1965

A Cephalometric Assessment of Cranial-Facial Morphology in Class I, Class II, and Class III Malocclusions

Robert R. Lokar
Loyola University Chicago

A CEPHALOMETRIC ASSESSMENT OF CRANIAL - FACIAL MORPHOLOGY IN CLASS I, CLASS II, AND CLASS III MALOCCLUSIONS

by

Robert R. Lokar

A THESIS SUBMITTED TO THE FACULTY OF THE GRADUATE SCHOOL

OF LOYOLA UNIVERSITY IN PARTIAL FULFILLMENT OF

THE REQUIREMENTS FOR THE DEGREE OF

MASTER OF SCIENCE

June

1965

AUTOBIOGRAPHY

The author was born in Milwaukee, Wisconsin, on October 15, 1929. The depression brought his family to Detroit, Michigan, in 1934. It was here that he began his formal education in the Detroit public school system. Upon completing grade school, he transferred to St. Theresa High School and from there received his diploma in June of 1947.

In September of the same year, he began his studies for a B.S. degree at the University of Detroit.

June of 1949 found him unsettled in his choice of vocation and thereupon he set out to try the world of accounting and selling.

During the following few years, an interest in dentistry was kindled, and in September of 1954, he began his predental studies. He was accepted into the University of Detroit Dental School in 1956 and graduated in 1960.

After three years of general practice in the Detroit area, he began his graduate studies in oral biology at Loyola University, Chicago, Illinois, in June, 1963.

ACKNOWLEDGEMENTS

To my wife and to our parents, I dedicate this effort.

My heartfelt thanks to my three board members. To Dr. Joseph R. Jarabak, D.D.S., Ph.D., for allowing me the opportunity of studying under his guidance at Loyola University.

To Dr. John Flanagan, B.S., Ph.D., for his help and interest in his endeavor; especially in the statistical discipline and the analysis of the data.

To Dr. Joseph Gowgiel, D.D.S., Ph.D., for his warmth, friendship and advice.

TABLE OF CONTENTS

Chapter		Page
I.	INTRODUCTION	1
	A. Introductory remarks	1
	B. Statement of problem	4
II.	REVIEW OF THE LITERATURE	7
III.	MATERIALS AND METHODS	22
	A. Materials	22
	B. Methods	23
	C. Landmarks and constructed points	26
IV.	FINDINGS	35
V.	DISCUSSION	52
	A. Introductory remarks	52
	B. Assessment of the cranial-facial morphology of the Class I malocclusion, as it relates to the Class II malocclusion	55
	C. Assessment of the cranial-facial morphology of the Class III malocclusion, as related to the Class I and Class II malocclusions	62
VI.	SUMMARY AND CONCLUSIONS	72
	A. Summary	72
	B. Conclusions	76
VII.	BIBLIOGRAPHY	79

LIST OF FIGURES

Figure		Page
1.	DETERMINATION OF GONION AND ARTICULARE	25
2.	CEPHALOMETRIC LANDMARKS	27
3A.	MECHANICAL DETERMINATION OF POINT A'	29
3B.	THE CHIN PLANE AND THE CHIN ANGLE	29
4.	DEMONSTRATION OF PLANES OF MEASUREMENT	30
5.	DEMONSTRATION OF ANGULAR MEASUREMENTS	32
6.	THE INFLUENCE OF THE SIZE OF THE GONIAL ANGLE ON THE REGISTRATION OF THE ANGLE Go-N-Gn, IN CLASS I AND CLASS II MALOCCLUSIONS	37
7.	COMPARISON OF THE MEAN SADDLE ANGLE VALUES.	39
8.	THE INFLUENCE OF INCREASED GONIAL ANGLE AND INCREASED BODY LENGTH (CLASS III) ON THE ANGLE Ar-S-Gn	41
9.	ILLUSTRATION OF HOW AN INCREASED GONIAL ANGLE INCREASES THE PROJECTED LENGTH OF THE MANDIBLE.	42
10.	TWO METHODS OF DETERMINING PROJECTED MANDIBULAR LENGTH.	43
11.	EFFECT OF THE SUMMATION OF CLASS III MEAN ANGLE VALUES AND INCREASED BODY LENGTH	47
12.	COMPARISON OF GONIAL ANGLES	49
13.	COMPARISON OF THE MEAN VALUES OF THE CLASS I, II, AND III MALOCCLUSIONS WITH SELLA AND THE S-N PLANE AS POINTS OF REFERENCE	64
14.	COMPARISON OF THE MEAN ARTICULAR ANGLES	66

LIST OF CHARTS

Chart | Page

I. MEANS AND STANDARD DEVIATIONS 83

II. TEST FOR SIGNIFICANT DIFFERENCE 84

CHAPTER I

INTRODUCTION

A. Introductory remarks.

Orthodontics is defined as the biomechanical science concerned with the prevention and correction of malocclusions and maintenance and preservation of the normal occlusion of the teeth. To this should be added the term "diagnosis", i.e., "The diagnosis, prevention and correction of malocclusions, etc...". Today treatment is not the great problem that it once was, but an accurate diagnosis still remains to be an enigma. To be able to accurately interpret and project information existing at a particular time, concerning a particular patient, calls for a well-founded knowledge of growth and development.

An understanding of the growth and development of not only the facial skeleton but also of the cranial base has become imperative for the correct evaluation of orthodontic problems. All recent investigations in the field of orthodontics have indicated that successful treatment depends largely on the growth and development of the patient.

It was only natural that in the early years of orthodontics the orthodontist directed his attention solely to the teeth and the manner in which they would interdigitate. Now, through a gradual process of diagnostic maturation, he has come to realize that the teeth are attached to jaws which, in turn, are intimately related to the cranial bases, i.e., the maxilla is secured to the anterior cranial base, and the mandible to the posterior cranial base.

Although the significance of the cranial base has long been recognized by biological workers, it is only in recent years that the orthodontist has become aware of its importance. He now agrees on its significant position as the "hafting zone" between the neuro-cranium and the splanchnocranium. Today, modifications in the form and proportions of the cranial base are held to be the reflection of adaptive changes that have occurred between the brain case and the face, as well as those between the head and the body. It would also follow then that any change that occurs between the anterior and posterior cranial base surely will reflect the manner in which the jaws will be related to each other and also influence the remaining facial structures including the dentition.

For example, if we inspect the upper face, we find it is attached to the anterior cranial base through sutures at the fronto-maxillary junction, anteriorly; at the zygoma, laterally; and through the pterygoid plates, posteriorly. The face therefore can be considered as an outgrowth of the underside of the anterior cranial base. While it is influenced by the proportional increases in the anterior and posterior base, any additional downward and forward growth must take place at the sutures mentioned above, which lie outside of the calvarium.

The growth of the mandible must be integrated with that of both the anterior and the posterior cranial base. Since the mandible articulates within the glenoid fossa of the temporal bone, which is intimately influenced by the downward and backward growth of the posterior cranial base, it must compensate for the development in this area.

The mandible must also keep pace with the growth of the anterior cranial base if it is to maintain its proper relation with the upper face and the maxillary dental arch. To accomplish this, the mandible has two major sites of growth. These growth sites are located at the head of each condyle. They are unique in the body because the articular surface of the cartilage has a fibrous tissue covering, instead of being a free cartilaginous surface; and also because cartilage growth is primarily appositional instead of interstitial.

As a corollary, if one part of the cranial base did change in its relation to the whole, it would be manifested in the part of the face to which it is related. For example, if the basilar part of the occipital bone were smaller than normal, it would have an effect not only on the cranium, but on the lower face as well.

This new insight of growth and development to orthodontic problems has caused the orthodontist to pose a number of questions. Some of which might be:

Just what effect does the cranial base flexure have on the dentition? Can it directly cause a dental malocclusion and yet leave the dentition's skeletal support within normal limits? Will an abnormal flexion of the cranial base necessarily result in a deviation of the facial skeleton from within normal limits? Will a malocclusion be clinically visible, because the dentition and the alveolar process have been carried along and influenced by this deviation of the facial skeleton? Just how much can we expect the dentition to adapt to gross irregularities in the cranial base and the facial skeleton?

These are but a few of the questions we hope to consider in this study of the relation of the cranial base, as defined by Bjork: (N-S-Ar), and its relation to certain standard facial landmarks as they exist within the Angle classification of malocclusion. Also encompassed in this work will be an attempt to more correctly analyze mandibular morphology in the way it relates to the cranial base and the facial plane.

B. Statement of the problem.

This study was designed to give a more complete assessment of cranial-facial morphology within the scope of the Angle System of Malocclusion classification.

This is because most works in the past (Bjork, Brodie, Hellman, etc.) have dealt with the relation of the cranial base to skeletal variations, and little had been done in the way of studying its relation to dental malocclusion. There are many ways in which malocclusions have been graded, rated, and grouped, but the most universal method is the Angle system of classification. Certainly, it is not the most profound or the most complete, but since it enjoys the greatest usage, it is felt that a more comprehensive view is necessary when this method of description is employed.

We hope to further prevent many of the pitfalls which occur by following a particular stereotyped concept. As has been stated by Bjork, Brodie, Coben and others, it is the concept of individual variation which is so important, rather than the fact that "such and such" a malocclusion fits into any particular group.

Sanborn (1952) and Blair (1952) have done similar studies on patients with malocclusions. This study will serve to confirm (or deny) their work and to add certain new concepts in the assessment of cranial-facial morphology. The fact that this avenue must be thoroughly investigated is aptly stated by Moss and Greenberg in 1955, "The etiology of various types of malocclusions is a problem of constant interest. There is a general agreement that an existing disharmony reflects, somehow, a lack of correlation between the growth of some or all components of the skull. The orthodontist, as well as other students of cranial growth, is confronted with the problems of understanding the admittedly complex interrelation between:

a. The neural skeleton

b. The facial skeleton

c. The teeth and the alveolar process".

Brodie (1946), in a paper on "Facial Patterns" states, "Instead of the teeth being the guide to the destiny of the face, they become more or less passive and at the mercy of the parts around them".

Hellman (1937) expressed this problem in another manner when he showed that patients, although possessing excellent occlusion, exhibited wide variations in their facial development.

We do not pretend to be unaware that in comparing what may be different dental malocclusions, we may actually be comparing similar skeletal patterns. Conversely, in a group of similar malocclusions, we may find a wide variance of skeletal types.

Sanborn, in his master's thesis (1952), in a study of Class III malocclusions, presents this view, "Although the Class III molar relationship was a common factor in all of the cases, it did not imply a typical skeletal pattern. The skeletal profiles showed considerable variation. Consequently, in the appraisal of a Class III malocclusion, it would seem that a broader concept of the condition may be found outside the denture area". This is, of course, the purpose of this paper; or more specifically, the problem that we want to assess.

CHAPTER II

REVIEW OF THE LITERATURE

> "Summing up the Angle Classification, it may be said that each class is characterized by a certain property of the bite, but that this property may also be found in other classes. An analysis of the bite, which is based upon the bite characteristics, similar to that already employed in this investigation, has the advantage that the effect of the various factors are clearly separated. As the change in the occlusion found in this investigation are, to a great extent, the secondary effects of changes in the facial skeleton and in the cranial base, and thus are dependent on factors outside the bite, the classification should, at least in the case of major deviations in the bite, be confirmed by means of roentgenographic examination."
>
> Arne Bjork

A review of the literature revealed little information that considered cranio-facial morphology as we are attempting to evaluate it, that is, from the standpoint of dental malocclusion, as defined by Angle. Numerous works in the past have concerned themselves with the development and growth of the cranial base. More recent works have come to consider the cranial base and how it relates to cranial-facial morphology.

Although recent anatomical research points toward the cranial base as an important region concerned with the growth of the neural and facial skeletons, all investigators do not agree on the "modus operandi". The works of Hofer, Starch, and Kummer indicate that these two anatomically adjacent regions have a greater degree of phylogenetic and ontogenetic independence than has previously been attributed to them by Weidenreich and Bolk. The older view holds that changes in the neural skeleton are necessarily followed by coordinated changes in the facial skeleton. That there is a correlation between the cranial base flexure and the growth of the neural and facial skeletons is more recently indicated by Bjork, Pankow and Lindegard.

It is well to remember that the basicranial region of the human skull base exhibits a characteristic flexure. The axis, about which the bending occurs, passes transversely through the body of the sphenoid bone, dividing the skull base into pre- and post-sella components. A further topographic distinction is the delimitation of the neural and facial skeletons by the skull base. It would follow then that a change in the form or position of the components of the sphenoid complex will greatly influence the angular relations of the skull base. This will also affect the maturation of both the neural and facial skeletons.

From both phylogenetic and ontogenetic views, the development of the cranial base has been associated with neural structures, that is, the sense organs and the brain. The contour and relation of the anterior and posterior parts have been thought to be adaptations to postural influence.

Bolk (1922) felt that the cranial base was adapted to the size and form of the brain. In his "Fetalization Theory", he concluded, "Man represents a fetus of a primate which has become mature". He considered the foramen magnum and the occipital condyles to be the more fixed points of the cranial capsule. His work reveals that the more central position of the cranial base in man was the position characteristic for the preservation of the fetal state. He also believed that the foramen magnum and the occipital condyles were shifted backwards in postnatal life. Dabelow (1931), one of Bolk's students, also proclaimed that the configuration and alteration of the cranial base was due to growth of the brain alone.

Weidenreich (1924) believed that the size of the brain was responsible to some degree for the form of the cranial base. However, he thought its configuration was primarily associated with the attainment of the upright gait. Of particular interest to him was the change of the cranial base angle which occurs in phylogeny. This "deflection angle" decreased from fish to man and was correlated with upright posture and the diminution of the face as the size of the brain increased and overrode it. He further correlated this deflection to the manner in which the skull met the vertebral column. Weidenreich believed that by means of the kyphotic downward bend of the skull base, there came about a curving and shortening of the visceral axis of the brain and a shifting of the nose-mouth region into a space underneath this arch.

A number of investigators have made cross-sectional studies of the change in the cranial base with age. Virchow (1924) designated the angle formed by the clivus and the planum ethmoidal as the "saddle angle", claiming this angle decreased from birth to puberty.

Keith and Campion (1922) were among the first to attempt to study quantitatively the growth of the cranial base in the human skull. Using a series of skulls, they suggested that the increase in size can occur at three sutures, namely, the spheno-occipital, the spheno-ethmoidal and the fronto-nasal. They found the amount of growth at the fronto-ethmoidal suture was very restricted. The spheno-ethmoidal junction was concerned not only with the growth of the face, but also with the increase of the brain case. Growth at the spheno-occipital junction permitted enlargement of the brain and backward movement of the auditory meatus. In this way, space was provided for the growth of the mandible and pharynx.

Scammon (1936) attributed a characteristic growth pattern to the neural structures. This growth curve was followed by the brain, the spinal cord, and the membranes covering it, the eye with its several parts, and the auditory mechanism. It is characterized by a gradual deceleration from birth to the period of ninety per cent of the final growth attainment at seven to ten years. The incremental growth of the cranial base conforms quite closely to this neural pattern. In a less striking manner, cranial growth is also allied to general body growth. A plateau occurs around puberty, and this is followed by a parapubertal acceleration in most cases. This may be related to endocrine influences during this period. Some heterogeneity in the growth pattern is to be expected since the cranial base is also contiguous with the face. He also noted that the rate of growth of the face after seven years is much greater than that of the brain.

In 1937, Broadbent, the developer of cephalometric roentgenography, suggested that certain planes in the head were more suitable for the purpose of serial comparison of the same and of different individuals than those commonly used at the time. All of these lay in the zone of junction between the cranium and the face. Among others, he mentioned S-N (center of sella turcica to fronto-nasal junction) and

S-B (center of sella turcica to the Bolton point). Since that time, the angle N-S-B has been employed by a number of workers as the cranial base angle.

Brodie (1941), using cephalometric roentgenology for serial studies, measured the cranial base by dividing it into four parts. These divisions were: (1) Center of sella turcica to the Bolton point, (2) center of sella turcica to the spheno-occipital junction, (3) center of sella turcica to nasion and (4) center of sella turcica to the spheno-ethmoidal junction. From these measurements, he concluded that the anterior cranial base at three months was longer than the posterior portion; but that postnatal growth of the two was almost equal. After one and one-half years, the growth of the various segments comprising the cranial base seemed to maintain the same relative size. Neither the absolute size nor the relative proportions of the cranial base were shown to have any influence on facial type.

Bjork (1947) studied the facial profiles of Swedish boys and conscripts, measuring the angle formed between nasion, sella turcica, and articulare, and found that this angle opened in some individuals and closed in others. This angle was then related to the degree of prognathism in the face.

Brodie (1951) measured the angle formed by Bolton point, sella turcica, and the nasion, and found that this angle remained unchanged in half of his cases and increased or decreased in the rest.

One of the most exemplary researchers on the problems of facial growth, cranial base growth and malocclusion is Arne Bjork. In his study on cranial base development (1955), he favors the premise that the cranial base is obliged to develop in conformity with the brain and the facial structures. This means it must follow two different growth rates: One on the internal surface and one on the external surface. Since the face, both upper and lower, will continue to grow until age twenty, the sutural growth in the cranial base will remain active to a greater or lesser degree in order to compensate for these changes. This occurs in spite of the fact that the cranial development has ceased at approximately the twelfth year of life.

Flexion of the cranial base occurs until age ten to twelve, and then becomes constant; but individual variations do occur and can be quite marked. Age changes in the cranial base form are proportional to those calculated within the facial structures. He does state at this time that, although individual variations may be great, the mean change that takes place with age will be relatively small.

In discussing changes in the bite with age, Bjork found these changes to lie outside the regression for age changes in the facial structure and the cranial base. It served to clearly indicate the fact that the development of the dental and alveolar arches not only reflect the general growth tendency of the case in question, but that this development is to be interpreted as a result of modifications, or secondary changes in the shape. Modifications of this kind, both dysplastic and compensatory, occur in all dimensions of the bite; their effect is to increase considerably both the variation in form and the range of its age changes. This may explain the tendency toward excesses in the distribution of some bite determinations. It follows, therefore, that variation in bite or dental arch form is not simply a direct consequence of variation in growth, and cannot be analyzed as such, as has often been done.

Bjork, in his first major study in 1947, brought one of the first significant assessments of cranio-facial morphology with a direct view at the role played by the cranial base. His study was conducted on 322 twelve-year old boys and 281 Swedish army conscripts. With this group he attempted to analyze the nature of prognathism.

Of the conscript group, the following main classes of occlusion (according to Angle) were observed:

		Crowding
CLASS 0	64	43%
CLASS I	146	43%
CLASS II	45	51%
CLASS III	26	57%

He found that class "O" normal occlusion was more frequently found in the prognathic group and this was statistically significant. Prognathism of the maxilla was measured to the tip of the anterior nasal spine. Prognathism of the mandible was measured to the most forward projection of the chin (pogonion). Conversely, crowding occurs more often in the less prognathic individual. He felt, as the opening quotation states, that evaluating prognathism under the subgrouping of Angle's classification was useless, or at least unnecessary. This was because he felt other properties of the bite or jaw relationship should be more easily evaluated; such as the degree of horizontal and vertical overbite. Also, it was observed that the loss of teeth limited the determination of the molar occlusion of 150 conscripts or 53% of the study group. Bjork did find, "The degree of horizontal overbite (i.e., occlusion of incisors) and the molar occlusion tend to keep step". It will be well to take notice that all cases of extreme positive overbite (maxillary) are confined to Class II, Div. 1, while those with extreme negative overbite (mandibular) occur in Class III.

He determined the arithmetical mean for the total group and its standard error, M $\pm$ the sum of (M), and then proceeded to divide the total material into two groups: One group on each side of the mean. Using this method, he studied maxillary prognathism and mandibular prognathism and compared the extremes in each group. Considered in this work was sagittal occlusion (maxillary and mandibular overbite or vertical occlusion), crowding, and loss of teeth.

His studies on the twelve-year old boys revealed basically the same information. The significant angular findings were: With growth the degree of mandibular prognathism increases, but there is a tendency for this to be equalized by a decrease in the chin angle.

Reidel (1948), in his master's thesis, studies the relation of the maxilla and its associated parts to the cranial base in normal occlusion and malocclusion. His study resulted in the following conclusions: There was no significant difference in the antero-posterior relation of the maxilla to the cranial base in patients presenting excellent occlusion and malocclusion of the teeth. There was evidence of a tendency for the maxilla to become more prognathic with growth in his sample.

The antero-posterior relation of the mandible to the cranial base was found to be significantly different in patients exhibiting excellent occlusion when they were compared to individuals possessing malocclusions.

Again, there was evidence for a tendency of the mandible to become more prognathic with growth. The difference between the angle S-N-A and S-N-B was found to be 2° in normal occlusions. The angle formed by the lines Go-Gn and N-S was thought to be important because it indicated the cant of the mandible. The angle of facial convexity was thought to be important and was found to tend to flatten in adulthood due to the increased mandibular prognathism. The axial inclination of the upper incisor to the sella-nasion plane was found to have a mean of 103.5°. The relative antero-posterior relation of maxillary central incisors to cranial base was not significantly different in patients presenting normal and Class II, Div. 1, malocclusions. The maxillary incisors were found to be slightly behind the N-P plane in Class II, Div. 2, malocclusions and far behind this point in Class III malocclusions. In patients exhibiting Class II, Div. 1, malocclusions, the maxillary incisors were about twice the distance anterior to the facial plane, as in patients having normal occlusions. Points A and B appear to bear a highly constant relation to the occlusal plane. A line connecting these points forms about a 90° angle with the occlusal plane in patients with a normal occlusion.

Bjork (1950), in an article titled, "Biological Aspects of Prognathism and Occlusion of the Teeth", brings forth one of the strongest reasons for evaluating facial morphology from the cranial base, (he will use what he calls the effective cranial base, viz., a line from nasion to either articulare or Basion). Although one might tend to consider the use of the Frankfort Plane, because of the greater variation in the cranial base plane, he felt that the Frankfort Plane was to be avoided because it passed through the face. Therefore, if we orient facial structures to a facial plane, we are compounding our problems because the plane of orientation is subject to the same variation as the rest of the facial skeleton.

In discussing prognathism, which he defines as the prominence of the facial skeleton in relation to the cranial base, he goes on to conjecture what may bring about a prognathic situation. These are:

1. A shortening of the cranial base.
2. A decrease in the saddle angle.
3. A decrease of the articular angle (therefore, a more forward inclination of the ramus).
4. An increase in jaw length in relation to the cranial base, as a whole.

He declares that individual facial prognathism mainly depends upon the formation of the cranial base and that the rate of increase of prognathism is greater during the latter years of adolescence. This is in keeping with the fact that the cranial base development is concluded earlier than the jaws, especially the mandible. This serves to straighten the facial profile. Alveolar prognathism was found to develop slower than basal prognathism, which causes the incisors to upright and the chin to become more pointed. Because of this, crowding of the incisors will result.

This study reaffirmed his opinion that proportional growth changes are not constant, but appear to vary from individual to individual. He also observed that the correlation between maxillary and mandibular prognathism appears to diminish as a result of racial mixture.

Sanborn (master's thesis, 1952), in investigating the facial pattern of the Class III patients by means of the Broadbent-Bolton technique made the following conclusions and observations:

1. Maxillary prognathism is less than normal in the Class III malocclusion.

2. Mandibular prognathism is greater than normal in the Class III malocclusion.

3. There was no significant difference in the saddle angle but the joint angle and the chin angle were more acute than normal.

4. The gonial angle and the mandibular plane were greater than normal and even though the body and ramus lengths were within normal limits, this led to a greater overall "effective" length of the mandible. The anterior cranial base (S-N) was found to be shorter than normal because the "t" value for this measurement was 1.997 with a probability of .05.

Blair (1952), in a cephalometric appraisal of the skeletal morphology of forty Class I, twenty Class II, Div. 1, twenty Class II, Div. 2, Angle malocclusions, formed a number of observations which are pertinent to this study.

Contrary to previous observers, he found no significant difference, except for size, between male and females. This, he felt, should allow future orthodontists to group subjects, regardless of sex, when doing angular measurements.

Statistically comparing the Class I malocclusions to the Class II, Blair found the Class I patient had a greater gonial and a more acute chin angle (as formed by the mandibular plane and the N-P plane). This resulted in these patients having a higher Y-axis (Nasion-sella turcica-gnathion) and a more "effective" length (this is determined by the distance from the head of the condyle to gnathion). The Class II, Div. 2, patients were found to have a larger chin angle and a more prognathic maxillary base (S-N-A).

Maxillary prognathism (S-N-A) was seen to be directly correlated with mandibular prognathism (S-N-B), and both are inversely correlated with the saddle angle (Nasion-sella-articulare).

The saddle angle was also found to be inversely correlated with the joint angle (Sella-articulare-gonion).

Dr. Blair, like many since, has stressed the theme of individual variability, warning future researchers to be careful when assessing inverse proportions, so as not to infer that a "compensatory variation" exists. Because he found little difference between Class I and Class II, Div. 1, malocclusions, whereas previous investigators had found great differences, he postulated the following possibilities:

1. Skeletal differences are not fully evident from the lateral aspect, i.e., differences in width dimensions may occur between malocclusion classes.

2. The antero-posterior discrepancy seen in Class II, Div. 1, malocclusion is restricted largely to the denture.

3. Variation within each malocclusion is great enough to mask any real morphological difference.

Lindegard (1952), using osteological material, studied the upper alveolar process and its relation to the cranial base. He reports that, as the angle of inclination of the alveolar plane increases, it moves under the cranial base. As a result of this process, he finds that the anterior portion of the alveolar plane moves downward and back, and the posterior portion of this same plane moves up and back. In effect, the maxillary incisor and cuspid teeth are displaced down and back and the molar teeth up and back, the alveolar process pivoting, as it were, about the premolars. This condition contains striking similarities to the work of Moss and Greenberg in 1955 on Class III malocclusions.

Moss and Greenberg (1955) in a study on postnatal growth of the human face used 151 human crania and 49 cephalometric oriented radiograms of adolescent malocclusions (28 Class II, Div. 1, and 21 Class III). The study attempted to correlate changes of the skull base with morphological growth and to integrate these data with existing information on the growth of the adjacent structures. In addition to this, the relation between cranial base flexure and dental malocclusion is examined. The following results were obtained by their study:

1. The cribiform angle (saddle angle) remains relatively constant throughout life.

2. The palatal angle is almost always parallel to the cribiform angle, i.e., the floor of the nose is parallel to the anterior cranial base.

3. The cribiform angle in the Class III cases showed a significant difference at the .01 level from the dentally normal group, viz., it was more acute.

4. The cribiform angle indicated that the median structures of the anterior cranial fossa are more stable than the more lateral structures.

5. The lateral areas of the skull undergo prolonged and progressive changes.

6. In the Class III material, the cribiform angle

> became more acute, i.e., the pre-sella portion of the medial areas of the skull base had a greater downward inclination relative to the clivus. The implication of these findings that this could be due to a cartilaginous defect in the fetal chondro-cranium receives support from Lindegard and his research in 1952.

Allan G. Brodie, Jr., in his master's thesis (1955), studied the cranial base by means of serial cephalometric roentgenograms. He divided the cranial base into three parts, viz., from Basion to the spheno-occipital junction (Ba-SO), from the spheno-occipital junction to the spheno-ethmoidal junction (SO-SE), and from the spheno-ethmoidal junction to Nasion (SE-Na). In this study of midsagittal landmarks, the serial cephalometric roentgenograms were employed to measure the incremental growth of the cranial base and the relative contribution made by each part of the cranial base to the whole. The conclusions brought to our attention in this study reveal that in any individual the relative contribution of each part remained virtually constant throughout the period studied. The contribution for the posterior part (Ba-SO) was 25%; for the sphenoidal part (SO-SE) it was 37%; and for the anterior part (SE-Na) it was 38%. This constancy in proportion was maintained in the entire group over the age range of three to eighteen years. It was also recognized that the pattern of incremental growth of the cranial base was characterized by rapid growth from birth to five years, deceleration between five and twelve years, with a plateauing between ten and thirteen years and then a gradual decrease to the point of growth completion. This work tended to confirm the results of A. G. Brodie in 1941 and Scammon in 1936.

Subtelny and Sakuda (1964), in a cephalometric study of the skeletal-dental relationships of twenty-five subjects with persistant open-bite were compared with a group of thirty subjects with normal occlusion. Their investigation resulted in the following observations: The S-N-A angle was smaller in the open bite cases and the premaxillary area of the maxilla seemed tipped up toward the base of the skull. A significantly greater eruption of the maxillary molars and the maxillary incisors was found. The mandibular plane was found to be excessively steep, there was a tendency for ramal height to be shorter than normal, and the gonial angle was more obtuse than normal. Upon assessing the cranial base, they found the posterior cranial base to be shorter than normal (S-Ba). Besides this finding on the posterior cranial base, the other major difference from the open bite and the Class III was the realization that the mandible was in a more retruded position than in either the normal or Class III, and that the vertical dimension of the face was larger than normal (as measured from Nasion to the lower border of the symphysis).

CHAPTER III

METHODS AND MATERIALS

A. Materials.

Selection of the lateral cephalometric roentgenograms of 50 Class I malocclusions, 50 Class II malocclusions and 13 Class III malocclusions was made from the private patient file of Dr. Joseph Jarabak, of Hammond, Indiana. To supplement the Class III sample, twelve lateral head films were used that came from the private patient file of Dr. Sheldon Rosenstein, of Chicago, Illinois. All cephalograms were taken prior to banding or separation. The racial extraction of all patients considered in this study was caucasian.

Of the 50 Class I malocclusion head films, 20 were male with a mean age of 12 yrs. 3.2 mos. The high being 15 yrs. 7 mos. and the low being 11 yrs. The remaining 30 female patients had a mean age of 12 yrs. 3.9 mos. with a high of 16 yrs. 7 mos. and a low of 9 yrs. 4 mos. The total mean age for the group was 12 yrs. 3.6 mos.

Of the 50 Class II patients, 24 were male and 26 female. The total group had a mean age of 12 yrs. 10.8 mos. The mean age of the males was 12 yrs. 10.8 mos. with a high of 16 yrs. 4 mos. and a low of 9 yrs. 9 mos. The mean age of the girls was 12 yrs. 10.7 mos. with a high of 20 yrs. 3 mos. and a low of 10 yrs. 5 mos.

Two factors were of major consideration in the selection of the samples: The patient had to have a bilaterally similar molar relationship, and the dental age had to be as similar as possible. Therefore, our patients would fit between the limits of all deciduous teeth being lost and the succedaneous teeth approaching the occlusal table to the point of completion of eruption of the second molars (Hellman's Stage III B to IV A).

To obtain a sufficient sample size (25) of Class III patients, it was necessary to discard these self-imposed dental age limitations and, therefore, we will see patients with a mean age of 12 yrs. 6.4 mos. and with a high limit of 22 yrs. and a lower limit of 8 yrs. This will encompass a growth period all the way from the period of the mixed dentition to that of a full complement of teeth.

The Class III sample was comprised of 11 females with a mean age of 11 yrs. 6.5 mos. with a high of 14 yrs. 7 mos. and a low of 8 yrs. 6 mos. The 14 males had a mean age of 13 yrs. 3.8 mos. with a high of 22 yrs. and a low of 10 yrs. 4 mos. Also to be noted in the selection of the Class III sample was the fact that the angle A-N-B would have a zero value, or a minus value. This was being somewhat selective, but it was done to discard the so-called Class I with a Class III tendency, or a pseudo-Class III.

B. Methods.

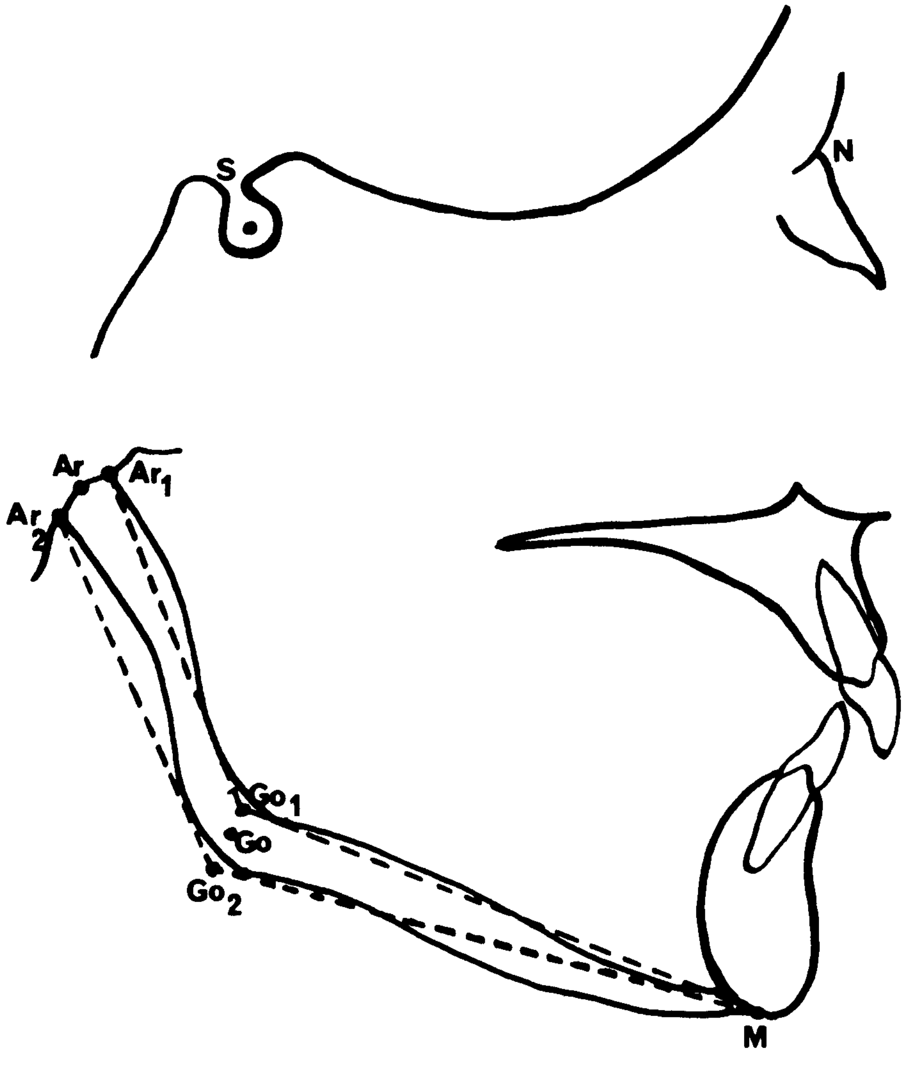
The roentgenographic technique was that described by Broadbent in 1931, in that the relation between the source of radiation, subject, and film was standardized. The lateral cephalometric roentgenograms of the patients, with their teeth in occlusion, were traced on acetate overlays.

Seventeen angles were drawn and measured on these tracings. To insure accuracy in the measuring technique, all points of intersection of two planes, therefore, the apex of an angle, were marked by a sharp needle. The needle was allowed to pass through the acetate tracing paper and through the headplate. This allowed the light from the tracing box to pass directly through the apex of the angle and be easily centered on the protractor. This markedly facilitated the recording of the true angular relationship of parts.

To further facilitate the accuracy of our tracing method, all landmarks that appeared hazy or ill-defined, were considered reason for discarding a headplate. If landmarks were well defined, but there was a double image, such as frequently occurs at the posterior border of the ramus and the inferior border of the body of the mandible, then by inspection, the median difference between the two images was plotted and used. (See Fig. 1)

All craniometric points and constructed points were judged by three separate inspectors, and an agreement of two of the three was deemed necessary before a particular point on any head film was judged valid.

The angles that were considered were measured twice and recorded twice, (at separate times) and then these values were compared. This was found to be an excellent method of checking the human error. If an error was found, then, of course, the particular angle was remeasured and the necessary corrections were made. As we shall see later, all major angles except the joint angle (S-Ar-Go) were broken down into component angles,



DETERMINATION OF GONION AND ARTICULARE

FIGURE 1

which not only allow for an intimate assessment of certain cranio-facial components, but by means of addition or subtraction permits another check on the angles and the measuring instrument.

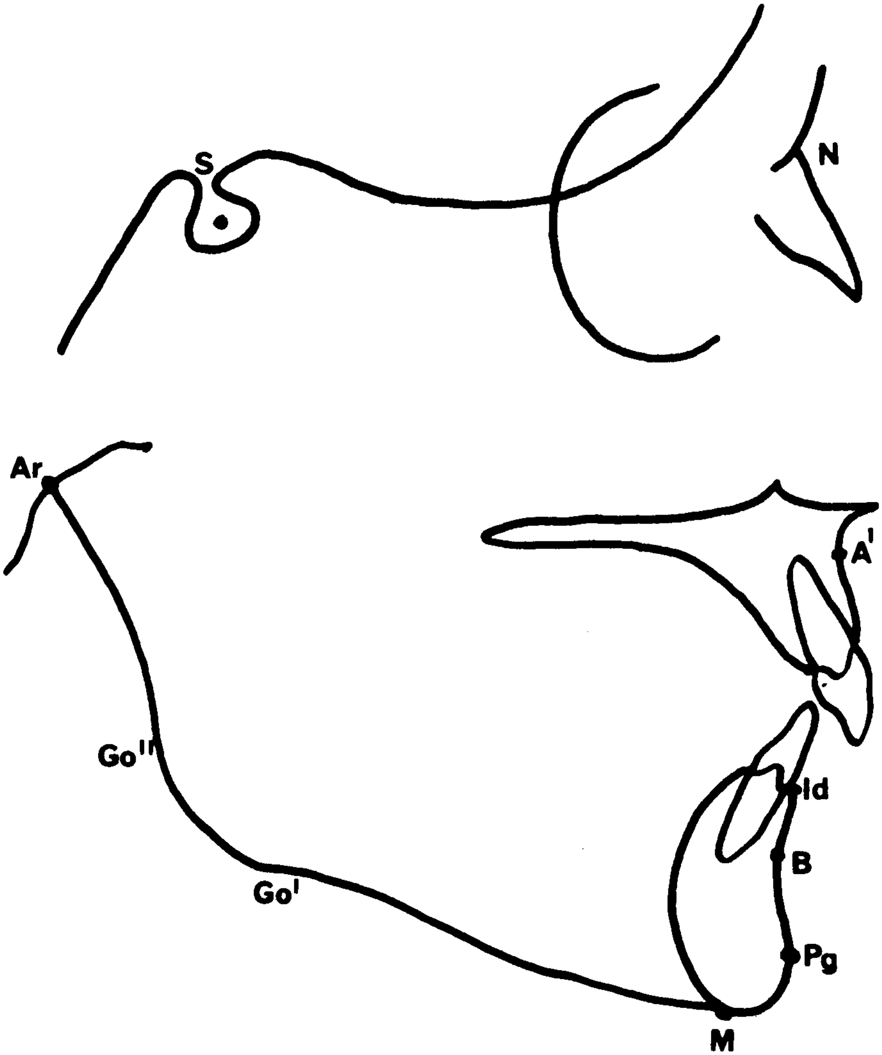
C. Landmarks and constructed points.

ARTICULARE (Ar): The point of intersection of the dorsal contours of the articular process of the mandible and the ventral aspect of the basilar portion of the occipital bone. The midpoint, (Ar), is used where double projections give rise to two points, Ar_1 and Ar_2. (See Fig. 1, Page 25, and Fig. 2)

GNATHION (Gn): A constructed (mechanical) point formed by the intersection of the Nasion-Pogonion plane (facial plane) and the Gonion-Menton plane (mandibular plane). Anthropometrically, Menton and Gnathion are the same landmarks on the skeleton when they are defined as the lowest point of the median plane in the lower border of the chin. Cephalometrically, Gnathion is defined as the midpoint between the most anterior and inferior point on the bony chin. Here we are simply calling the junction of the most anterior and inferior planes, "mechanical Gnathion". (See Fig. 4)

GONION (Go): A constructed (mechanical) point formed by the intersection of the mandibular plane and the ramus plane. The midpoint Go is used where double projection gives rise to two points, Go_1 and Go_2. (See Fig. 1, Page 25)

GONION PRIME (Go'): The most inferior point on the lower border of the body of the mandible at the gonial angle. (See Fig. 2)



CEPHALOMETRIC LANDMARKS

FIGURE 2

GONION DOUBLE PRIME (Go"): The most dorsal point on the posterior surface of the ramus at the gonial angle. (See Fig. 2, Page 27)

INFRADENTALE (Id): The point of transition from the crown of the most prominent mandibular medial incisor to the alveolar projection.(See Fig.2)

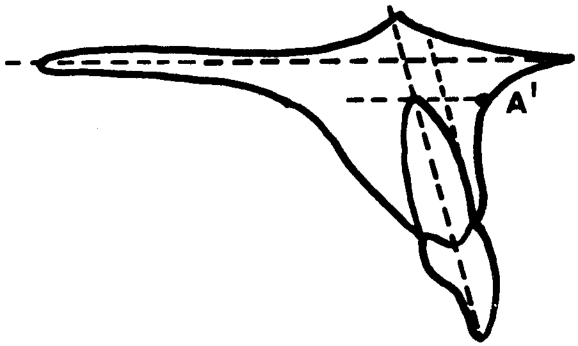
NASION (N): The anterior limit of the naso-frontal suture. (See Fig. 2)

POGONION (Pg): The point of intersection of the most anterior curvature of the symphysis with a line tangent from Nasion. Pogonion will then vary according to the amount of rotation occurring in the mandible. (See Fig. 2, Page 25, and Fig. 4, Page 30)

SELLA (S): The center of Sella Turcica (the midpoint of the horizontal diameter). (See Fig. 2, Page 25)

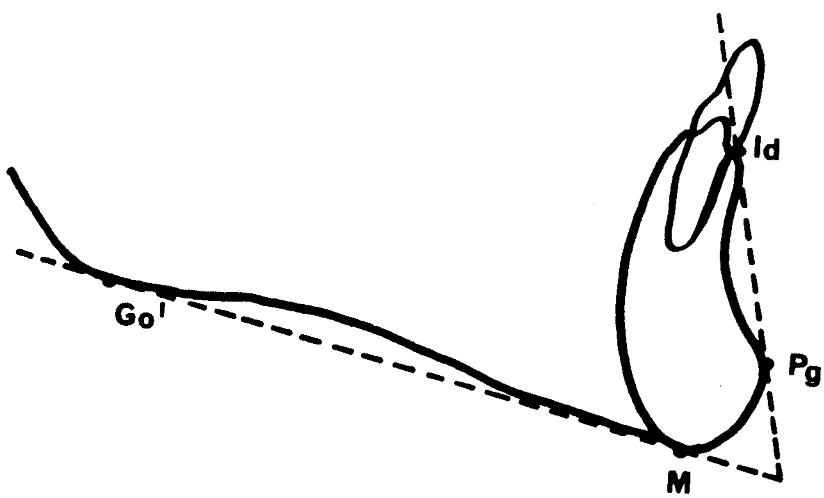
SUPRAMENTALE (Point B): The deepest point on the anterior contour of the alveolar process between Infradentale and Pogonion. (See Fig. 2)

SUBSPINALE (Point A): The deepest point on the anterior contour of the alveolar process, between the tip of the anterior nasal spine and prosthion. Since, as recent investigators have pointed out, the anterior nasal spine often masks the alveolar process in the midline, Point A was mechanically determined. To accomplish this, a line was drawn through the long axis of the maxillary left central incisor; another line was drawn parallel to this and tangent to the labial surface of the root; a third line was drawn parallel to the maxillary plane and intersecting the apex of the tooth. On this line, 2 mm. anterior to the point of intersection with the tangent to the root, a pin point was placed. This point is used to designate the anterior limits of the maxillary base and was given the



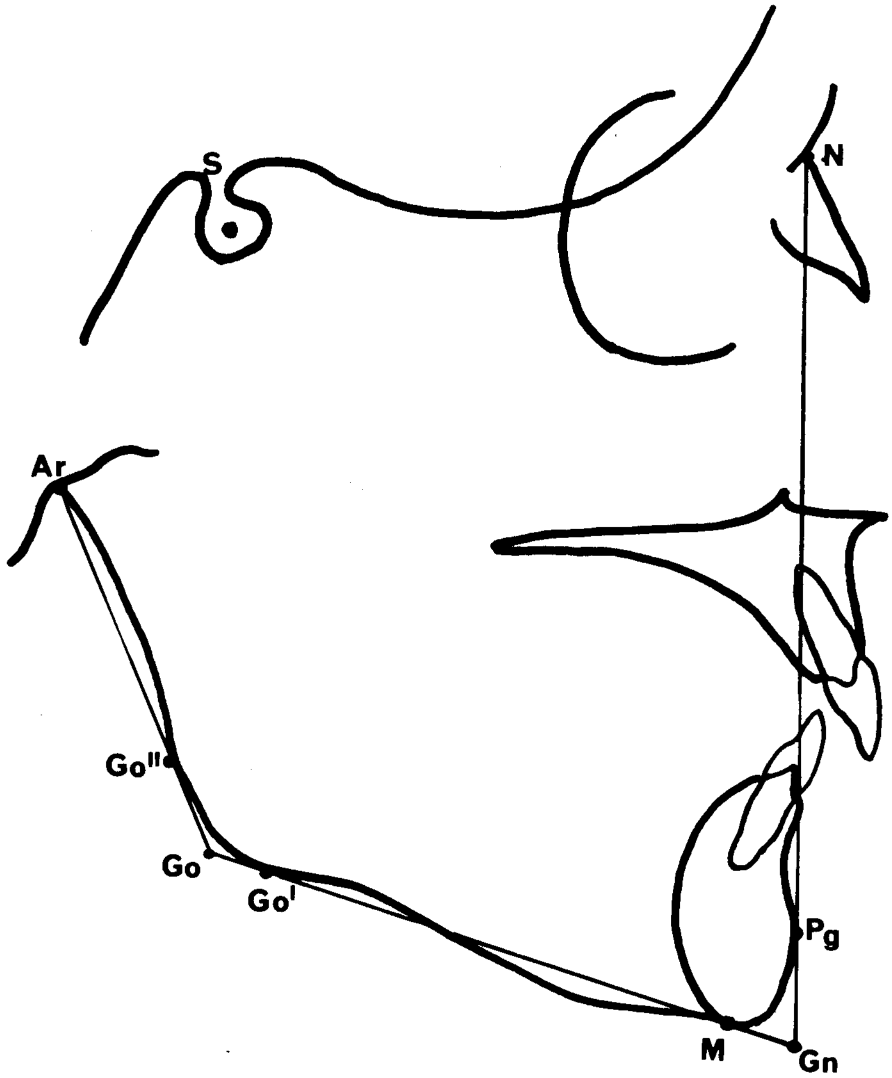
MECHANICAL DETERMINATION OF POINT A'

FIGURE 3A



THE CHIN PLANE AND THE CHIN ANGLE

FIGURE 3B



DEMONSTRATION OF PLANES OF MEASUREMENT

FIGURE 4

name of A Prime (A'). (See Fig. 3A)

D. Planes.

FACIAL PLANE (N-Pg): Obtained by a line intersecting Nasion and tangent to Pogonion. (See Fig. 4, Page 30)

CHIN PLANE (Pg-Id): A line tangent to Pogonion and intersecting Infradentale. (See Fig. 3B, Page 29)

MANDIBULAR PLANE (Go-Gn): A line tangent to the lower border of the mandible connecting Menton (M) and Gonion Prime (Go"). (See Fig. 4, Page 30)

RAMUS PLANE: A line intersecting Articulare (Ar) and tangent to the most posterior border of the ramus at the gonial angle (Go"). (See Fig. 4, Page 30)

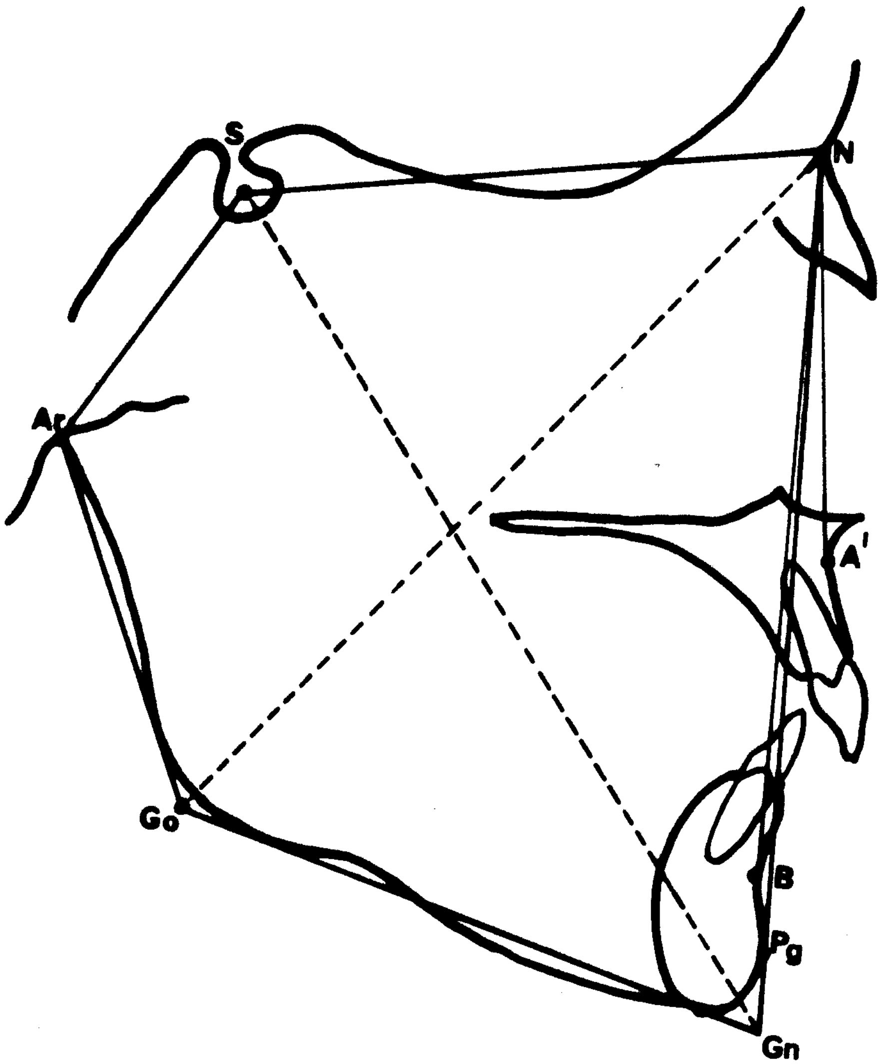
E. Angular measurements.

All angles measured are the result of the plotting of three points or the intersection of two planes. Every plane mentioned in this investigation is at right angles to the film surface and is defined by two points in the plane of the film. All angles were measured and recorded twice at separate times and compared for validity. Any angle that was broken down into parts, or subangles, was checked to be sure the parts equaled the whole. Seventeen angular relations were considered and they were as follows: (See Fig. 5, Page 32)

S-N-A -- for determination of maxillary denture base prognathism.

S-N-B -- for determination of mandibular denture base prognathism.

A-N-B -- used to determine the antero-posterior divergence of the



DEMONSTRATION OF ANGULAR MEASUREMENT

FIGURE 5

apical bases to each other.

S-N-Gn -- the superior facial angle. Here it is felt that the facial plane should be oriented to the anterior cranial base instead of to the Frankfort horizontal plane as recommended by Downs. The reason is because the Frankfort plane is influenced by the growth of facial structures and is not as valid a plane of orientation as is the anterior cranial base. It is also true that the landmarks which determine the limits of the Frankfort plane are not always easily determined on a lateral cephalogram. The facial plane will assist in the determination of general face type and the relation of the denture bases to the face.

S-N-Go -- the angle reflecting the posterior face height.

Go-N-Gn -- the angle reflecting the contribution of the body of the mandibular prognathism. (The mandibular body prognathism angle.)

N-S-Ar -- (saddle angle) the angle reflecting the relation of the anterior and posterior cranial base.

N-S-Gn -- (growth axis angle) the angle reflecting the anterior face height and growth direction of the facial skeleton. Again, it is important to note that the consideration is to anterior cranial base and not to the Frankfort horizontal for the aforementioned reasons.

Ar-S-Gn -- the angle reflecting the projected length of the mandible.

S-Ar-Go -- the joint angle representing the relationship of the mandible to the cranial base when the teeth are in occlusion.

Ar-Go-Gn -- the gonial angle.

N-Go-Ar -- the ramus angle represents the contribution of the ramus of the mandible to the total gonial angle.

N-Go-Gn -- the body angle represents the contribution of the body of the mandible to the total gonial angle.

Go-Gn-N -- the inferior facial angle reflecting the relation of the facial plane to the mandibular plane.

Go-Gn-Id -- (the chin angle) the angle representing the relation of the chin and anterior alveolar process to the mandibular plane. It is formed by the intersection of the mandibular plane and the chin plane.

N-Id Difference -- the angle that indicates the angular difference in the readings of the inferior facial plane angle and the chin angle. A chin angle reading larger than the inferior facial angle reading results in a plus (+) value. A lesser chin angle reading results in a minus (-) value.

Go-Gn to S-N -- (the mandibular plane angle) the angle reflecting the angular relation of the mandibular plane to the anterior cranial base.

CHAPTER IV

FINDINGS

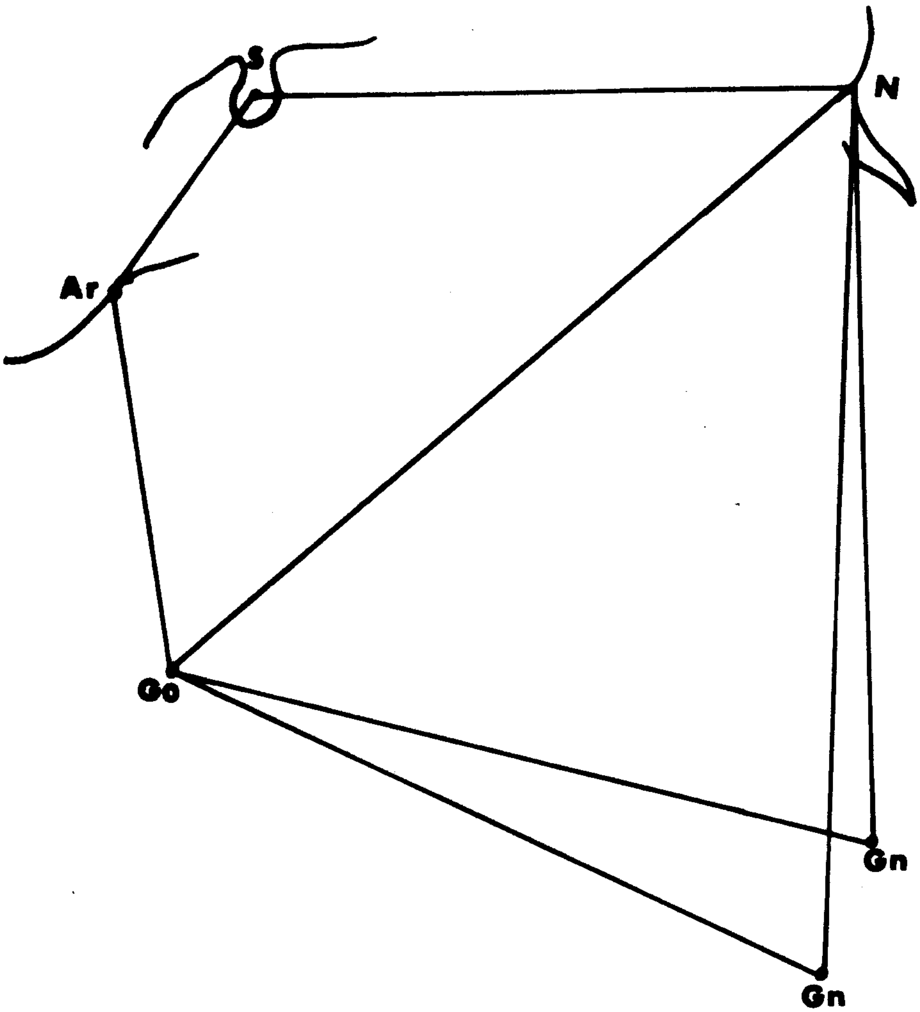
The statistical analysis of the seventeen angular relations considered in this study can be found on charts No. 1 and No. 2. Chart No. 1 considers the average (arithmetic mean) value for each of these angles, and also the standard deviation or sigma of the individual scores. The second chart deals with the results obtained in employing Student's small "t" test for determining the significant difference between the mean angles. The results are to be interpreted in the following manner. Values from 0.00 to 1.67 are to be regarded as revealing that there is no significant difference between the two angles compared. Values from 1.67 to 2.00 tell us that the difference between the angles is not significant, but there is a tendency for angles to have a real difference. The word "tendency" is used, therefore, to denote this relationship. Any "t" score value above 2.00 indicates that, between the two angles compared, there is a significant difference. This means that within 95% confidence limits this can be assumed and that this level of confidence is "two-tailed". Therefore, our veracity lies in both a positive and negative (above and below) direction, about the mean.

Comparison of the Class I sample and the Class II sample.

Comparison of Class I means and standard deviations to Class II means and standard deviations resulted in the following angles being found significantly different:

1. Angle S-N-Gn (Superior Facial Angle): The Class I mean (M=76.48) was found to be smaller than the Class II mean (M=77.56). This was a "one-tailed" or a skewed finding (t=1.71) and, therefore, not very distinct. There is a great deal of overlapping of the Class II and Class I facial plane angles. This must be considered, therefore, a tendency for the Class I sample to be more retrognathic. (See Fig. 6)
2. Angle Go-N-Gn (Mandibular body prognathism angle): The Class I malocclusions (M=37.64) were found to be significantly smaller (t=2.83) than the Class II malocclusions (M=38.94). This angle relates how effectively the length of the body of the mandible is oriented to the anterior cranial base. By this it simply means that if the body of the mandible were perfectly horizontal to the anterior cranial base, then the Go-N-Pg angle reading would be at its maximum for that particular body length. The actual or real body length can best be determined by a linear measurement from Gonion to Gnathion. (See Fig. 9, Page 42.) This angle also relates how much of the prognathism, that is seen to exist in the S-N-Pg readings, is due to the length of the body of the mandible (from linear readings) and the manner that it relates itself to the anterior cranial base.

From previous studies, it is known that there is no



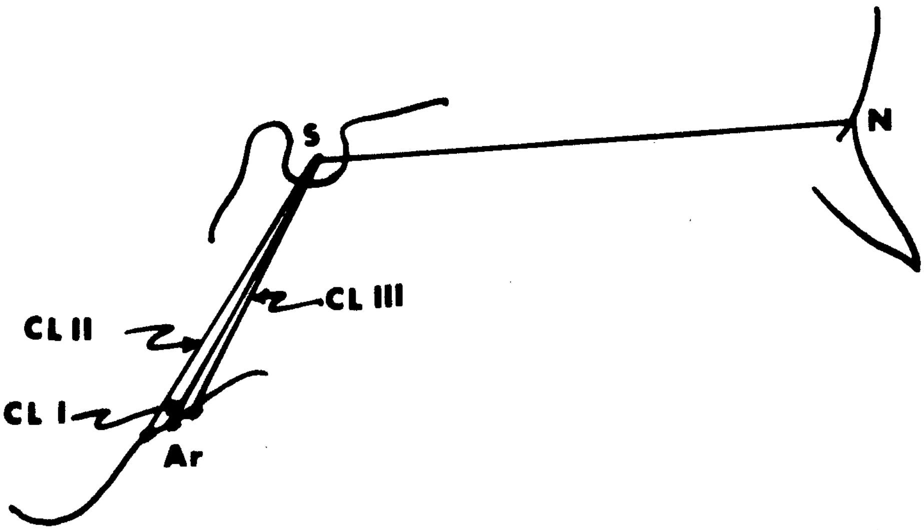
THE INFLUENCE OF THE SIZE OF THE GONIAL ANGLE ON THE REGISTRATION OF THE ANGLE Go-N-Gn IN CLASS I AND CLASS II MALOCCLUSIONS

FIGURE 6

significant difference in the length of the body of the mandible in Class I or Class II malocclusions.

If this is accepted as being true, then the difference in the readings mentioned above must be attributed to factors other than that of body length. The conclusion that must be reached is that the body of the Class II mandible is more horizontally related to the anterior cranial base. This fact is verified by the reading for the body angles and the mandibular cant angles. (See Fig. 6, Page 37)

3. Angle N-S-Ar (The "saddle" angle): This angle is significantly larger (t=2.22) in a Class II malocclusion (M=125.00), as compared to the Class I malocclusion (M=123.07). This finding indicates that there is a more distal positioning of the condylar fossa and the mandible at this point of reference for the Class II malocclusions. (See Fig. 7)
4. Angle N-S-Gn (The growth axis angle): This would indicate that the growth pattern is more vertically oriented in the Class I patient (M=69.83) as opposed to the Class II patient (M=68.1). This would also indicate that the Class I patient has a greater facial height.
5. Angle Ar-S-Gn (The projected mandibular length angle): This angle is found to be significantly larger (t=4.20) in the Class II malocclusion (M=56.90) when compared with the Class I sample (M=53.24). This angle inversely recognizes the length of the mandible; therefore, the smaller the Ar-S-Gn, the greater is the



COMPARISON OF THE MEAN SADDLE ANGLE VALUES

FIGURE 7

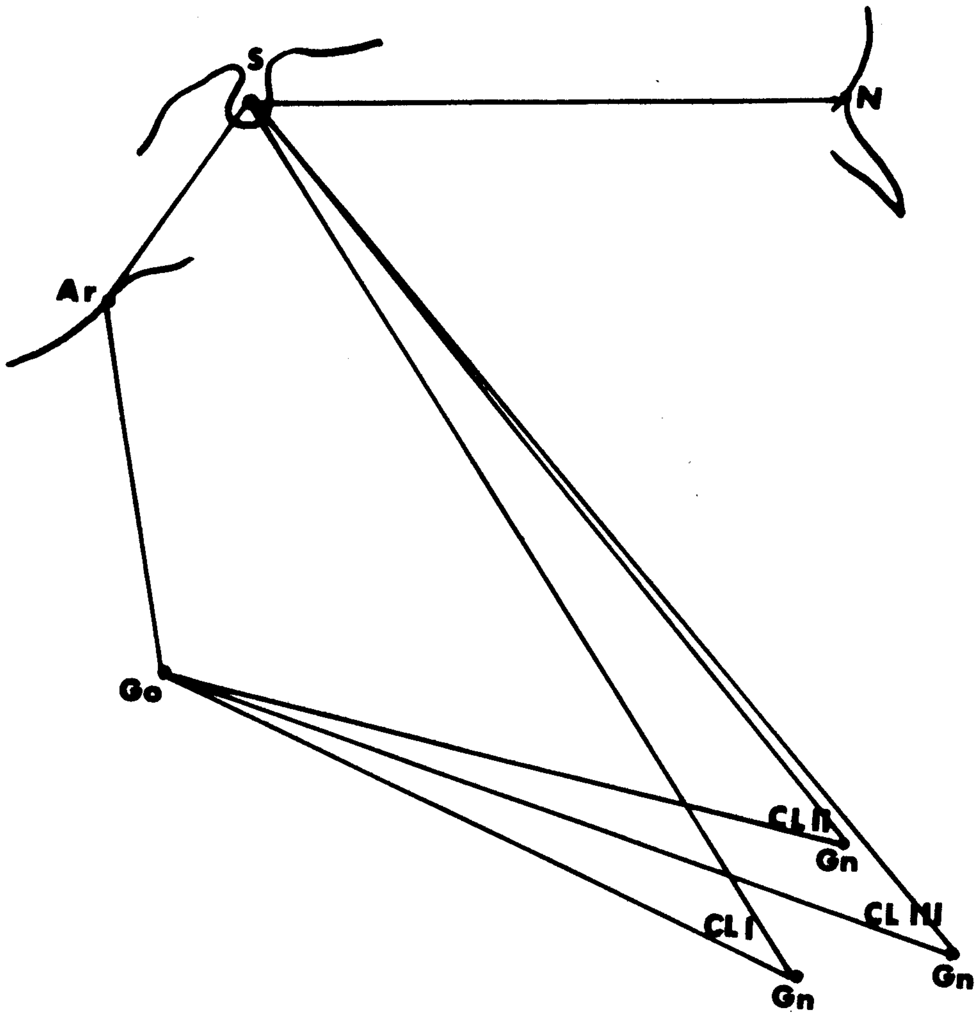
gonial angle and projected mandibular length. This is, of course, if all parts (ramus and body) are equal. (See Fig. 8)

6. Angle S-Ar-Go (The joint angle): The Class I malocclusion (M=146.08) was larger (t=1.69) than the Class II malocclusion (M=143.98).

   This finding must be viewed with a certain degree of discretion because the difference is a tendency rather than a clearly defined case of a real difference. Our distinction here is not great, and there is a good deal of overlapping between the samples. Theoretically, this will result in the Class I cases being assessed as having a more posteriorly positioned chin and a greater cant to the mandibular plane when compared to the Class II cases.

7. Angle Ar-Go-Gn (Gonial angle): This angle was found to be significantly larger (t=2.93) in the Class I malocclusion cases (M=127.98), as compared to the Class II cases (M=124.26). This finding allows the observation that the Class I malocclusion mandibles have a greater projected length. (See Figs. 9 and 10) It must be emphasized, this does not imply that the morphologic length is greater.

8. Angle N-Go-Gn (The body angle): This represents the angular relationship of the body of the mandible to the ramus at gonion. This angle in the Class I malocclusion cases (M=75.80) was found to be significantly larger (t=4.92) than the Class II cases (M=71.52). These figures would indicate that the increased gonial angle found in Class I malocclusions was in reality due



THE INFLUENCE OF INCREASED GONIAL ANGLE AND INCREASED BODY LENGTH (CLASS III) ON THE ANGLE Ar-S-Gn

FIGURE 8

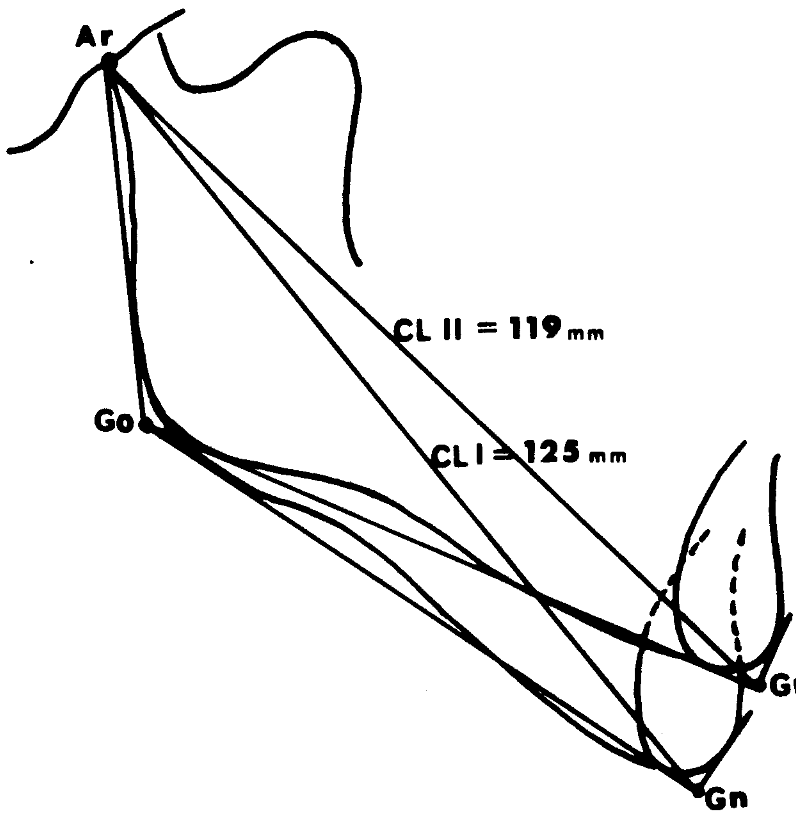
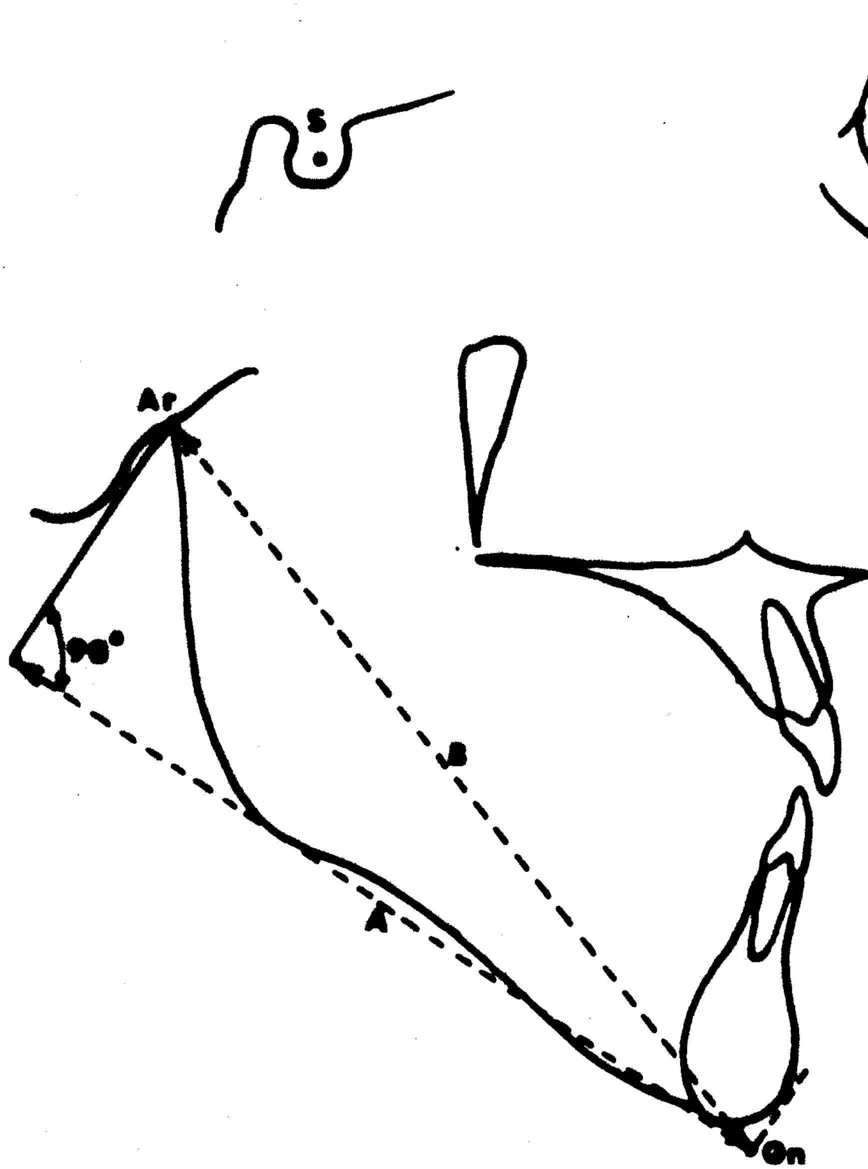


ILLUSTRATION OF HOW AN INCREASED GONIAL ANGLE INCREASES THE PROJECTED LENGTH AT THE MANDIBLE

FIGURE 9



TWO METHODS OF DETERMINING PROJECTED

MANDIBULAR LENGTH

FIGURE 10

to an incrased angular relationship between the body of the mandible to the ramus. The spatial relationship of the ramus of the Class I and Class II malocclusions remained constant when assessed to the anterior and posterior cranial bases.

9. Angle Go-Gn-N (The inferior facial angle): This angle relates the mandibular plane to the facial plane. It was found to be significantly more acute (t=4.62) in the Class I cases (M=66.08). The Class II sample (M=69.68) showed a much more horizontal relationship to the facial plane. These figures confirm the previous assessment that in the Class I malocclusions the face grows more in the vertical direction than in the Class II malocclusions.

10. N-Id Difference: This angle records the difference between the angular readings of the chin plane and the facial plane as measured to the mandibular plane. In the Class I malocclusions and the Class II malocclusions, the alveolar process is related to the mandibular plane in the same manner (see Angle Go-Gn-Id). The Class I cases (M=3.60), because of their steeper mandibular plane tend to place Infradentale (Id) anterior to the facial plane. This finding confirms the clinical observation that the Class I malocclusion is usually bimaxillary protrusive. The Class II sample (M=0.47) tended to place Infradentale on the facial plane.

11. Angle Go-Gn to S-N (The mandibular plane relation to the anterior cranial base): This is significantly larger in the Class I sample (M=36.73) and reaffirms its more vertically oriented

growth pattern. The Class II sample (M=32.66) is found to more closely approximate the mean values for normal occlusion which is 32.28.

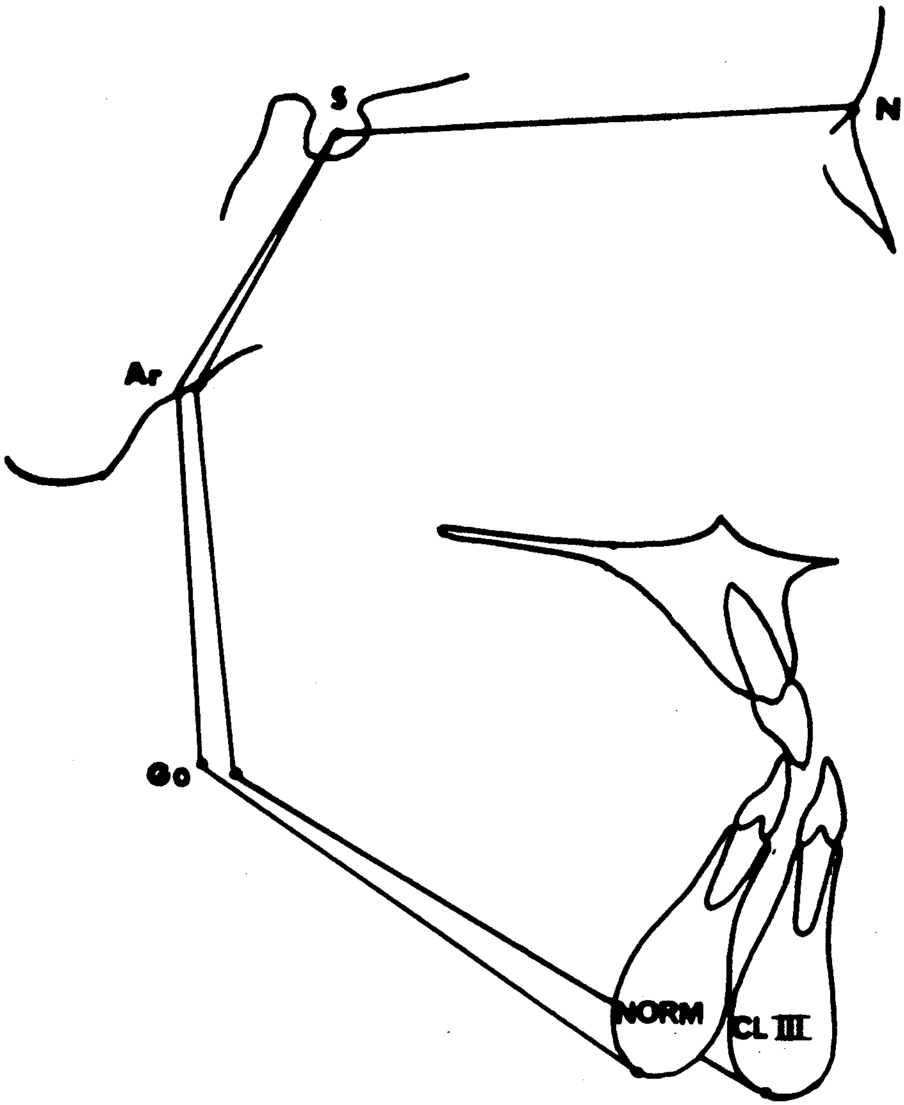
Comparison of the Class I sample with the Class III sample.

Angles of significant difference:

1. Angle S-N-B (The mandibular base angle): This angle was found to be significantly larger in the Class III sample. This was expected because of the prognathism of the lower jaw and the mesial relationship of the mandibular teeth.
2. Angle A-N-B (The angle denoting the anterior-posterior divergence of the maxillary denture base to the mandibular denture base): This would obviously differ from the Class I sample because of the anterior relationship of the lower jaw to cranial anatomy in the Class III sample.
3. Angle S-N-Gn (The superior facial plane angle): This angle was significantly larger (t=5.15) in the Class III sample (M=81.32) when compared with the Class I sample (M=76.48). This confirms the result obtained for the angle S-N-B, indicating the prognathism of the lower jaw and a prognathic facial profile.
4. Angle S-N-Go (Posterior facial height angle): The Class III sample (M=40.74) was found to be significantly larger (t=2.76) than the Class I sample (M=38.64). This would indicate that the increase in posterior face height may be due to the tendency of the Class III sample to have a more acute saddle angle

and a more obtuse articular angle. This angle is also affected by the tendency of Class III malocclusions to have a shorter anterior cranial base. (See Fig. 11)

5. Angle Go-N-Gn (The mandibular body prognathism angle): The Class III sample was found to have a significantly larger body prognathism reading than the Class I sample. This is due to the more horizontal relation of the body of the Class III mandible to the anterior cranial base plus a tendency for greater body length. (See Fig. 11)
6. Angle N-S-Gn (The growth axis angle): The Class I sample was found to have a more vertically oriented growth pattern than the Class III sample. The more horizontal reading in the Class III sample was due to a summation of effects that resulted in the more anterior projection of Gnathion.
7. Angle Ar-S-Gn (Projected mandibular length angle): The Class III sample (M=55.26) was found to have a tendency toward greater length than the Class I sample (M=53.24). This would be true because of the greater body length of the Class III sample which results in a more forward position of Gnathion. This would overshadow the more obtuse Gonial angle in the Class III sample. (See Fig. 8, Page 41)
8. Angle Go-Gn-N (The inferior facial angle which relates the mandibular plane to the facial plane): The Class III sample (M=63.78) was significantly smaller (t=6.02) than the Class I sample (M=66.08) because of the forward projection of Gnathion. This



EFFECT OF THE SUMMATION OF CLASS III MEAN ANGLE

VALUES AND INCREASED BODY LENGTH

FIGURE 11

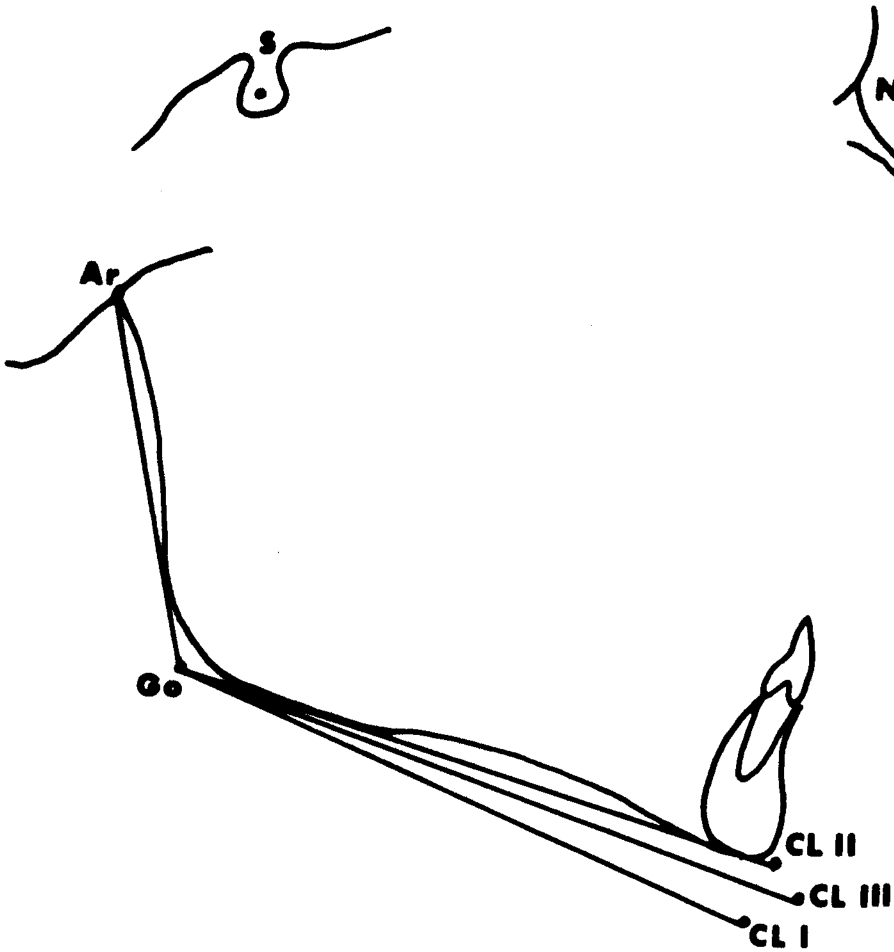
resulted in a more acute relationship between the facial plane and mandibular plane.

9. Angle Go-Gn to S-N (Angular relation of the mandibular plane to the anterior cranial base): There is the tendency here (t=1.85) for the Class I sample to have a more vertically oriented mandibular plane angle than the Class III sample. In essence, the Class III sample has a tendency to fall in between the growth patterns of the Class I sample and the Class II sample. In this position it is not significantly different from either classification. (See Fig. 12)

Comparison of the Class II sample with the Class III sample.

Angles of significant difference:

1. Angle S-N-B (Angle of mandibular prognathism): The Class III (M=80.68) sample is significantly larger than the Class II sample (M=75.76). This reflects the fact that the Class III mandibular base projects anteriorly, not only beyond the Class I mandibular base, but also beyond the Class II mandibular base.
2. Angle S-N-B (The angle denoting the anterior-posterior divergence of the maxillary denture base to the mandibular denture base): There is a significant difference here because the "B" points of these two samples are skewed in opposite directions.
3. Angle S-N-Gn (Superior facial angle): This is significantly larger in the Class III sample and serves to confirm the two previous observations.



COMPARISON OF GONIAL ANGLES

FIGURE 12

4. Angle S-N-Go (The angle of posterior face height): This is significantly larger in the Class III sample when compared to the Class II sample, as it was in the Class I sample. The reason is probably due to the tendency for Class III malocclusion to have a shorter anterior cranial base and the tendency for an additive effect in the saddle and articular angles. (See Fig. 11, Page 47)
5. Angle Go-N-Gn (The mandibular body prognathism angle): This was found to be significantly larger (t=2.78) in the Class III sample. The indication here is that, contrary to certain previous linear investigations, such as Sanborn (1952), the body length in the Class III mandible is in large part responsible for the prognathism present. This parallels the result obtained for the Class I sample. The important facet that must be realized is that linear evaluations are one-dimensional and not two-dimensional. They must, therefore, be referred to certain spatial relationships to bring out their true value.
6. Angle N-S-Ar (The saddle angle): This was found to be significantly larger in the Class II sample, when compared with the Class III sample. This would result in the observation that the Class III sample would have a more forward projection of the mandible than a Class II malocclusion.
7. Angle N-S-Gn (Growth axis angle): The anterior face height is shorter and the growth pattern is more horizontally oriented in the Class III sample than in the Class II sample.
8. Angle N-Go-Gn (The body angle): The angular relationship of the

body of the mandible (M=75.94) to the ramus is greater in the Class III malocclusion than in the Class II sample (M=71.52); and it is almost the same as the Class I (M=75.80).

9. Angle Ar-Go-Gn (The gonial angle): This reflects the composition of the ramus and the body to form the mandible. It is significantly greater (t=3.06) in a Class III malocclusion (M=128.52) than in the Class II (M=124.26).

10. Angle Go-Gn-N (Inferior facial plane angle): This angle was found to be more acute in the Class III sample because of the increased horizontal projection of the mandible, when compared to the Class II sample.

11. Angle Go-Gn to S-N (The relation of the mandibular plane to the anterior cranial base): There is a tendency for the mandibular plane in the Class III sample to be more obtuse than the Class II sample. It also had a tendency to be more acute than the Class I sample. In essence, in this study, the Class III mandibular plane was found to lie between those of the Class I and the Class II. (See Fig. 12, Page 49)

CHAPTER V

DISCUSSION

A. Introductory remarks.

The studies of Bjork (1953, 1955) have given the field of orthodontics some very interesting and indeed valuable information. Among his many thought-provoking statements, he has said that, "Shape is a function of growth which leads to the necessity for knowing the relationship between variations in shape and variations in growth" and also that, "coordinated variation in shape is an expression of the coordinated variation in growth". It would be well to note here that these coordinated variations of which he speaks, when evaluated for the group, will result in what is recognized as "mean values" for that group.

Knowing these coordinated variations in shape for a group or population is most necessary. The necessity arises from the fact that the whole must be known before the parts can be assessed; the development of the species understood before one can fully comprehend the development of the individual. For example, status of disease or abnormality is always based on what is normal for the species. To proceed the point one step further, it has been found that normality in eyesight is based on 20-20 vision. This by no means indicates perfection, but rather the average or norm. This leads one to realize that it is imperative when the morphological problem of an individual is evaluated against statistical norms, that we keep these facts in mind. One must not attempt to discredit the morphology that exists simply because it does not comply to what is considered a norm or ideal. The individual must be inspected for, not so much how he may deviate from a statistical norm, but rather how well his individual variation in shape and growth has coordinated to produce a functioning entity.

Conversely, he may also be evaluated from the standpoint of how significantly his existing cranio-facial morphology has been influenced by a particular problem in the bite. It is well to remember that the patient is an individual, with individual morphological problems, to which "means" are applied only as guidelines to facilitate proper assessment.

Bjork (1955), in his study on cranial base development, points out that the cranial base, upper face and mandible grow until approximately the age of twenty. He also states that the sutural growth in the cranial base remains active in greater or lesser degrees, as long as the facial structures continue to grow. He found the reason that the face becomes more prognathic during the adolescent years is simply because the cranial base development is concluded earlier than the jaws.

As has been stated earlier, Bjork felt that the dental and alveolar arches not only reflect the general growth tendency of the individual, but that in the case of malocclusions, certain secondary or modifying changes occurred. These modifications could be either dysplastic and/or compensatory. In studying these modifications, he found that the compensatory changes were more frequent (greater) during adolescence and that the dysplastic changes occurred earlier in life. He goes on to say, "These notes on the development of the bite have been included because they serve to illustrate the influence of functional forces, especially those of the soft tissues, on the development of the alveolar and dental arches. The extent to which such factors influence the normal development of the head and the face as a whole is not easy to determine, although it is appreciable in certain cases of dysplastic facial growth".

The question that comes to mind, since the cranial base, mandible and upper face may grow until the age of twenty, is whether forces exerted to the jaws through the biological levers (the teeth) can sufficiently affect the development of the cranial base? Will there be some adaptation in the area? The cranial base, as a hafting zone that separates the neural and facial skeleton, is said to be influenced by the growth of both elements. Bjork states that dysplastic changes seem to be established earlier in life than compensatory changes; therefore, it does seem possible that, if a malocclusion were to approach a certain degree of severity, it could exert an influence on existing growth patterns, especially if this influence occurred early enough in life.

Moss, in 1964, points out that "the sutures are not primary growth sites, but rather, centers of secondary, compensatory and adjusting growth". He further states that, "the form (size and shape) of a bone, its spatial relationship and its growth are direct and mechanically obligatory responses to the growth of the functional matrix (the tissues and spaces related to a given function). Therefore, the biological processes that we wish to study are not those of bone growth "per se", which are secondary, but rather those of the functional matrix, which are primary. The growth of the neural and facial skeleton is directly influenced by the neural and facial matrix".

The point that is to be made in the introductory remarks of the discussion is that it does not seem impossible that if an aberration in the occlusion were severe enough, that it could affect the pattern of development of the cranial base or facial skeleton. The proof is not to be had in this study, but it does show that there are some distinct differences and yet some striking similarities between the three major classes of malocclusion. The immediate results of a perverted swallowing habit, or lip or thumb-sucking habit, are easily viewed, but can it be said that the influence or damage stops here?

Certainly it does not seem impossible to consider a severe thumb-sucking habit or an overly large developing dentition as exerting an influence comparable to that of a functional matrix. It might even be that certain facets of a malocclusion may directly affect the functional matrix itself.

B. Assessment of the cranial-facial morphology of the Class I malocclusion, as it relates to the Class II malocclusion.

Past investigations have revealed varied differences between Class I and Class II malocclusion. The most common observation was that the Class II, Div. 1, malocclusion had a tendency to a more procumbent maxillary denture base (Wylie - 1948, Blair - 1952). Other investigations have stated that the mandible is more retrognathic in the Class II malocclusion (Craig - 1950, Baldridge - 1941). A third finding, upon which most researchers concurred, was that the Class I malocclusion has a more obtuse gonial angle (Renfroe - 1948, Elsasser and Wylie - 1948, and Blair - 1952). These observations led to their evaluating the Class II mandible as having a less effective or projected length than the Class I mandible.

It is felt that a word of caution should be given in using the term "effective length". This could lead to the consideration that a less "effective length" would necessarily result in orthodontic problems. It must be remembered that the mandible is a three-dimensional structure containing three-dimensional teeth, involved in the spatial concept of occlusion. Its effective length is a measurement that extends from condyle to condyle along the entire alveolar process. The author believes that a better term in assessing the dimension from Articulare to Gnathion would be "projected length"

The three observations above had led to the general assessment that the facial complex of the Class II malocclusion was convex or retrognathic. The cranial base has been considered to play a passive role in these studies and has not been given a place other than that of a plane of reference.

Blair (1952), in his assessment of the cranial-facial morphology of the Class I and Class II malocclusions, states that a high degree of variability of facial skeletal pattern could be seen within each classification of malocclusion studied. In his sample, and with the method he used, only minor differences could be shown in the mean skeletal patterns of Class I and Class II, Div. 1, malocclusions.

In studying his results and those of his predecessors, the possibility existed that a different means of assessment would not necessarily mean the revelation of any new information. Fortunately, the attempt to a more complete evaluation of the Class I and Class II malocclusions, and their relationship to the cranial base, has resulted in some new information of this field.

In assessing the information from this study, the observation can be made that the Class I and Class II samples presented some striking similarities. The most prominent of these was the seeming desire for the mean values of the cranio-facial complex to produce an equalization between the saddle and articular angles. The purpose of this "counter balancing" appears to be a need for the body to maintain a constancy in the cranial base and its relation to the gonial angle. For example, if we add the mean value for the saddle angle and the mean value for the joint angle of the Class I malocclusions, the following result is obtained: $123.07^{\circ} + 146.08^{\circ} = 269.15^{\circ}$. Doing the same thing for the Class II malocclusions, the result is $125.00^{\circ} + 143.98^{\circ} = 268.98^{\circ}$. This results in a difference of only 0.17° for the sums of the two means. The degree of similarity has led the author to feel that there appears to be a negating or equalizing effect between these two areas. This tendency for equalization seems to be also verified by the mean values of the ramus angle (N-Go-Ar) and the posterior facial height angle (S-N-Go). For all practical purposes, the posterior facial height angle was the same in the Class I and Class II samples. The same is true for the ramus angle. Previous studies by Craig (1950) and Blair (1952) state that there was no significant difference between the saddle and joint angles in either the Class I or Class II malocclusion. This study disagrees with their results, but because of the tendency for equalization found to exist in the Class I and Class II saddle and joint angles, the net result is the same.

This observation of the constancy of Gonion tends to confirm the results of Gilmour (1950) and Blair (1952) who stated that there was no significant difference in the anterior-posterior position of Gonion in the Class I and Class II malocclusions. In each of their studies, the position of Gonion was measured in relation to the anterior cranial base by means of the angle N-S-Go. This study attempts to relate Gonion not only to the anterior cranial base, but also to the posterior cranial base.

The observations that the gonial angle of the Class I sample was larger than the Class II sample verifies the work of Renfroe (1948) and Blair (1952). The unique aspect here was that in analyzing the parts of the gonial angle a certain consistency seemed to exist. It was found that the ramus angulation, as designated by the ramus angle, was the same in Class I and Class II malocclusions. The body angulation, as designated by the body angle, was found to be significantly larger in the Class I malocclusion. It, therefore, becomes obvious that the reason that the gonial angle is larger in the Class I malocclusions is because the body of the mandible has an increased angular relationship to the ramus. Again, it is worthy to note that the ramus in both cases was rather constant in spatial relationship to the cranial base. This is an observation that has not been made before.

The anterior face height, as designated by the growth axis angle (N-S-Pg) and the body angle (N-Go-Gn), indicated quite strongly that the Class I sample has a longer face height than the Class II sample. Blair found, in his study, that there was no significant difference between the length of the body of the mandible in the Class I and Class II malocclusions. This being true, it is assumed that increased angulation of the body in the Class I mandible could result in an increased facial height. A linear study in the future might be valuable in confirming this.

Conversely, it could be assumed that the smaller recordings in the Class II malocclusions indicated a closed vertical dimension. The two most common reasons for a closed vertical dimension in the Class II malocclusion are the Class II molar relationship and the deep Curve of Spee in the mandible. These facts would lead one to wonder just how much adjustment of the skeletal morphology occurs between a successfully treated Class I and Class II malocclusion after establishment of proper molar relationship and vertical dimension. Will this modeling result in the production of similar gonial angles and identical mandibular plane angles? These questions naturally arise when these differences are seen and makes one wonder if successful treatment might resolve them.

The superior facial angle (S-N-Pg) and the body prognathism angle (Go-N-Pg) point out the dramatic differences that can result when parts of similar length are related in a different manner. (See Fig. 1, Page 25) It is known that there is no significant difference between the lengths of the body or the ramus in the Class I and Class II malocclusions. It is noted, however, that the Class I mandible has a greater projected length which is, of course, due to the larger gonial angle found in these mandibles. Here it is found that, even though there is a greater projected length to the mandible in the Class I malocclusion (Wylie - 1948, Gilmour - 1950, and Blair - 1952) that due to the constant anterior-posterior position of gonion, the anterior-posterior projection of the mandible is influenced. What happens is that, in effect, the body rotates upward and forward at gonion in the Class II malocclusion when compared to the Class I malocclusion. This results in the Class II mandibular symphysis having a more forward position to cranial anatomy. This is something that linear measurements, alone, cannot illustrate. The angle (Go-N-Pg) was, therefore, said to show the projected body prognathism. This angle will relate how effectively the length of the body of the mandible is oriented to facial depth, or in another way, how parallel it is to the anterior cranial base. This, again, is possible because of the constancy of Gonion in the Class I and Class II malocclusions. This anterior-posterior relationship of the lower face is also reflected by the angle (S-N-Pg) and relates this projection to the anterior cranial base.

Assessment of the growth axis angle (N-S-Gn) and the mandibular plane angle (Go-Gn to S-N) leads to some interesting observations. Before proceeding, it would be wise to note that, when using angular measurements, the tendency is to use one angle to confirm the validity of another. It is an equally good idea to inspect angles for the discrepancies that they relate. One must aske himself, "where do angles differ, how do they differ, why do they differ"? As has been said before, angles are not absolute measurements but rather they show the interrelationship of parts. If they are used in this manner, then they are invaluable and can, at times, eliminate linear measurements.

In this study, the cant of the mandible to the anterior cranial base strongly confirms the results of the growth axis angle. In assessing these angles, it must be remembered that any increase in the length of the body of the mandible will automatically cause a decrease of the growth axis angle, but at the same time the Go-Gn-SN will be left completely unaffected. This observation forces one to admit that it is not possible, therefore, to look at one or two angles, or linear measurements in any analysis and say with certainty wherein the problem lies. It is relationship of parts and the compensation that they relate or do not relate that is so important. The individual does vary greatly, as has been frequently repeated by Moss, Coben and Bjork; but he will tend to conform and adpat to within functional limits. It is up to the student of orthodontics to recognize where compensation is taking place or when a truly abnormal deviation does exist. More will be said of these similarities and differences when speaking of the Class III malocclusions.

The difference which was found between the relation of the chin plane and the facial plane to the mandibular plane (N-Id difference) in the Class I malocclusions was a confirmation of clinical observation. As is often noted, the Class I malocclusion is a case of bimaxillary protrusion with or without crowding. The unique finding in this investigation is the alveolar process in both Class I and Class II are related to the mandibular plane in the same manner. It is the deflection of the body of the mandible that causes the alveolar process to lie ahead of the facial plane in the Class I malocclusion and, therefore, the bi-alveolar protrusion can, for the most part, be related to the greater cant of the mandibular plane.

The reason that this study did not show any significant difference between the "A" points, as have other investigators, was probably due to the mechanical means used in determining the position of the maxillary base. Investigators who have found the maxillary base to be more prognathic in the Class II malocclusions may have inadvertently registered the anterior nasal spine as the deepest point on the anterior surface of the alveolar process between the tip of the anterior nasal spine and prosthion. This is a very common but incorrect method and it is contrary to the definition of the "A" point. The feeling that the position and angulation of the maxillary central incisors influence the forward position of the maxillary alveolar process was the reason for the mechanical determination of this point. The clinical observation that there are not as many gross maxillary-mandibular base discrepancies in Class II malocclusions as cited in the literature seems borne out by this study.

C. Assessment of the cranial-facial morphology of the Class III malocclusion as related to the Class I and Class II malocclusions.

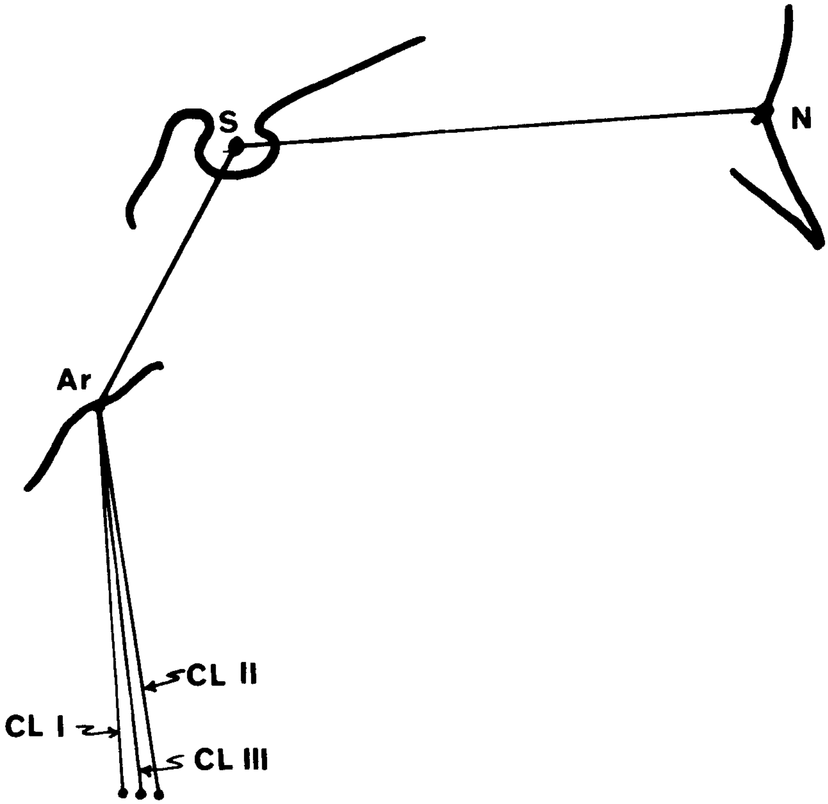
The prominence of the mandible to the upper face has always been held to be the primary characteristic of the Class III malocclusion. In an attempt to determine whether this prominence is real, apparent, or both, the mandible in this study has been related to the cranial-facial complex and to itself.

The maxillary base (S-N-A) of the Class III malocclusion showed a tendency to be more retrognathic than the Class II malocclusion. This finding is confirmed by the result of Sanborn (1952) who showed the maxillary base to be significantly smaller than that of normal occlusions. Whether this is a result of the tendency for the anterior cranial base to be shorter than normal in the Class III is a matter of conjecture, but it does support the clinical observation that the middle face exhibits apparent underdevelopment.

The prominence of the mandible to the upper face beyond values for normal occlusion is a readily admitted feature of the Class III malocclusion. This study also served to confirm this viewpoint when compared to Class I and Class II malocclusions. The angles S-N-Pg and S-N-B were both found to be large enough to be considered statistically different in the Class III sample.

Bjork (1947) theorized that, if the saddle angle (N-S-Ar) became smaller, the tempero-mandibular joint would be more forward to cranial anatomy. This, in turn, would influence the position of the mandible to the upper face and cause an increase in the amount of prognathism. A reduction in the joint angle, S-Ar-Go, would also increase the degree of prognathism. Statistical data in this study showed that there was a significant difference between the saddle angle of the Class II sample and the Class III sample. This served to confirm the results of Moss and Greenberg (1955) who found the saddle angle to be more acute in Class III malocclusions.

Reference to Chart No. 1 will readily show that the mean saddle angle of the Class III was more acute than either the Class I or the Class II. The mean joint angle was positioned between that of the Class I and Class II. (See Fig. 13) A more important observation is the



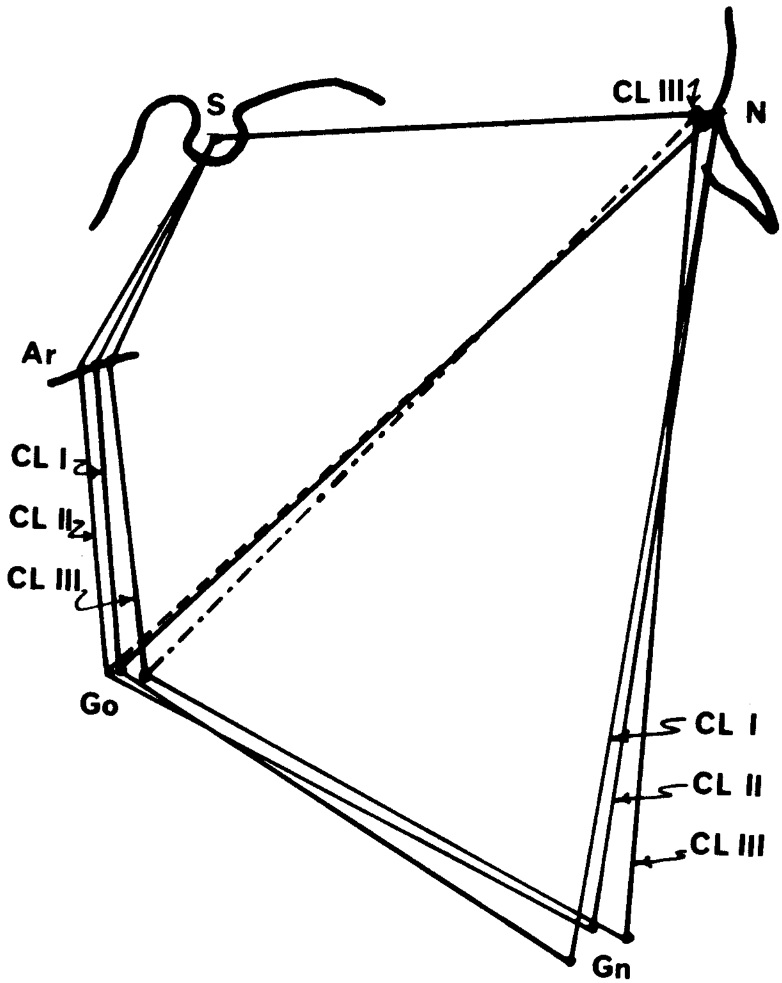
COMPARISON OF THE MEAN ARTICULAR ANGLES

FIGURE 13

additive effect that the mean values for the saddle and articular angles give to the Class III sample. They are additive in the sense that they both tend to cause a more anterior position of the mandible to cranial anatomy. The articular angle does not tend to offset the effect of the saddle angle as it does in the Class I and Class II malocclusions. (See Fig. 14)

The joint angle finding in this study differed markedly from that of Bjork (1947) and Sanborn (1952). They both found that the joint angle decreased in cases of mandibular prognathism. This study found all the malocclusion joint angle values to be larger than normal (M=142.14). The mean Class III value was found to lie between that of the Class I and Class II malocclusions. The only explanation that can be given for this difference is that the samples of Bjork and Sanborn each had a mean age of over 21 years. The possibility exists that further changes may occur in this angle with age and completion of growth. This possibility has been indicated by Bjork in his studies on growth of the mandible. Of the 322 twelve-year old boys that Bjork also studied in 1947, only eight of these were considered to have Class III malocclusions. This is an exceptionally small sample, from which one could draw any conclusions, considering the fact that two of the eight had forced bites. Then again, molar relationship was not a factor here but rather mandibular overbite and this might tend to show only the more extreme portion of the Class III population.

The net effect of the mean values for these angles (articular and saddle) resulted in an increased posterior face height and an anterior



COMPARISON OF THE MEAN VALUES OF THE CLASS I, II, AND III MALOCCLUSIONS WITH SELLA AND THE S-N PLANE AS POINTS OF REFERENCE

FIGURE 14

positioning of the gonial angle to the cranial anatomy. This was found to be statistically important. This value was recorded by the posterior facial height angle S-N-Go, which was significantly larger than that of the Class I or Class II sample. In effect, it has been found that the gonial angle of the Class III malocclusion is positioned downward and forward to cranial anatomy, causing the mandible to be positioned anterior to the position recorded in the Class I and Class II samples. (See Fig. 14, Page 66) Theoretically, if there is a simultaneous shortening of the anterior cranial base and a concomitant underdevelopment of the maxilla, this will result in the most severe type of skeletal Class III malocclusion. According to Sanborn, this will happen ten per cent of the time. Sanborn found, in his study by comparing Class III to normal occlusion, that 45% of the patients fell in the category of the mandible being more prognathic than normal. The second largest group, 33%, fell in the category of the mandibular prognathism being within normal limits, but the maxillary prognathism was below normal limits. Ten per cent of his sample had a normal maxillary and mandibular prognathism and the remaining 10% had a maxillary retrognathism, concomitant with a mandibular prognathism.

The ramus angle reading of the Class III sample was the same as the values registered for the Class I and Class II samples. At first, this may seem confusing, but when it is realized that this Class III sample had a tendency for a shorter anterior cranial base (Sanborn - 1952), the problem or reason is readily apparent. (See Fig. 14, Page 66) This result may be graphically described in the following manner: The posterior cranial base and the ramus, after having obtained a fixed angular relationship to each other, move toward Nasion along the S-N plane, as if along a rail. At the same time, as this complex moves forward, it rotates about Sella-turcica. This will result in the ramus angle remaining constant but opening the posterior facial height angle. Actually, of course, there is no shortening of the anterior cranial base occurring during growth, but rather a lack of linear development.

Assessment of the gonial angle revealed that the Class III and Class I gonial angles were significantly larger than the Class II gonial angle. The Class II gonial angle is also noted to be the closest to the value accepted as normal (M=123.03). This finding was expected because Sanborn's study found the Class III gonial angle to be significantly larger than normal. The mean angle obtained by Sanborn (133.64) was much larger than the mean value obtained in this study (M=128.52), but this could possibly be due to the fact that the mean age of his sample was 21.83 years. The mean age for this study was 12 years and 6.4 months. It could be that with growth and the influence of the malocclusion, there will be further remodeling of the gonial angle and posterior border of the ramus with the result that the gonial angle becomes more obtuse and the posterior border of the ramus assumes a more acute relationship to the posterior cranial base. If this did occur, then this would also explain the fact that Sanborn also found a more acute articular angle.

Assessment of the body angle (N-Go-Gn) revealed that in the Class III sample, the increased gonial angle was due to an increased angular relationship of the body to the ramus. This finding paralleled the results obtained for the Class I sample. In each case, the gonial angle and the body angle was found to be significantly larger than that of the Class II sample.

In attempting to evaluate the results from the growth axis angle (N-S-Gn) in regard to anterior face height and growth direction, it was found that it is necessary to compare this reading with the Go-Gn to S-N angle. In the Class I and Class II sample, where parts of the mandible are relatively equal in size, the readings for these two angles can be interpreted in a similar manner. This simply means that a large growth axis angle or a large Go-Gn to S-N angle in either a Class I or Class II malocclusion, can be interpreted as meaning that growth is in a vertical direction. Conversely, a lesser value for these angles indicates growth is in a horizontal direction.

This is not necessarily true of the Class III readings. Here it can be seen that due to the forward position of the mandible in the Class III malocclusion, beyond what may be considered normal values, a significantly smaller reading is recorded for the N-S-Gn. The mean value (M=66.52) for this angle would indicate a more horizontal growth pattern and shorter anterior face height in the Class III malocclusion, as compared to the Class I and Class II malocclusions. Bearing this in mind, one may proceed to evaluate and compare the results for the Go-Gn to S-N readings. Here it is found that this reading is also smaller in the Class III malocclusions when assessed against the Class I sample. This is not true for the Class II sample. In this case, the Class III sample mean is larger than that of the Class II sample. This result, at first, might indicate a discrepancy in our readings between the Class II and the Class III sample. It seems to infer that the reverse is now true, viz., that a greater face height and a more vertical growth pattern now exist in the Class III malocclusions.

This problem is resolved when these findings are combined to properly assess the Class III sample as having a more vertical growth pattern than the Class II sample, but as having a more forward position of the mandibular base. It is this forward position of Gnathion which can be due to either a decreased saddle angle, a decreased articular angle, increased body length, or all three, which will result in the registration of a horizontal growth axis reading. The author feels that in assessing malocclusions against cephalometric norms, this type of comparison is an important factor in analysis. By this, it is meant that one must not base a judgment on a singular value, but rather on many values and the manner in which they relate the parts to the whole and to each other. It must also be remembered that, when comparing a malocclusion to normal occlusion, a comparison is made of a cranio-facial distortion to parts that are ideally related and may have a tendency to dismiss the adjustment nature has performed in the patient we are evaluating.

The angle, Go-N-Pg, which evaluates the prognathism of the body of the mandible and the manner in which the body is related to the S-N plane indicates that the body prognathism of the Class III mandible is greater than the Class II mandible. Both of these are found to be greater than the Class I body prognathism. In reading this angle, it would be well to remember that the length of the body of the mandible and the degree of parallelism it has with the anterior cranial base are assessed. Therefore, in this evaluation, the knowledge of the angular relation of the mandibular plane to the anterior cranial base and the actual measurement of the length of the body of the mandible must be incorporated. Knowing this, one can proceed to accurately assess how much of the Go-N-Pg reading is due to actual body length and how much of this value has been affected by increased or decreased angulation of the body of the mandible to the anterior cranial base. For example, in this case, the growth pattern is in a more vertical direction in the Class III sample (Go-Gn-SN=34.84) than the Class II sample (Go-Gn-SN=32.66), but there is still a significantly larger body prognathism recording. How can it happen that we have a vertically growing mandibular body and get a larger body prognathism reading? It would seem that the reading should become smaller as it does for the Class I. The explanation is that, even though the Class III is a more vertically directed growth pattern than the Class II, the actual linear body length is greater in the Class III, sufficiently greater to result in a larger body prognathism angle reading.

The inferior facial angle is another indicator and coordinator of the degree of mandibular prognathism with growth direction. Reading of this angle indicates the cant of the mandibular plane and the manner it relates to the facial plane. A good example of this is had by comparing the results obtained for the Class I sample with the Class III sample. Here one might expect that, since the Class I malocclusions have a greater cant to the mandibular plane than the Class III malocclusions, they would have the more acute inferior facial angle. Instead, it is the Class III, because of its greater degree of mandibular prognathism, which results in a significantly smaller inferior facial angle.

The results obtained in analyzing the chin angles very closely parallels the work of Bjork (1947). The angle, in essence, had the same value in each malocclusion, although the distribution of the individual scores, about the mean, was greater in the Class III. This was probably due to the body's attempt to contain the lower denture within the confines of the maxillary denture. This often resulted in the lingual positioning of the lower alveolar process.

Bjork (1955), in his study on growth of the mandible, found that in the sagitally growing mandible, of which the Class III is a good example, there is also a tendency for the backward eruption of incisors.

This variability of the individual scores is even more evident when the difference between the inferior facial angle and the chin angle is observed. Here one can see, arithmetically, the two extremes found in the Class III mandible. This would be all the way from the mandibular incisors being tipped lingually by the restraining effect of the maxillary incisors, to the point that growth of the mandible has carried procumbent incisors beyond the influence of the maxilla.

CHAPTER VI

SUMMARY AND CONCLUSIONS

A. Summary.

1. This study was a cephalometric assessment of the craniofacial morphology of 50 Class I, 50 Class II, and 25 Class III malocclusions. All of the Class I and Class II samples plus 13 Class III cephalograms were obtained from the private patient file of Dr. Joseph Jarabak, of Hammond, Indiana. The remaining 12 cephalograms were obtained from the private patient file of Dr. Sheldon Rosenstein, of Chicago, Illinois.
2. Seventeen various angles were drawn, measured twice and recorded twice at different intervals. All angles composed of two smaller angles were always checked to be sure the parts equalled the whole.
3. The mean and standard deviation was obtained for each angle in each classification. The Student's "t" test was employed to determine if a significant difference existed between the corresponding angle in each malocclusion. A value between 0.00 to 1.67 indicated that no significant difference existed. A value of 1.68 to 2.00 indicated there was

a tendency for a significant difference. The term tendency was used to denote this range. A value above 2.00 indicated a real or significant difference did exist.

4. The following angles were found to be significantly larger in the Class II sample, when compared to the Class I sample:
   a. Go-N-Pg: The mandibular body prognathism angle.
   b. N-S-Ar: The saddle angle.
   c. Ar-S-Gn: The mandibular length angle.
   d. Go-Gn-N: The inferior facial angle.
5. The following angles were found to be significantly larger in the Class I sample when compared to the Class II sample:
   a. N-S-Gn: The growth axis angle.
   b. N-Go-Gn: The body deflection angle.
   c. Ar-Go-Gn: The gonial angle.
   d. Go-Gn to S-N: The mandibular plane, to anterior cranial base, angle.
   e. N-Id difference: The difference between the inferior facial angle and the chin angle.
6. The following angles reflected tendencies:
   a. S-N-Pg: Superior facial angle tended to be larger in the Class II sample.
   b. S-Ar-Go: The joint angle tended to be larger in the Class I sample.
7. The following angles were significantly larger in the Class III sample, when compared to the Class I sample:

a. S-N-B: Mandibular base prognathism angle.

b. S-N-Pg: Superior facial angle.

c. S-N-Go: Posterior facial height angle.

d. Go-N-Pg: Body prognathism angle.

8. The following angles were found to be significantly larger in the Class I sample, when compared to the Class III sample:

   a. N-S-Gn: The growth axis angle.

   b. Go-Gn-N: The inferior facial angle.

9. The following angles revealed a tendency for significant difference:

   a. Ar-S-Gn: The mandibular length angle tended to be larger in the Class III sample.

   b. Go-Gn to S-N: The mandibular plane angle tended to be larger in the Class I sample.

10. The following angles were found to be significantly larger in the Class III sample, when comparing them with the Class II sample:

    a. S-N-B: The mandibular base prognathism angle.

    b. S-N-Pg: The superior facial angle.

    c. S-N-Go: The posterior facial height angle.

    d. Go-N-Pg: The body prognathism angle.

    e. N-Go-Gn: The body angle.

    f. Ar-Go-Gn: The gonial angle.

11. The following angles were found to be significantly larger in the Class II sample in comparing them with the Class III

sample:

a. N-S-Ar: The saddle angle.

b. N-S-Gn: The growth axis angle.

c. Go-Gn-N: The inferior facial angle.

d. N-Id difference: The difference between the inferior facial angle and the chin angle.

12. The following angles were found to have a tendency for significant difference:

a. S-N-A: The maxillary prognathism angle tended to be smaller in the Class III sample.

b. Go-Gn to S-N: The mandibular plane angle tended to be larger in the Class III sample.

B. Conclusions.

1. The saddle angle is larger in the Class II malocclusions.

2. The body tends to produce a constant relationship between the cranial bases and the gonial angle in the Class I and Class II malocclusions. There is a tendency for the saddle and joint angles to balance their differences to achieve this aim.

3. The Gonial angle is significantly larger in the Class I malocclusion, as compared to the Class II malocclusion.

4. Because of the rather constant position of Gonion, the differencer in the size of the gonial angles was due to the increased angular relationship of the body to the ramus. In effect, the body rotates downward and backward (in the Class I) with

Gonion acting as the point of rotation.

5. The increased angular relationship of the Class I body results in an increased facial height in the Class I malocclusion. This should be confirmed by a linear study.
6. The posterior face height of the Class I and Class II patients is the same.
7. The Class I malocclusions were found to have a more vertically directed growth pattern than the Class II malocclusions, or the Class III malocclusions.
8. The alveolar process of the Class I malocclusion tends to be more protrusive than the Class II malocclusion. This is due in part to the greater cant of the mandibular plane in the Class I sample.
9. The Class III malocclusion was significantly more prognathic than the Class I or Class II sample. This is reflected by the S-N-B and S-N-Pg.
10. The greater body prognathism angle in the Class III sample, when compared to the Class I and Class II sample, was due to a combination of the cant of the mandible and its slightly larger body length.
11. The posterior face height of the Class III malocclusions was greater than that of the Class I or Class II malocclusions. This was due to the saddle angle being smaller than the Class II and Class I samples. This projected the gonial angle downward and forward in the Class III and resulted in a greater posterior face height.

12. The gonial angle of the Class III malocclusion is larger than the Class II which had a value close to that of those for a normal occlusion.

13. The body tends to maintain the alveolar prognathism at a constant position to the mandibular plane, although there is a greater degree of variability in the Class I and Class III malocclusions.

14. The prognathic mandible is the greatest single identifying factor in the Class III malocclusion. Various types of skeletal profiles are associated with the Class III malocclusions. These have been grouped by Jarabak (1964) and Sanborn (1952) according to similarities in the amount of maxillary and mandibular prognathism. This appears to be true because a Class III malocclusion could arise due to the poor morphological arrangement of parts, as described by Bjork, or an overgrowth of the mandible.

BIBLIOGRAPHY

Adams, J. W. 1948 Cephalometric studies on the form of the human mandible. Angle Orthodontist; 18:8.

Baldridge, John Philip 1941 A study of the relation of the maxillary first permanent molars to the face in Class I and Class II malocclusions (Angle). Master's thesis, Univ. of Illinois.

Bjork, Arne 1947 The Face in Profile. Svensk Tandlakare - Tidskrift, Vol. 40, No. 5B, suppl., Lund Berlingska Boktryckeriet.

__________ 1951 Some Biological Aspects of Prognathism and Occlusion of the Teeth. Angle Orthodontist; 21:3.

__________ 1951 The Significance of Growth Changes in Facial Pattern and Their Relationship to Changes in Occlusion. Dental Record; 71:197-208.

__________ 1953 Variability and Age Changes in Overjet and Overbite. A.J.O.; 39:779.

__________ 1953 Estimating of the Age Changes in Overjet and Sagittal Jaw Relations. Transaction of the European Orthodontic Society.

__________ 1955 Facial growth in man, studied with the aid of metallic implants. Acta Odont. Scandinav.; 13:9-34.

__________ 1955 Cranial Base Development. A.J.O.; March, 195-198.

__________ 1961 Relationship of the jaws to the cranium. Lundstrom's Ed., Introduction to Orthodontics, New York, McGraw Hill Book Co., pp. 104-140.

__________ 1963 Variations in the Growth Patterns of the Human Mandible: Longitudinal Radiographic Study by the Implant Method., J. D. Research; 42:400-411.

Blair, E. S. 1952 A Cephalometric Roentgenographic Appraisal of the Skeletal Morphology of Class I, Class II, Div. 1, Class II, Div. 2 (Angle) Malocclusions. Master's thesis, University of Illinois.

Bolk, L. 1915 On the position, shifting, and inclination of foramen magnum in the skull of primates. Zeitschr., F. Morph. u. Anthrop., B. D. 17, s. 611.

Bolk, L. 1926 The problem of human evolution. 25th Versam. d. Anat. Gesellsch.

Broadbent, B. H. 1931 A new X-Ray technique and its application to orthodontics. The Angle Orthodontist; 1:45-66.

__________ 1937 The face of the normal child. 7:209-233.

Brodie, A. G. 1941 On the growth pattern of the human head from the third month to the eighth year of life. Am. J. Anat.; 68:208-262.

__________ 1953 Late growth changes in the human face. The Angle Orthodontist; 23:146-157.

Brodie, Allan, Jr. 1952 A cephalometric study of the cranial facial morphology. Master's Thesis, University of Illinois.

Coben, S. E. 1955 The integration of facial skeleton variants. A.J.O.; 41:6.

Craig, C. E. 1950 The Skeletal Patterns Characteristic of Class I and Class II, Div. 1, Malocclusions (Angle) in Normal Laterales. Master's Thesis, University of Illinois.

Dabelow, A. 1931 On the correlation in the phylogenetic development of skull form. Morphol. Jahrb., 63:1-49.

Elsasser, W. A. and Wylie, W. L. 1938 The Cranio-facial Morphology of Mandibular Retrusion. Am. J. Phys. Anthrop.; 6:461-473.

Gilmour, W. A. 1950 Morphology of the Adult Mandible in Class II, Div. 1, Malocclusion and in Excellent Occlusion. Angle Orthodontist; 20:137-146.

Hellman, Milo 1931 Morphology of the face, jaws, and dentition in Class III malocclusion of the teeth. J. Am. Dent. Assoc.; 13:2150.

__________ 1939 Some Facial Features and Their Orthodontic Implications. Am. J. Orth.; 25:927.

Hofer, H. 1952 The alteration in shape of the skulls of mammals and birds; with special consideration to the type of flexion and to the skull base. Anat. Anz.; 99:102-113.

Keith, Sir Arthur and Campion, C. 1922 A contribution to the mechanism of growth of the human face. Int. J. Orth., Oral Surg., and Rad.; 8:607-633.

Kummer B. 1952 Analysis of the origin of skull base form in man and primates. Verhandl. d. Anat. Gesellsch.; in: Anat. Anz.; 99:122-126.

__________ 1952 Researches on the ontogenetic development of the human skull base angles. Zeit. f. Morph. u. Anthrop.; 43:331-360.

Lindegard, B. 1952 On the relationship between the upper alveolar process and the cranial base. Kungl. Fysiograt. Sallsk. Lund Forhndl.; 22:1-10.

__________ 1953 Variation in human body build. Acta Psych. et. Neurol., suppl., 86:1-163.

Moss, M. L. and Greenberg, S. N. 1955 Postnatal Growth of the Human Skull Base. The Angle Orthodontist. Vol. 25, No. 2, p. 77-84.

__________ 1964 Vertical growth of the human face. A.J.O., Vol. 50, No. 5, May 1964, p. 359-376.

Pankow, G. 1948 Researches on the flexion of the human skull base. Z. Menschl. Vererb.- u. Konstit. Lehre.; 29:69-139.

__________ 1951 On the regularity of growth of the skull base during human ontogenesis. Anat. Nachricht.; 1:243-248.

Reidel, R. A. 1948 A Cephalometric Roentgenographic Study of the Relation of the Maxilla and Associated Parts to the Cranial Base in Normal and Malocclusion of the Teeth. Master's Thesis, Northwestern University.

__________ 1960 A review of the retention problem. The Angle Orthodontist. Vol. 30, No. 4, Oct., p. 179-199.

Renfroe, E. W. 1948 A Study of the Facial Patterns Associated with Class I, Class II, Div. 1 and Class II, Div. 2, malocclusions. The Angle Orthodontist. 18:12-15.

Rickets, R. M. 1955 Facial and denture changes during orthodontic treatment as analyzed from the T. M. Joint. A.J.O., March, Vol. 41, No. 3, p. 163-179.

Sanborn, Richard 1953 The relation of the cranial base to Class III malocclusions. Master's Thesis, University of Illinois.

Scammon, J. W. 1936 Neural Structures and Their Growth Patterns. Int. J. Orth. and Oral Surg., 22:321-332.

Starck, D. 1955 Shape and formation of the skull base in Chiroptern. Verhandl. d. Anat. Gesellsch. in: Anat. Anz.; 99:114-121.

Subtelny, J.Daniel and Sakuda, Mamoru 1964 Open-bite: Diagnosis and Treatment. A.J.O., May, Vol. 50, No. 5, p. 337-358.

Weidenreich, F. 1924 The special form of the human skull in adaptation to the upright gait. Ztschr. f. Morph. u. Anthrop. Bd. XXIV.

__________ 1941 The brain and its role in the phylogenetic transformation of the human skull. Trans. Amer. Phil. Soc.; 31:321-342.

CHART NO. 1

MEANS AND STANDARD DEVIATIONS

ANGLE	CLASS I M	CLASS I S.D	CLASS II M	CLASS II S.D	CLASS III M	CLASS III S.D
S-N-A	79.18	3.26	79.89	3.75	78.10	4.07
S-N-B	75.43	2.90	75.76	3.49	80.68	4.21
A-N-B	3.75	2.30	4.12	1.56	-2.58	2.07
S-N-Gn	76.48	2.93	77.56	3.26	81.32	4.14
S-N-Go	38.64	1.99	38.62	2.34	40.74	3.46
Go-N-Gn	37.64	2.25	38.94	2.31	40.58	2.40
N-S-Ar	123.07	4.90	125.00	3.56	121.78	5.37
N-S-Gn	69.83	3.04	68.10	3.53	66.52	3.00
Ar-S-Gn	53.24	4.51	56.90	4.06	55.26	4.08
S-Ar-Go	146.08	6.33	143.98	5.96	145.36	5.61
Ar-Go-Gn	127.98	6.07	124.26	6.54	128.52	5.03
N-Go-Ar	52.14	3.96	52.74	4.22	52.58	3.39
N-Go-Gn	75.80	3.99	71.52	4.59	75.94	3.46
Go-Gn-N	66.08	3.38	69.68	4.30	63.78	3.72
Go-Gn-Id	69.68	6.01	69.18	4.65	69.52	7.25
N-Id Diff.	3.60	5.95	-0.47	5.35	4.94	7.38
Go-Gn-S-N	36.73	4.26	32.66	5.36	34.84	4.05

CHART No. 2

TEST FOR SIGNIFICANT DIFFERENCE

"t" VALUES

ANGLE	CLASS I-II	CLASS I-III	CLASS II-III
S-N-A	-1.00	+1.14	+1.81
S-N-B	-0.51	-5.53	-4.97
A-N-B	-0.93	+11.76	+13.96
S-N-Pg	-1.71	-5.15	-3.92
S-N-Go	+0.05	-2.76	-2.72
Go-N-Pg	-2.83	-5.07	-2.78
N-S-Ar	-2.22	+0.99	+2.66
N-S-Gn	+2.62	+4.42	+2.00
Ar-S-Gn	-4.20	-1.92	+1.62
S-Ar-Go	+1.69	+0.49	-0.97
Ar-Go-Gn	+2.93	-0.40	-3.06
N-Go-Ar	-0.73	-0.49	+0.17
N-Go-Gn	+4.92	-0.15	-4.60
Go-Gn-N	-4.62	+2.56	+6.02
Go-Gn-Id	+0.46	+0.09	-0.21
N-Id Diff.	+3.57	-0.77	+2.69
Go-Gn-S-N	+4.15	+1.85	-1.93

APPROVAL SHEET

The thesis submitted by Dr. Robert R. Lokar has been read and approved by the three members of his examining board.

The final copies have been examined by the Director of the thesis and the signature which appears below verifies the fact that any necessary changes have been incorporated and that the thesis is now given final approval with reference to content, form, and mechanical accuracy.

The thesis is therefore accepted in partial fulfillment of the requirements for the degree of Master of Science.

May 21-65
(Date)

Joseph R. Jarabak
(Signature of Advisor)