxilla. Along with the forward ramus alignment, the mandibular corpus of the type III^{2**} is longer relative to the maxilla.

Further increasing these positional and anatomical length discrepancies, the majority of the cases show a wide horizontal ramus breadth relative to MCF. The type III^{2**} gonial angle, contrary to types III^{1} and III^{2*}, is closed. This is a compensatory action that serves to align the mandibular to the maxillary dentition, and also to reduce the protrusive expression of the mandibular corpus. This gonial angle adjustment, however, is insufficient to fully offset the various prognathic features also present.

The type III^{2***}, as also seen in types III^{2*} and III^{2**}, has undergone a backward positioning of the middle cranial fossa accompanied by a long posterior height of the nasomaxillary complex. Subsequently, the ramus, which has a neutral alignment position in this type, has undergone a possible developmental responce. The long vertical PM caused a downward and backward ramus rotation. However, this is offset by the relative

forward positioning of the mandible caused by the backward MCF, and the ramus is in a resultant neutral position.

The type III^{2***} mandibular corpus is longer relative to the maxilla, thereby becoming a primary anatomical contributor to this type of mandibular prognathism. However, this length discrepancy is offset in all of the cases by a narrow horizontal ramus width relative to the MCF dimension. All of the cases had an extremely open gonial angle. This further increased the horizontal mandibular prognathic expression, and it also contributed to an open bite in this type. The type III^{2***} individual was the only type present in the sample that demonstrated a strong open bite tendency from 6 years of age. A negative Curve of Spee augmented this feature.

The type III^{3} individual exhibited the most severe combination of mandibular prognathic relationships. This type is characterized by a backward MCF alignment, and in contrast to types III^{2*}, III^{2**}, and III^{2***}, a short vertical PM exists. Both features contributed to the upward and forward nature of ramus alignment that occurs. This forward position of the ramus decreases the vertical expression of the ramus to accomodate the short midface and basicranial alignment thereby places the mandible on a more protrusive position relative to the maxilla.

The type III^{3} mandibular corpus is also anatomically longer relative to the maxilla, and the gonial angle is open in

almost every case. Both of these factors add to the cumulative prognathic pattern. The only compensatory action in this Class III type is a narrow horizontal ramus width relative to the MCF dimension. This reduces the horizontal extent of mandibular corpus protrusion. However, with the multiple anatomic relationships that contribute to mandibular prognathism, this single compensatory action is insufficient to counterbalance the composite Class III tendency. It does, however, reduce the severity involved.

In Table VI the developmental pathway for each individual in the sample is diagrammed from three years of age to late adolescence. The upper part of the table reflects more maxillary protrusive tendencies, and the tendencies for mandibular protrusion increase toward the bottom of the page. By following each case number, an understanding of how growth and development affected each of the anatomical combinations through time.

The three year old column reveals a very mixed nature of combinations, with no two individuals showing the same pattern. There also occurs a relatively large incidence of neutral values (0) for the vertical PM and relative corpus lengths compared to the older age levels. This reflects the growth changes in the basicranium and upper face, with the mandible lagging.

The 6 year old level shows 5 different craniofacial compositions with 5 subtypes for the 20 individuals, and this reveals

the very mixed nature of the anatomical status at the age involved. The growth of the ACF has essentially ceased, and the maxilla is now elongating from the posterior in response to displacement and further eruption of the permanent dentition. However, the mandibular corpus, which normally follows the growth of the maxilla, is already now longer in every case from this age until late adolescence.

Looking at the 6-9 age range (Table VIII), MCF alignment and mandibular corpus length both remain relatively stable with only 2 changes respectively. Ramus alignment however, exhibits quite a variable pattern with 10 changes. This reflects the continual adjustment of the ramus to the lower arch position, relative to the vertically enlarging nasomaxillary complex and erupting permanent dentition in both arches. The horizontal Class III ramus width is also variable at this age, and it is continually compensating for remaining MCF growth, increases in pharyngeal space, and the need for a longer corpus as the permanent dentition erupts.

In Table VI the 9 year old column shows a reduction in the extent of variability as developing craniofacial relationships react to growth and developmental changes.

In Table VIII at the 9-14 age range, the greatest total number of changes among the anatomic parts and relationships is observed. This coincides with Bjork's (1963) findings identifying a pubertal growth spurt between the ages of 11 to 14. The MCF

alignment demonstrates a twofold increase in forward positioning, as the MCF nears the end of its growth period. The large number of changes in the vertical PM relates to the increased growth of the nasal part of the ethmomaxillary in conjunction with the enlarging airway.

Variability seen for the horizontal ramus width and gonial angle reflects continuous adjustments in lower arch position accompanying the enlarging nasomaxillary complex and pharynx.

The 14 year column in Table VI shows a further reduction in variability as more individuals complete growth adjustments to the changing circumstances during the late adolescent growth period.

In the 14-16 age range (Table VIII) the total number of changes has declined dramatically, reflecting achievement of anatomic and functional stability in the combinations of anatomical parts and relationships, as the adult mandibular prognathic pattern is approached. In all of the individual groups, except for MCF alignment, the least amount of change is seen for any of the age ranges studied. This reflects a decline from the more rapid pubertal growth period in most areas of the Class III craniofacial pattern. However, a few cases did exhibit changes, which according to Bjork (1963) represents a latent or extended pubertal growth spurt. Bjork found this to be a common occurrence, especially in adolescent males. The most frequent change at this

age was the ramus alignment. These factors reflect the action of ramus growth and remodeling in accomodating continued vertical nasal growth, as well as late eruption of the second molars, thereby positioning the mandibular arch accordingly.

The 16 age column (Table VI) shows a continued decrease in the incidence of changing craniofacial patterns. At this stage, all of the individuals in the sample are contained in only three separate craniofacial combination patterns with 3 subtypes of Type III^3. The occurrence of neutral effects (0) is also at the lowest point for any age level, as the anatomic parts and relationships have by now become established in either augmenting or reducing the mandibular protrusive effects. In this study, these three adult Class III craniofacial types were categorized according to the core anatomical relationships and the frequency of the reciprocal (compensating) anatomical adjustments. This evaluation led to the recognition of five different mandibular protrusive types.

In Tables VII and IX and Figures 15 to 20, Class I subtypes corresponding to the same combinations of anatomic variables are shown. Comparing the Class I and Class III, several significant observations were made. The frequency of individuals having a short vertical PM and those having a long vertical PM was equal for both the Class I and III. Comparing the ramus horizontal relative to the MCF width, a 15% greater incidence having a narrower ramus is seen in the Class III. Ten percent

more of the Class III individuals had a open or obtuse gonial angle as compared to the Class I. The ramus alignment was forward in 20% more of the Class III cases than in the Class I.

The two anatomic features expressing the largest distinction between the Class I and Class III cases were the MCF alignment and mandibular corpus length relative to the maxilla. MCF alignment had undergone a backward positioning in 25% more of the Class III than the Class I individuals, thereby setting up more mandibular protrusive tendencies and in other areas of the Class III craniofacial composition. The most consistent difference between these two craniofacial classes is mandibular corpus length. All of the various Class III types demonstrated a longer mandibular corpus, in comparison to only 70% of the Class I.

Thus, in comparing the adult craniofacial composite between the Class I and Class III, it is evident they can be generally similar in the arrangement of the various anatomic parts and the nature of their regional relationships. It is, therefore, the cumulative summation of several of the mandibular protrusive relationships and the extent of offsetting effects that quantitatively separate the final expression of a given Class I from that of a Class III craniofacial combination.

Continued growth, according to Enlow et al. (1969), can have one of the following effects: (1) sustain a balanced or an

imbalanced condition; (2) improve or correct an unbalanced condition; or (3) aggravate the original status of balance or imbalance. Clinically, the ability to determine an existing condition and then predict which of the effects that growth will have, is very important. Growth prediction, however, has historically not been very accurate beyond the 70% level. This has been due to the lack of individualization of the growth analysis using the current methods for prediction. In this study, various anatomical parts and relationships were analyzed according to their stability through time. If a significant percentage of certain anatomic parts, or combinations of them, remain stable through time, then the accuracy of prediction can be improved.

In analyzing Table VIII only the MCF alignment is seen to remain relatively stable from three years of age to late adolescence. However, due to the small sample, comparative percentages are not conclusive. In those cases having a forward MCF alignment at age 6, 5% continued this alignment to late adolescence. For those having a backward MCF alignment at age 6, 65% continued this alignment. At the 9 and 11 age levels in which a backward MCF alignment occurred, 80% returned retained the alignment.

The Class III mandibular corpus length relative to the maxilla is the most stable relationship throughout all age levels. However, until 9 years of age, the large number of neutral values

(0) makes this feature difficult to use in prediction. By the age of 9 years, all but two individuals have a long mandibular corpus relative to the maxilla. Therefore, from 9 to late adolescence, 90% of the cases retained the prognathic mandibular corpus pattern.

An obtuse gonial angle, according to Bjork (1963), is a characteristic feature of the Class III mandible. In the present study, however, the gonial angle was found to be quite variable until 9 years of age. Even at 9 years, the number of neutral positions is significant enough to reduce the pattern prediction accuracy to 65%. By the age of 14, the mandible has undergone the majority of its pubertal growth adjustments, and the definitive adult gonial angle pattern has become stable in 90% of the cases.

Remodeling along the ramus' anterior and posterior borders, according to Enlow (1975), is what actually is being reflected by the gonial angle. Therefore, Enlow feels that the narrow horizontal width of the ramus relative to MCF is more indicative of a Class III mandible, than simply the gonial angle. This study has shown that both the gonial angle and ramus horizontal width have similar patterns of stability through time. It isn't until 9 years of age that ramus width begins to stabilize, as 65% of the ramus patterns then continue on to late adolescence. But by the age of 14, as with the gonial angle, the pubertal adjustments become refinements rather than massive bony archi-

tectual changes. This is reflected in the increase in stability of the ramus width pattern from 65% to 90% as late adolescence is approached.

Looking at the various Class I types developmentally, in contrast to the Class III (Tables VIII and IX), the pubertal surge in changes between 9-14 years of age, followed by a dramatic decrease in changes late in adolescence are not seen. Rather, the Class I exhibits a constant, high level of variability from age 6 to late adolescence. This was most significant during the 14-16 age range. The Class III is quite stable, with only 10% average change among relationships, in this age range. However, the Class I is indeed quite variable, expressing changes from 10 to 45% depending on the anatomic part or relationship considered. Thus, the Class I craniofacial type is in a more or less constant dynamic state of change and regional accomodation as growth proceeds forward a relatively balanced composite state.

In an attempt to forecast facial patterns before puberty, several anatomic parts and relationships were combined, as based on their high degree of stability through time. This combination was intended to provide a morphometric and anatomically-based method for pattern predictions. Bjork (1969) feels that the growth of the mandible during late adolescence cannot be determined from the prepubertal size. He also feels that the changes in the shape of the face during late adolescence weakly correlates

with that at 12 years of age. The present study, however, has shown that certain anatomic parts and relationships of the Class III craniofacial composite remain relatively stable from 9 years of age to late adolescence.

Combining the MCF alignment and mandibular corpus length relative to the maxilla, one finds that this combination remains relatively stable in 80% of the cases beyond both the 9 and 14 age levels. With the addition of the gonial angle, the stability drops at the 9 year level to 78%. However, due to the decrease in variability of the late adolescent gonial angle, the addition of the gonial angle increases the pattern stability prediction at the 14 year level to 90%. To be able to predict mandibular growth patterns, the horizontal width of the ramus relative to the MCF was also added to the prediction combination. This reduces the pattern stability prediction at the 9 year level to 78%, down 2% from the original two-variable combination. However, the addition increases the prediction at the 14 year level to 90%, up 10% from the original combination. Thus, a prediction combination including: MCF alignment, mandibular corpus length relative to the maxilla, gonial angle, and horizontal width of the ramus relative to MCF width, could predict the pattern from the 9 year level with 78% accuracy, slightly better than Johnston's grid. The accuracy is extremely good at the 14 year level, but by this time treatment would likely already have been started and growth prediction becomes a secondary consideration.

The Class I composites proved too variable to show pattern stability above 50%. Prediction at or below this level is clinically useless.

A word of clarification on growth prediction is needed at this point. The determination of craniofacial pattern stability from this study, is only one aspect in the multifactorial problem of growth prediction. However, the finding of relatively stable anatomical parts and relationships within the dynamic craniofacial complex will increase the accuracy and individualization of the present prediction models being used today and refinement of this concept shows promise that a more effective system can be developed. These levels of prediction confidence are for this sample; further research is needed to determine confidence levels in other samples.

The early recognition of a developing mandibular prognathic craniofacial composite has great significance to treatment success. Two very important questions should be (but not always are) answered before an appropriate treatment plan can be determined. The first is which anatomical part(s) is primarily at fault, or does a combination effect exist? Secondly, has the present craniofacial composition contributed to a tendency for a deep or an open bite. The latter usually cannot be determined before the second molars have erupted.

Frankel (1972) feels that treatment should commence as soon as a maxillary and mandibular skeletal imbalance is detected. His use of a Functional Corrector (FR III) to eliminate all dental and soft tissue constraints on the maxilla assumes that a constrained maxilla is the chief problem. However, if the maxilla is in a normal position and the mandible has an abnormal protrusive positioning or growth pattern, then the FR III, according to Hamilton (1983), is fairly ineffective.

In this study, the Class III mandibular corpus was horizontally long relative to the maxilla in 100% of the cases beyond 9 years of age. This condition, along with the added ramus growth, only augments the Class III nature of the adolescent mandible. Experimental studies by Adams et al. (1972) indicate that extraoral forces applied to the chin in a superioposterior direction reduce the proliferative capacity of the prechondroblastic zone. This form of treatment would function effectively for the long face type III^{2***} open bite craniofacial pattern. However, extraoral treatment on the short face type III^{3} deep bite could be expected to result in undesirable anatomical consequences.

Creekmore (1978) states the feelings of most clinicians today on Class III treatment. In order for functional or extraoral treatment to be effective, therapy must be continued over the entire growth period. This has proven to be unsuccessful in most of the Class III cases treated today.

The present study demonstrates that certain areas of the craniofacial complex (MCF alignment, mandibular corpus length) are early contributors to mandibular prognathism. Other areas (ramus alignment, gonial angle) contribute during later development. Thus, mandibular prognathic correction in early adolescents, 9-11 years of age, may result in the individual returning to a prognathic profile due to subsequent growth and development within such regions. This study, then, supports the rationale for the currently used treatment sequence involving (1) "unlocking" the maxilla if it is dentally impeded at an early age and allowing both jaws to grow until after puberty; (2) orthodontically removing the natural dental compensations after puberty; and (3) then reevaluating the case to determine if surgically repositioning of the mandible or maxilla, or both, to a presumed morphologically and anatomically balanced position is possible, relative to the rest of the craniofacial composite. Relapse following surgical orthodontic treatment of mandibular prognathism is due to unsuccessfully maintaining or establishing an equilibrium between the anatomical parts and the functional relationships throughout the craniofacial complex. Through the use of morphometric and anatomic analysis such as the counterpart analysis, a better understanding of craniofacial balance can be achieved, and the amount of surgical and orthodontic relapse should become significantly reduced.

Whitney (1983), in an analysis similar in design to the present study, analyzed Class II craniofacial patterns. In comparing the three general malocclusion categories, Class I, II and III, certain significant developmental and anatomical differences were identified. This Class II data is presented in Tables X and XI. Overall, as would be expected, the Class II expresses more maxillary protrusive relationships (+), the Class III more mandibular protrusive combinations (-), and the Class I demonstrates combinations that contain both maxillary and mandibular protrusive tendencies.

Looking at Tables VII and X Classes I and II both show a high degree of variability within the craniofacial composites from age 6 to late adolescence. The Class III in Table VI, though highly variable at 6 years of age, shows a steady decrease in craniofacial composite variability through time. At the 16+ age level the Class III shows one third the number of groups that the Class I and II exhibit. The Class II actually increases in variability of craniofacial compositions from 9 years of age to late adolescence.

With regard to where the actual variations occur in the Class II craniofacial composition, in Table XI it is seen that quite a degree of variability occurs in all six anatomic parts and relationships. The MCF alignment, which is fairly stable in the Class III (Table VIII), is quite variable in the Class II, as it is in the Class I types (Table IX).

The mandibular corpus, which is significantly stable in the Class III, is extremely variable in the Class II at all age levels. The Class I, however, showing a fairly variable pattern before 14, becomes extremely variable in 45% of the mandibular corpus lengths after 14 years of age. Whether this reflects a response to latent mandibular second molar eruption, preparation for third molar eruption, or a latent growth of the mandibular corpus to balance the complex, cannot be determined from this study.

Looking specifically at mandibular relationships, the variable ramus alignment of the Class III is quite stable in the Class I, and it is the most stable anatomic relationship in the Class II craniofacial composition. The horizontal width of the ramus and gonial angle, before the age of 14, are extremely variable in the Class III, less so in the Class II, and represent the most stable of anatomic relationships in the Class I.

The horizontal width of the ramus is unique in the manner by which it appears well balanced with little variability early in the Class I development. It then enlarges at puberty and remains fairly variable through late adolescence. The Class II and II horizontal ramus width shows the opposite developmental pattern. It is extremely variable early in development, remaining so through puberty, and then becomes relatively stable through late adolescence. The early variability of the Class II and III

ramus width possibly represents an early attempt at balancing a developing malalignment of the other anatomic structures. The increase in variability during puberty reflects ramus accomodation for the growth of the pharyngeal space and airways. The decrease in late adolescence is due partly to a decline in the growth of the pharynx and, possibly, arriving near a physiologic limit in capacity to adjust for other regional malalignments. The Class I ramus width, however, remains variable late in adolescence, reflecting this craniofacial type's more successful role in the balancing of the composite of anatomical structures.

The Class III craniofacial type seems to show larger amounts of change up to and partly through puberty. But from late puberty on through late adolescence, the craniofacial pattern appears to only undergo refinements, not total architectual turn over. The Class II however, shows slightly less change early in development, but continues to show significant changes through late adolescence. Some portion of the Class II craniofacial construction seems to be changing at all age levels, which is reflected in the large number of subtypes for this craniofacial complex. This North American Caucasoid Class I sample showed a Class II tendency in the nature of some anatomical parts and relationships, and a Class III tendency in others. In summary, the Class I appears not be to a separate dental classification, but rather a craniofacial composition that has achieved a degree of

balance for the various compensated maxillary and mandibular protrusive tendencies among the different anatomical parts and relationships occurring throughout the craniofacial complex.

SUMMARY AND CONCLUSIONS

Numerous theories attempting to account for the skeletal pattern involved in the Class III individual have been proposed. Each has looked at a possible primary contributor to the prognathic profile. However, there is ample reason to assume that more than one skeletal imbalance, in different areas of the craniofacial complex, are contributing to the Class III skeletal pattern.

The purpose of this study is to longitudinally evaluate the various anatomic counterparts and their interrelationships, within the Class III craniofacial complex and to determine which of these contributes earliest and to the greatest degree to the prognathic profile. Also studied was the longitudinal stability of various combinations of these anatomic parts and relationships. This information will aid in the ability to predict a Class III skeletal pattern early in development and allow treatment to be initiated accordingly. Using Enlow's counterpart analysis, hypothetical groups were formed based on random combinations of these primary and secondary anatomic parts and relationships.

The results of this study may be summarized:

1. The 20 Class III 16 year old sample consisted of 3 different $_3$craniofacial compositions with 3 subtypes of Type III^3, all demonstrating a prognathic mandible with a Class III malocclusion. The 20 Class I 16+ year old sample consisted of 4 different $_3$craniofacial compositions with 2 subtypes of Type I^3 and 2 subtypes of Type I^4, all demonstrating a Class I occlusion.

2. The most stable Class III anatomic parts and relationships are the middle cranial fossa alignment and the mandibular corpus length relative to the maxilla. The most variable Class III anatomic relationships are the ramus alignment and horizontal width of the ramus relative to the MCF dimension. The Class I subjects are similar to the Class III, in variability of the anatomic relationships, varying only 10-15% in all but two areas. The Class III sample has 25% more backward positioned MCF than the Class I and 90% of the Class III subjects, from 9 years of age, had a mandibular corpus longer than the maxillary corpus, compared to only 70% of the Class I.

3. The Class III sample exhibited a steady decrease in the number of different craniofacial compositions, from 6 to 16+ years of age. In contrast, the Class I sample maintained a high level of different craniofacial compositions, throughout the same time period. However, both groups did express a pubertal growth spurt, reflected in the significant increase in variability among the anatomical relationships, between the age levels of 9 and 14.

4. In the Class III group, the combination of anatomic relationships which included; middle cranial fossa alignment, mandibular corpus length relative to maxilla, ramus horizontal width relative to MCF and the gonial angle, exhibited a pattern stability of 78% at the 9 year level and a 90% stability at the 14 year level. The Class I anatomic combinations were too variable to predict better than 50%. These levels of prediction confidence are for this sample; further research is needed to determine confidence levels in other samples.

Information from Whitney (1983) on a sample of 20 skeletal Class II analyzed in a similar manner, was compared to the Class III and Class I data from this study.

The results of this comparison may be summarized:

1. The Class II 16+ year old sample consisted of 6 different craniofacial compositions with 4 different subtypes, demonstrating a Class II malocclusion.

2. The middle cranial fossa alignment and mandibular corpus length relative to the maxilla, which was very stable in the Class III sample, is extremely variable in the Class II pattern.

3. The Class II sample exhibited a steady increase in the number of different craniofacial compositions, even after the 14 year age level. This is contrary to the Class III sample, which showed a steady decrease in the number of compositions, especially after the 14 year level. The Class I sample did not fluctuate but rather, maintained a significant number of different craniofacial compositions.

The overall results from this study and the Class II comparison may be summarized:

1. The Class III craniofacial complex exhibits a large amount of change early in development and maintains it partly through puberty. The craniofacial pattern then appears to only undergo refinements, not total architectual turn over.

2. The Class II craniofacial complex showed less change early in development, but significant increases in the number of changes from before puberty to late adolescence. Many portions of the Class II craniofacial pattern appear to be changing at all age levels, as reflected by the large number of individual counterpart changes for each age level.

3. The Caucasoid Class I sample showed Class II tendencies in some anatomic parts and relationships and Class III in others. It appears from this study that Class I individuals are not a separate dental classification but rather, a craniofacial composition that has balanced or compensated for the various maxillary and mandibular protrusive tendencies, within their present craniofacial complex.

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