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A MORPHOMETRIC STUDY OF ORTHOPEDIC AND FUNCTIONAL THERAPY FOR THE HYPERDIVERGENT SKELETAL PATTERN

by

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Abstract

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Treatment of the hyperdivergent skeletal pattern and management of the associated vertical and horizontal dysplasias have plagued the dentofacial orthopedic profession to the present. There is ample reason to assume that skeletal morphology can be significantly altered as evidenced by the headboard effects produced in the Peruvian and Colombian Indian societies and by the Milwaukee brace. It has also been an accepted fact in general orthopedics that with physical therapy, by the improvement of soft tissue tone and function, skeletal form can also be altered. Orthodontics has attempted to use these two principles in the treatment of the hyperdivergent skeletal open bite pattern. The vertical pull chin cup has been used to produce a Milwaukee brace-type effect to decrease the open bite, and to decrease the gonial and mandibular plane angles. Functional regulators have been used to change function by producing an anterior oral seal, stimulating nasal breathing, and by encouraging a more favorable tongue and muscle posture.

The purpose of this study was to evaluate the skeletal changes in form and interrelationships of the skeletal parts produced by vertical pull chin cup therapy and functional regulator therapy. Also studied were the rebound tendencies associated with the vertical pull chin cup therapy and the treatment effects of the vertical pull chin cup on the adult skeletal open bite pattern.

This study involved 73 subjects divided into five groups:

1. untreated "normal" individuals;
2. individuals with hyperdivergent skeletal patterns treated with vertical pull chin cups only;
3. individuals with hyperdivergent skeletal patterns treated with vertical pull chin cups, cervical headgear, and fixed intraoral orthodontic appliances;
4. adult individuals with hyperdivergent skeletal patterns treated with vertical pull chin cup therapy, cervical pull headgear, and fixed intraoral orthodontic appliances;
5. individuals with hyperdivergent skeletal patterns treated with the functional regulator.

Changes in growth during the treatment period were assessed utilizing the counterpart analysis (Enlow, 1971). This analysis is intended for the evaluation of the dimensions and alignment of actual anatomic counterparts, in contrast to conventional cephalometric planes and angles. The planes described in the counterpart analysis correspond with the key fields and sites of growth and remodeling that occur naturally in the individual.

An analysis of variance and Tukey's test were used to test for significant statistical differences among the measurements taken indicating the change that occurred during the various treatments.

The results of the study may be summarized:

1. There is a statistically significant difference among the treatment changes that took place when comparing vertical pull chin cup and functional regulator therapies.

2. Significant changes that took place during functional regulator therapy include a less forward alignment of the middle cranial fossa relative to the PM vertical, a clockwise rotation of the inferior maxillary plane, a downward alignment rotation of the corpus of the mandible relative to the ramus and a clockwise rotation of the functional occlusal plane. The resultant effect is to close the bite in the vertical dimension and to produce a mandibular protrusive effect in the horizontal dimension.

3. Significant changes that took place during vertical pull chin cup therapy include a forward alignment of the middle cranial fossa relative to the PM vertical, a counterclockwise rotation of the inferior maxillary plane, a posterior rotation of the ramus plane, an upward alignment rotation of the corpus of the mandible relative to the ramus, and a counterclockwise rotation of the functional occlusal plane. The resultant effect is to close the bite in the vertical dimension and to produce a mandibular retrusive effect in the horizontal dimension.

4. From the above factors, vertical pull chin cup therapy was recommended for skeletal open bite patterns that have Class III skeletal tendencies which would benefit from the vertical pull chin cup's mandibular retrusive effect. Functional regulator therapy was recommended for skeletal open bite patterns that have Class II tendencies which would benefit from the functional regulator's mandibular protrusive effect.

5. Cervical pull headgear and orthodontic treatment during vertical pull chin cup therapy produced a greater counterclockwise rotation of the inferior maxillary plane and thus compromised the effect of the vertical pull chin cup.

6. Vertical pull chin cup therapy has very little effect in changing the morphology or anatomic positional relationships in adult subjects.

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DEDICATION

TO

Dr. and Mrs. William N. DiPalma, by beloved parents; their light of inspiration will always shine brightly.

and

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INTRODUCTION

The clinical management of the hyperdivergent skeletal pattern has been a problem that dentofacial orthopedics has confronted with much frustration and anxiety. The cause and development of the hyperdivergent skeletal pattern has been a subject of debate for many years. Numerous theories for the cause of this skeletal pattern have been proposed. These theories usually describe skeletal anatomic, functional, or neurophysiologic characteristics that can be found in a given sample of hyperdivergent skeletal pattern subjects. Treatment has usually been directed at what was thought by the clinician to be the most important cause of the problem. Actually, the hyperdivergent pattern is the result of a myriad of causes and the frustration and anxiety of the orthodontist is a result of not being able to address all of these causes with a treatment regimen that addresses only one cause.

Defining what the skeletal problems are and what effects can be expected from treatment has been a major problem to the clinician. The various methods of conventional cephalometric analyses have been based on population norms and means. These measurements based on a population standard have little comparative relation with hyperdivergent pattern subjects. Conventional analyses also have very little biologic interpretation because their

constructs do not usually have any specific relation to actual fields and sites of growth and remodeling.

Obviously an analysis that evaluates an individual based on the individual's own existing relationship of anatomic "parts" and how these "parts" change in size, rotation, and displacement with treatment would allow for a more accurate assessment of the skeletal aberrations involved. It would also describe how changes took place with treatment. The counterpart method is such an analysis. It is a method by which craniofacial parts are compared to each other to determine their nature of fit. This method can describe for a specific individual how a growth pattern has occurred and can account for the biologic activities that occur at the actual fields of growth.

The basis for this method of analysis are the relationships between and among the skeletal anatomic counterparts as they express themselves in the horizontal and vertical dimension. The anterior cranial fossa, the nasomaxillary complex, and the corpus of the mandible are mutual horizontal counterparts. The middle cranial fossa, the pharyngeal space, and the ramus are also horizontal counterparts. In the vertical dimension the ramus/middle cranial fossa composite is a counterpart to the nasomaxillary complex. Any changes that take place in the size of these parts and accompanying rotational effects will modify the overall expression of these parts and their relationships with each other.

The anatomic manifestation of the hyperdivergent skeletal pattern may be the result of many theoretical combinations of disproportionate size and rotation of counterparts. It is easy to imagine the effects a short ramus, a long nasomaxillary complex, and a counterclockwise rotation of the maxilla would have on the overall expression of the skeletal pattern. Many other factors are involved in the anatomic manifestation of the hyperdivergent skeletal pattern and in each individual they are all exhibited to different degrees. It is also reasonable to assume that different treatment procedures will express different skeletal effects. Therefore, it would seem appropriate to select a treatment procedure for an individual in which the effects of that treatment best address the imbalances found in that particular individual.

LITERATURE REVIEW

Definition and Description

There has been a tendency in the past to categorize facial and skeletal patterns according to relative directions of overall facial growth. Although not very specific or descriptive, skeletal patterns that develop in a vertical direction relative to normal standards have been commonly categorized simply as vertical dysplasia. Actually, "vertical dysplasia" embodies a multitude of different patterns that can be the result of many different craniofacial morphogenic patterns. Several different clinical morphologies that fall into this "catch-all" category, which in themselves have many different skeletal variations, are: the long face syndrome, the extreme clockwise rotater, the backward "rotater", the high angle type, adenoid faces, the idiopathic long face, total maxillary alveolar hyperplasia, the hyperdivergent pattern, and skeletal openbite. There are many divergent anatomic patterns in which all the cranial parts may be arranged to cause vertical dysplasia to exist, but due to the relative lack of success in clinically managing excessive vertical problems in the past, there has unfortunately been a tendency to view these patterns as all being aberrations of essentially the same problem.

Of the vertically dysplastic morphologies, one that has been confronted with much frustration and anxiety by orthodon-

tists is that general group referred to as the skeletal open bite. Of the many different morphologic variables that may result in a skeletal open bite there are certain basic characteristics which may be used to define this composite group of patterns. Nahoum (1974) described these subjects as having slightly longer total anterior facial height, and counterclockwise rotations to the palate which would tend to shorten upper facial height and lengthen lower facial height. Thus, he found the distance from SN to the maxillary central incisors to be shortened. He also found the posterior facial height to be shorter than the norm, an obtuse gonial angle, and a notched mandibular plane. When a dental open bite accompanies a skeletal open bite the maxillary occlusal plane may be tipped upward anteriorly in conjunction with the palatal plane, while the mandibular occlusal plane is canted downward, constituting a negative curve of Spee as described by Trouten (1979). Nahoum's studies (1974) also indicated that the dentoalveolar height is at least normal except for the mandibular molars, which is significantly shorter.

Schendel (1976) attempted to distinguish between long faces with open bites and long faces without open bites. After cephalometrically evaluating the two different dental patterns he concluded that open bite and non-open bite are two variants of long face syndrome in which an increased ramus height is seen in

the non-open bite subjects.

Anatomical Basis of the Hyperdivergent Skeletal Pattern

Beginning with the advent of roentgenographic cephalometrics, orthodontists have worked to gain an understanding of the anatomical basis for malocclusion. In this time much has been learned about the hyperdivergent pattern, or skeletal open bite, by comparing skeletal open bite patterns to skeletal patterns that are accepted as normal.

Hapak (1964) examined 52 untreated skeletal open bites in accordance with Downs' method of analysis. His findings demonstrated that with growth the Frankfort-mandibular plane angle increases, and that lower face height, total face height and alveolar height in the lower incisor area are increased. He concluded that a variety of skeletal patterns may exhibit an open bite, but more importantly, there appears to be reciprocal growth or balancing growth to attempt to preserve harmony in dentofacial relations and that when this mechanism fails a malocclusion results.

Bjork (1969) extended this concept. By using metallic implants Bjork demonstrated that variations in growth do occur between facial regions and that such variations do produce rotations of the mandible in either a forward or a backward direction. He further demonstrated that the apparent constancy of downward and forward facial growth is a result of rotations combined with

remodeling. In this way a pattern of facial growth may be constant in that remodeling will tend to maintain certain proportionality and spatial relationships.

In reference to the skeletal open bite Bjork (1969) reasoned that vertical growth of the condyles must equal the vertical growth of the maxillary complex or a rotation of the mandible will occur affecting the extent of overbite. Also, if the posterior aspect of the maxilla develops vertically and the maxilla rotates in a counterclockwise direction, then a mandible that had been growing adequately in ramal height can be rotated excessively downward and backward permitting the development of an open bite. In many instances adjustment by the mandibular incisors can offset the development of a dental open bite by continued vertical drift. However, excessive rotation of both the maxilla and mandible may be too great for the incisor eruption to compensate.

Isaacson (1970) attempted to be more specific by examining extreme variations in vertical facial growth and the associated variations in skeletal and dental relations. He contended that the linear consistancy of the growth pattern is not necessarily a result of regular, equal increments of growth by the different facial components. He suggested that growth consistancy may be achieved by very unequal amounts of growth at the major facial growth sites accompanied by mandibular rotations and

remodeling. Thus, remodeling changes can tend to reshape the mandible to recreate former spatial relationships maintaining the consistancy of pattern and resultant growth direction.

In an attempt to explain other characteristics commonly associated with skeletal open bites, Isaacson studied MP-SN relationships and speculated that backward rotating mandibles increase facial height and, therefore, elongate the facial musculature. He went on to conclude that as muscles are elongated the passive stretch tension increases and this could be expected to cause the maxillary arch to be more constricted resulting in the higher incidence of posterior crossbite seen in the high MP-SN patterns.

Current concepts delineating the anatomic basis for skeletal open bite were established by Trouten (1979) utilizing the counterpart analysis of Enlow (1971). He found the anatomic basis related to a combination of open gonial angle, downward alignment of the mandibular and occlusal planes, a negative curve of Spee, a slight maxillary protrusive tendency, a more posteriorly aligned ramus, excess vertical PM dimension, and a palatal plane that was below the deepest surface of the occipital fossa indicating a counterclockwise rotation during vertical development of the nasomaxilla.

Functional Basis of the Hyperdivergent Skeletal Pattern

It seems safe to say that today most craniofacial biologists

would agree with Dullemeijer (1974) that all craniofacial structures are both genetically and environmentally influenced. It is also probable that each structure, and indeed parts of each structure, respond to different levels of environmental and genetic influence. Hunter (1965) contended that vertical dimensions of the craniofacial skeleton are more genetically controlled than are anteroposterior dimensions, although the extent to which this supposition may be true is presently difficult to evaluate.

Stressing the role of functional influence and the functional matrix as a determining factor of the skeletal pattern, Frankel (1982) states that the skeletal unit itself is the last to exert its own influence, its shape being completely subordinate to the other elements or to the functional matrices. The fact that soft tissue plays a role in the establishment of dental and skeletal pattern has long been recognized. Angle (1907) emphasized the morphogenic relevance of the soft tissue environment to the dentition and believed relapse is caused by forces on the teeth resulting from an improper soft tissue environment. More recently Linderman (1963) suggested that a poor postural performance affecting the related musculature plays a part in the development of skeletal malformations. Ballard (1965) thought more attention should be paid to the size and shape of the soft tissues. He believed that the faulty interdental posture of the tongue is a compensatory behavioral response that serves to establish an anterior oral seal when the lips cannot do so.

Harvold (1975) has shown that there are nonphysiologic conditions in the oronasopharyngeal spaces which contribute to the development of craniofacial deformities. He observed dramatic changes in the morphology of the mandible of rhesus monkeys in which plastic onlays were placed in the palatal vault which displaced the tongue inferiorly. The conclusion was that diminishing the lingual volume can lead to an alteration in tongue posture which may also change the postural position of the mandible as well.

Profitt (1978) went so far as to differentiate between the effect different types of function have on subsequent morphology. He showed that rapid movement functions, such as swallowing, chewing, and speaking, have little impact on the morphology of the dentition whereas the impact of postural alterations leading to changes in lip and tongue resting pressure is significant.

It seems reasonable to assume, as Frankel suggests, that there is a functional relationship between space conditions in the oral cavity and postural positions on the tongue and mandible. Also, as far as functional factors are concerned, aberrant postural behavior does play a primary role in the etiology of skeletal deformities. Many factors have been implicated as contributory in the development of skeletal open bite. Kuhn (1967) suggests any combination of a number of functional factors contribute to the skeletal open bite pattern. The most notable functional factor he

mentions is the congested airway. A congested airway may result from any one or a combination of factors, including a congested nasal passage, congested nasal or oral pharynx due to allergies, large tonsils and adenoids, or a basic anatomic insufficiency. It is thought that a congested airway leads to a mouth breathing functional pattern and an aberrant tongue posture which in turn underlies responsive changes in mandibular and facial morphology. Other contributory factors Kuhn (1968) mentioned are tongue thrust, detrimental tongue posture, occlusal disharmonies (prematurities, atypical occlusal anatomy, and poor restorations), and TMJ disturbances.

Straub (1960), in reporting on malfunctions of the tongue, concluded that the open bite is the usual result of an abnormal swallowing habit and that abnormal swallowing interferes with normal growth. Linder-Aronson (1970) also found this to be true as he demonstrated tongue thrusting during swallowing in almost all open bites. He theorized this is the way that subjects create an anterior oral seal which is necessary for deglutition in the skeletal open bite pattern. He also mentioned the importance of considering the size of the tongue in relation to the size of the oropharynx, as this space influences the position of the tongue as it pertains to its function in respiration and deglutition.

Physiologic Basis of the Hyperdivergent Skeletal Pattern

An area that is not discussed as much as the anatomical

and functional basis of the hyperdivergent skeletal pattern is the neurophysiologic basis for its development. Some investigators have implied that because many skeletal open bite patterns seem to demonstrate some abnormal neuromuscular and neurophysiologic responses that the skeletal pattern may be the result of direct influence from the nervous system. Whitman (1951) and McDonald and Aungst (1967) reported subtle neuromuscular differences between skeletal open bite patterns and non-skeletal open bite patterns. They also noted that in many skeletal open bite subjects the gag reflex was missing. Bloomer (1967), in tests of stereognosis of skeletal open bite subjects, demonstrated their inability to identify differently shaped objects with the tongue. He also observed that many subjects were not able to execute alternate repetitive movements with the tongue (Dysdiadokokinesia). Henkin (1967) believes these conditions are probably due to a deficient proprioceptive mechanism. He maintains that tongue thrust may contribute to open bite deformity and that this condition is sometimes associated with tactile hypesthesia and disorders of oral motor activity. He then concluded that open bites have both anatomic and neurologic components.

Gershater (1968) observed in his investigations an extremely high incidence of skeletal open bite in emotionally disturbed and mentally retarded children, which lends credence to the view held in the field of general orthopedics that aberrant

muscle tone is accompanied by skeletal, neural, and psychic disturbances. Frankel (1982) also points out that the extensive representation of the oral region in the brain explains why emotional and nervous stress are particularly manifested in the muscular environment around the mouth. He suggests that this neurophysiologic fact relates to the poor postural performance of the oral facial muscles, as a characteristic feature of the hyperdivergent pattern, and that it may be attributed to an adverse psychosocial makeup of the affected child.

Treatment of Hyperdivergent Skeletal Patterns

Much has been written to define a hyperdivergent or skeletal open bite pattern and much has been said about the many causes of these patterns. Treatment can depend on just how a clinician defines this pattern and what the clinician believes to be the cause. It is apparent from the previous pages that skeletal open bite is a combination of definable and describable multi-expressions that result from, as of yet, mostly unknown multifactorial functional causes. Therefore, it seems reasonable to state that most treatments for the hyperdivergent pattern have been aimed at its symptoms and not the underlying "disease" itself. These sentiments were expressed by Isaacson (1970) who contended that an anterior open bite in a growing child with a high MP-SN angle can be corrected by vertical elastics to produce a fine dental result without regard to the main skeletal cause of

the dental open bite. He suggested a preferable treatment plan that would involve inhibition of further vertical molar drift to produce a forward mandibular rotation which would improve the profile and close the bite. Often, treatment of the effect (dental open bite) is met with failure due to the inability of the dentition to completely compensate for a combination of skeletal problems after vertical elastic therapy. Subtelney and Sakuda (1964) pointed out that maxillary incisor teeth have been found to be supererupted in skeletal open bite cases making it difficult to anticipate any further incisor eruption. They maintain that teeth that have been caused to drift vertically when they have already drifted vertically beyond normal limits quickly relapse. They suggested that treatment must be instituted in these cases to reduce the vertical dimension in the posterior region in an effort to reduce the anterior open bite.

Most clinicians who view hyperdivergent patterns as mainly skeletal problems (involving mainly the hard tissues), direct most attention to the posterior maxillary teeth. Kuhn (1967) felt that the control of posterior tooth eruption is the most managable factor available to the orthodontist in the overall control of the anterior vertical dimension of the lower face. Subtelny and Musgrave (1974) thought treatment should have an orthopedic effect directed towards the posterior maxilla and not just the maxillary posterior teeth. Their objectives were to

change the positional relationships of the jaws by reducing the downward and vertical growth of the posterior aspect of the maxilla and preventing further vertical dental eruption in the maxillary and mandibular molar regions. Orthodontic management would involve the use of high pull head gear to the maxillary molars. They also recommended instituting treatment early enough such that treatment would be to prevent a skeletal open bite from occurring or to minimize its expression. In this manner treatment procedures would be instituted at a time that vertical jaw growth and vertical alveolar growth are vigorously active so that specific areas may be mechanically prevented from expressing full vertical development while other areas are permitted to express full potential for vertical development.

Many authors, including Subtelny and Sakuda (1964), have warned against not coordinating the treatment plan so that a favorable effect on the dentition is not an unfavorable effect on the skeleton. They warned that in skeletal open bite cases the maxillary molars are already excessively erupted and cervical head gear should not be used for molar anchorage as it may cause extrusion and distalization resulting in a further clockwise mandibular rotation.

Sassouni and Nanda (1964) felt that treatment plans are often not coordinated because the clinician cannot properly diagnose the vertical problem. They maintained that a cephalo-

metric analysis should include a discriminatory analysis of vertical proportions because vertical proportions are in many cases at the origin of anteroposterior dysplasias.

Haas (1980) maintained that growth can be utilized in the management of vertical dysplasia, and that it is necessary to use an analysis that can properly evaluate the skeleton as well as the teeth in the vertical dimension. He thought that the true vertical situation is one of deficient posterior facial height and not excessive anterior facial height. In this light, the vertical dimension is not viewed as difficult to control, or is the Kloehn cervical head gear contraindicated in cases of vertical dysplasia. He stated that the Kloehn cervical head gear affects the growth of the maxilla and the maxillary teeth in growers, and the position of the maxillary teeth in the anteroposterior and vertical planes in nongrowers.

The Haas philosophy (1981) assumes that orthopedic manipulation can only redirect growth, not control its amount. Therefore, when directing a horizontal force to the maxilla, as with a cervical head gear, the maxilla is free to slide on the undersurface of the cranial base with no changes in the body of the maxilla. This is the result of most of the cranial sutures being oriented in planes roughly parallel to the plane of the cranial base. Haas maintains this orientation readily accommodates the slide of the maxilla. The net effect is to push the maxilla

down and back. To prevent an anterior vertical opening of the mandible a vertical pull chin cup is worn. He maintains that the vertical force from the chin cup does not prevent the maxilla from being displaced downward, but responds by adding growth at the condyle. Therefore, the increase in posterior facial height with the growth of the ramus accommodates the repositioned maxilla.

Haas (1980) likens the effect of the vertical pull chin cup to that of the Milwaukee brace when a maximum vertical orthopedic correction is desired. It has the potential to intrude posterior teeth in nongrowing patients and, thus, causes a positive rotation of the mandible. In a growing child Haas notes that the posterior teeth can be depressed and eruption prevented. He also contends this can also prevent posterior alveolar bone growth and maxillary descent. If the force is active over a long period of time, Haas maintains that mandibular morphology can be altered.

Pearson (1978) used Bjork's structural method for predicting significant growth rotations from a cephalogram. In this manner he was able to select patients with backward rotational growth tendencies. He found vertical pull chin cup therapy helpful in the control of maxillary and mandibular molar eruption. After therapy he reported that anterior open bites became closed with a subsequent decrease in the mandibular plane angle, decreased gonial angle, and an inhibition of posterior molar erup-

tion. He also recommended the use of the vertical pull chin cup on nongrowers with backward rotational skeletal patterns to help minimize treatment extrusion.

Functional or myofunctional treatments have also been advocated by a great many clinicians in the treatment of hyperdivergent patterns, but mostly as an adjunctive treatment. A form of myofunctional therapy used widely in the 1950's and to a lesser extent today is the palatal crib or tongue crib. Together with a variety of tongue and lip exercises, and intraoral functional appliances, the clinician has a wide variety of treatments from which to choose depending again upon his analysis of the problem being treated.

Sandusky (1976) recommended interceptive orthopedic treatment during the mixed dentition phase for skeletal open bite patterns, before the neuromuscular patterns become practically uncorrectable. Sandusky recommended the vertical pull chin cup no matter which intraoral appliance is used. In addition he advocated myofunctional therapy in patients with extreme neuromuscular patterns. His primary concern is to intercept the skeletal open bite tendency in the young patient when the primary neural feedback circuits are developing which might allow the patient to acquire a new pattern of musculature behavior which would be unattainable at an older age.

Proffit (1978) and Straub (1962) strongly advocate myofunctional therapy and the various kinds of exercises in combination with speech therapy to overcome abnormal behavioral patterns of the tongue. Kuhn (1967) referred to the apparent relationship between high plane hyperdivergent patterns and weak muscle function to recommend a technique utilizing isometric exercises for those patients who do not demonstrate a strong muscle contraction as determined by palpation over the masseter and temporalis areas. Cut pieces of rubber tubing are closed on vigorously between the upper and lower posterior teeth in order to increase that particular patient's masticatory muscle strength. It is hoped that by changing the character of the functioning muscle to a comparatively more normal state, the morphology of the supporting structures can be influenced to do the same.

Frankel (1982) contended it is reasonable to assume that if alterations in the postural activity of the orofacial musculature can lead to skeletal open bite (as in Harvold's experiments, 1975), then the correction of faulty postural activity of the orofacial musculature may lead to a correction of the associated skeletal deformity. He continued by pointing out that the skull is almost exclusively of membranous origin and that the intermediate connective tissues have an adaptive and compensatory growth capacity being highly sensitive to biomechanical influences and, thus, functional forces. Frankel, therefore, maintained that

treatment designed to overcome a poor postural performance would be effective in the orofacial complex.

Proper function of the orofacial complex must allow for the functional demands of respiration, mastication and digestion. Central to this theme is the ability to maintain a lip seal with proper nasal respiration. Bosma (1975) concluded that airway maintenance is an extremely important factor governing the postural behavior of the orofacial musculature. Frankel used this fundamental consideration in developing a therapeutic strategy aimed at overcoming the deviant pattern of mandibular rotation through re-establishment of nasal breathing by correcting the anterior oral seal and faulty tongue posture. He found that if a competent lip seal is attained the correction of a clockwise rotational pattern of the mandible as an adaptation of form to altered function can be hoped for.

Frankel (1982) compared 30 hyperdivergent open bite patterns treated with the functional regulator and lip seal exercises to untreated hyperdivergent open bite patterns. He found significant differences in skeletal development between the treated and untreated group. In the treated group facial proportions changed causing once hyperdivergent skeletal patterns to fall within the normal range, whereas the untreated controls remained unchanged or became worse. He concluded that the improvement in facial appearance evident after treatment may

result as much from changes in the soft tissue mask as from the skeletal changes.

Theoretical criticisms exist with regard to functional therapy. Most investigators agree that nearly all patients can be thought to swallow without tongue thrusting on a voluntary or conscious level. However, Graber (1972), stated that deglutition has reflex and involuntary components which are initiated and executed on a subconscious level. Kydd (1964) reported that although swallowing occurs 1200-1500 times per day, of which the patient is not generally aware of this activity. Several investigators, including Barrer (1974), Tully (1969), and Speidel (1972) maintain that there is no actual evidence to support the claim of beneficial therapeutic effects of myofunctional therapy in the treatment of skeletal open bites.

It is apparent that many different methods of treatment are available to treat the hyperdivergent pattern based on the fact that this pattern is the result of many different skeletal, neuromuscular, and functional causes.

Orthopedic Effects and Craniofacial Growth

It is an established fact that craniofacial growth and form can be altered by external intervention. The Peruvian Indians bound the skulls of their infants bewteen boards and produced pronounced craniofacial malformations. Perez-Martinez (1960) has illustrated a variety of cranial deformities induced by the Colom-

bian Indians. In these findings it is interesting to note that no reduction in brain size or cranial volume occurred. It is thought that only the position and configuration of the cranial bones had been altered. The methods employed are believed not to involve primarily the application of pressure as such, but rather to provide a mold within which the cranium develops. Apparently, the direction rather than the timing or amount of growth was modified. A pressure effect cannot be entirely discounted, however, because a bony remodeling response is also likely.

Before the advent of cephalometry many authors believed that orthodontic treatment had a definite influence upon the growth of bone and that the achievement of a good occlusion would eliminate and develop a more harmonious facial pattern. Brodie (1938), however, concluded after cephalometric appraisal of orthodontic results that the skeletal bone pattern was predetermined and that actual bone changes accompanying the correction of a malocclusion were restricted to the alveolar processes. Weislander (1963) believed that these findings have influenced orthodontic thinking to the present day and have compounded the pessimism concerning the value of correcting a malocclusion before all permanent teeth are present.

The Milwaukee brace has been long known to have an effect on the growth of the facial and neurocranial structures. Alexander (1966) has demonstrated the pronounced extent of

deformation that can occur in the mandible through the adverse influence of the Milwaukee brace. He showed that the 5-10 pounds produced by the brace and applied to the inferior surface of the mandible for 22-24 hours per day produced flaring of the incisors, depression of the posterior teeth, basal changes in the recontouring of the mandible, and a more acute gonial angle. Graber (1967) suggested that if these heavy forces could be used by the orthodontist he would probably be able to produce orthopedic-like results in the craniofacial region. In contrast, the average head gear is worn 10-14 hours per day and produces 6-12 ounces of force.

Klein (1957) first demonstrated in circumpubertal children that in addition to tooth movement there were associated skeletal changes with head cap therapy. He demonstrated a remodeling of the palate in a more posterior position than is normally seen, and observed a clockwise rotation of the palate. In adults, however, he observed no skeletal changes, only tooth movements.

Weislander (1963) evaluated the effects of occipital anchorage upon the dentofacial area in the mixed dentition. He reported a change in the growth pattern affecting not only the maxilla but also the surrounding bony structures in direct contact with the maxilla. He indicated that the effects of orthodontic treatment in these cases are not limited simply to the dentoalveolar area. He reported that a posterior change in the position of

the pterygomaxillary fissure occurs, that ANS revealed a smaller amount of anterior movement, and that a clockwise rotation of the anterior part of the palatal plane takes place. Thus, he concluded that head gear can indeed alter the morphology of the sphenoid bone.

McHugh (1972) also reported on the orthopedic effects of treatment using extraoral appliances during active growth. He evaluated the effects of high pull head gear therapy in conjunction with full edgewise therapy on 10 youngsters with skeletal open bites. He demonstrated that the palatal plane tipped up posteriorly relative to the Frankfort plane. He also found a retarded extent of vertical drift of the maxillary posterior alveolus and molar teeth.

Baumrind (1974) took a more pessimistic view with regard to skeletal changes, and in particular, to changes in the palatal plane. He admitted the fact that the direction of force to the maxillary molar teeth will have some effect on the cant of the palatal plane. However, he maintained that these changes do not on the average produce clinically significant differences.

The effect orthodontic and orthopedic forces have on the skeletal bases has been the subject of many controversies. This is in part due to semantics, as suggested by Sassouni (1972), where different investigators use similar terminology to describe opposite things. It is also due to the techniques used to record

the changes observed and measured. The nature of conclusions depends, also, on the manner of experimentation and data analysis. Finally, controversy may develop as a result of diverse interpretations of essentially similar experimental findings.

STATEMENT OF THESIS

The objective of this investigation is to examine the changes that take place during the treatment of the hyperdivergent skeletal pattern when treated with the vertical pull chin cup and when treated with the functional regulator. Of primary interest is to determine if these two different treatment procedures produce significantly different changes in growth during the treatment period. The effect of cervical pull headgear and fixed intraoral orthodontic appliances during the vertical pull chin cup treatment period will be examined as well as the tendency for relapse to occur after vertival pull chin cup therapy.

METHODS AND MATERIALS

Source

The lateral cephalograms of the treated cases utilized in this study were obtained from the files of private practitioners. The untreated cases were made available from the Bolton-Brush Collections housed at Case Western Reserve University.

Sample

Group I

A sample of 15 control subjects exhibiting a Class I occlusion were utilized. These subjects were selected at random, and without regard to sex according to the following criteria:

1. no orthodontic treatment prior to the ages studied;
2. ANB value of 0-4°;
3. normal overbite (1-2 mm) and overjet (1 mm);
4. normal anterior vertical dimension (McNamara, 1982), (ANS to Me).

Two lateral cephalograms were utilized for each control case. The average age for the first cephalogram for the subjects in this group was 13 years, 1 month, and the range was 12 years, 1 month, to 15 years, 0 months. The average age for the second cephalogram was 14 years, 7 months, and the range was 13 years, 2 months to 16 years, 0 months.

Group II

A second sample of 15 treated cases was studied. These cases were selected according to the following criteria:

1. at the start of treatment the subject was in the growing phase;
2. treatment consisted of vertical pull chin cup therapy only (2-4 pounds per side maximum force);
3. four premolar teeth were extracted prior to the initiation of treatment;
4. initial and post-treatment cephalograms available (11 subjects have post-retention cephalograms available).

In this group, the average age at the time of the initial cephalogram was 11 years, 0 months, and the range was 8 years, 10 months to 13 years, 2 months. The average age at the end of vertical pull chin cup therapy was 12 years, 7 months, and the range was 9 years, 6 months to 14 years, 11 months. The average post-retention age was 15 years, 8 months, and the range was 13 years, 9 months to 16 years, 9 months.

Group III

A third sample of 15 treated cases was studied. These cases were selected according to the following criteria:

1. at the start of treatment the subject was still in the growing phase;
2. treatment consisted of vertical pull chin cup therapy in conjunction with fixed appliance and cervical pull headgear therapy (2-4 pounds per side maximum force);

3. initial and end of active treatment cephalograms available (10 subjects had post-retention cephalograms available).

In this group the average age at the time of the initial cephalogram was 10 years, 10 months, and the range was 9 years, 0 months to 13 years, 3 months. The average age at the end of active treatment was 15 years, 7 months, and the range was 11 years, 4 months to 23 years, 7 months. The average post-retention age was 18 years, 9 months, and the range was 16 years, 10 months to 27 years, 2 months.

Group IV

A fourth sample of 10 treated cases was studied. These cases were selected according to the following criteria:

1. at the start of treatment the subject was in the non-growing (adult) phase;
2. treatment consisted of vertical pull chin cup therapy in conjunction with fixed appliance and cervical pull headgear therapy (4 pounds per side maximum force);
3. initial and end of active treatment cephalograms available (6 cases had post-retention cephalograms available).

In this group the average age at the time of the initial cephalogram was 26 years, 3 months, and the range was 17 years, 8 months to 37 years, 8 months. The average age at the end of treatment was 28 years, 7 months, and the range was 20 years, 8 months to 43 years, 0 months. The average post-retention age was 30 years, 8 months, and the range was 21 years, 1 month to 42 years, 5 months.

Group V

A fifth sample of treated cases was studied. These cases were selected according to the following criteria:

1. at the start of treatment the subject was in the growing phase;
2. treatment consisted of functional regulator therapy for a hyperdivergent skeletal pattern;
3. initial and end of functional regulator therapy cephalograms available.

In this group the average age at the time of the initial cephalogram was 9 years, 11 months, and the range was 7 years, 11 months to 12 years, 10 months. The average age at the end of functional regulator treatment was 11 years, 6 months, and the range was 9 years, 9 months to 13 years, 11 months.

Technical Details

The cephalograms of the untreated subjects selected from the Bolton-Brush Collection utilized a Broadbent cephalometer. The cephalograms of the treated subjects were taken with either a Wehmer or a Moss cephalometer.

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

Statistical Methods

Statistical computations were made by the author with a Texas Instruments TI-55 calculator. Means and standard devia-

tions were recorded for 22 variables for the five groups before treatment, end of treatment, and post-retention radiographs. Means and standard deviations were also computed for the change in each variable from before to end of treatment and end of treatment to post-retention cephalographs. The 22 variables examined are as follows:

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

14. Vertical anterior maxillary plane.
15. Mandibular plane alignment.
16. Gonial angle alignment.
17. Occlusal plane alignment.
18. Curve of Spee.
19. Inferior maxillary plane alignment.
20. Palatal plane alignment.
21. Maxillary nerve/palatal plane alignment.
22. Lower anterior facial height.

Data was further analyzed utilizing an SPSS (Statistical Package for the Social Sciences) program by the computer housed at the Jennings Computer Center at Case Western Reserve University. Analyses of variance determined which variables showed statistically significant differences in the changes that took place during treatment for each variable. Where differences were found to be significant, comparisons were performed utilizing the Tukey method of multiple comparison, which is sensitive for comparing several means. In this method, the means are ranked in descending order of magnitude and evaluated according to a criterion of the highest significant difference. A 0.05 level of significance was chosen.

TABLE I

DEFINITIONS OF ANATOMIC LANDMARKS

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

TABLE I continued

Points	Definition
SE	Sphenoethmoidal junction, the point at which the floor of the anterior cranial fossa intersects the averaged image of the great wings of the sphenoid bone.
SPr	Superior prosthion, the point of contact of the alveolar process between the maxillary central incisors.

TABLE II

DEFINITIONS OF CEPHALOMETRIC PLANES

Points	Description
Ar to Go	The alignment of the ramus is demonstrated by the line connecting articulare with constructed gonion.
ARa	Anterior ramus plane, demonstrated by a line from the intersection of FOP and the anterior border of the ramus drawn parallel to PRa up to REF.
FOP	Functional occlusal plane, demonstrated by a straight line (disregarding any dentoalveolar curve which may be present) drawn from the most anterior maxillary-mandibular premolar contact to the most posterior maxillary-mandibular molar contact.
IMP	Inferior maxillary plane, demonstrated by a line from SPr through the distal cementoenamel junction of the last fully erupted maxillary molar.
√MCF	Middle cranial fossa, demonstrated by a line from SE to Ar.
NOA	Neutral occlusal axis, demonstrated by a dashed line drawn perpendicular to PM through the most posterior maxillary-mandibular molar contact of the last fully erupted molars.
NRa	Neutral ramus, demonstrated by a dashed line drawn from Ar to a point midway betweem Ar and the neutral PM line at the level of gonion.
PM	PM vertical, demonstrated by a line from SE through the averaged inferior most point of the pterygomaxillary fissure.
PMN	Plane of the maxillary nerve, demonstrated by a line projecting anteriorly from foramen rotundum to a point 3 mm superior to the averaged orbitale (Enlow, 1982).

TABLE II continued

Points	Description
PRa	Posterior ramus plane, demonstrated by the line from Ar to the intersection of FOP with the posterior border of the ramus.
REF	Reference line, demonstrated by the line from Ar parallel to FOP.

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

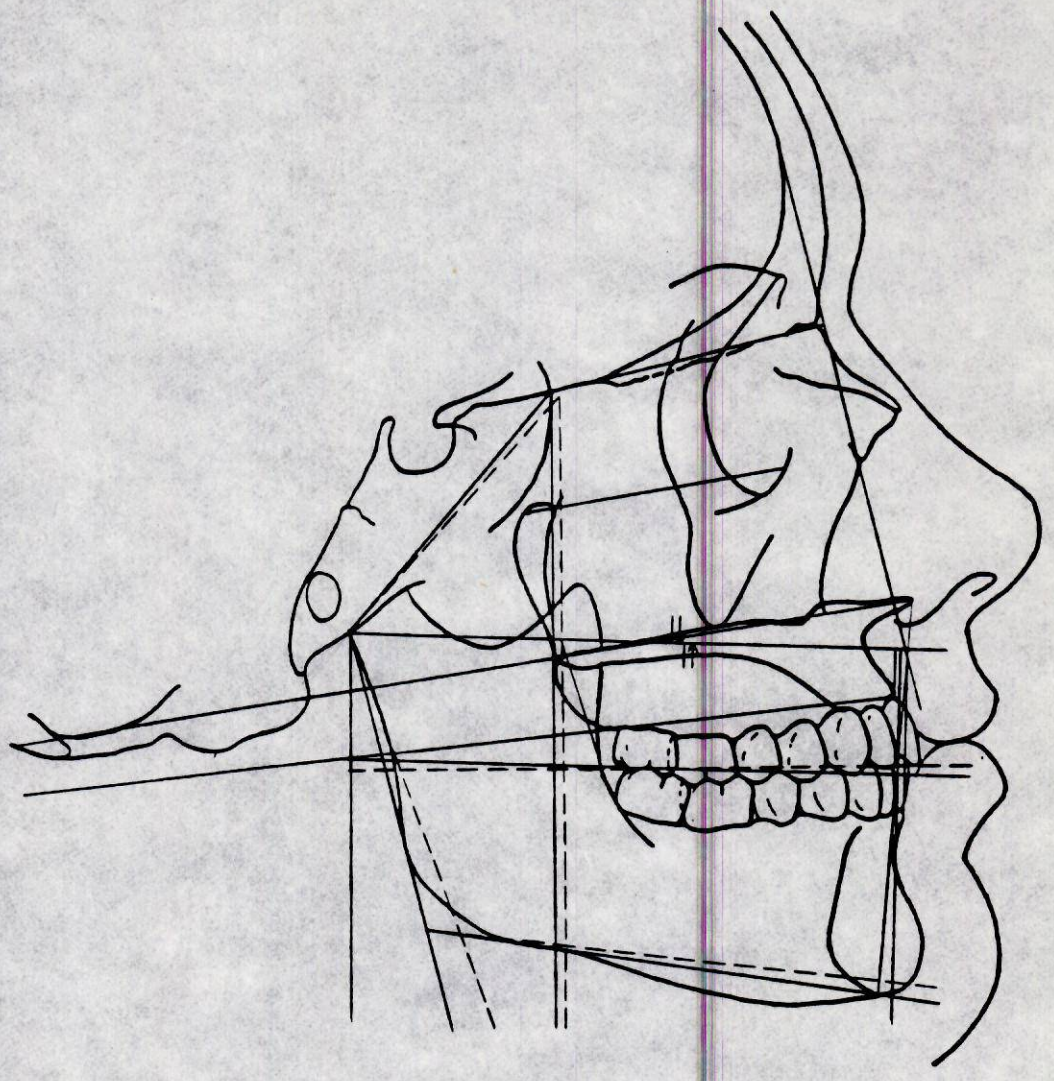


Figure 2. Aggregate cranial floor/maxilla and ramus/corpus horizontal dimensions at A and B points. This diagram demonstrates the comparison of lengths from Ar to A point and Ar to B point. The measurements are made in millimeters along REF. The lines from A point to REF and B point to REF are drawn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

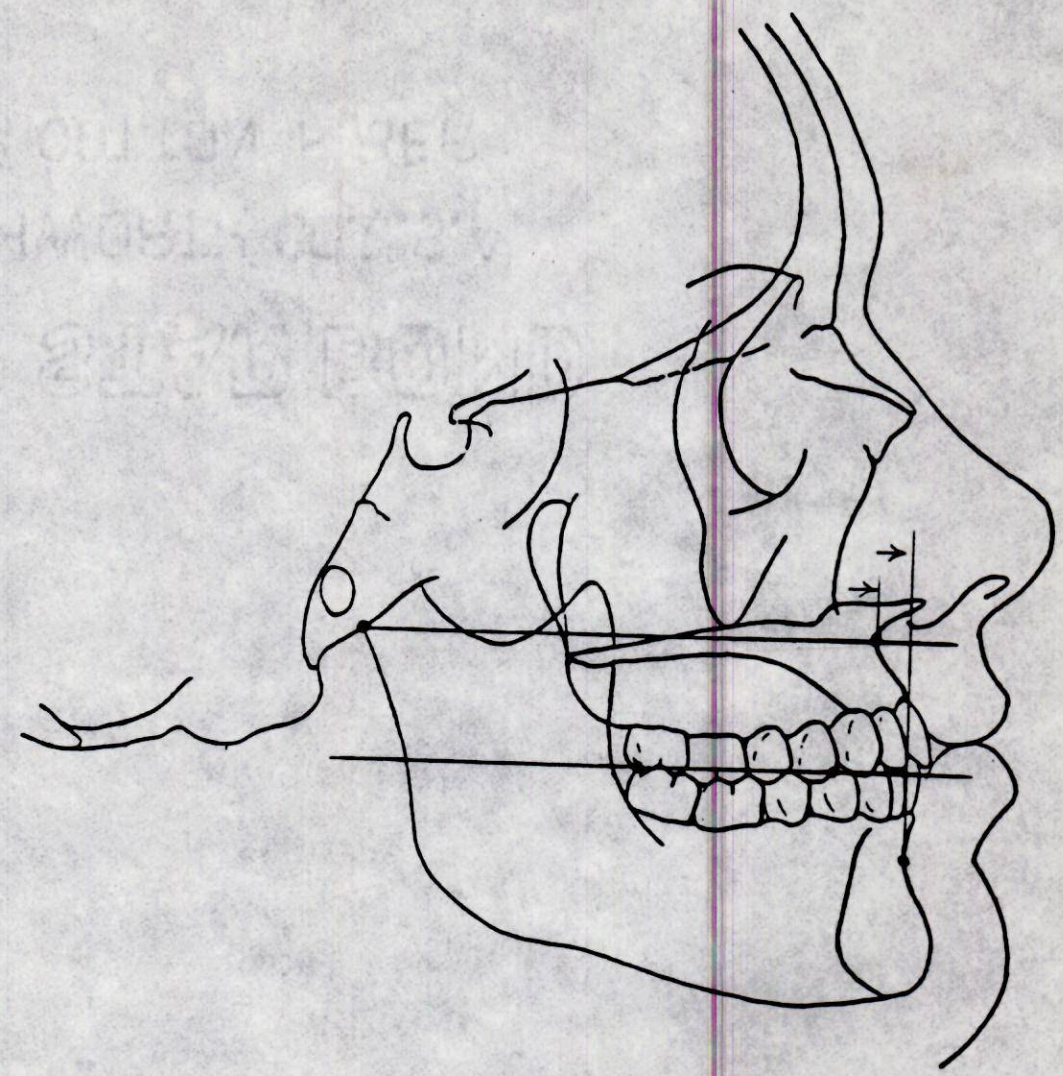


Figure 3. Aggregate cranial floor/maxilla and ramus/corpus horizontal dimensions at SPr and IPr. This diagram demonstrates the comparison of lengths from Ar to SPr and Ar to IPr. The measurements are made in millimeters along REF. The lines from SPr to REF and IPr to REF are drawn perpendicular to REF.

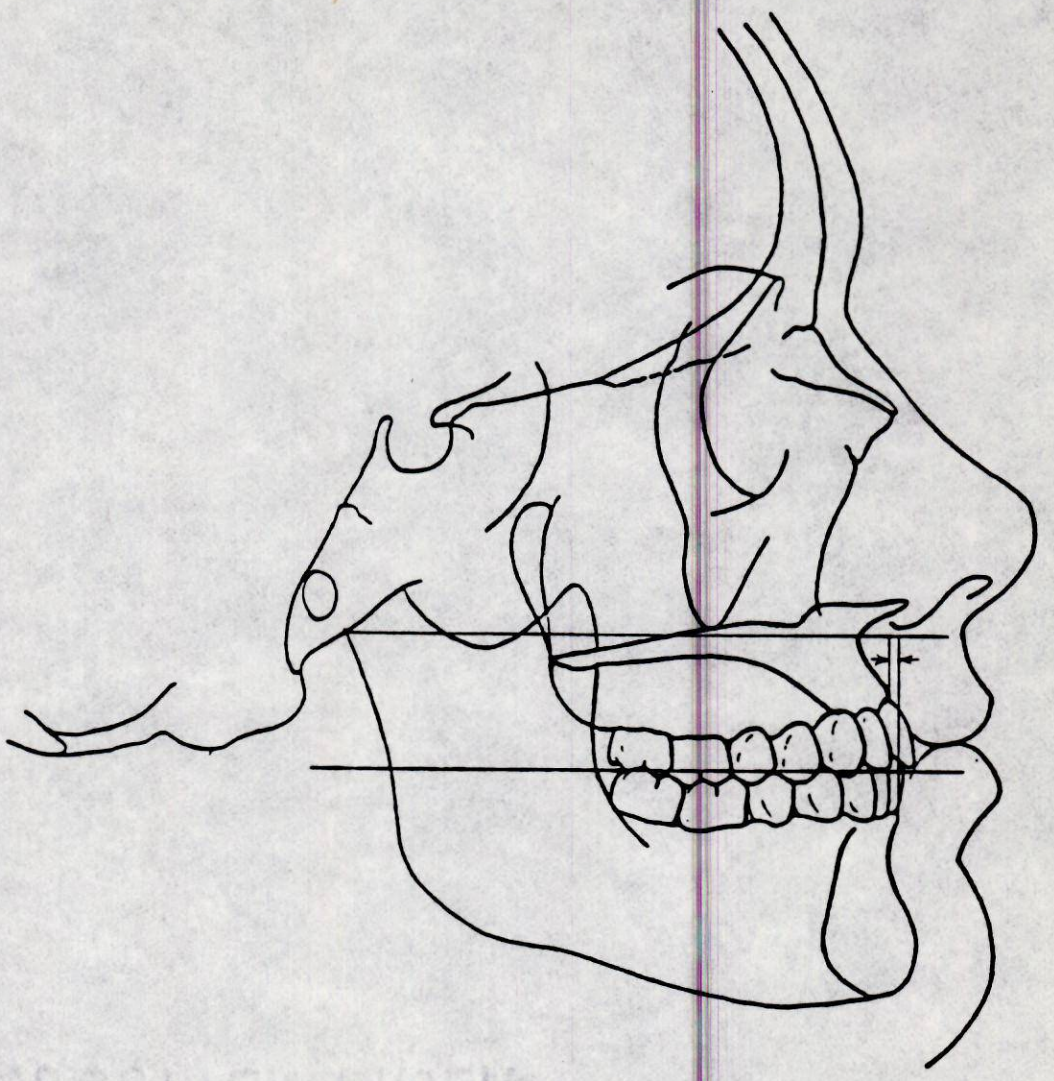


Figure 4. Middle cranial fossa (MCF) and posterior maxillary (PM) relative alignment. This diagram compares the neutral MCF/PM alignment (dashed line), which has an internal angle of 40.3° to the patient's MCF/PM alignment. The neutral MCF/PM alignment is drawn using a preconstructed template which has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

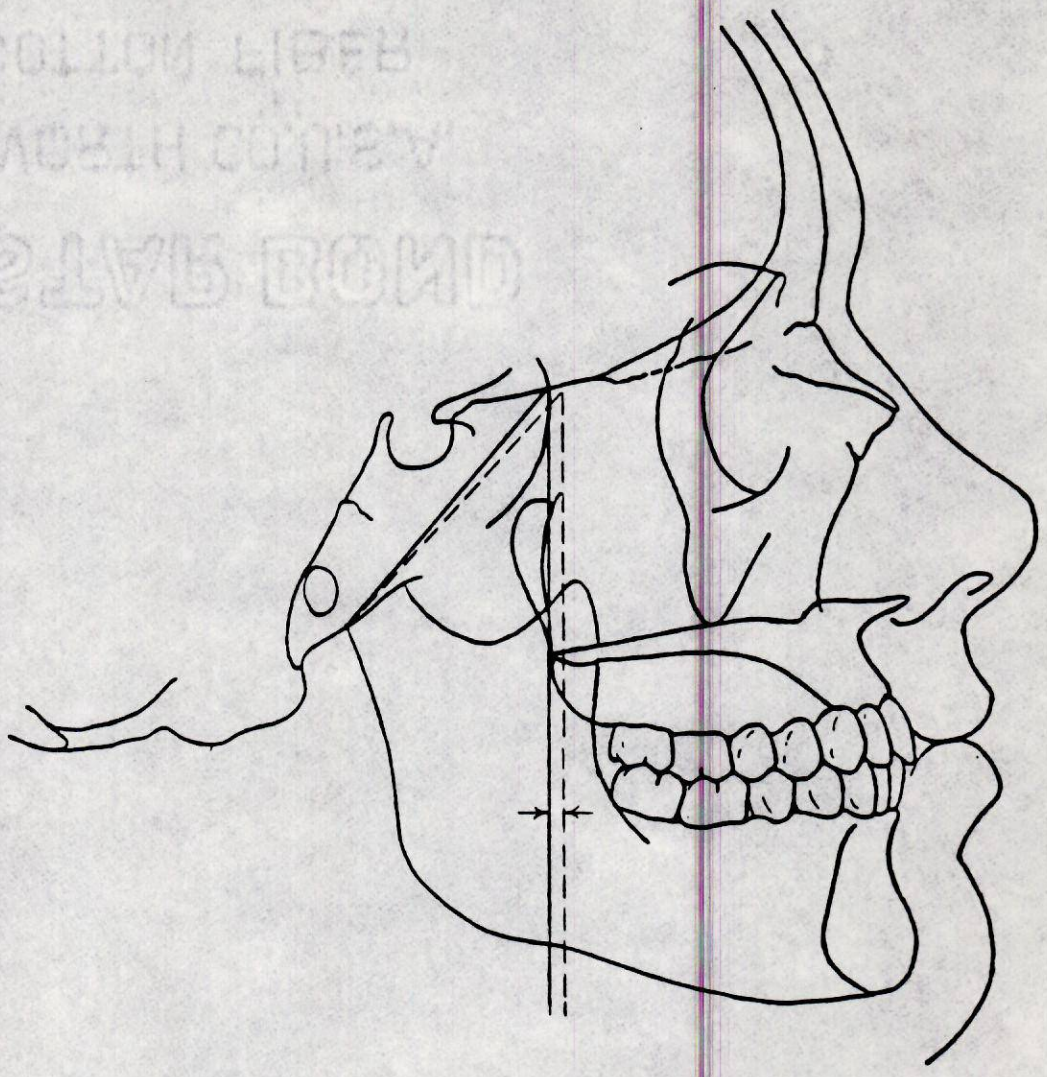


Figure 5. Ramus alignment. This diagram demonstrates the alignment of the subject's ramus plane and its relationship to the neutral ramus plane. A line from Ar to Go represents the individual's ramus plane. The neutral ramus plane is represented by a line from Ar to the midpoint between Ar and the neutral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

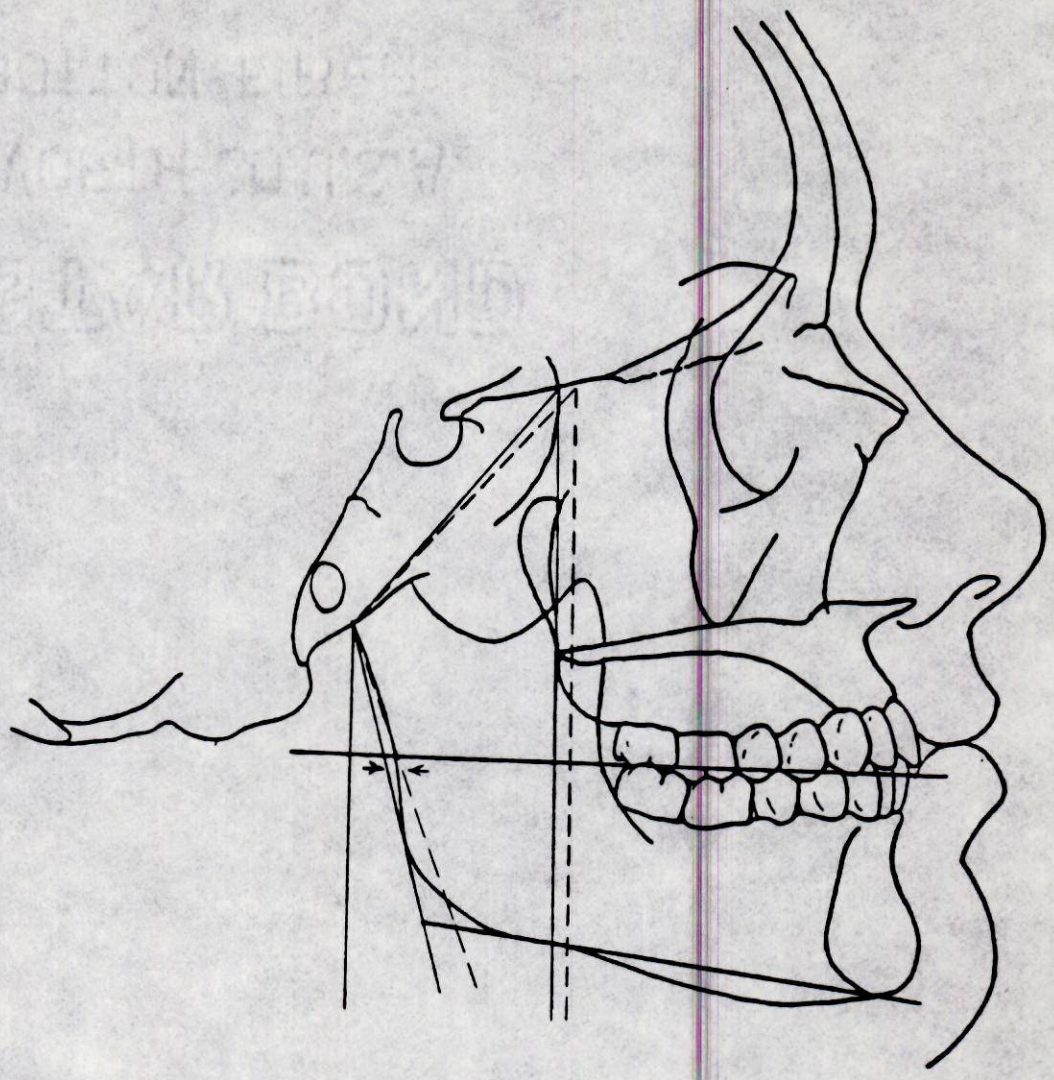


Figure 6. Ramus/MCF horizontal dimensions (skeletal). This diagram demonstrates the comparison of the horizontal dimensions of the middle cranial fossa (Ar to PM neutral) with the width of the ramus (Ar to ARa), and resultant effect on retrusive/protrusive placement of the maxilla and mandible. This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

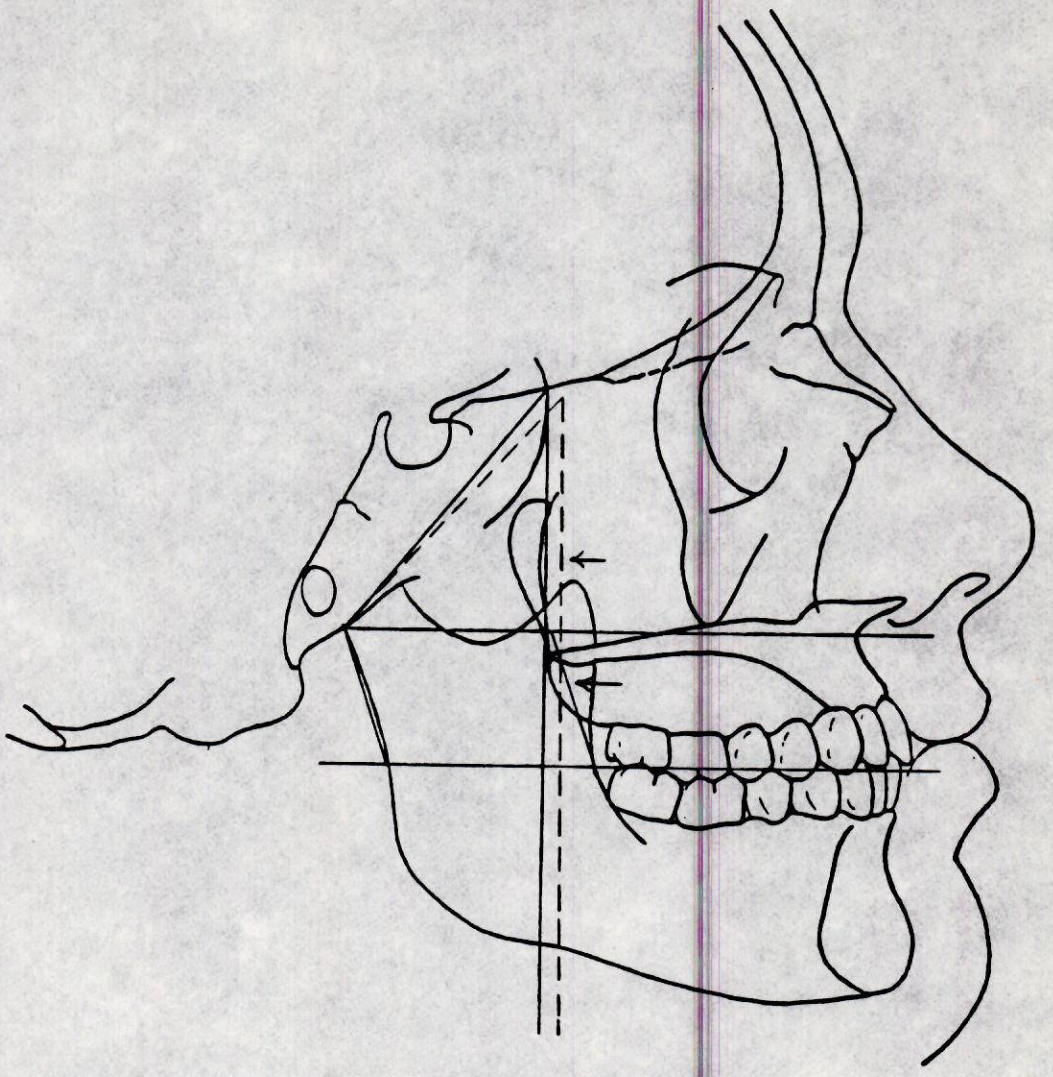


Figure 7. Ramus/MCF horizontal dimension (dental). The neutral positions of the molars are demonstrated with this measurement. The distal surfaces of the maxillary and mandibular first molars are indicated on REF by short vertical lines. The maxillary molar is corrected to its neutral position by adding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

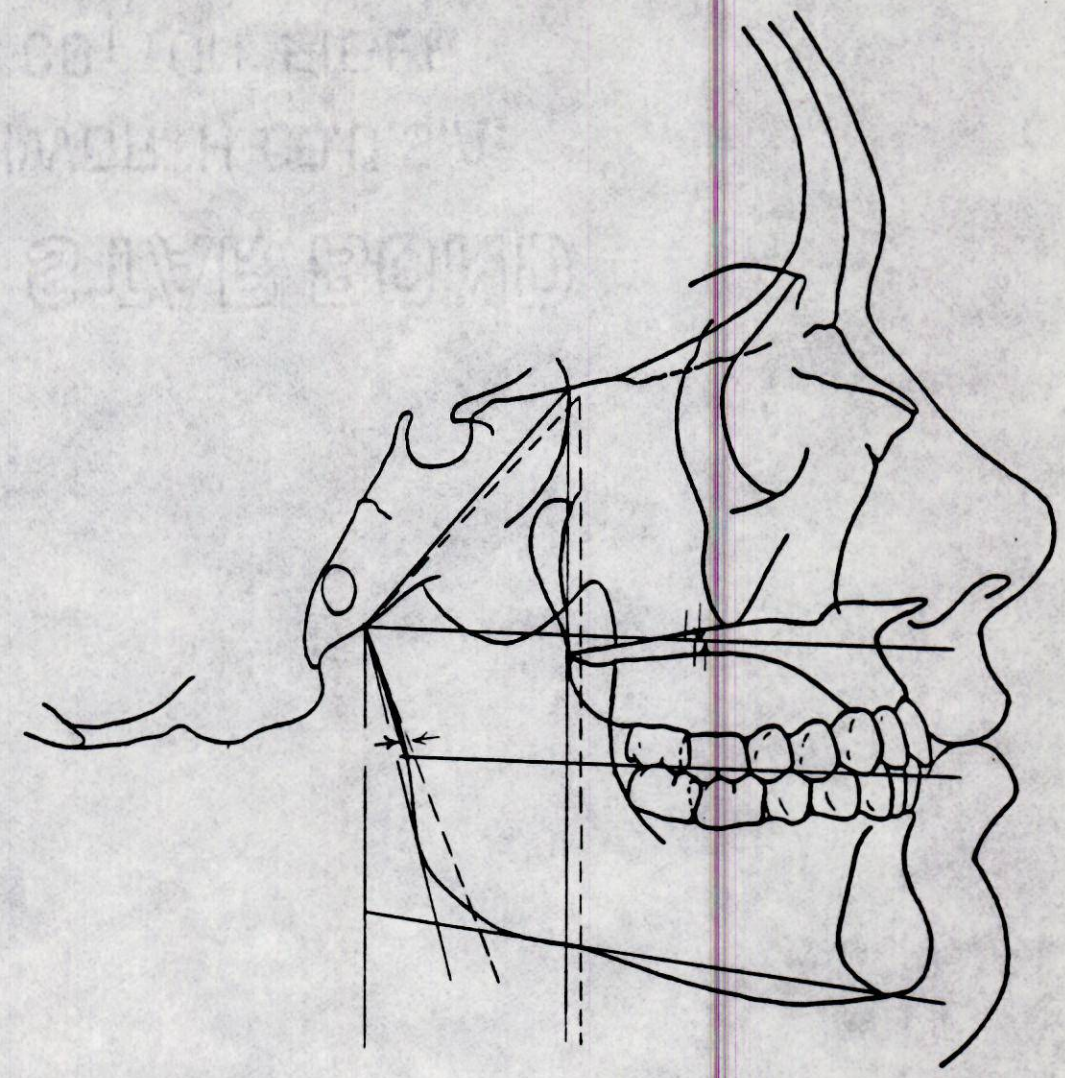


Figure 8. Molar positions (composite). Short vertical lines along REF indicate the distal surfaces of the maxillary and mandibular first molars. The measurement is made in millimeters along REF from Ar to the short vertical lines.

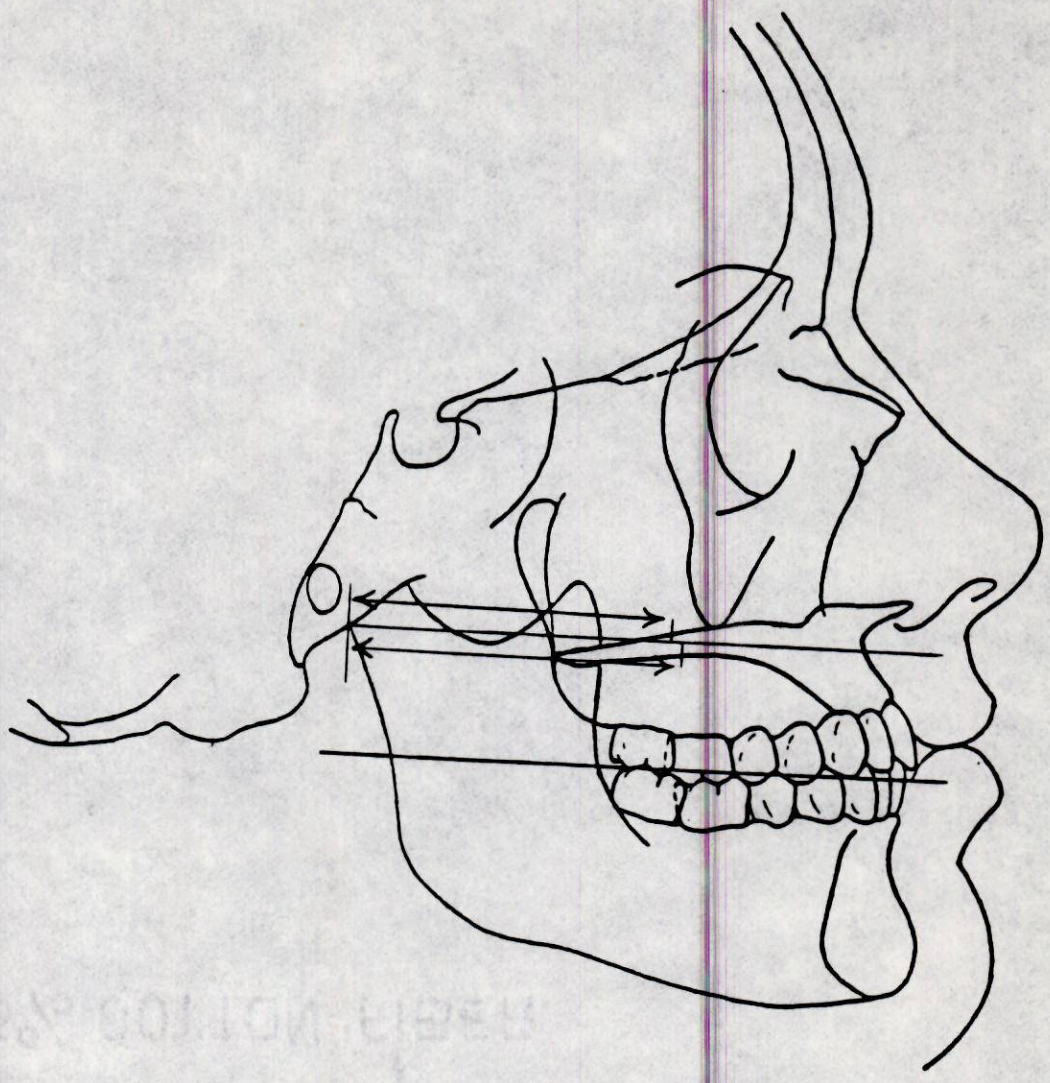


Figure 9. Maxillary/mandibular arches, skeletal dimensions, A point compared with B point. This diagram compares the length of the maxillary skeletal arch with the length of the mandibular skeletal arch. The maxillary skeletal arch is measured in millimeters from PM (solid line) along REF to A point.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

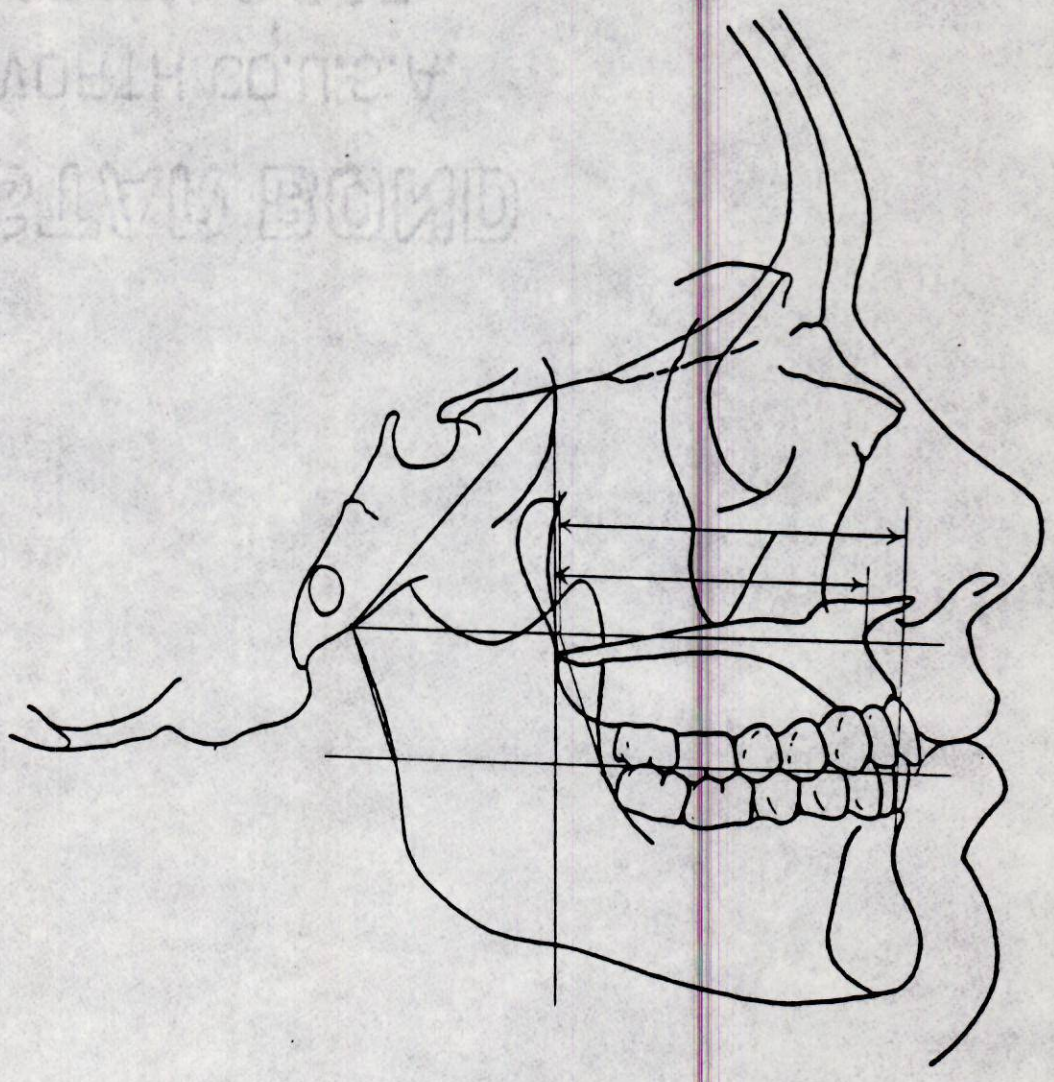


Figure 10. Maxillary/mandibular arches, dental dimensions, A point compared with B point. This is similar to the previous measurement except that the distances are measured to the distal surfaces of the first molars.

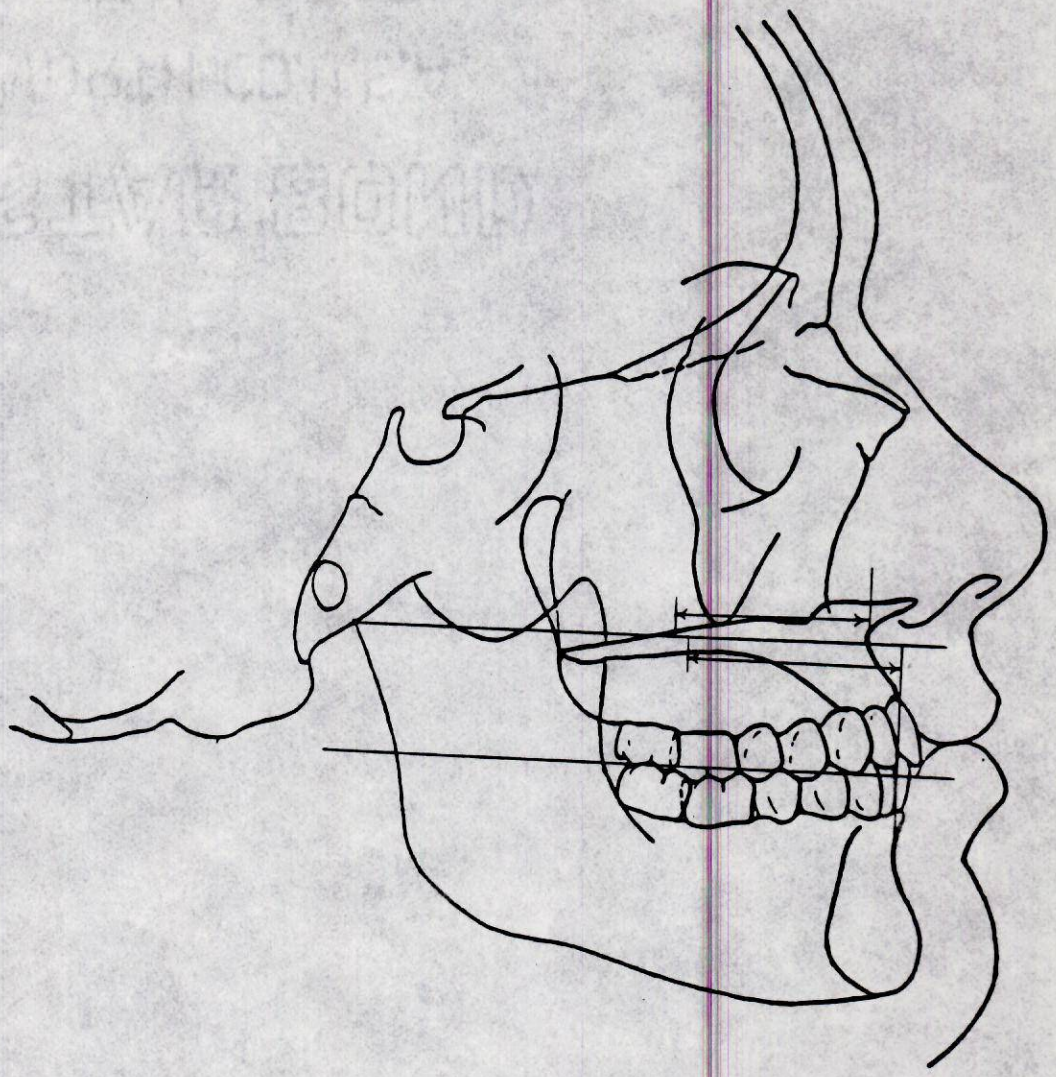


Figure 11. Maxillary/mandibular arches, skeletal dimensions, SPr compared with IPr. This comparison is identical to Figure 9 except that PM is measured to SPr and ARa is measured to IPr.

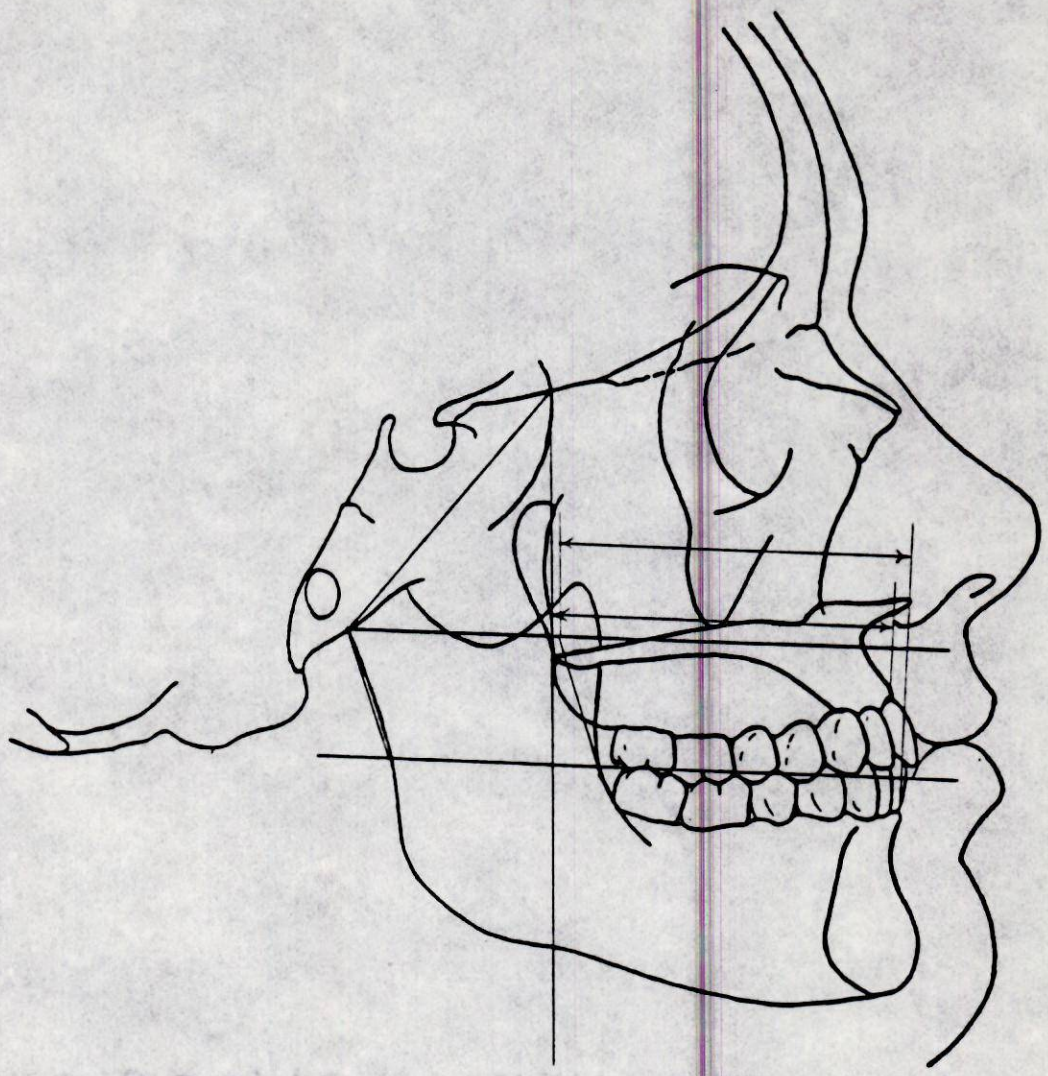


Figure 12. Maxillary/mandibular arches, dental dimensions, SPr compared with IPr. This measurement is identical to that in Figure 10 except that the distal of the maxillary first molar is measured to SPr and the distal of the mandibular first molar is measured to IPr.

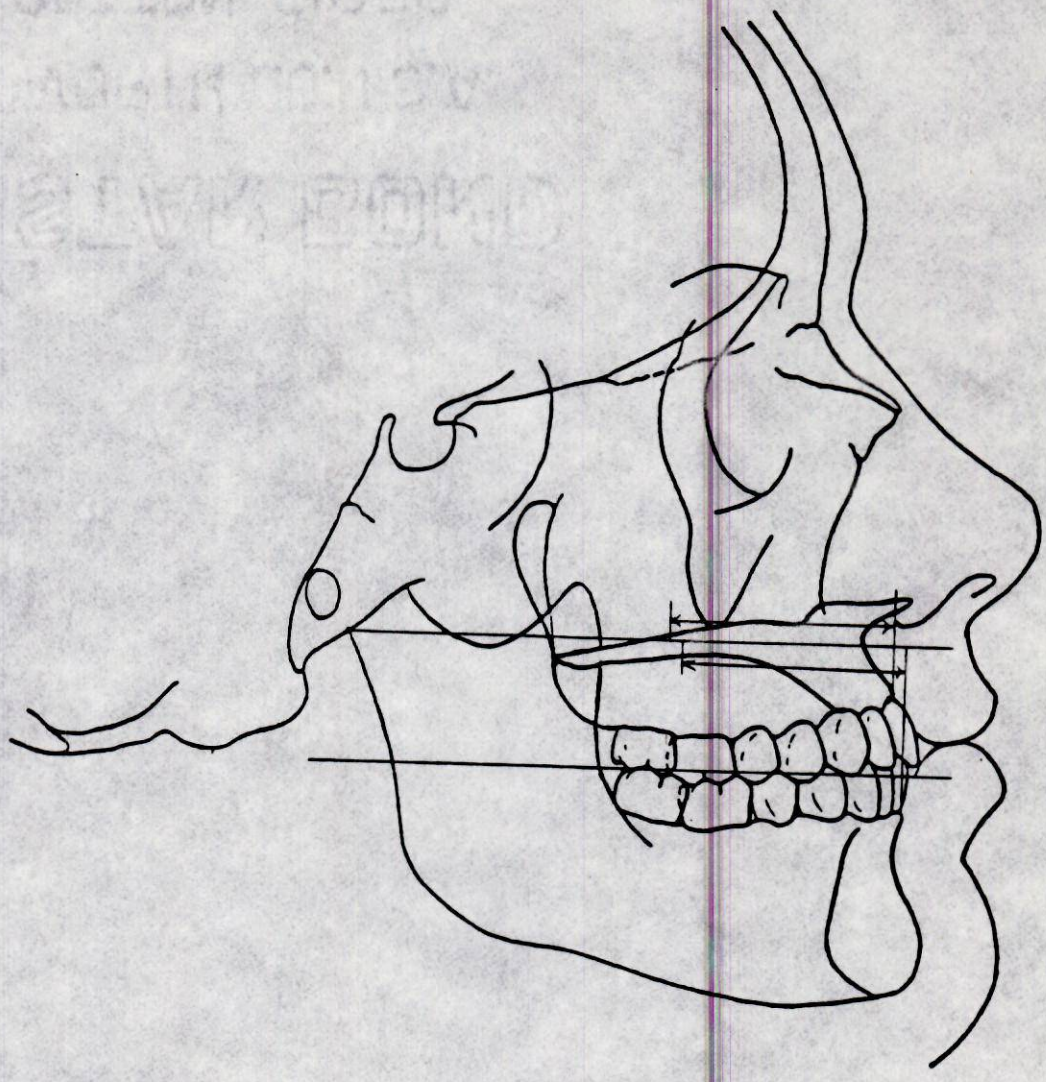


Figure 13. PM as compared with ramus/MCF vertical dimensions. The individual's relative posterior vertical nasomaxillary height is determined by this measurement. When the MCF rotates forward or backward, and the ramus rotates the same amount in the corresponding direction, no vertical disproportion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

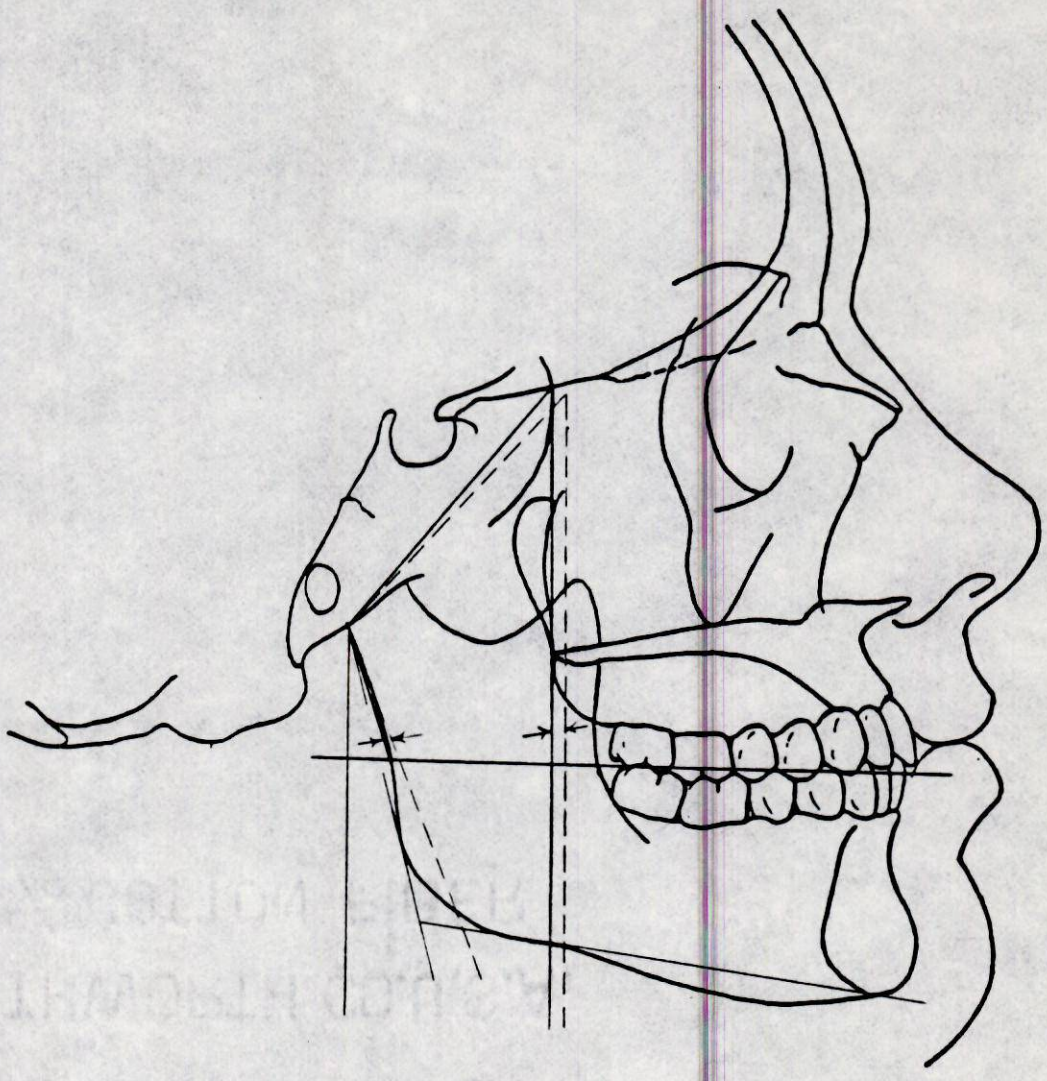


Figure 14. Corpus-occlusal alignment. This diagram demonstrates the extent of occlusal rotation as compared to the extent of ramus rotation. NOA acts as a reference line to determine the amount and direction of the occlusal rotation. NRa acts as a reference line to determine the amount of ramus rotation.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

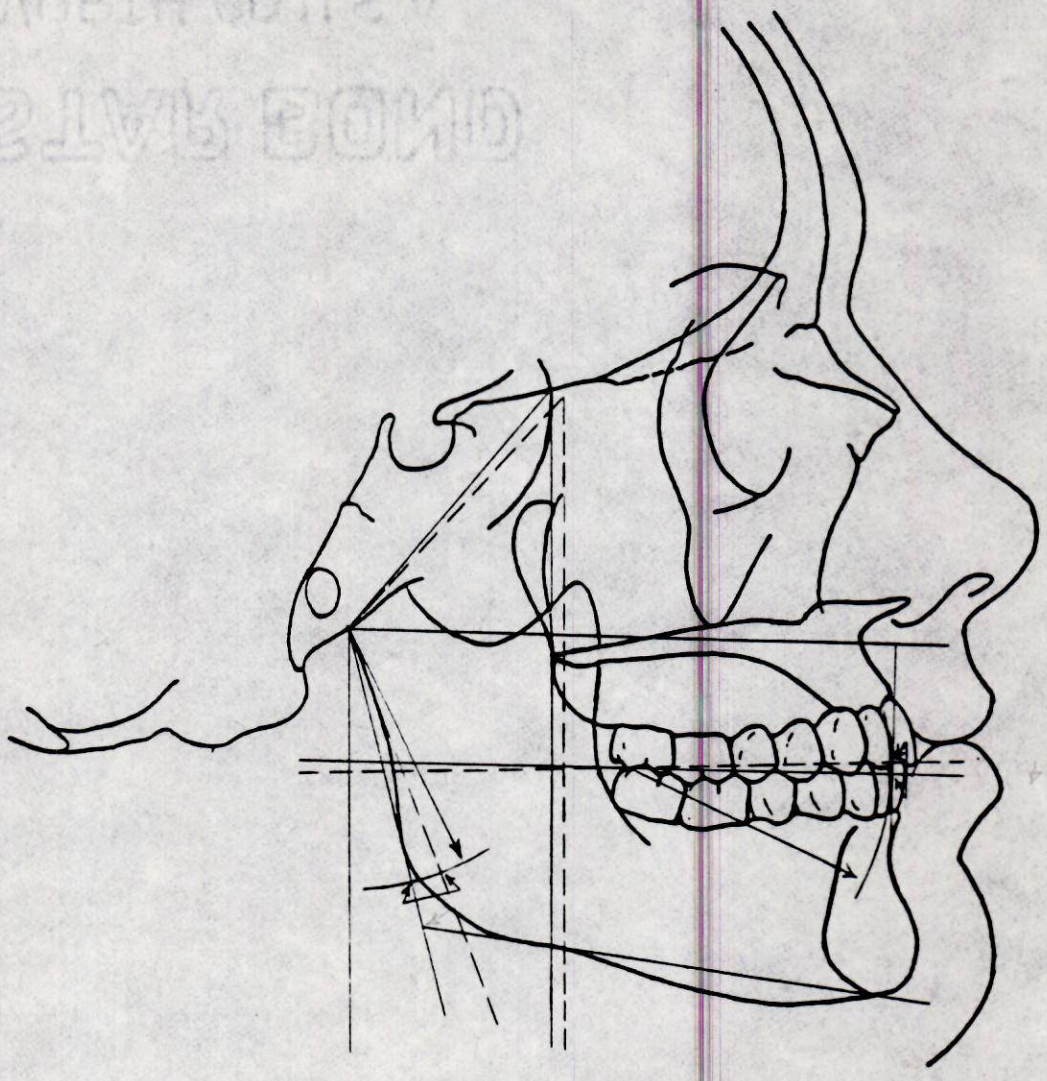


Figure 15. Vertical anterior maxillary plane. This diagram demonstrates the anterior boundary of growth of the nasomaxillary complex. A line from the most anterior point of the endocranial surface of the frontal bone (representing the frontal lobe of the cerebrum) is drawn perpendicular to a line from the posterior boundary of the cribiform plate to the anterior boundry of the cribiform plate. The distance from SPr to the perpendicular is measured in millimeters. If SPr is in front of the perpendicular it is a negative value, if SPr is behind the perpendicular it is a positive value. A negative value can normally be expected until full nasomaxillary growth is attained.

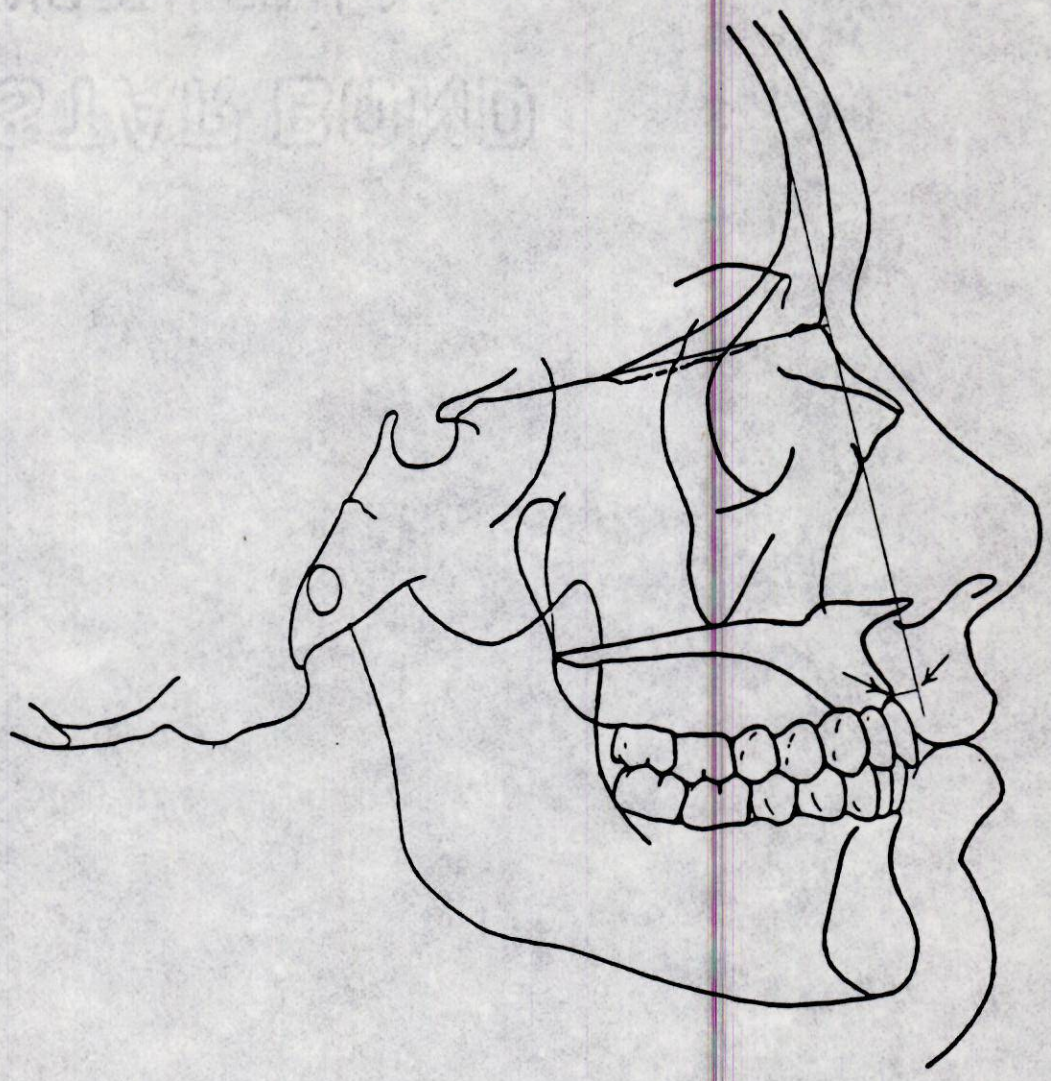


Figure 16. Mandibular plane alignment. The dashed line represents the neutral gonial angle as determined from the Michigan Standards (Riolo et al., 1975). The subject's mandibular plane is indicated by the line Me to Go. The distance between the neutral mandibular plane and the subject's mandibular plane is measured along the line through B point perpendicular to REF. If Me to Go is above the neutral mandibular plane, it is positive, if below, it is negative.

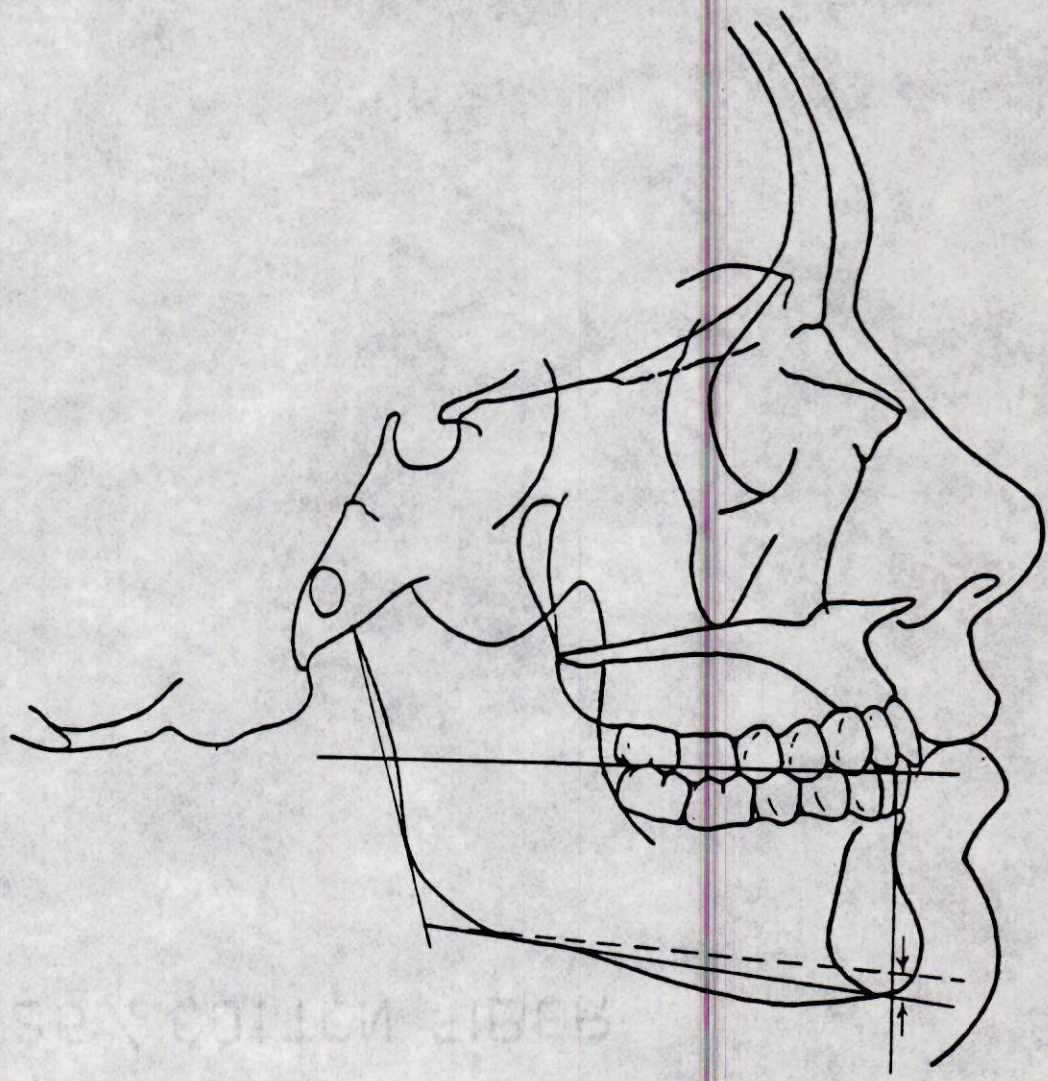


Figure 17. Gonial angle alignment. This diagram is similar to that in Figure 17. However, the measurement here is of two angles made in degrees. The neutral gonial angle and Ar to Go to Me.

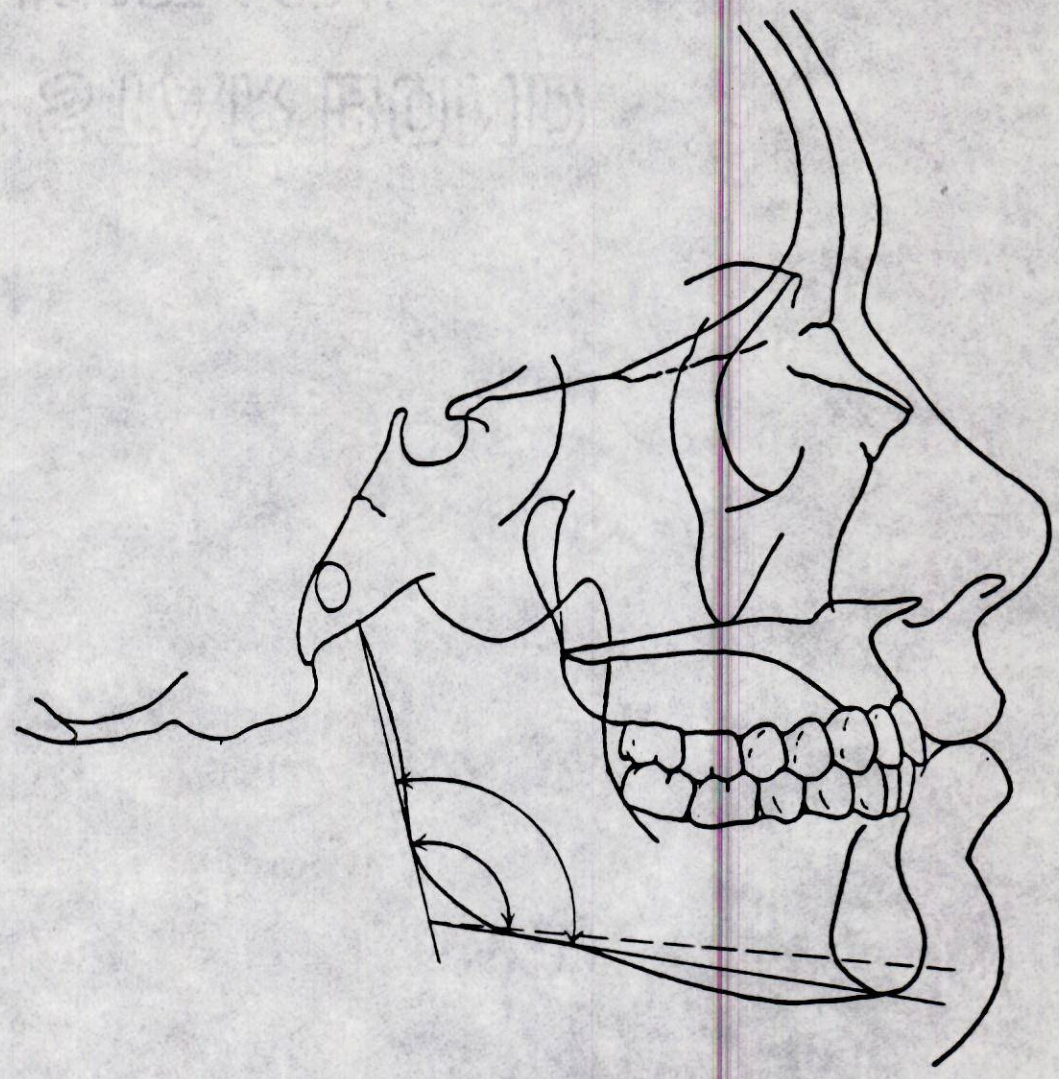


Figure 18. Occlusal plane alignment. This diagram demonstrates the direction and amount of occlusal plane rotation. The measurement is made between FOP and NOA along a perpendicular from IPr to FOP. If FOP is above NOA it is a positive number, if below NOA it is a negative number. Positive and negative values indicate counterclockwise and clockwise rotations, respectively.

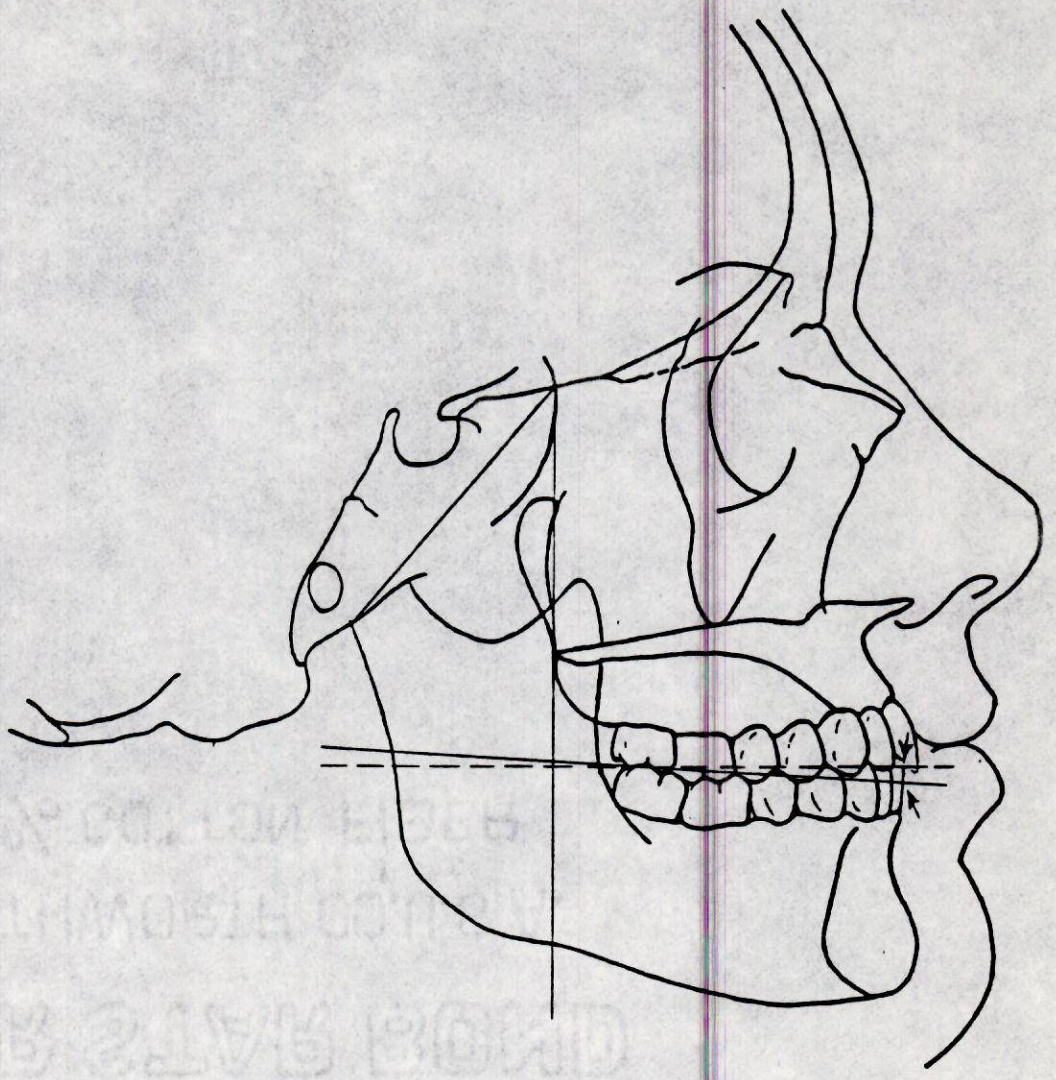


Figure 19. Curve of Spee. This is demonstrated by measuring the distance between the incisal edge of the mandibular central incisors and FOP. If the central incisors are above FOP it is a positive number, if below FOP it is a negative number.

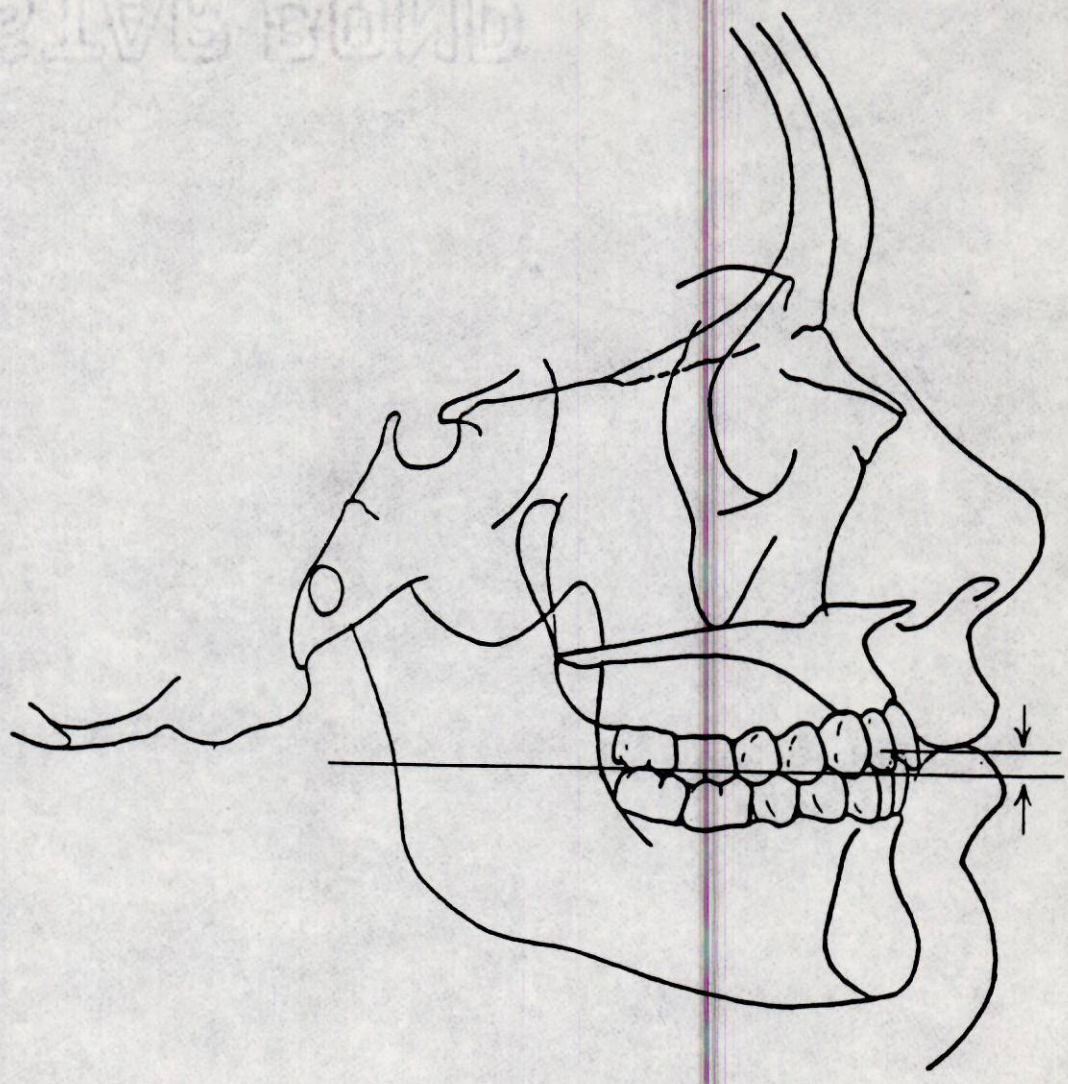


Figure 20. Inferior maxillary plane. This diagram demonstrates the alignments relationship between the inferior boundry of the nasomaxillary complex and the occipital fossa, theoretically representing the position establishing the inferior boundry for the nasomaxillary growth field. The line from SPr through the cementoenamel junction of the last fully erupted maxillary molar represents the inferior maxillary plane. The distance between this plane and occipital point is then measured. If IMP is above O it is a positive number, if IMP is below O it is a negative number. Positive and negative values represent clockwise and counterclockwise rotations, respectively, of IMP in relation to O.

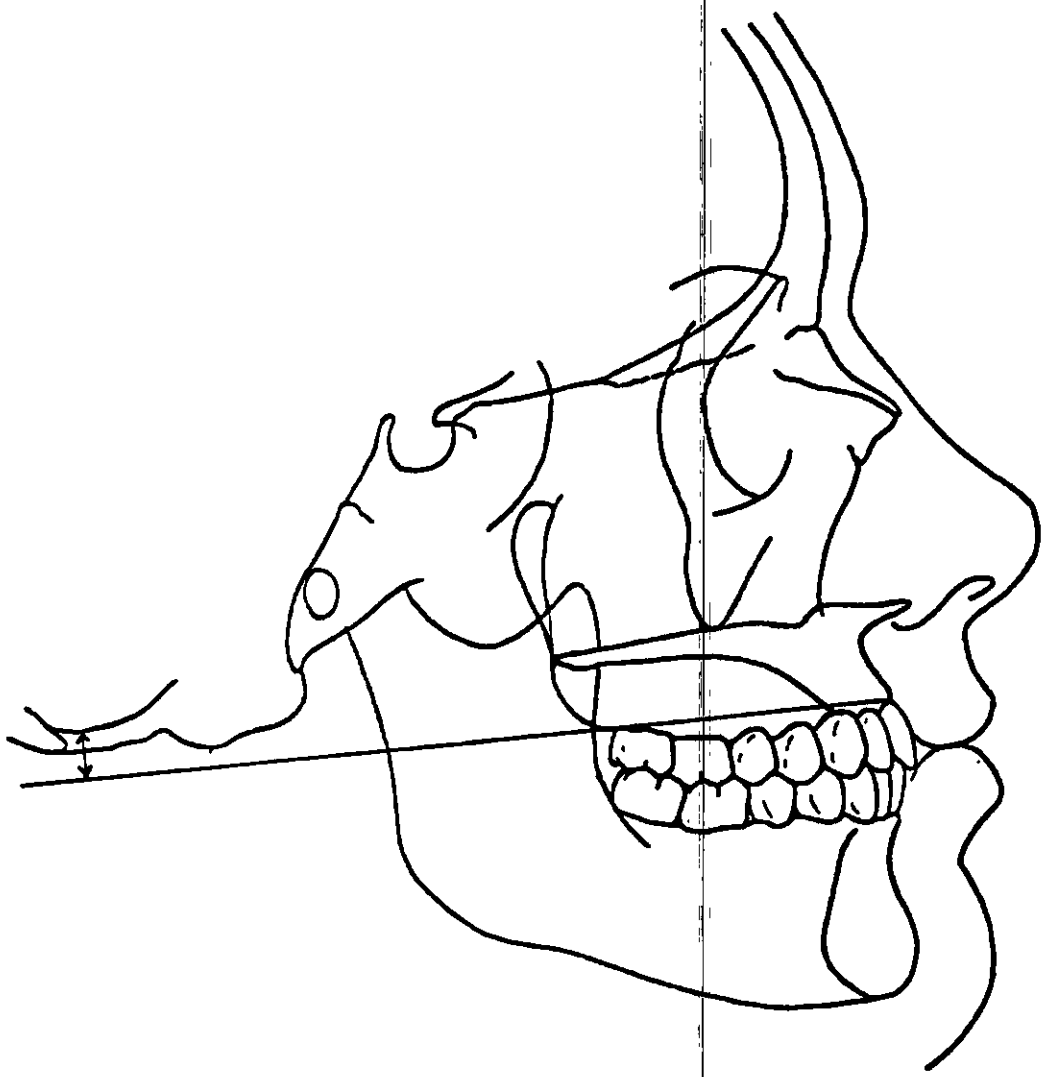


Figure 21. Palatal plane alignment. This diagram demonstrates the alignment between the palatal plane and the occipital fossa. The palatal plane is represented by the line from ANS through PNS. The distance between the plane and occipital point is measured. If the palatal plane is above O it is a positive number. If it is below O it is a negative number. Positive and negative values represent clockwise and counterclockwise rotations, respectively.

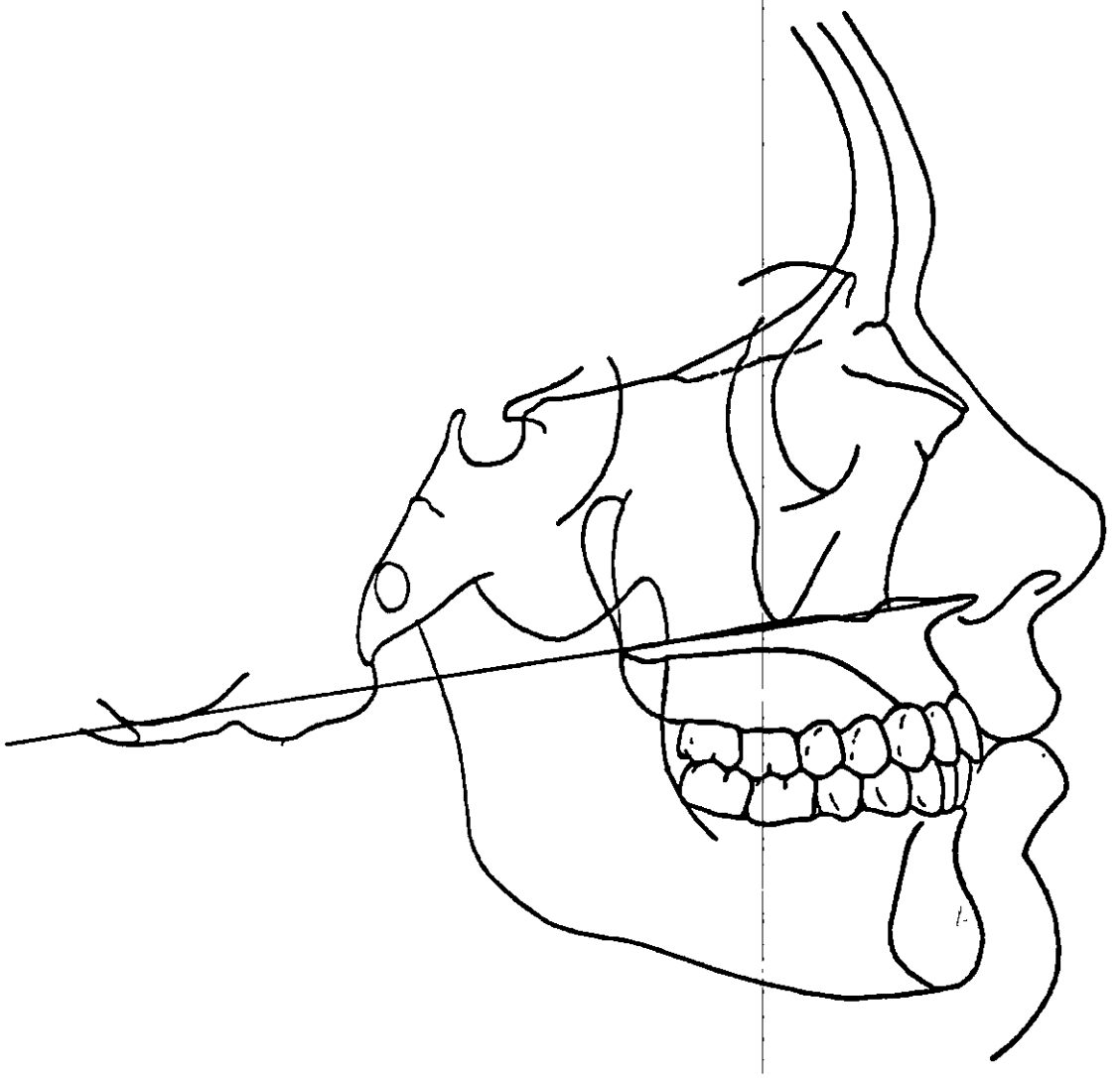


Figure 22. Maxillary nerve/palatal plane alignment. This diagram demonstrates the alignment relationship between the maxillary nerve and the palatal plane. The plane of the maxillary nerve is represented by a line from foramen rotundum in the pterygomaxillary fissure to a point 3 mm above orbitale (representing the course of the nerve prior to its downturn into the orbital floor). The palatal plane is determined as illustrated in Figure 21. An angular intersection is made between these two planes. If the angle is zero, the planes are in a neutral position. If the vertex of the angle is behind the subject, the angle is positive and indicates a clockwise rotational alignment of the palate. If the vertex is in front of the patient, the angle is negative and indicates a counterclockwise rotational alignment of the palate relative to the maxillary nerve.

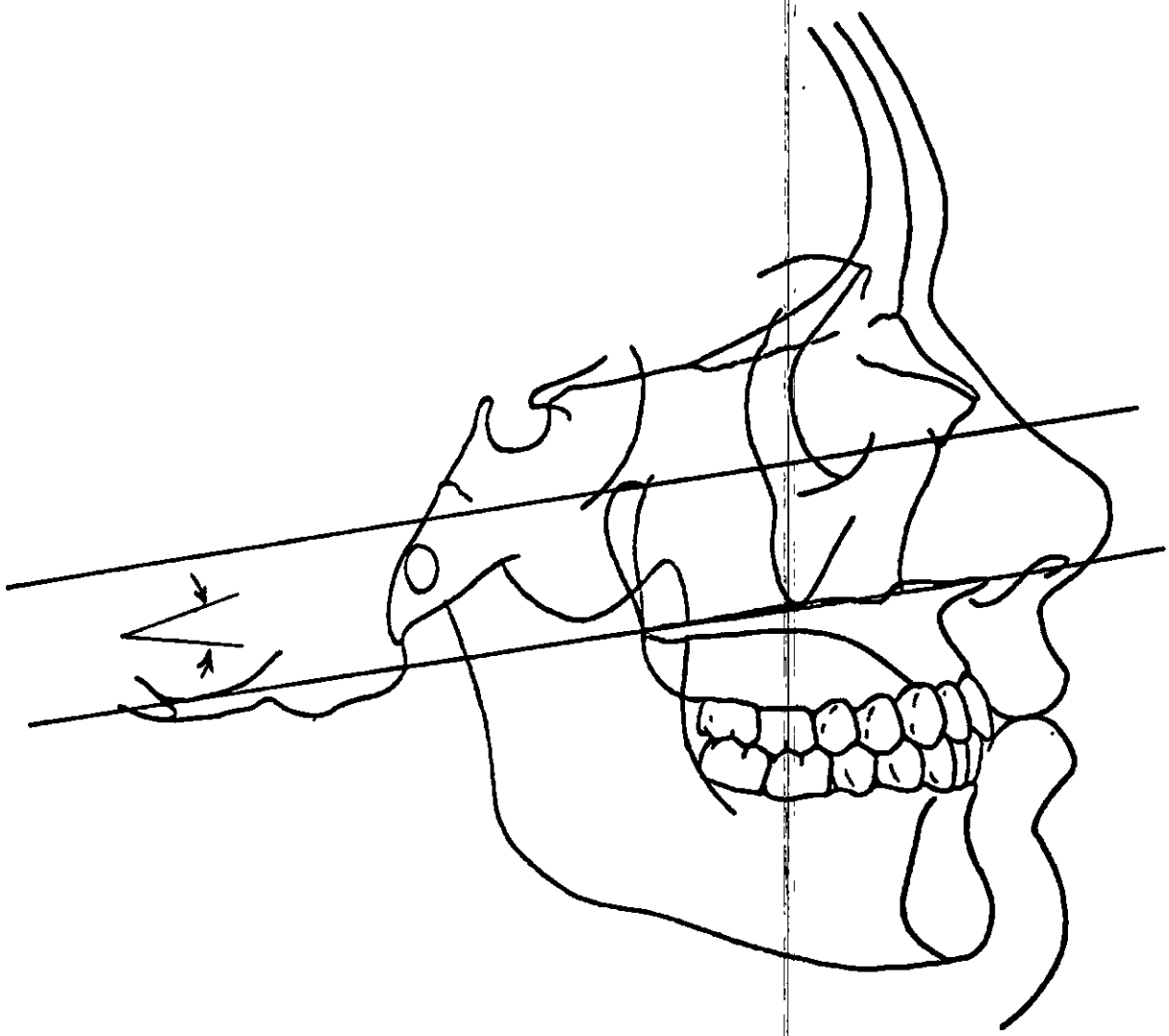
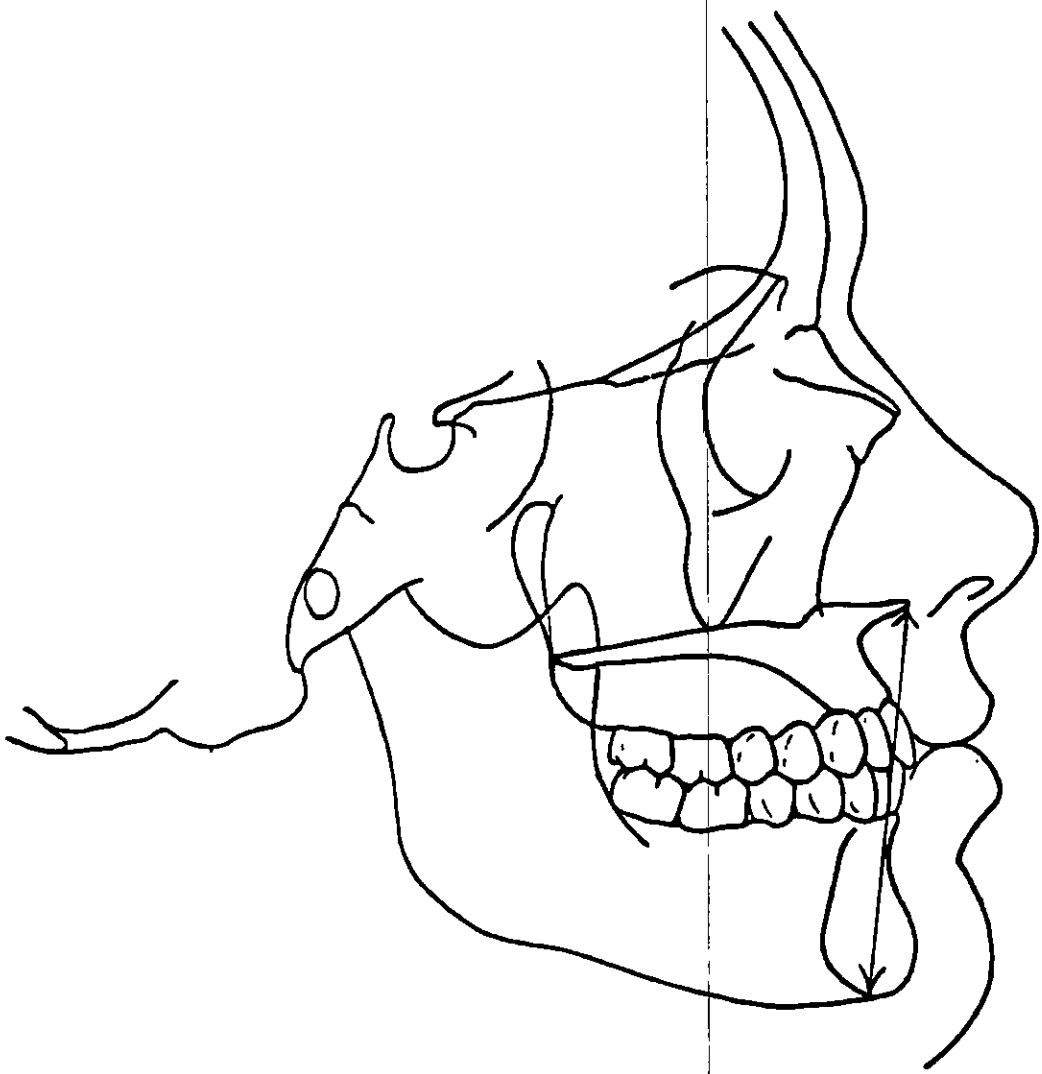


Figure 23. Lower anterior facial height. This diagram demonstrates the height of the lower face (defined here as that facial space from the palate to the inferior border ot the mandible). It is measured from ANS to Me as determined by McNamara (1982).



RESULTS

1. Aggregate cranial floor/maxilla and ramus/corpus horizontal dimension at A point and B point. Groups II, III, and IV demonstrated an increase in the overall, composite dimension of the aggregate cranial floor/maxilla relative to the ramus/corpus horizontal dimension, indicating a maxillary protrusive effect. The greatest change among these groups was demonstrated by Group III, which also exhibited a rebound change toward the neutral position at post-retention. Group V demonstrated the opposite effect as the ramus/corpus horizontal dimension at B point increased relative to the cranial floor/maxilla dimension at A point, indicating a mandibular protrusive effect. Group I also exhibited an increase in mandibular protrusion as the ramus/corpus dimension increased relative to the cranial base/maxilla dimension.

2. Aggregate cranial floor/maxilla and ramus/corpus horizontal dimension at SPr and IPr. Groups II, III, and IV demonstrated a change during treatment that produces a mandibular protrusive effect. Group I demonstrated a change during the time studied resulting in a maxillary protrusive effect.

3. Middle cranial fossa (MCF) and posterior maxillary (PM) relative alignment. This relationship is made relative to a population mean. Groups II and III expressed a change in this alignment during treatment resulting in a maxillary retrusive tendency. The control group also demonstrated a maxillary retrusive tendency in the time period examined. Groups IV and V had similar changes but of a much smaller magnitude.

4. Ramus alignment. The vertical ramus plane of Group I demonstrated no change in the time period examined. Groups II and III demonstrated a change in the alignment of the vertical ramus plane in a posterior direction producing a mandibular retrusive effect. Group V demonstrated a mandibular protrusive change as the vertical ramus plane moved anteriorly with treatment. Maxillary protrusive changes seen in Group IV relapsed at post-retention.

5. Ramus/MCF horizontal dimensions (skeletal). The horizontal dimension of the ramus becomes "shorter" in relation to the horizontal dimension of the MCF for all five groups. This results in a maxillary protrusive effect as the middle cranial fossa displaces the maxilla in an anterior direction to a greater extent than the ramus displaces the corpus of the mandible forward. It is interesting to note that the change in Group V is much less than that observed in the other groups. Also, at the time of post-retention for Groups II, III, and IV. The "distalization" of the anterior ramus relative to PMN had increased further. Therefore, the maxillary protrusive effects are greatest in Groups II, III, and IV, and least in Group V.

6. Ramus/MCF horizontal dimension (dental). The neutral molar positions represent the maxillary and mandibular first molars relative to each other without skeletal rotational effects. Groups I, III and IV demonstrate neutral molar position changes that produce a maxillary protrusive tendency. In Group III this tendency continued to post-retention. The The change in neutral molar position for Groups II and V indicate a mandibular protrusive tendency. The tendency for this change in Group II, however, completely rebounded.

7. Molar positions (composite). The composite molar positions represent the maxillary and mandibular first molars as they relate to each other including the rotational effects of the cranial floor and ramus alignment. The change in composite molar position over the time period examined for Groups I, III, and V produced a mandibular protrusive tendency. This tendency was least for Group I and greatest for Group V. With treatment, Group II demonstrated a maxillary protrusive tendency. However, between the end of treatment and post-retention Group II relapsed significantly.

8. Maxillary/mandibular arches, skeletal dimensions, A point compared with B point. The mean changes for the treatment periods of Groups I, II, IV, and V demonstrates the mandibular skeletal arch horizontal dimension increasing relative to the maxillary skeletal arch horizontal dimension. The mean change observed for Group III produced a maxillary protru-

sive tendency. This tendency, however, began to reverse between the end of treatment and post-retention.

9. Maxillary/mandibular arches, dental dimensions, A point compared with B point. Groups I, IV, and V demonstrated very small maxillary protrusive tendencies. Groups II and III demonstrated a more significant maxillary protrusive change. Significant relapse, however, was also noted for Group III.

10. Maxillary/mandibular arches, skeletal dimensions, SPr compared with IPr. The increase in mandibular horizontal skeletal dimension measured to IPr for the treatment periods examined was greater than the increase in maxillary horizontal skeletal dimensions to SPr for Groups II, III, IV, and V. Also, this tendency continued to post-retention. Group I showed a slight maxillary protrusive tendency.

11. Maxillary/mandibular arches, dental dimensions, SPr compared with IPr. Groups I, IV, and V demonstrate a very small mandibular protrusive change during active treatment. Groups II and III both demonstrate a maxillary protrusive change during treatment that is lost at post-retention.

12. PM as compared with ramus/MCF vertical dimensions. In examining the mean change in the relative vertical length of the PM the tendency in Group I was to become slightly longer, producing a maxillary protrusive effect. In Groups II and III the relative vertical length of the PM also lengthened but to a greater extent than in Group I. After active treatment this tendency continued in Group II, whereas with Group III rebound occurred. In Group IV, no change in this dimension occurred. In Group V a mandibular protrusive change occurred as the vertical length of the PM decreased.

13. Corpus/occlusal alignment. In Group I the corpus occlusal rotations nearly equaled the ramus rotations. With Groups II and III however, the downward and backward ramus rotation was greater than the downward corpus/occlusal rotation resulting in a mandibular retrusion effect. At post-retention, this change continued for Group II, but reversed for Group III. Group III had a slight rotational change in the direc-

tion of mandibular protrusion, which also rebounded at post-retention. Group V had a significant change toward mandibular protrusion as the posterior ramus was repositioned anteriorly and the corpus/occlusal rotation was downward and back.

14. Vertical anterior maxillary plane. In Groups I and V maxillary protrusive effects were observed as SPr moved anteriorly relative to the vertical anterior maxillary plane. In Groups II, III and IV the change during treatment was for SPr to move slightly posterior relative to the vertical anterior maxillary plane. This direction, however, reversed by the time of post-retention, the net effect being SPr moved anteriorly from the beginning of treatment until post-retention.

15. Mandibular plane alignment, gonial angle alignment. Relative to the neutral gonial angle, Groups IV and V demonstrated a slight opening of the gonial angle, Group I demonstrated a small opening, and Group III a significant opening producing a mandibular protrusive effect. Group II demonstrated a closing of the gonial angle with treatment resulting in a relative mandibular retrusion. It is interesting to note that no relapse in gonial angle took place and that in Groups III and IV the gonial angle deviation continued just as the closing of the gonial angle continued in Group II after treatment to post-retention.

16. Occlusal plane alignment. In Group I FOP did not change in relation to NOA. Group III demonstrated a significant upward rotation during the treatment period which partially relapsed afterward, whereas Group II demonstrated a small upward rotation during treatment that continued following treatment. The net effect for these two groups is a maxillary protrusive influence. While Group IV demonstrated no change in occlusal plane alignment during treatment, Group V demonstrated a significant mandibular protrusive effect as FOP rotated downward in relation to NOA.

17. Curve of Spee. The Curves of Spee during the treatment period of Groups II, III, IV, and V all increased, exhibiting a maxillary protrusive effect. The Curve of Spee for Group I decreased slightly over the time period examined, producing a mandibular protrusive effect.

18. Inferior maxillary plane. Groups I, II, and III demonstrated significant changes in a downward direction of IMP relative to occipital point. Groups II and III also continued to change in this same direction following treatment. In contrast, Group V demonstrated a significant upward rotation of IMP relative to occipital point.

19. Palatal plane alignment. The palatal plane in Group I had a tendency to rotate upward in relation to occipital point. The palatal planes in Groups III and IV rotated upward in relation to occipital point to a greater extent during treatment, but had a tendency to relapse after treatment. Groups II and V demonstrated downward palatal rotations relative to the occipital fossa.

20. Maxillary nerve/palatal plane alignment. Very little deviation occurred as a net result in this relationship in the time periods examined. The greatest deviation was observed in Group IV during treatment, however, this change completely rebounded after treatment.

21. Lower anterior facial height. Only during the treatment period of Group II was any decrease in anterior facial height observed. This decrease, however, was not maintained and as in Groups I, III, and V the lower anterior facial height increased significantly. Group III increased the most while Group V exhibited similar changes to Group I. Group IV demonstrated a very small increase in lower anterior vertical dimension.

Descriptive Statistics

The mean treatment changes and post-treatment changes for all subjects and the standard deviations of these changes are presented in graph form in Tables III to XXIV, and in numerical form in Tables XXV to XXIX.

Inferential Statistics

The treatment and post-treatment changes for Group VI

TABLE III

AGGREGATE CRANIAL FLOOR/MAXILLA AND RAMUS/CORPUS HORIZONTAL DIMENSIONS AT A POINT AND B POINT
(Variable #1)

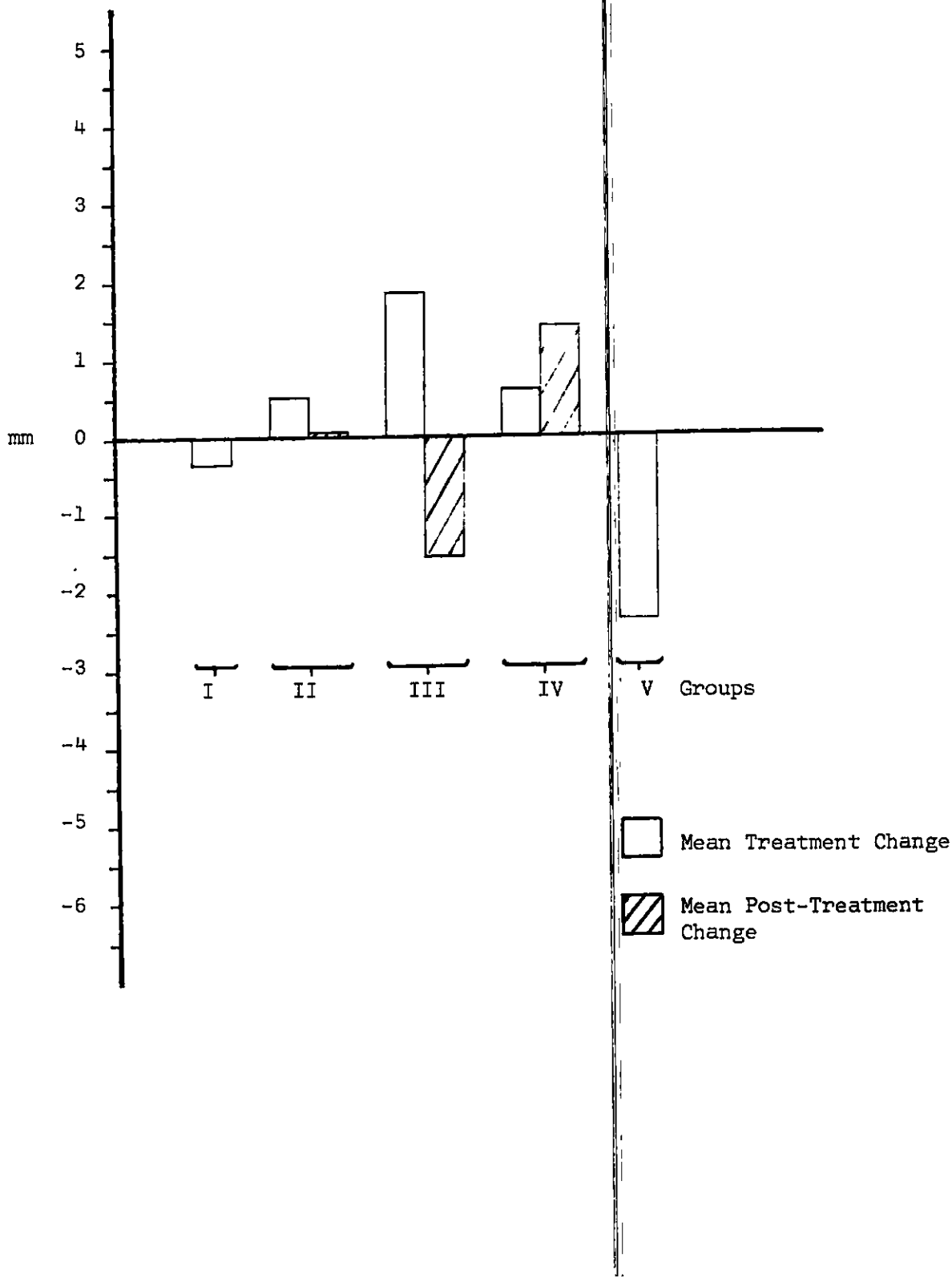


TABLE IV

AGGREGATE CRANIAL FLOOR/MAXILLA AND RAMUS/CORPUS
HORIZONTAL DIMENSIONS AT SPr AND IPr
(Variable #2)

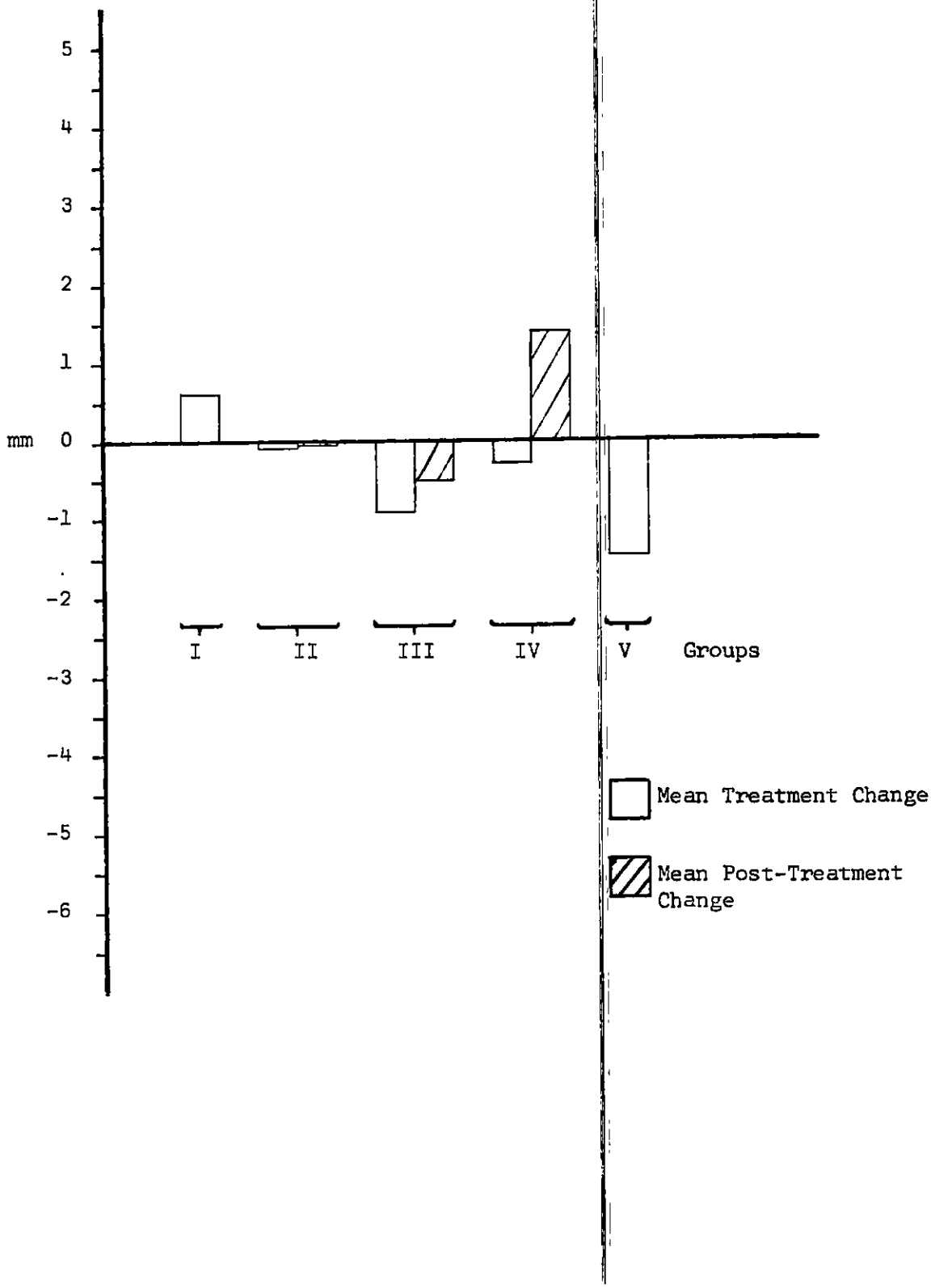


TABLE V

MIDDLE CRANIAL FOSSA (MCF) AND POSTERIOR MAXILLARY (PM) RELATIVE ALIGNMENT
(Variable #3)

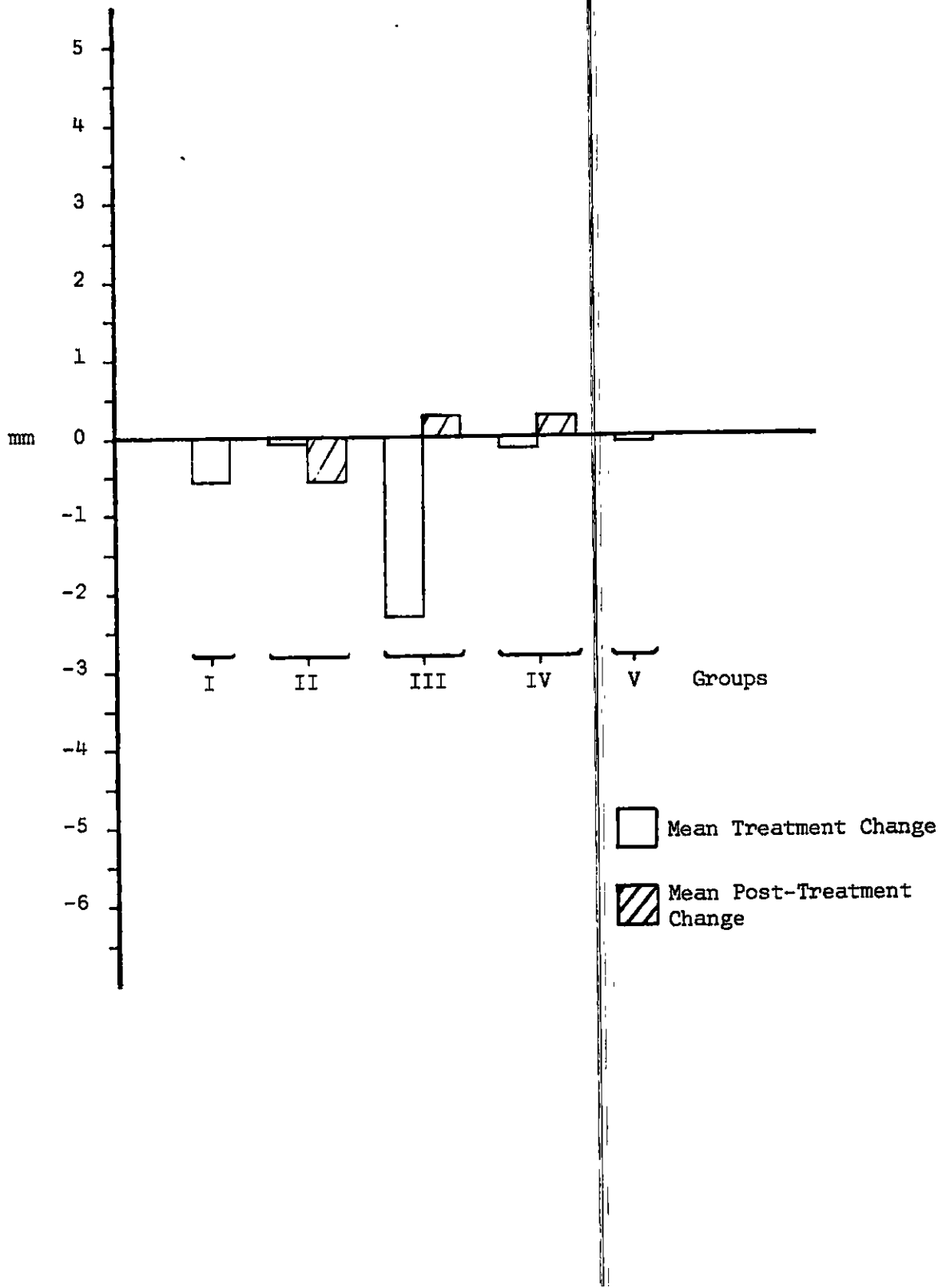


TABLE VI

RAMUS ALIGNMENT
(Variable #4)

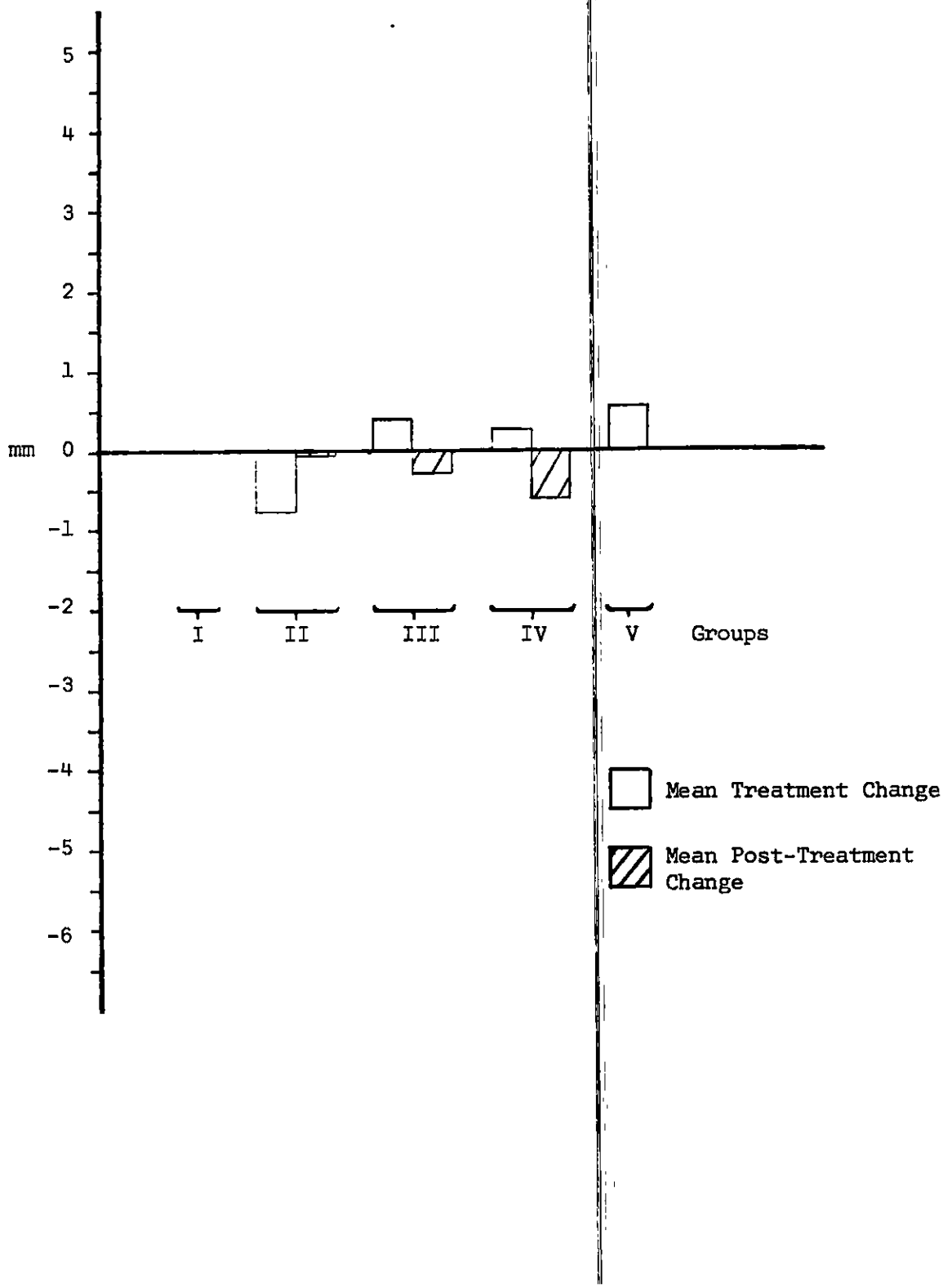


TABLE VII

RAMUS/MCF HORIZONTAL DIMENSION (SKELETAL)
(Variable #5)

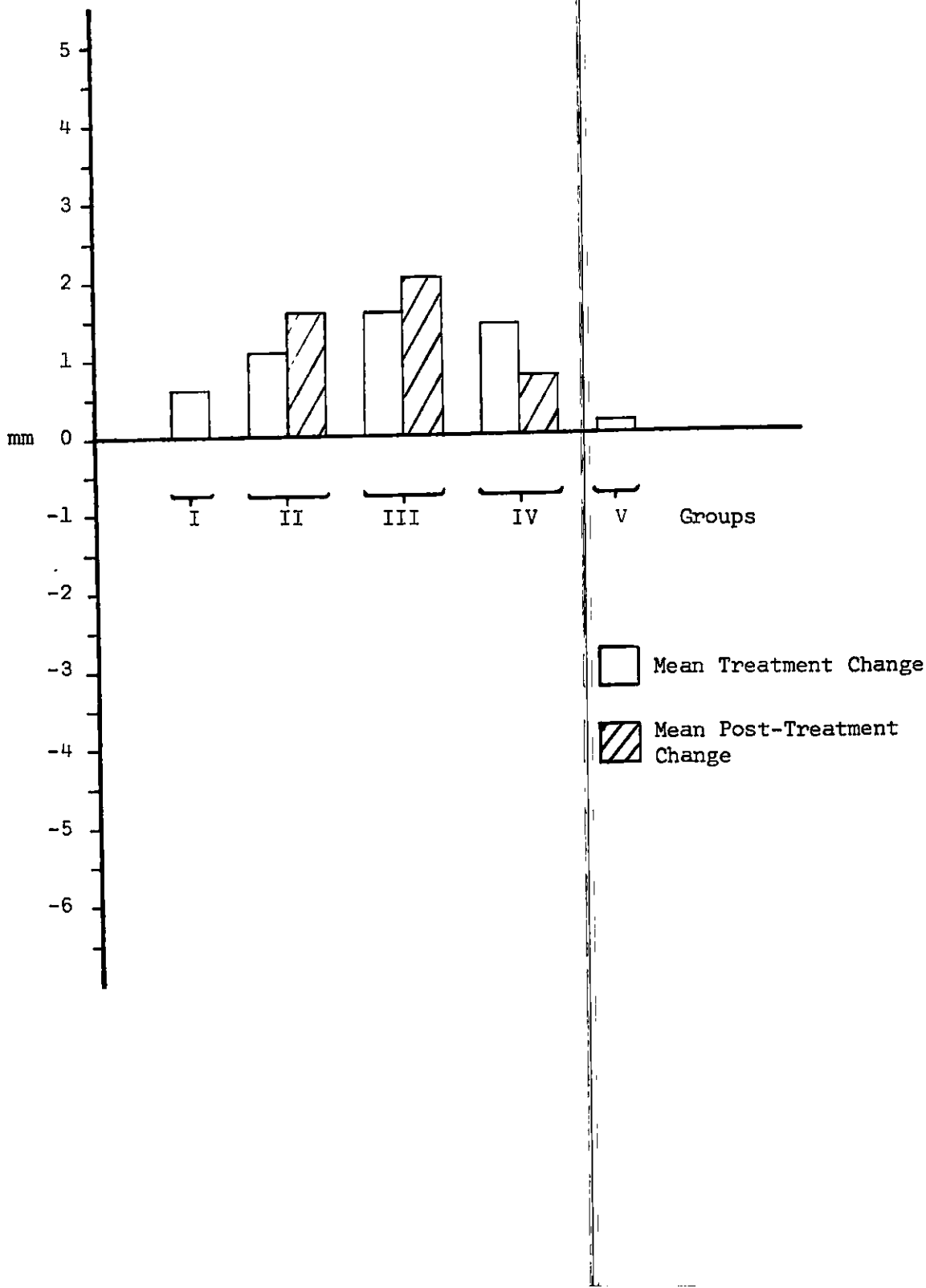


TABLE VIII

RAMUS/MCF HORIZONTAL DIMENSION (DENTAL)
(Variable #6)

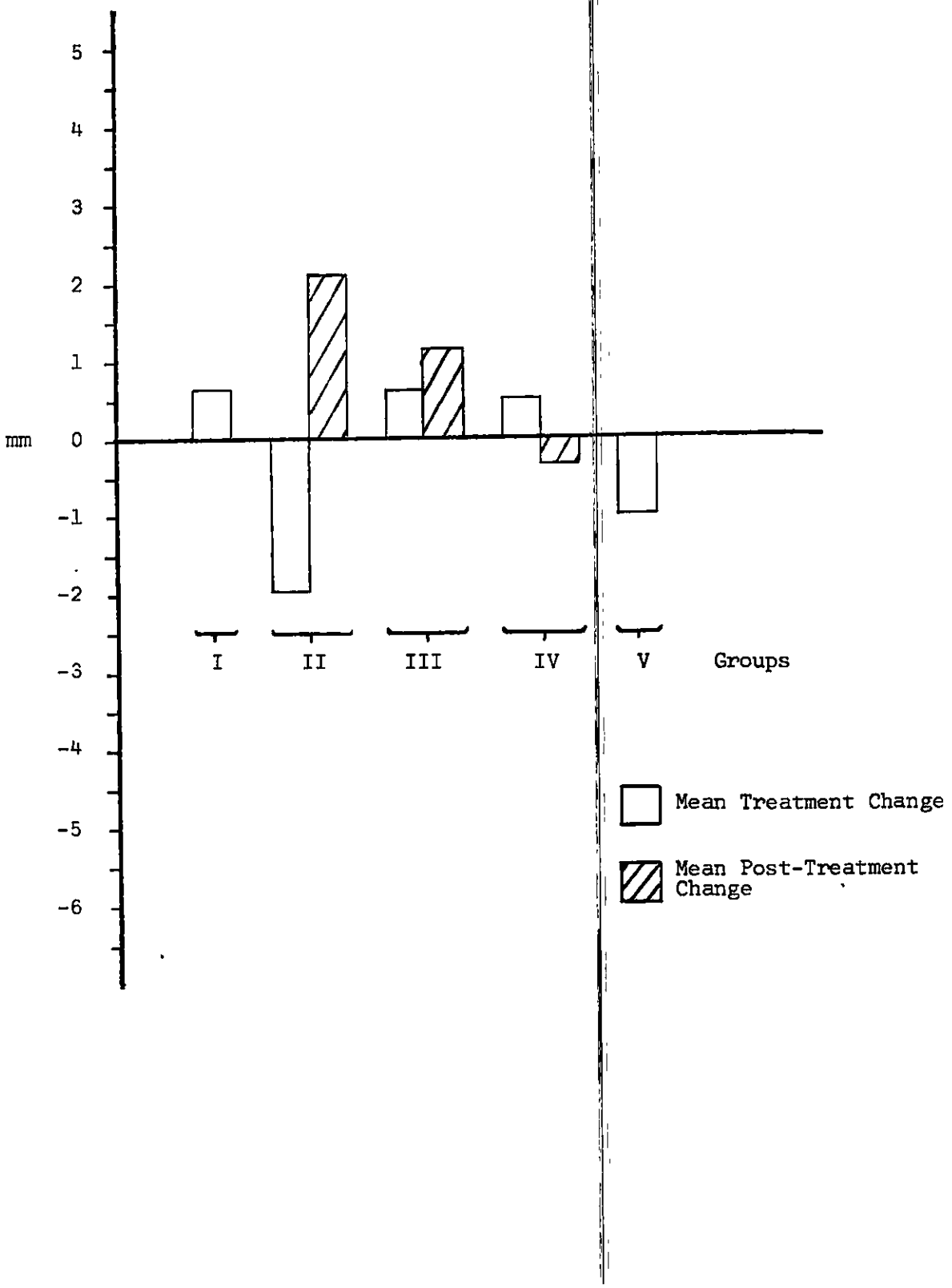


TABLE IX

MOLAR POSITION (COMPOSITE)
(Variable #7)

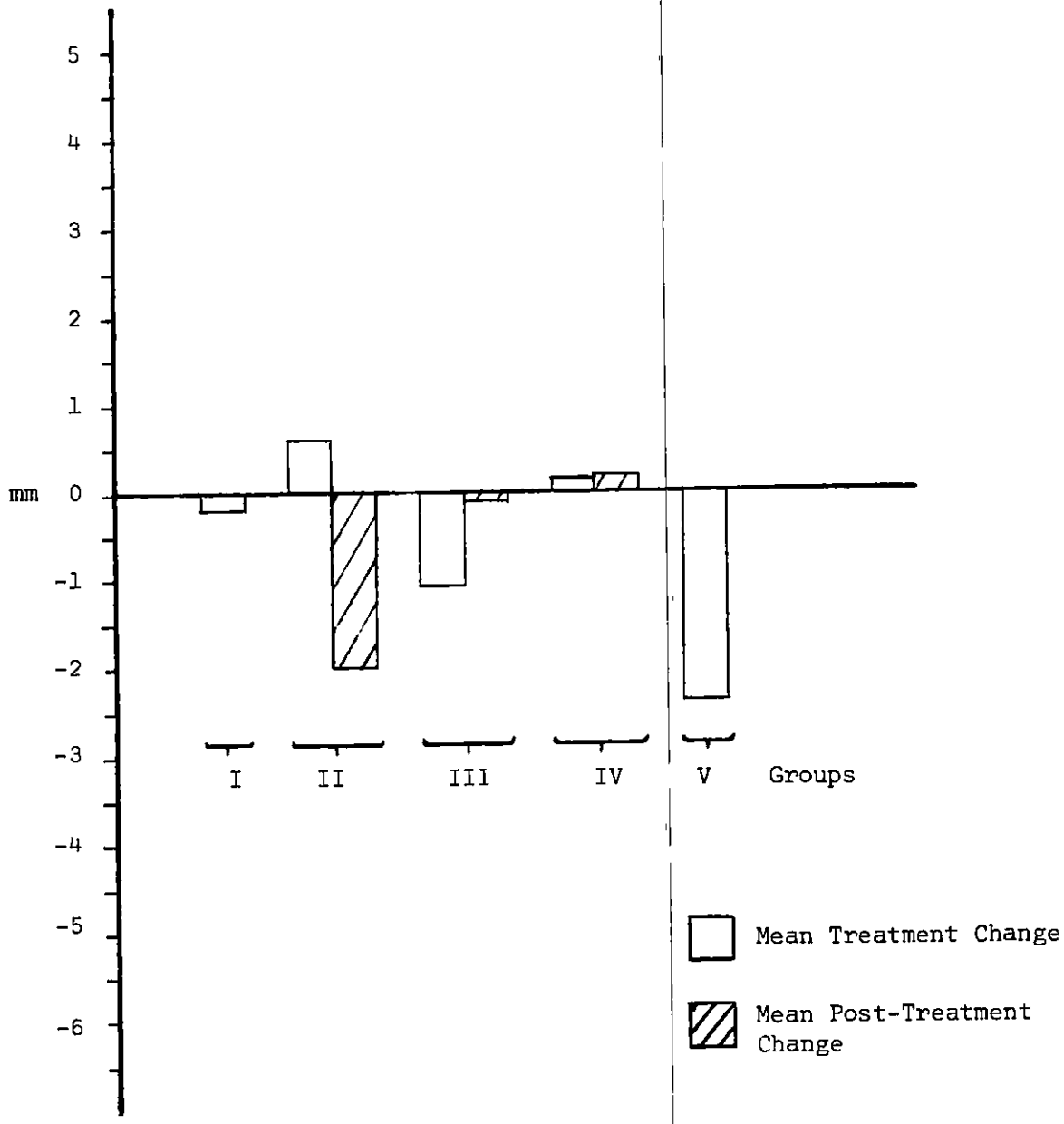


TABLE X

MAXILLARY/MANDIBULAR ARCHES, SKELETAL DIMENSIONS,
A POINT COMPARED WITH B POINT
(Variable #8)

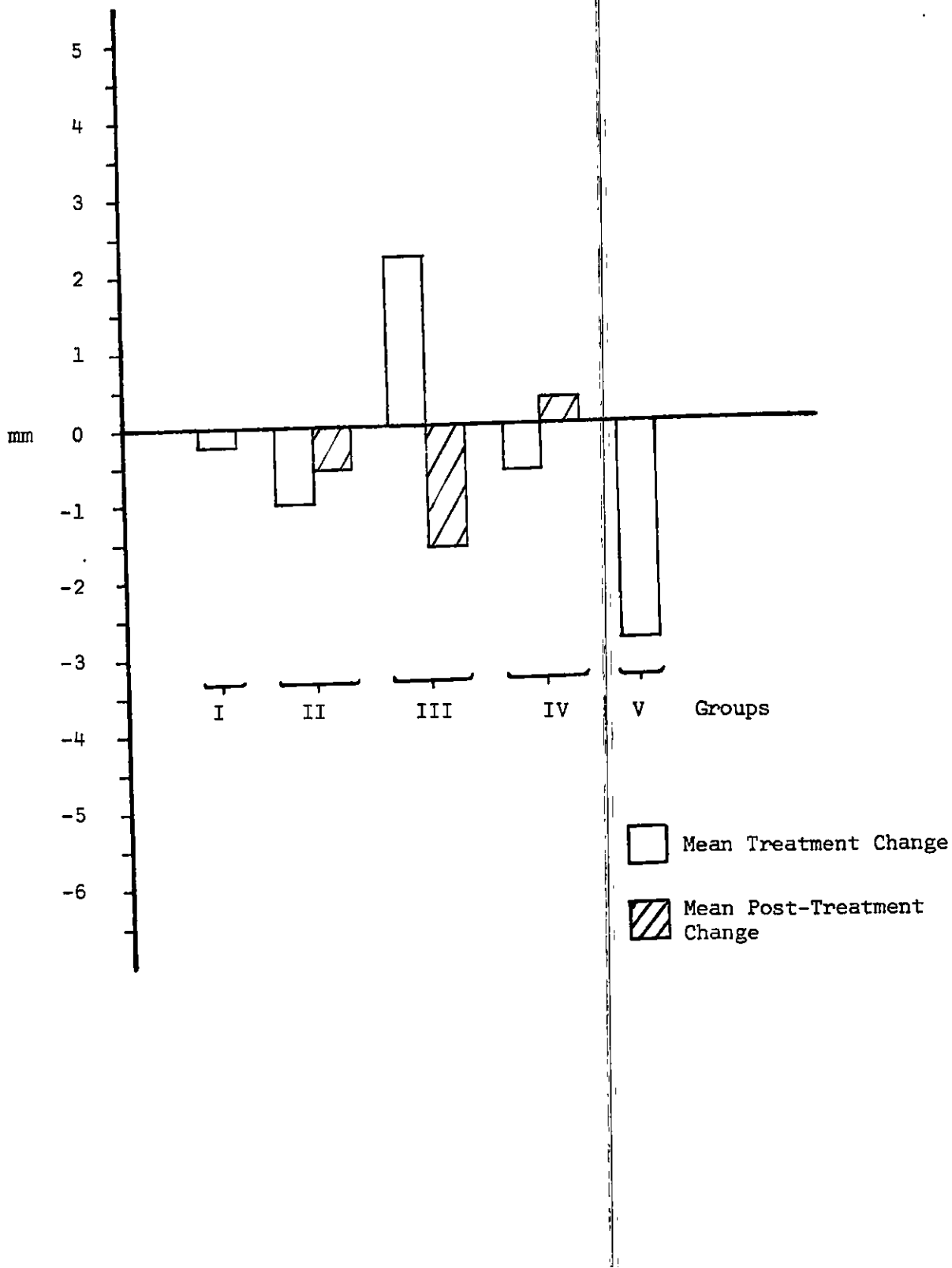


TABLE XI

MAXILLARY/MANDIBULAR ARCHES, DENTAL DIMENSIONS,
A POINT COMPARED WITH B POINT
(Variable #9)

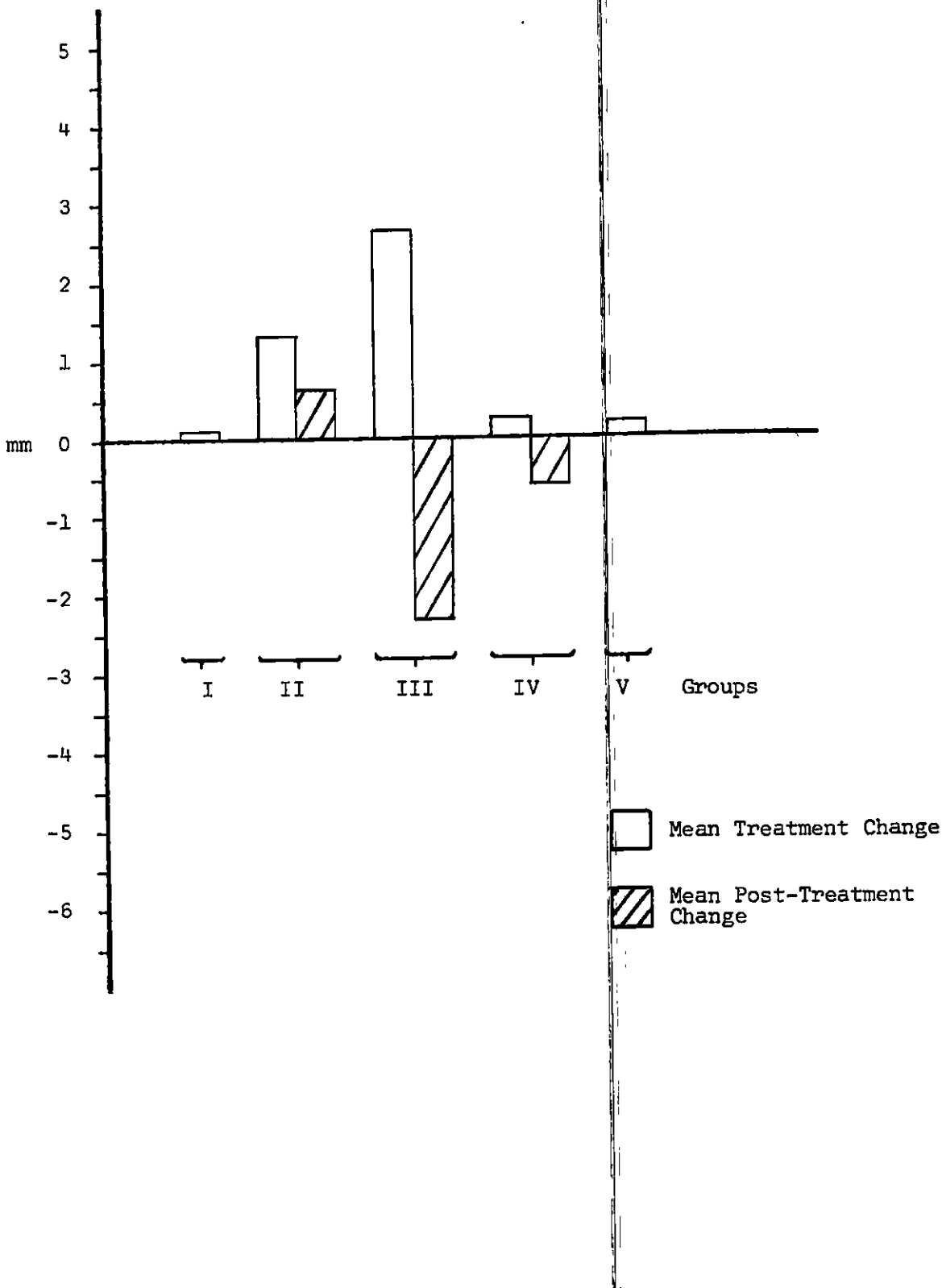


TABLE XII

MAXILLARY/MANDIBULAR ARCHES, SKELETAL DIMENSIONS,
SPr COMPARED WITH IPr
(Variable #10)

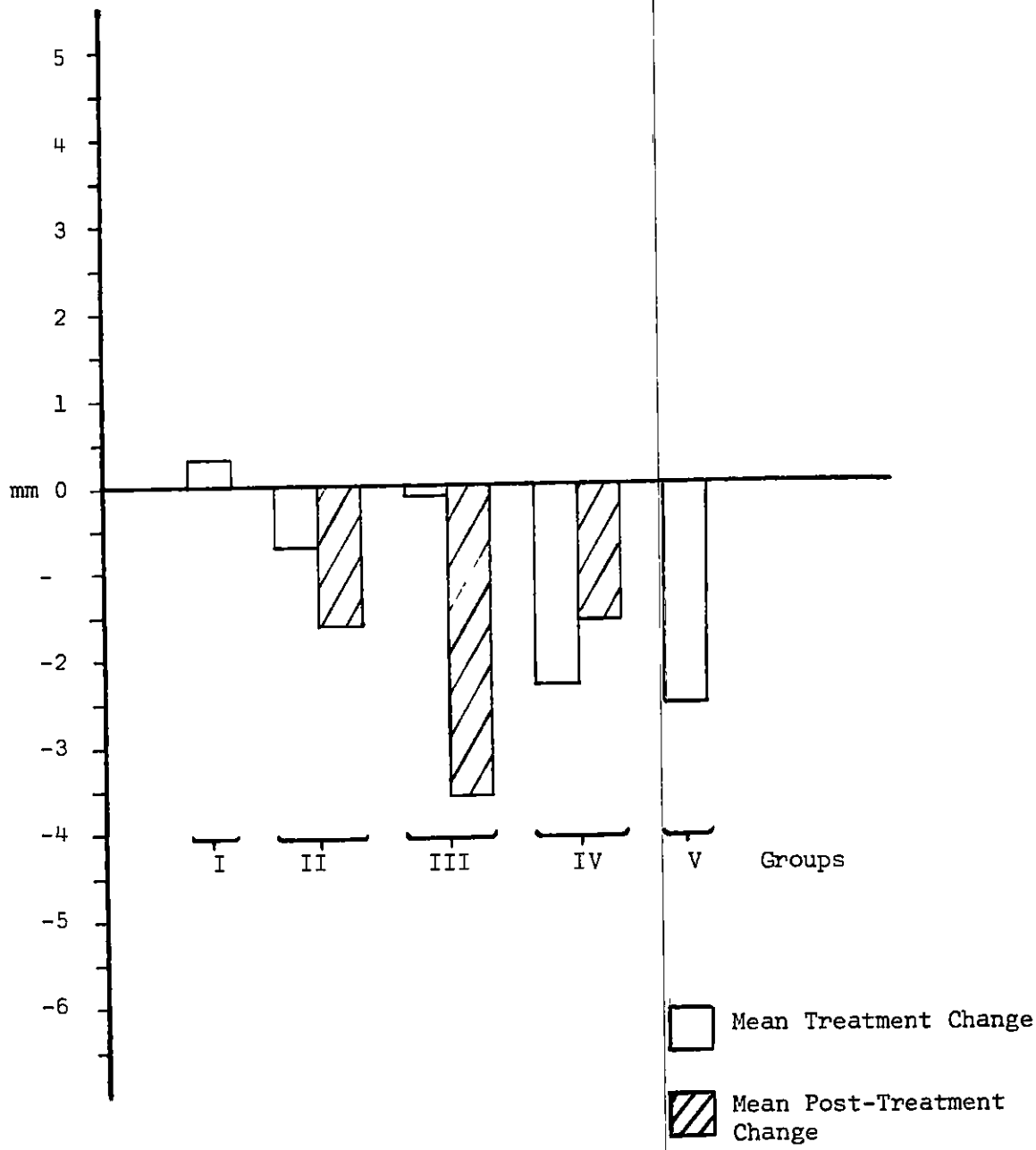


TABLE XIII

MAXILLARY/MANDIBULAR ARCHES, DENTAL DIMENSIONS,
SPr COMPARED WITH IPr
(Variable #11)

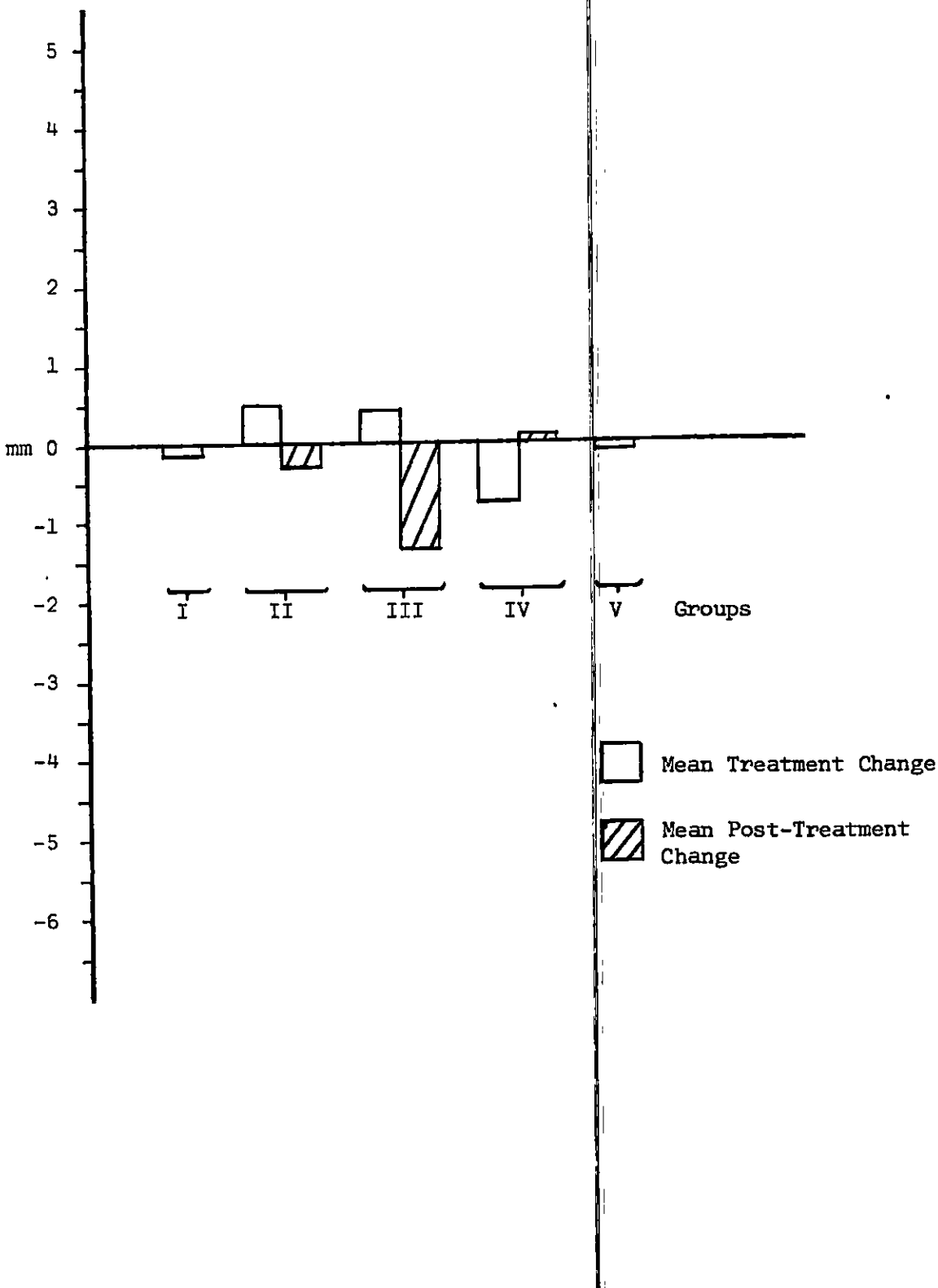


TABLE XIV

PM AS COMPARED WITH RAMUS/MCF VERTICAL DIMENSIONS
(Variable #12)

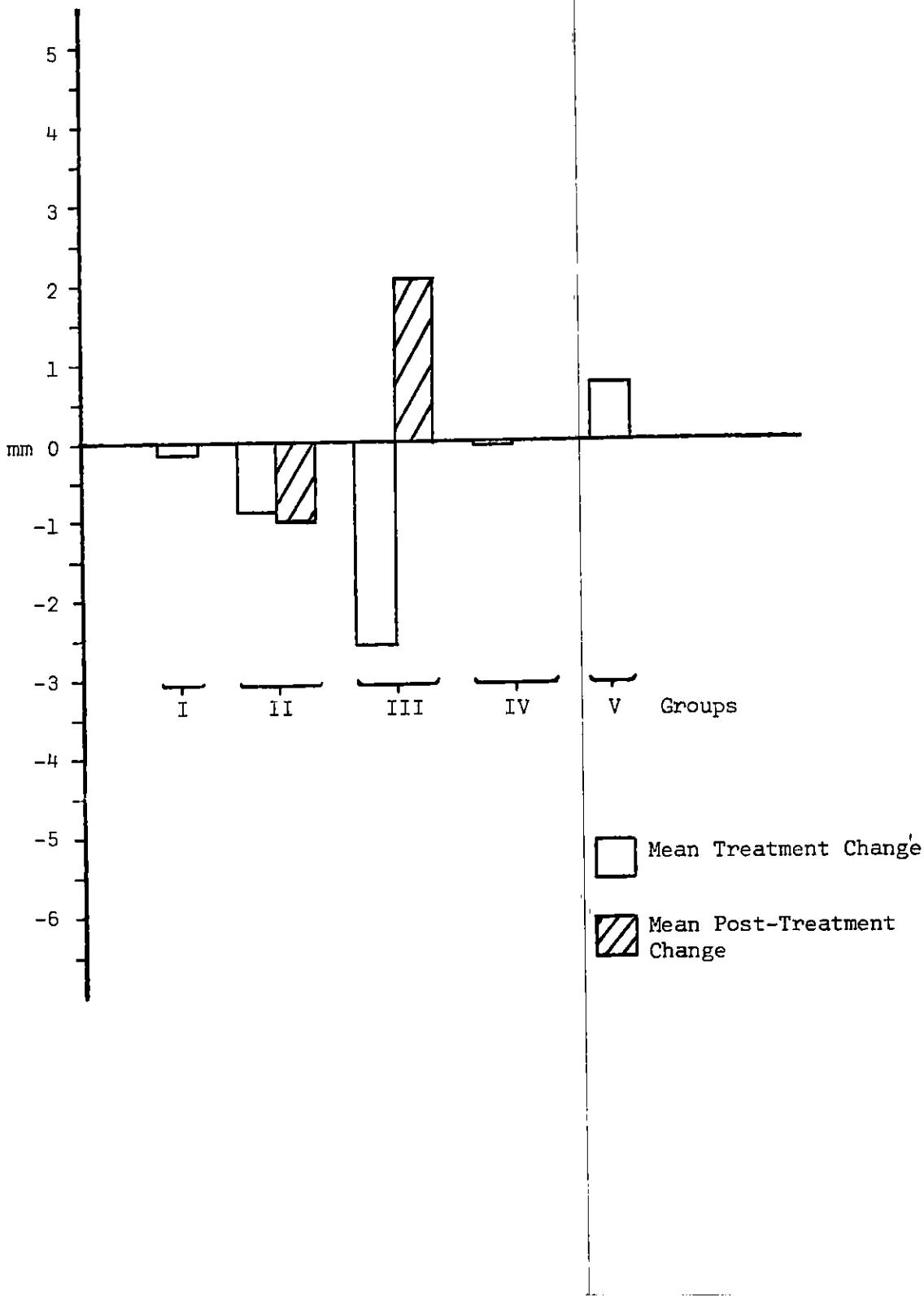


TABLE XV

CORPUS/OCCLUSAL ALIGNMENT
(Variable #13)

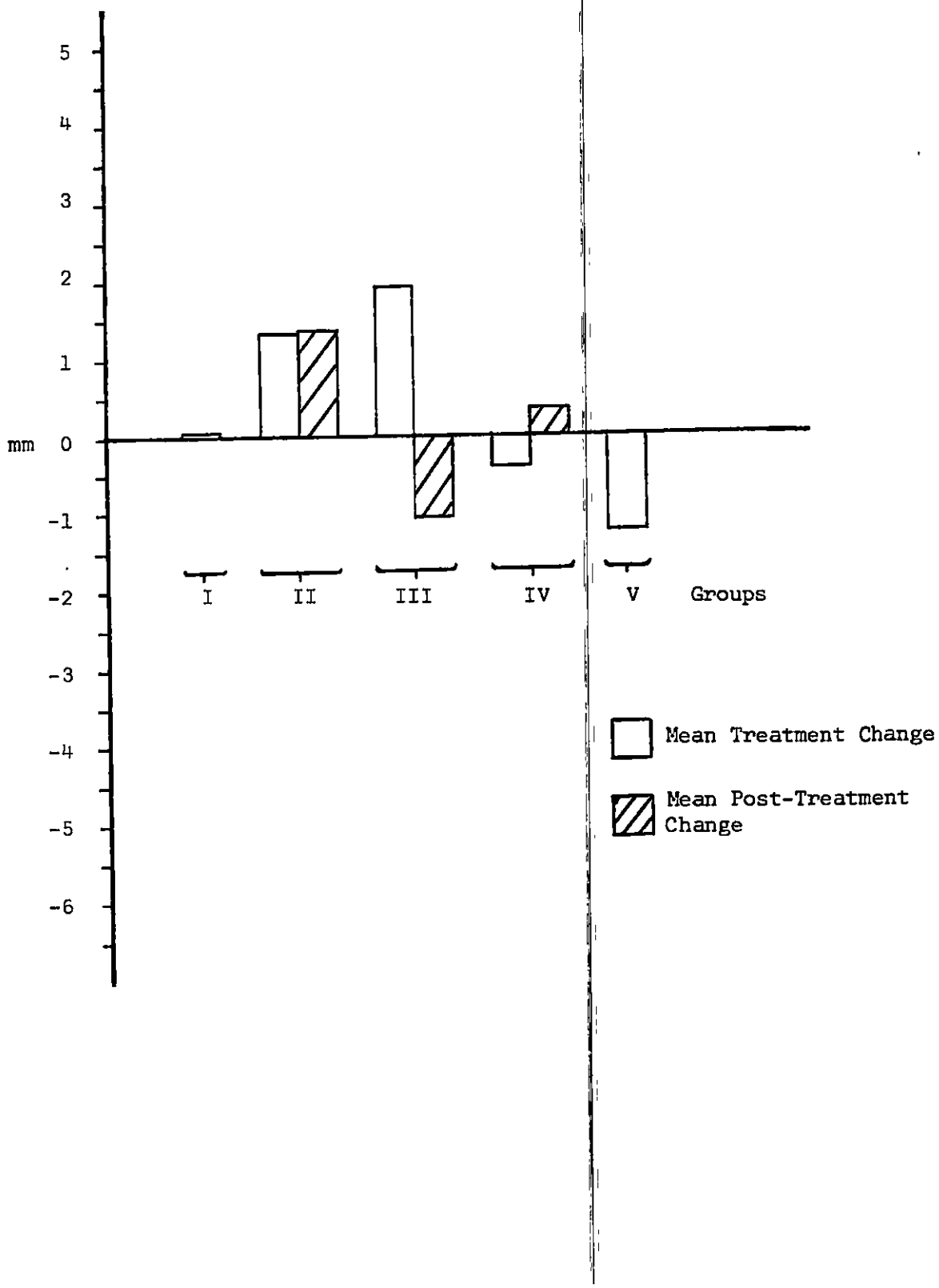


TABLE XVI

VERTICAL ANTERIOR MAXILLARY PLANE
(Variable #14)

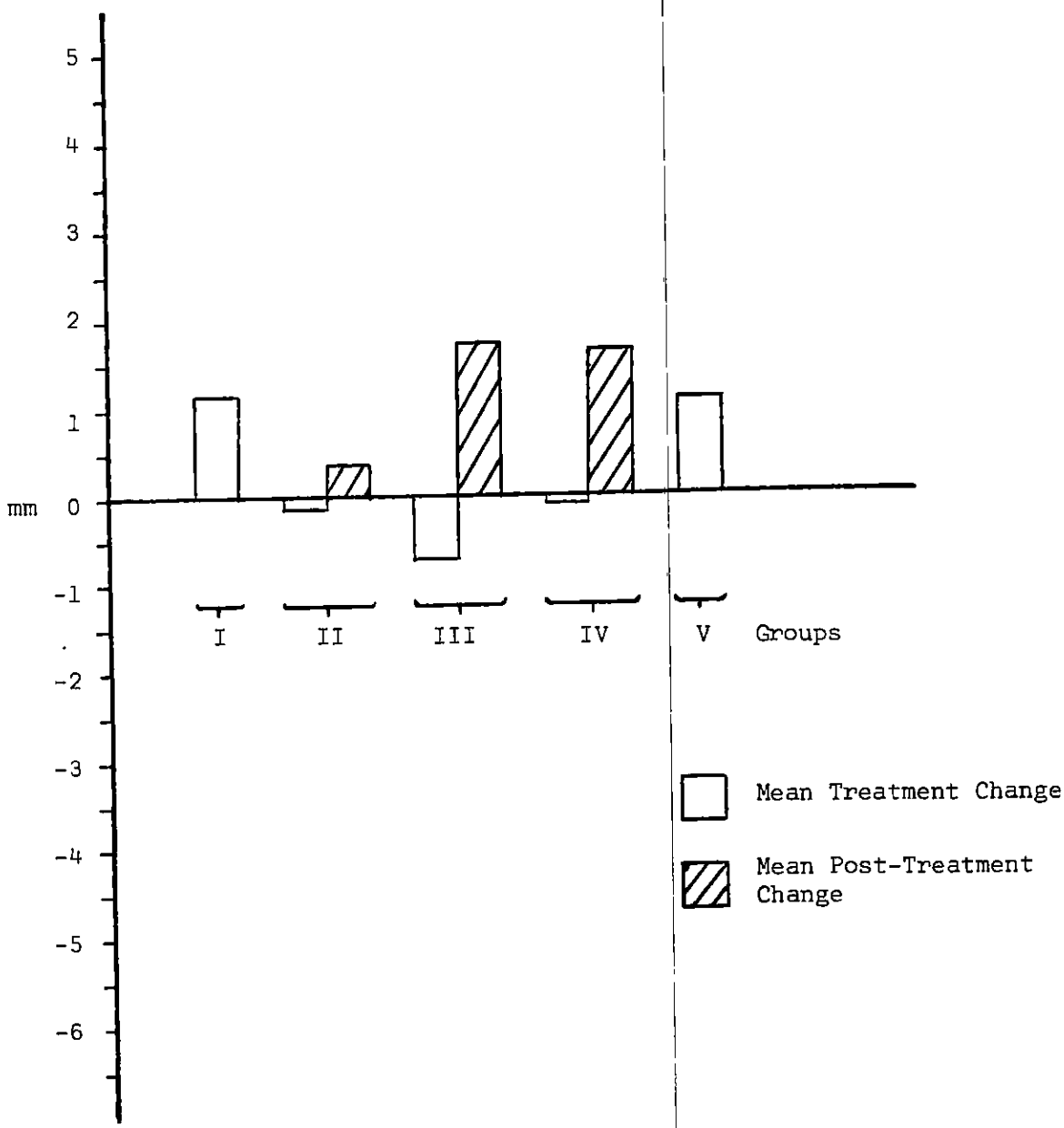


TABLE XVII

MANDIBULAR PLANE ALIGNMENT
(Variable #15)

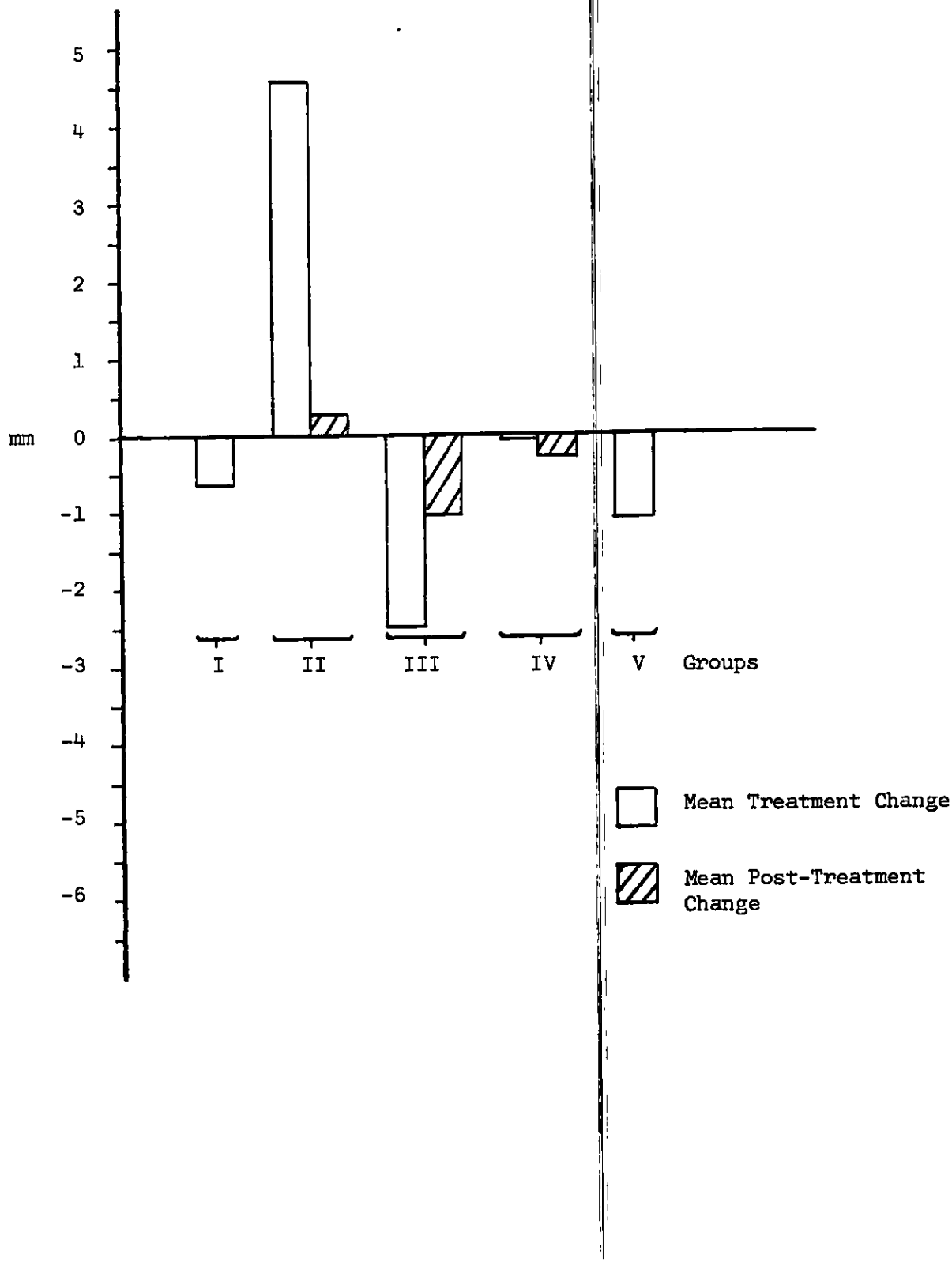


TABLE XVIII

GONIAL ANGLE ALIGNMENT
(Variable #16)

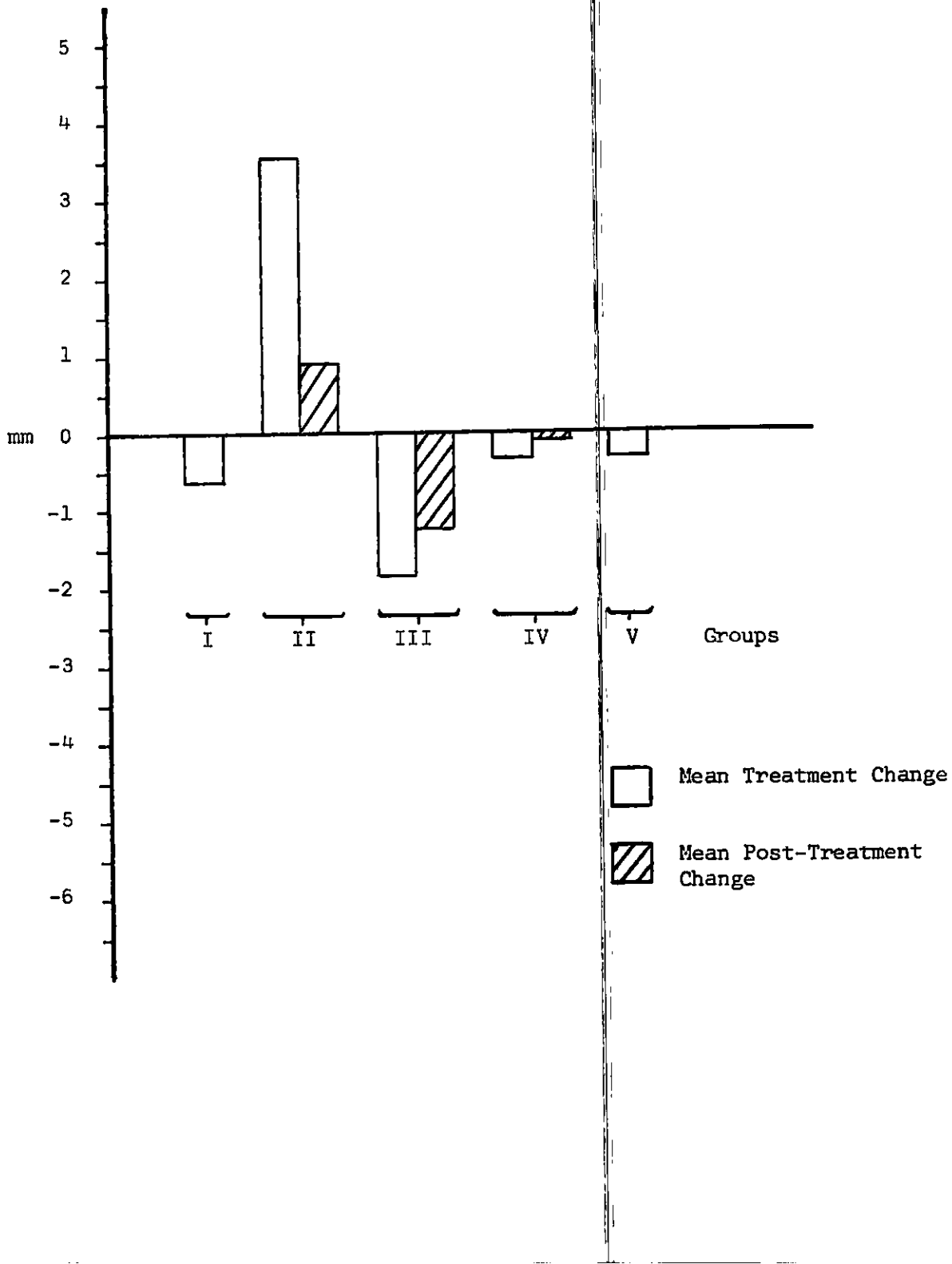


TABLE XIX

OCCLUSAL PLANE ALIGNMENT
(Variable #17)

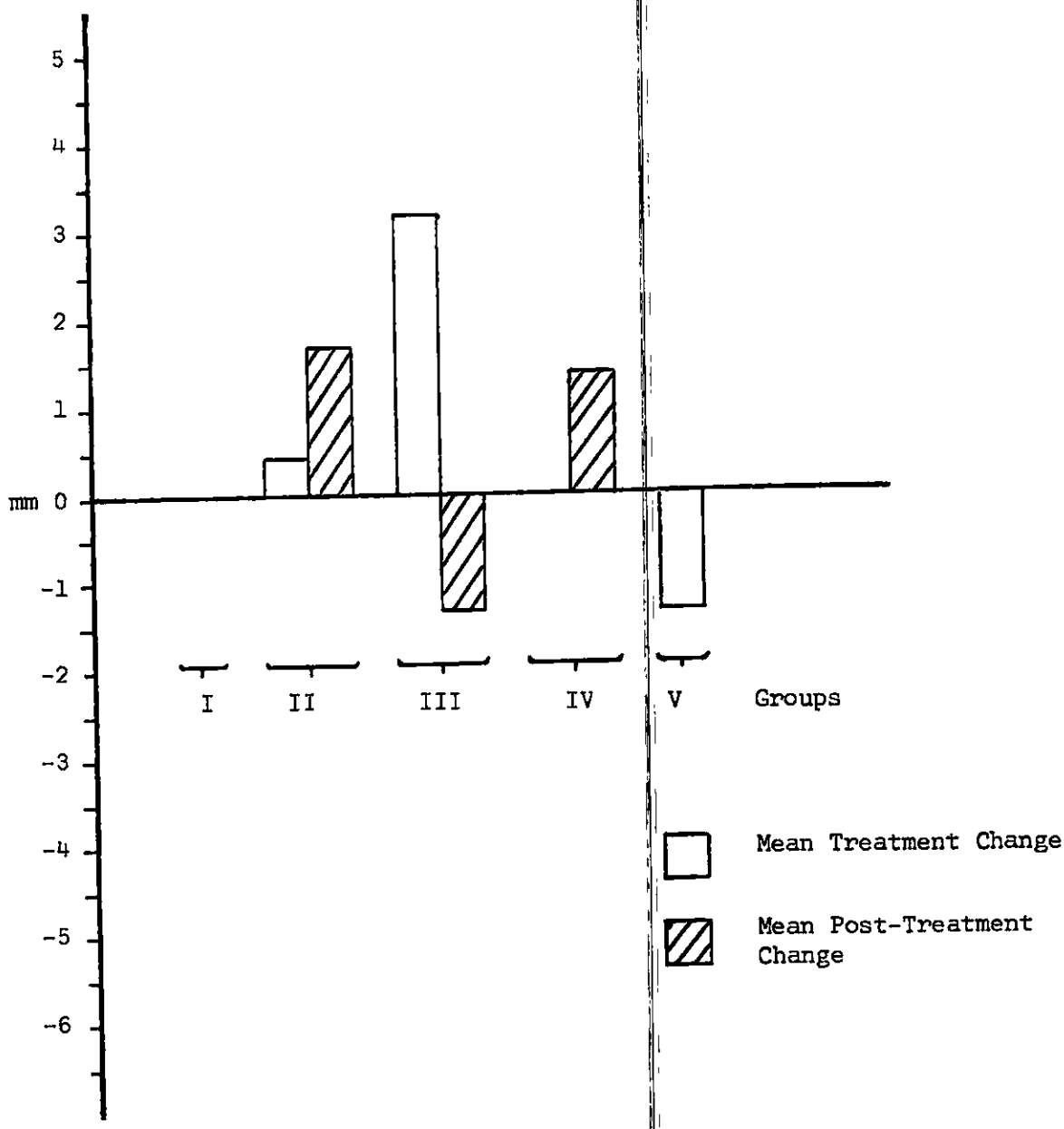


TABLE XX

CURVE OF SPEE
(Variable #18)

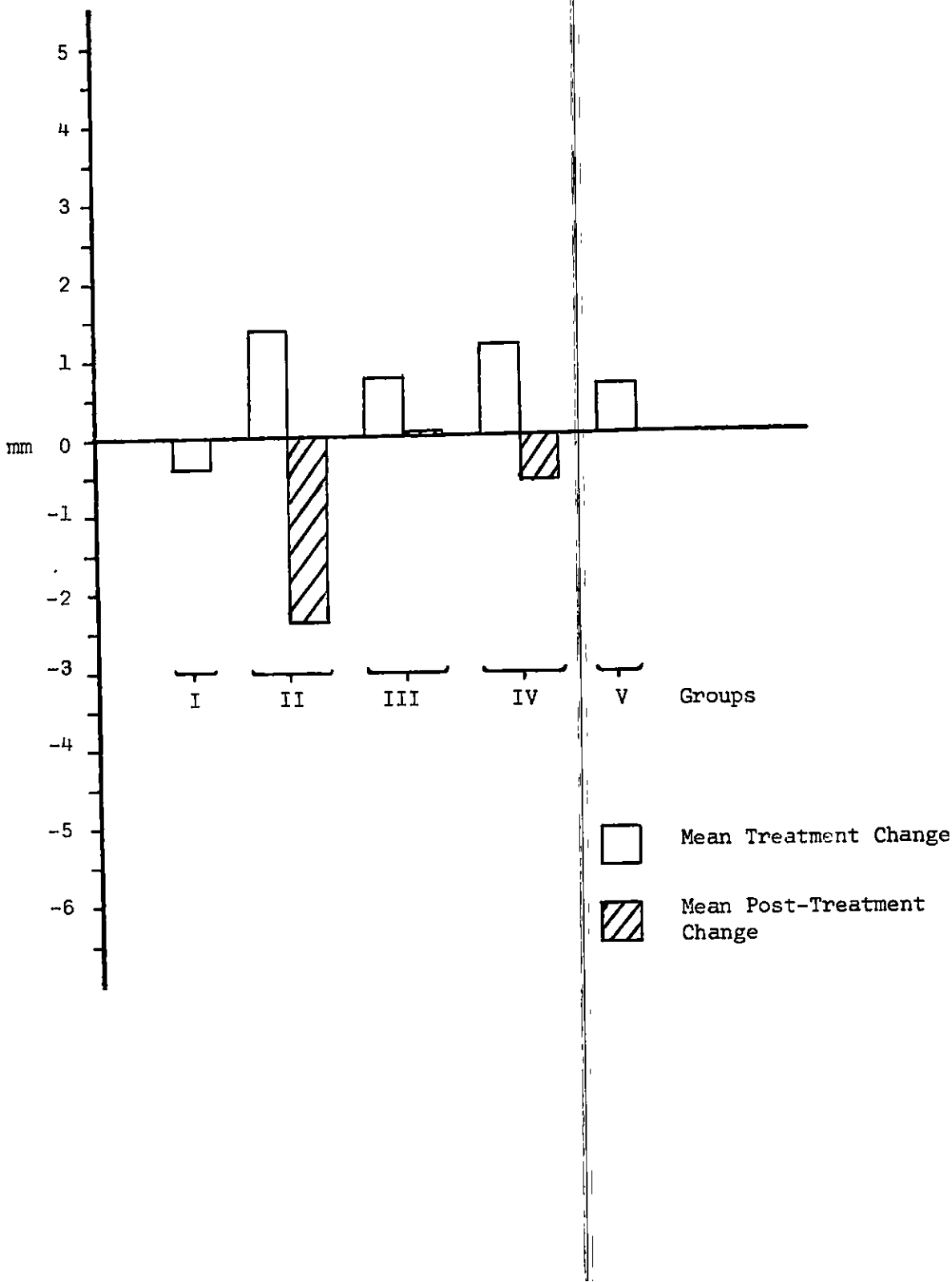


TABLE XXI

INFERIOR MAXILLARY PLANE ALIGNMENT
(Variable #19)

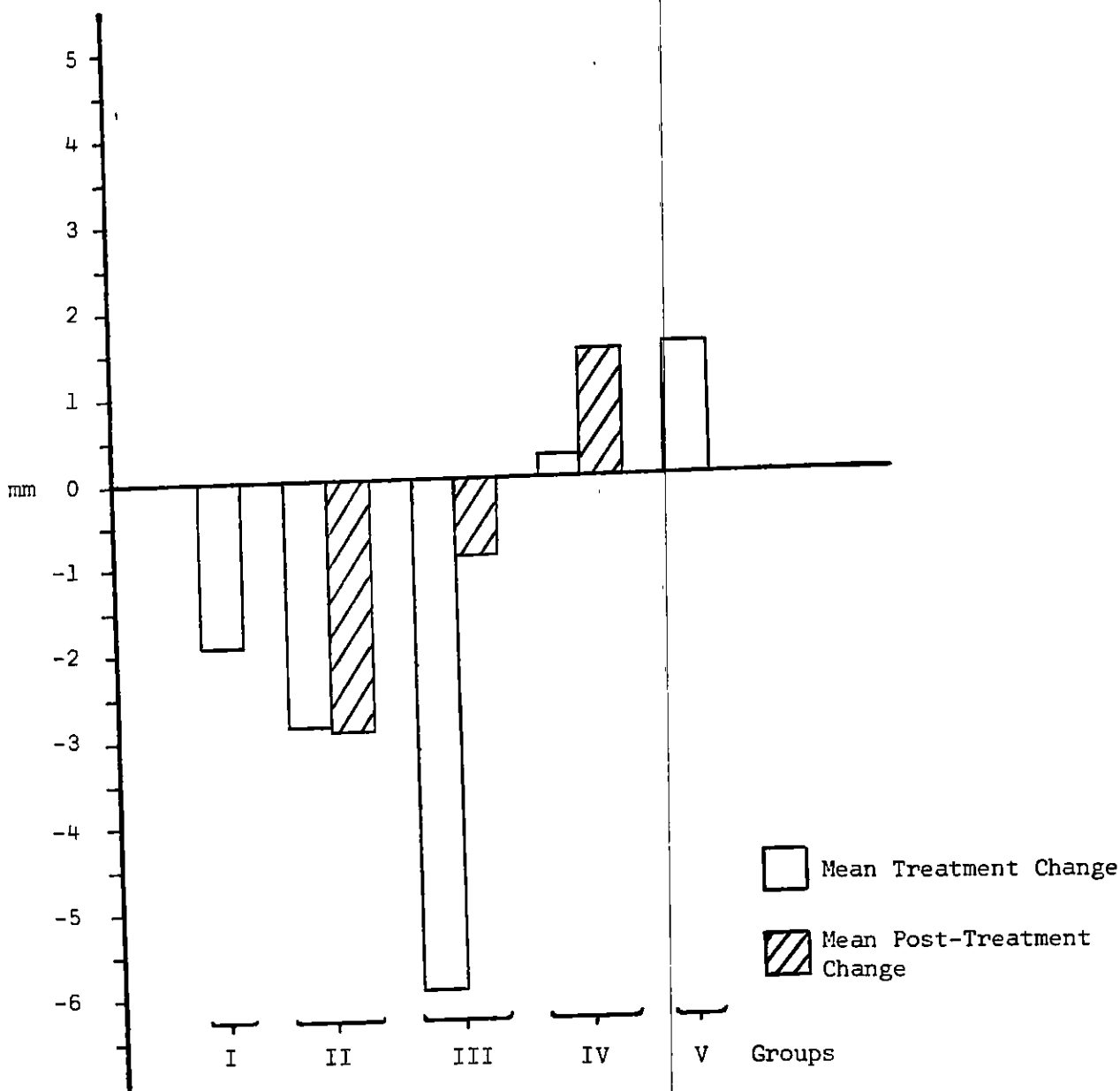


TABLE XXII

PALATAL PLANE ALIGNMENT
(Variable #20)

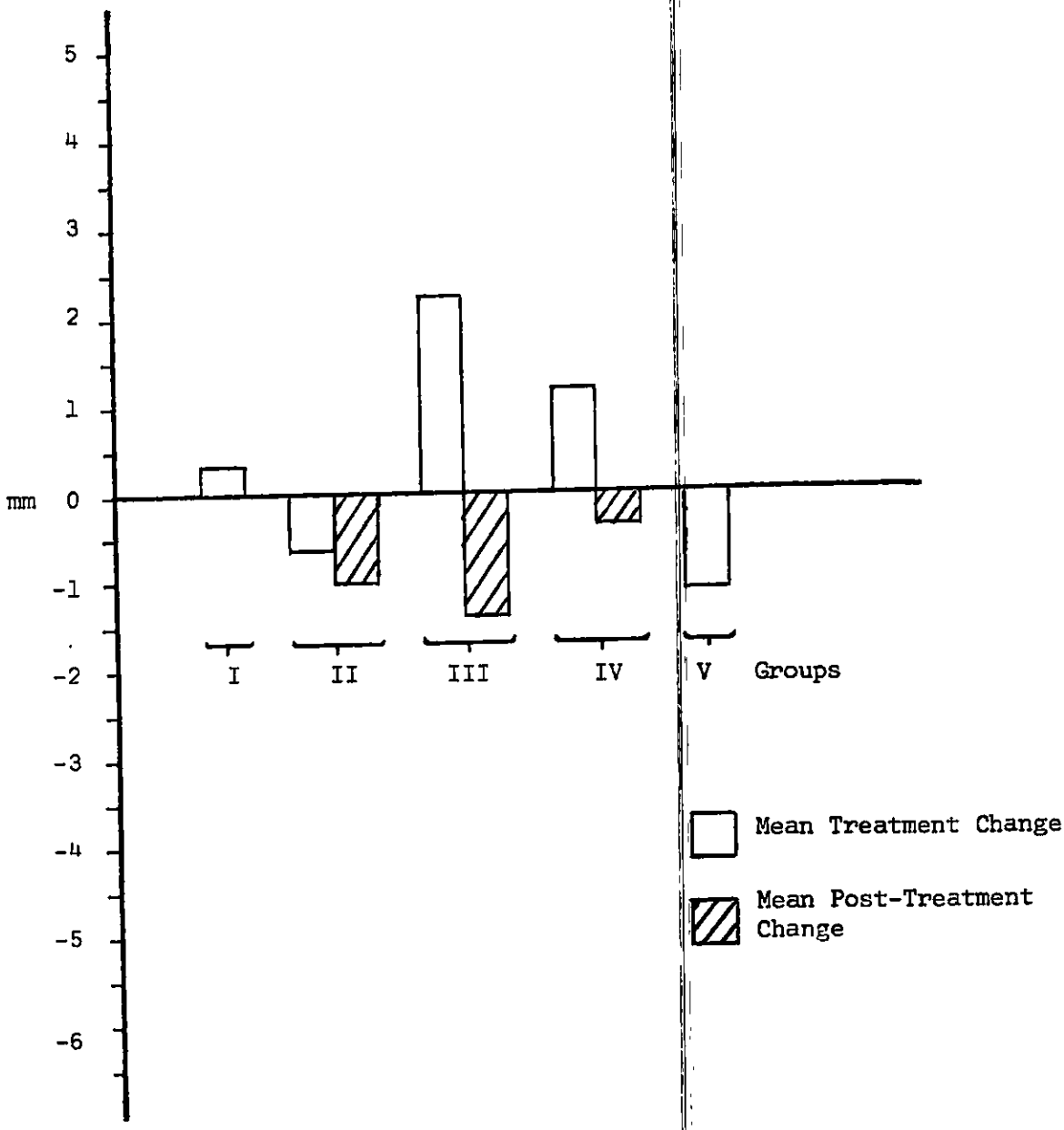


TABLE XXIII

PLANE OF THE MAXILLARY NERVE
(Variable #21)

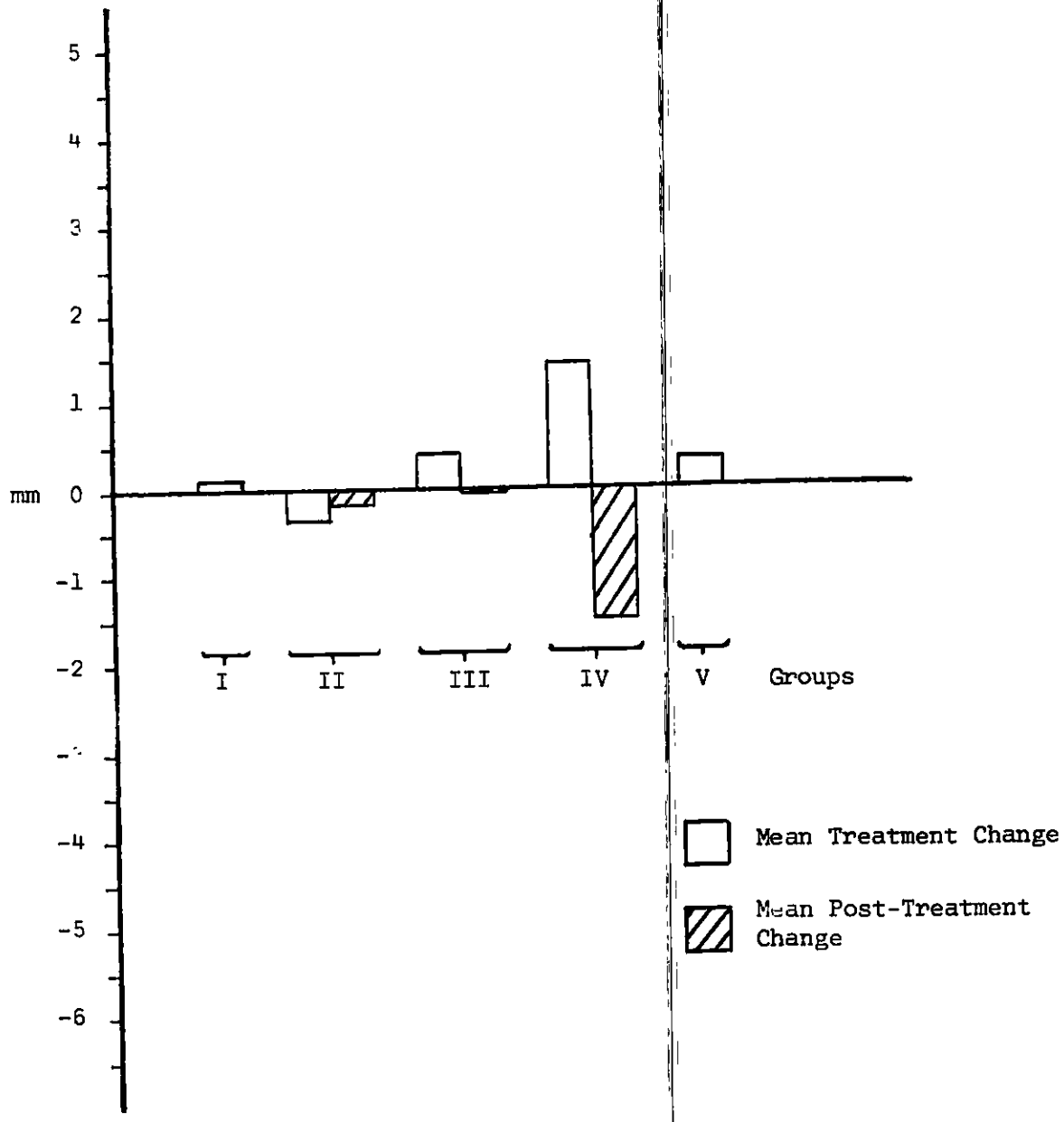


TABLE XXIV

LOWER ANTERIOR FACIAL HEIGHT
(Variable #22)

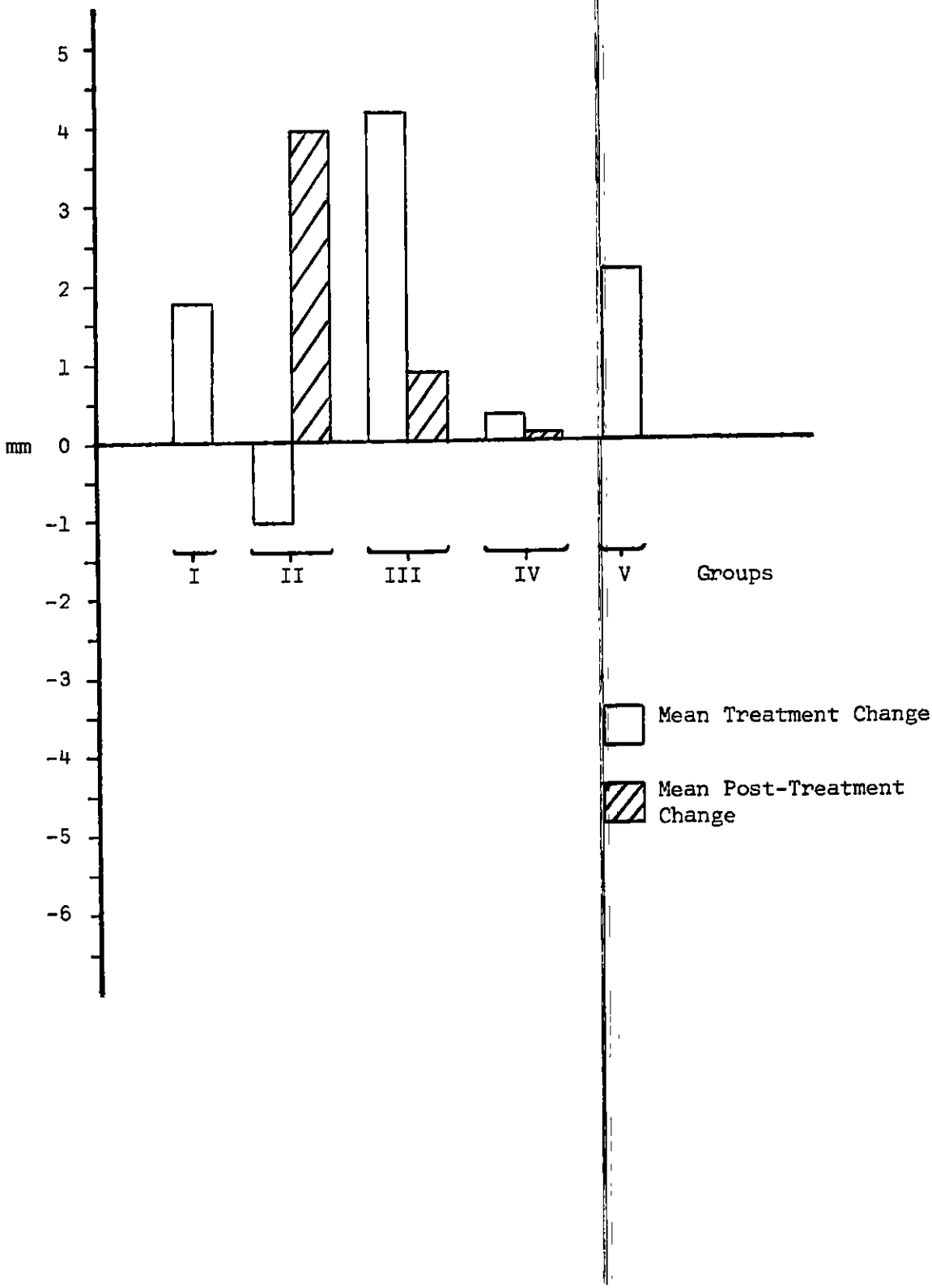


TABLE XXV

MEANS AND STANDARD DEVIATIONS OF MEASURED VARIABLES

GROUP I
(Control)

Variable		Initial Cephalogram	Second Cephalogram	Change Between Cephalograms
1. Ar--A	X	-1.933	-2.300	-0.367
-Ar--B	S.D.	2.112	1.699	1.778
2. Ar--SPr	X	1.646	1.046	0.600
-Ar--IPr	S.D.	1.470	2.088	2.277
3. PM--NPM	X	1.133	0.500	-0.633
	S.D.	2.453	2.719	1.077
4. ArGo--NRa	X	-1.633	-1.633	. .
	S.D.	1.067	1.407	0.776
5. Ar-NPM	X	-0.400	0.166	0.567
-Ar--ARa	S.D.	3.699	3.518	1.210
6. Ar-- M_1C	X	-3.393	-2.786	0.607
-Ar-- M_1C	S.D.	4.193	4.362	1.624
7. Ar-- M_1	X	-1.357	-1.571	-0.214
-Ar-- M_1	S.D.	1.064	1.035	0.469
8. A--PM	X	-2.700	-2.933	-0.233
-B--ARa	S.D.	3.267	2.884	1.980
9. A-- M_1	X	-0.633	-0.467	0.617
-B-- M_1	S.D.	2.142	1.382	2.059
10. SPr--PM	X	-0.467	-0.167	0.300
-IPr--ARa	S.D.	2.875	2.418	2.590

TABLE XXV continued

Variable		Initial Cephalogram	Second Cephalogram	Change Between Cephalogram
11. SPr-- M_1 -IPr-- M_1	X	2.167	2.033	-0.133
	S.D.	2.024	1.093	1.369
12. PM +PRa	X	0.467	0.233	-0.233
	S.D.	2.142	2.449	1.678
13. FOP--NOA -ArGo--NRa	X	0.633	0.667	0.034
	S.D.	2.310	2.575	1.609
14. SPr	X	-2.633	-1.433	1.200
	S.D.	5.087	4.136	4.221
15. NMP -MP	X	2.000	1.400	-0.600
	S.D.	4.881	5.445	3.037
16. NGo -Go	X	1.733	1.067	-0.666
	S.D.	3.863	4.204	2.197
17. NOA -FOP@IPr	X	-1.400	-1.400	. .
	S.D.	2.627	3.424	1.927
18. Spee	X	2.500	2.100	-0.400
	S.D.	0.802	1.183	0.967
19. IMP	X	-5.433	-7.400	-1.967
	S.D.	6.472	35.807	2.341
20. PP	X	-3.200	-2.900	0.300
	S.D.	6.114	6.533	1.568
21. PMN	X	-0.933	-0.800	0.133
	S.D.	1.831	1.925	0.812
22. ANS--Me	X	61.533	63.300	1.767
	S.D.	5.310	5.516	1.792

TABLE XXVI

MEANS AND STANDARD DEVIATIONS OF MEASURED VARIABLES

GROUP II

(Vertical Pull Chin Cup Treatment)

Variable		Pre-Treatment	End of Treatment	Post-Retention	Treatment Change	Post-Treatment Change
1. Ar--A -Ar--B	$\bar{X}$ S.D.	-0.929 2.738	-0.429 3.390	-0.050 2.153	0.500 3.113	0.050 2.753
2. Ar--SPr -Ar--IPr	$\bar{X}$ S.D.	1.214 2.137	1.071 1.940	1.050 1.322	-0.143 2.349	-0.050 2.153
3. PM--NPM	$\bar{X}$ S.D.	1.433 1.462	1.300 2.366	1.400 1.912	-1.330 1.737	-0.600 0.994
4. ArGo--NRa	$\bar{X}$ S.D.	-3.133 1.837	-3.867 2.224	-4.450 2.315	-0.733 1.132	-0.050 1.322
5. Ar--NPM -Ar--ARa	$\bar{X}$ S.D.	-2.464 1.975	-1.285 2.687	-0.400 1.969	1.179 2.232	1.600 2.132
6. Ar-- M_1C -Ar-- M_1C	$\bar{X}$ S.D.	-5.071 2.973	-7.071 3.500	-5.100 3.062	-2.000 2.378	2.100 3.107
7. Ar-- M -Ar-- M	$\bar{X}$ S.D.	-2.714 3.262	-2.214 1.837	0.050 2.074	0.571 4.173	-2.000 1.000
8. A--PM -B--ARa	$\bar{X}$ S.D.	0.214 3.528	-0.789 4.505	-1.050 2.919	-1.000 3.107	-0.550 4.935
9. A-- M -B-- M	$\bar{X}$ S.D.	0.500 2.184	1.786 3.338	2.250 2.475	1.321 2.539	0.650 2.759
10. SPr--PM -IPr--ARa	$\bar{X}$ S.D.	2.250 3.030	1.536 3.592	-0.400 1.997	-0.714 3.251	-1.600 4.101
11. SPr-- M_1 IPr-- M_1	$\bar{X}$ S.D.	2.607 1.258	3.107 1.893	2.500 1.633	0.500 1.414	-0.350 2.427
12. PM +PRa	$\bar{X}$ S.D.	-1.250 2.979	-2.143 3.905	-1.900 2.914	-0.893 1.723	-1.000 2.285

TABLE XXVI continued

Variable		Pre-Treatment	End of Treatment	Post-Retention	Treatment Change	Post-Treatment Change
13. FOP--NOA -ArGo--NRa	$\bar{X}$	-0.100	1.233	2.000	1.333	1.350
	S.D.	2.089	3.316	2.527	2.743	3.083
14. SPr	$\bar{X}$	-5.179	-5.250	-3.850	-0.133	0.300
	S.D.	5.022	6.750	4.479	4.514	6.308
15. NMP -MP	$\bar{X}$	-4.357	0.250	1.550	4.607	0.250
	S.D.	8.296	9.177	7.384	2.795	6.339
16. NGo Angle -Go Angle	$\bar{X}$	-3.733	-0.617	1.500	3.567	0.350
	S.D.	6.400	6.052	5.543	2.456	4.123
17. NOA -FOP @ IPr	$\bar{X}$	-5.393	-5.000	-3.950	0.467	1.700
	S.D.	3.712	3.990	2.650	3.593	3.409
18. Spee	$\bar{X}$	1.500	2.923	0.167	1.300	-2.400
	S.D.	4.813	2.423	0.707	2.374	2.025
19. IMP	$\bar{X}$	0.357	-2.535	-6.950	-2.893	-2.950
	S.D.	7.989	8.229	7.676	2.733	6.039
20. PP	$\bar{X}$	-0.750	-1.393	-2.850	-0.643	-1.000
	S.D.	2.092	3.712	3.292	1.946	1.972
21. PMN	$\bar{X}$	0.214	-0.107	-0.400	-0.300	-0.150
	S.D.	3.418	3.415	4.471	1.678	2.028
22. ANS--Me	$\bar{X}$	68.286	67.214	71.750	-1.071	3.950
	S.D.	4.065	4.475	5.524	1.685	2.773

TABLE XXVII

MEANS AND STANDARD DEVIATIONS OF MEASURED VARIABLES

GROUP III
(Vertical Pull Chin Cup, Cervical Pull Headgear, and Fixed Intraoral Orthodontic Appliances--Growers)

	Variable		Pre-Treatment	End of Treatment	Post-Retention	Treatment Change	Post-Treatment Change
1.	Ar--A	X	0.033	1.800	-0.050	1.767	-1.550
	-Ar--B	S.D.	4.422	4.435	3.539	5.261	3.166
2.	Ar--SPr	X	1.033	0.133	-0.350	-0.900	-0.500
	-Ar--IPr	S.D.	3.341	2.431	1.717	3.631	1.881
3.	PM--NPM	X	0.533	-1.700	-2.300	-2.233	0.250
		S.D.	3.176	3.040	3.093	2.434	1.034
4.	ArGo--NRa	X	-3.467	-3.033	-1.700	0.433	-0.250
		S.D.	3.142	3.810	3.450	1.689	1.477
5.	Ar-NPM	X	-0.267	1.333	4.650	1.600	2.050
	-Ar--ARa	S.D.	2.796	3.574	3.300	2.181	2.047
6.	Ar-- M_1C	X	-3.133	-2.533	0.950	0.600	1.200
	-Ar-- M_1C	S.D.	6.396	5.872	4.031	5.520	1.783
7.	Ar-- M_1	X	-1.100	-2.1[illegible]	-1.950	-1.100	-0.100
	-Ar-- M_1	S.D.	2.892	1.457	0.926	3.095	0.876
8.	A--PM	X	0.133	2.467	-1.900	2.267	-1.600
	-B--ARa	S.D.	4.402	5.205	3.221	5.561	5.957
9.	A-- M_1	X	1.167	3.833	2.400	2.667	-2.350
	-B-- M_1	S.D.	5.851	4.190	3.665	5.697	4.090
10.	SPr--PM	X	1.167	1.033	-2.800	-0.133	-3.600
	-IPr--ARa	S.D.	3.579	3.038	1.751	3.335	3.152

TABLE XXVII continued

Variable		Pre-Treatment	End of Treatment	Post-Retention	Treatment Change	Post-Treatment Change
11. SPr-- M_1 -IPr-- M_1	X	1.967	2.433	0.650	0.400	-1.400
	S.D.	4.951	2.543	2.739	4.785	2.866
12. PM +PRa	X	-1.267	-3.867	-2.100	-2.600	2.100
	S.D.	4.735	3.558	4.465	3.631	3.332
13. FOP--NOA -ArGo--NRa	X	-0.567	1.333	-0.950	1.900	-1.100
	S.D.	3.479	3.080	2.279	3.019	1.970
14. SPr	X	-6.200	-6.867	-3.900	-0.667	1.750
	S.D.	8.213	7.286	7.279	5.167	3.522
15. NMP -MP	X	-11.133	-13.733	-17.250	-2.167	-1.050
	S.D.	6.893	9.369	8.626	6.141	1.707
16. NGo -Go	X	-8.400	-10.067	-12.150	-1.800	-1.250
	S.D.	5.475	7.186	7.142	3.668	1.400
17. NOA -FOP@IPr	X	-5.767	-2.567	-3.850	3.233	-1.350
	S.D.	3.229	3.530	3.786	3.156	2.897
18. Spee	X	-0.333	0.367	0.450	0.700	0.050
	S.D.	2.469	1.807	1.571	1.546	1.723
19. IMP	X	-2.367	-7.730	-7.850	-6.033	-0.850
	S.D.	6.064	8.633	6.955	6.914	4.565
20. PP	X	-4.300	-2.633	-1.200	2.267	-1.400
	S.D.	5.102	5.811	5.458	3.326	2.961
21. PMN	X	-1.700	-1.567	0.100	0.400	-0.050
	S.D.	3.789	6.155	3.373	2.407	1.674
22. ANS--Me	X	79.333	83.500	85.200	4.200	0.800
	S.D.	5.219	5.669	5.154	3.453	1.687

TABLE XXVIII

MEANS AND STANDARD DEVIATIONS OF MEASURED VARIABLES

GROUP IV
(Vertical Pull Chin Cup, Cervical Pull Headgear, and Fixed Intraoral Orthodontic Appliances--Non-Growers)

Variable		Pre-Treatment	End of Treatment	Post-Retention	Treatment Change	Post-Treatment Change
1. Ar--A	X	-2.600	-2.100	-0.833	0.600	1.417
-Ar--B	S.D.	4.937	4.169	3.327	3.071	2.478
2. Ar--SPr	X	1.250	1.000	-0.500	-0.250	1.417
-Ar--IPr	S.D.	4.030	2.769	3.391	3.561	1.656
3. PM--NPM	X	-1.950	-2.150	-2.583	-0.200	0.250
	S.D.	2.958	3.009	3.930	0.675	1.084
4. ArGo--NRa	X	-3.600	-3.650	-1.833	0.250	-0.583
	S.D.	5.435	6.056	3.869	0.979	0.492
5. Ar-NPM	X	1.850	3,200	4.333	1.450	0.750
-Ar--ARa	S.D.	2.310	2.606	2.041	2.074	1.332
6. Ar-- M_1C	X	-2.500	-2.000	0.500	0.500	-0.333
-Ar-- M_1C	S.D.	6.339	5.686	3.521	3.894	1.538
7. Ar-- M_1	X	-1.050	-0.900	-2.167	0.150	0.167
-Ar-- M_1	S.D.	4.645	3.978	1.693	3.528	1.472
8. A--PM	X	-2.450	-3.050	-1.750	-0.600	0.333
-B--ARa	S.D.	5.644	5.575	4.436	3.957	1.033
9. A-- M_1	X	-0.450	-0.200	-0.333	0.250	-0.583
-B-- M_1	S.D.	3.954	4.745	7.508	4.335	3.470
10. SPr--PM	X	1.050	-1.300	-1.167	-2.350	-1.580
-IPr--ARa	S.D.	4.469	5.084	4.457	3.019	2.131

TABLE XXVIII continued

Variable		Pre-Treatment	End of Treatment	Post-Retention	Treatment Change	Post-Treatment Change
11. SPr-- M_1 -IPr-- M_1	X	2.450	1.700	1.833	-0.750	0.167
	S.D.	2.891	3.182	4.834	3.225	1.169
12. PM +PRa	X	-4.450	-4.500	-4.167	-0.050	. .
	S.D.	5.289	6.032	3.459	1.092	1.304
13. FOP--NOA -ArGo--NRa	X	-0.350	-0.750	-0.333	-0.400	0.333
	S.D.	3.334	4.251	4.320	2.525	1.992
14. SPr	X	-6.818	-6.909	-10.167	-0.091	0.167
	S.D.	8.635	8.080	5.981	2.427	3.764
15. NMP -MP	X	-12.350	-12.400	-18.00	-0.050	-0.333
	S.D.	9.849	9.980	4.147	0.685	1.366
16. NGo -Go	X	-9.400	-9.750	-13.667	-0.350	-0.167
	S.D.	7.442	7.254	3.204	0.669	0.753
17. NOA -FOP@IPr	X	-6.600	-6.600	-3.500	. .	1.417
	S.D.	4.593	5.348	2.049	2.838	1.882
18. Spee	X	0.200	1.400	0.833	1.200	-0.583
	S.D.	2.300	0.994	0.983	2.830	1.686
19. IMP	X	-2.550	-2.300	-5.833	0.250	1.500
	S.D.	8.732	10.945	7.488	4.535	2.236
20. PP	X	-4.500	-3.250	-6.000	1.200	-0.333
	S.D.	5.708	5.007	4.604	0.686	0.816
21. PMN	X	-0.450	1.000	-1.167	1.450	-1.500
	S.D.	2.217	1.826	0.983	1.863	1.643
22. ANS--Me	X	85.100	85.400	87.470	0.300	0.167
	S.D.	6.433	6.226	6.037	3.011	1.472

TABLE XXIX

MEANS AND STANDARD DEVIATIONS OF MEASURED VARIABLES

GROUP V
(Functional Regulator Treatment)

Variable		Pre-Treatment	Post-Treatment	Treatment Change
1. Ar--A	X	1.611	-0.778	-2.389
-Ar--B	S.D.	2.470	3.490	2.671
2. Ar--SPr	X	2.778	0.889	-1.833
-Ar--IPr	S.D.	2.952	2.998	2.149
3. PM--NPM	X	0.556	0.472	-0.083
	S.D.	2.532	2.709	1.342
4. ArGo--NRa	X	-3.666	-3.139	0.528
	S.D.	2.543	2.716	1.131
5. Ar-NPM	X	0.556	0.778	0.222
-Ar--ARa	S.D.	3.280	2.788	3.435
6. Ar-- M_1C	X	-2.000	-2.944	-1.000
-Ar-- M_1C	S.D.	3.162	4.130	2.834
7. Ar-- M_1	X	1.111	-1.306	-2.417
-Ar-- M_1	S.D.	2.040	2.327	2.074
8. A--PM	X	0.639	-2.250	-2.889
-B--ARa	S.D.	2.418	2.691	3.596
9. A-- M_1	X	0.417	0.611	0.194
-B-- M_1	S.D.	2.045	3.104	3.208
10. SPr--PM	X	2.417	-0.222	-2.583
-IPr--ARa	S.D.	3.815	4.152	4.507

TABLE XXIX continued

Variable		Pre-Treatment	Post-Treatment	Treatment Change
11. SPr-- M_1 -IPr-- M_1	X S.D.	2.261 1.961	2.194 2.321	-0.167 1.838
12. PM +PRa	X S.D.	-2.028 3.575	-1.306 3.475	0.722 1.638
13. FOP--NOA -ArGo--NRa	X S.D.	1.778 2.290	0.588 2.711	-1.278 2.353
14. SPr	X S.D.	-5.556 4.731	-4.472 4.125	1.083 3.126
15. NMP -MP	X S.D.	-3.583 9.244	-4.694 9.184	-1.111 2.682
16. NGo -Go	X S.D.	-2.722 6.689	-3.056 6.519	-0.333 2.701
17. NOA -FOP@IPr	X S.D.	-4.444 3.933	-5.806 3.956	-1.361 2.721
18. Spee	X S.D.	0.056 2.623	0.694 2.829	0.639 1.687
19. IMP	X S.D.	-1.694 7.211	-0.111 9.368	1.583 6.645
20. PP	X S.D.	-4.389 6.586	-5.556 5.719	-1.167 3.989
21. PMN	X S.D.	0.222 1.556	0.500 1.948	0.278 1.320
22. ANS--Me	X S.D.	74.806 11.283	77.028 10.798	2.222 3.762

(vertical pull chin cup and orthodontic treatment on adults) were very small and were, therefore, not considered in the analysis of variance.

Table XXX presents the recults of the univariate F test for the subjects examined in Groups I, II, III, and V for each variable. A P value less than 0.05 was selected to determine if a gi· en result was statistically significant.

Table XXXI presents the results of the Tukey Analysis for each variable that was found to be significant. This demonstrates which treatment is significantly different from other treatments for that variable at the 0.05 level of significance.

TABLE XXX

RESULTS OF ANALYSIS OF VARIANCE

CHANGE FROM BEFORE TREATMENT
TO AFTER TREATMENT

	Variable	Significance of F (at the 0.050 level)
1.	Aggregate cranial floor/maxilla and ramus/corpus horizontal dimensions at A and B point	0.0051
2.	Aggregate cranial floor/maxilla and ramus/corpus horizontal dimensions at SPr and IPr	not significant
3.	MCF and PM relative alignment	0.0025
4.	Ramus alignment	0.0219
5.	Ramus/MCF horizontal dimensions (skeletal)	not significant
6.	Ramus/MCF horizontal dimensions (dental)	not significant
7.	Molar positions (composite)	not significant
8.	Maxillary/mandibular arches, skeletal dimensions, A point compared with B point	not significant
9.	Maxillary/mandibular arches, dental dimensions, A point compared with B point	not significant
10.	Maxillary/mandibular arches, skeletal dimensions, SPr compared with IPr	not significant
11.	Maxillary/mandibular arches, dental dimensions, SPr compared with IPr	not significant

TABLE XXX continued

Variable	Significance of F (at the 0.050 level)
12. PM as compared with ramus/MCF vertical dimensions	0.0008
13. Corpus/occlusal alignment	0.0024
14. Vertical anterior maxillary plane	not significant
15. Mandibular plane alignment	0.0000
16. Gonial angle alignment	0.0000
17. Occlusal plane alignment	0.0004
18. Curve of Spee	not significant
19. Inferior maxillary plane alignment	0.0032
20. Palatal plane alignment	0.0084
21. Maxillary nerve/ palatal plane alignment (plane of the maxillary nerve)	not significant

TABLE XXXI

SIGNIFICANT DIFFERENCES AMONG THE MEANS

#	Variable	Pairs of Groups Significantly Different at the 0.05 Level
1.	Aggregate cranial floor/ maxilla and ramus corpus horizontal dimensions at A point and B point.	Group III (vertical pull chin cup and orthodontic treatment) with Group V (functional regulator treatment).
3.	Middle cranial fossa (MCF) and posterior maxillary (PM) relative alignment	Group III (vertical pull chin cup and orthodontic treatment) with Group II (vertical pull chin cup treatment only) and Group V (functional regulator treatment)
4.	Ramus alignment	Group II (vertical pull chin cup treatment only) with Group V (functional regulator treatment)
12.	PM as compared with ramus/MCF vertical dimensions	Group III (vertical pull chin cup and orthodontic treatment) with Group I (untreated) and Group V (functional regulator treatment)
13.	Corpus/occlusal alignment	Group V (functional regulator treatment) with Group II (vertical pull chin cup treatment only) and Group III (vertical pull chin cup and orthodontic treatment)
15.	Mandibular plane alignment	Group II (vertical pull chin cup therapy only) with Group I (untreated), Group III (vertical pull chin cup and orthodontic treatment) and Group V (functional regulator treatment).

TABLE XXXI continued

# Variable	Pairs of Groups Significantly Different at the 0.05 Level
16. Gonial angle alignment	Group II (vertical pull chin cup treatment only) with Group I (untreated), Group III (vertical pull chin cup and orthodontic treatment) and Group V (functional regulator treatment).
17. Occlusal plane alignment	Group III (vertical pull chin cup and orthodontic treatment) with Group I (untreated) and Group V (functional regulator treatment)
19. Inferior maxillary plane alignment	Group V (functional regulator treatment) with Group III (vertical pull chin cup and orthodontic treatment) and Group II (vertical pull chin cup treatment only).
20. Palatal plane alignment	Group III (vertical pull chin cup and orthodontic treatment) with Group V (functional regulator treatment) and Group II (vertical pull chin cup treatment only
22. Lower anterior facial height	Group II (vertical pull chin cup treatment only) with Group I (untreated), Group III (vertical pull chin cup and orthodontic treatment), and Group V (functional regulator treatment).

Figure 24. Treatment changes during vertical pull chin cup therapy (composite result). This diagram represents the composite significant changes that took place during vertical pull chin cup therapy. The solid line represents the relative before treatment alignments, the dashed line represents the relative treatment changes. Only relative positional changes are represented. No attempt was made to demonstrate absolute changes in size. The alignment of the MCF is up and back, the inferior maxillary plane rotated counterclockwise, the ramus rotated down and back, and the corpus of the mandible rotated up relative to the ramus.

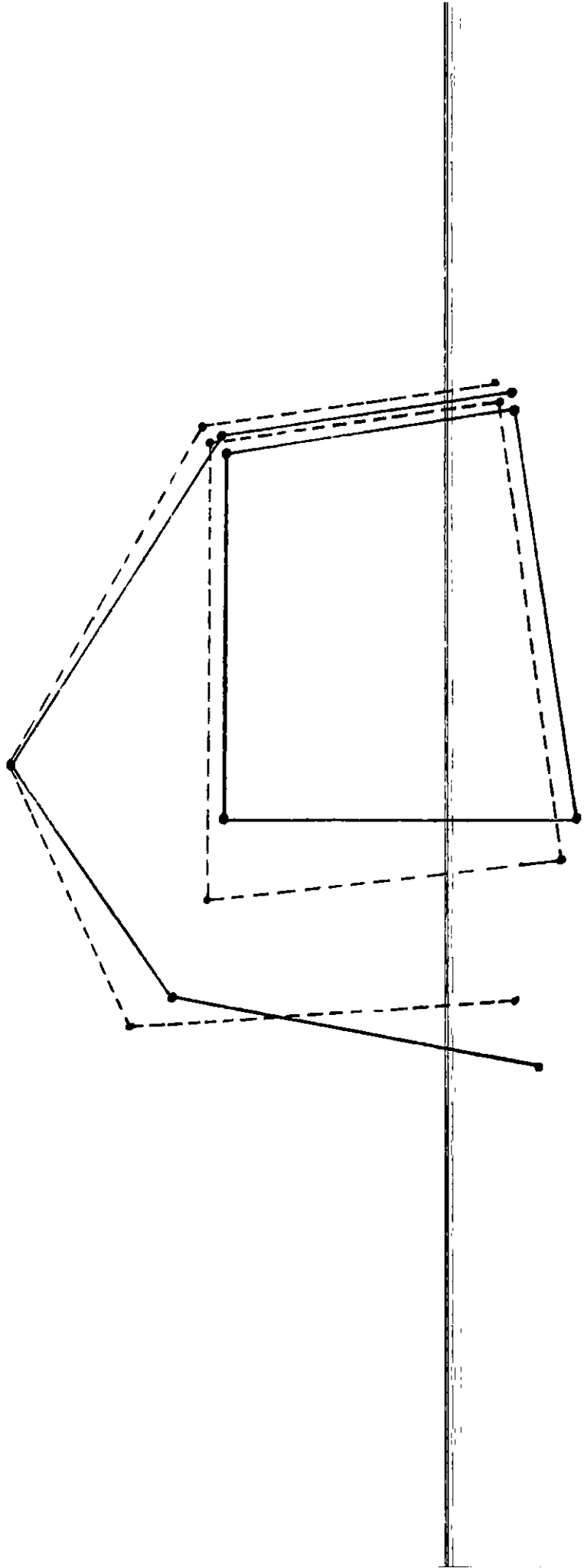
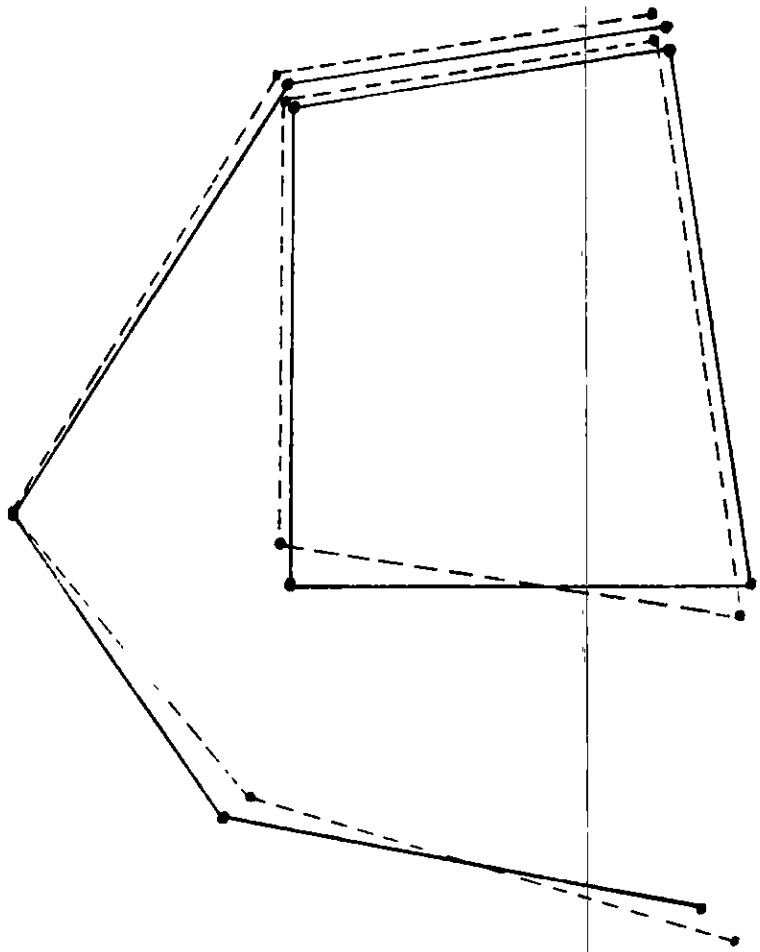


Figure 25. Treatment changes during functional regulator therapy (composite result). This diagram represents the composite significant changes that took place during functional regulator therapy. The solid lines represent the relative before treatment alignments, the dashed lines represent the relative changes that occurred during treatment. Only relative positional changes are represented. No attempt was made to demonstrate absolute changes in size. The alignment of the MCF is slightly up and back, the inferior maxillary plane rotated in a clockwise direction, the ramus rotated forward, and the corpus of the mandible rotated down relative to the ramus.



DISCUSSION

The hyperdivergent skeletal pattern is the result of a combination of definable and discernible multiexpressions that result from mostly unknown multifactorial causes. Usually when dentofacial orthopedic treatment is initiated most of the skeletal pattern has already been established. Treatment, as it relates to the facial complex, is only one more environmental factor among a plethora of others that work to influence the morphology of the skeletal complex. It is the hope of this study to attempt to describe the myriad of changes that take place due to the many environmental, genetic, functional, neurophysiologic and treatment influences during that time in which treatment is instituted. Therefore, it is well understood that many variables contribute to changes that take place during growth and no attempt will be made to attribute any changes solely to the effects of dentofacial orthopedic treatment.

As mentioned earlier, the hyperdivergent skeletal pattern is a composition of skeletal parts which has been found to have the following characteristics; open gonial angle, increase mandibular plane angle, downward aligned occlusal plane, negative Curve of Spee, a more posteriorly aligned ramus, excessive vertical PM dimension, counterclockwise rotation during the vertical development of the nasomaxillary complex, excessive posterior alveolar/

molar drift, and a short ramus height (Trouten, 1979; Isaacson, 1970; Bjork, 1969; Hapak, 1964; Schendel, 1976; Nahoum, 1974; Pearson, 1979; Haas, 1981). Assuming that this is a morphologically unbalanced pattern, although it may be functionally balanced, one must ask where would it be desirable to effectuate change such that the skeletal pattern demonstrates a greater amount of morphologic balance. With this in mind the three different therapeutic approaches demonstrated by Groups II, III, and V can be evaluated for desirable and undesirable effects, if any effects at all.

In evaluating the horizontal dimension it is important to assess the skeletal pattern before treatment to determine if it is a Class II skeletal tendency or a Class III skeletal tendency. This is important because treatment will effect the horizontal dimensional relationships of the maxilla and the mandible differently. In evaluating the horizontal dimensional changes that took place in the treatment periods examined, Groups II and III, both utilizing vertical pull chin cup therapy, produced very similar results, that of maxillary protrusion. The aggregate length of the middle cranial fossa and maxilla to A point increased to a larger extent than the composite mandibular length measured to B point. This is a result of several component effects. In Groups II and III the middle cranial fossa rotation and effective horizontal length relative to that of the ramus, displaces the maxilla anteriorly to a

greater extent than the mandibular corpus is displaced anteriorly by the ramus. Therefore, skeletal open bite patterns that exhibit a Class III (mandibular protrusive) tendency would benefit from the treatment effects of the vertical pull chin cup because it would produce a relative maxillary protrusive effect (or a relative mandibular retrusive effect). However, this relative maxillary protrusive effect may be an undesirable effect in the management of skeletal open bites with a Class II (maxillary protrusive) tendency. In contrast, Group V, utilizing functional regulator therapy, produced more of a mandibular protrusive effect. The aggregate length of the middle cranial fossa and maxilla at A point increased to a lesser extent that the composite mandibular length of the ramus and mandibular corpus measured to B point. This is a result of several component effects. In the functional regulator group the displacement of the maxilla by the MCF relative to the displacement of the corpus by the ramus was less than all other groups. In this group the maxilla was displaced only 0.222 mm more than the corpus was displaced by the ramus. This was less than the 0.567 mm relative difference observed in the control group and significantly better than all three vertical pull chin cup groups, including the nongrowers in Group IV. Also, in this group the corpus of the mandible relative to the maxilla increased the most when compared to all groups. Therefore, skeletal open-bite patterns that exhibit a Class II (mandibu-

lar retrusive) tendency would benefit from the treatment effects of the functional regulator because it would produce a relative mandibular protrusive effect. However, the effect may be undesirable in the management of skeletal patterns that exhibit a Class III (mandibular protrusive) tendency.

These relationships can be understood further when considering other variables that influence the rotational position of the ramus. A vertically short ramus or vertically long maxilla (one relative to the other) or a counterclockwise rotation of the inferior maxillary plane are all consistent with a hyperdivergent skeletal pattern. If this pattern is also a Class II skeletal tendency, therapy then directed at producing a clockwise rotation of the inferior maxillary plane, a relative increase in ramus vertical length and a subsequent forward rotation of the ramus and downward rotation of the corpus of the mandible relative to the ramus would produce a desirable result in the horizontal dimension. If this skeletal pattern is a Class III tendency, therapy directed at producing a relative increase in ramus height (even at the expense of a posterior ramus rotation) along with an upward corpus rotation relative to the ramus would produce a desirable result in the horizontal dimension.

In examining the inferior maxillary plane alignment both vertical pull chin cup groups demonstrated a tremendous amount of counterclockwise rotation, Group II demonstrated -2.893 mm

and Group III demonstrated -6.033 mm. The change in Group III is probably more severe due to the use of cervical pull headgear during treatment. In contrast, the functional regulator subjects expressed a clockwise inferior maxillary plane rotation. The results suggest that for the vertical pull chin cup Groups II and III the ramus rotates posteriorly to accomodate the increasing length of the posterior maxilla as the nasomaxillary complex rotates counterclockwise. In order to close the bite the corpus of the mandible thus rotates upward. In the functional regulator gorup a clockwise inferior maxillary plane rotation is expressed. To compensate for this relative shortening of the posterior maxilla the ramus rotates anteriorly displacing the corpus anteriorly and also produces a relative downward rotation of the mandibular corpus.

At this point the question must be asked as to the influence of treatment on the biologic mechanism which has produced this pattern initially and has resulted in unfavorable rotational and displacement changes. The histologic pattern of the ramus as described by Enlow (1975), demonstrates resorptive remodeling of the anterior border of the ramus and bone deposition remodeling at the posterior border of the ramus. If the relative vertical height of the ramus is short, as described earlier, causing a posterior positioning of the ramus, an opening of the bite and a retrusive mandible, is anterior ramus resorption

increased to help compensate for the developing horizontal imbalance, and does this compensation lead to the development of a Class III open bite pattern? In other words, is the body trying to correct a horizontal problem that results from a vertical problem by lengthening the corpus of the mandible as a result of increased anterior ramus resorption? Truly, these are effective compensations which would only exacerbate the skeletal open bite problem unless the vertical problem between the ramus and maxilla can be compensated. The morphological shape of the mandible in a hyperdivergent skeletal pattern is often very distinctive and is typified by a distal inclination of the condyle, significant antegonial notching, a forward slope to the anterior border of the symphysis, and an increased symphyseal height. This morphology is common to mandibles that are a component of a mandibular protrusive pattern. Yet, this mandibular morphology often exists in a Class II skeletal open bite pattern. It is possible that the posterior vertical problem is so severe that the horizontal problem cannot fully compensate, but does to a certain extent resulting in a mandible that is normally seen in skeletal Class III patterns.

The different treatment procedures examined demonstrated a significant difference in the effect on the change in gonial angle. Group II, treated with the vertical pull chin cup alone, demonstrated a mean gonial angle closure of 3.567 degrees. This

decrease was maintained after therapy as the gonial angle decreased 0.85 degrees further following treatment. This decrease in gonial angle is due to a rotation of the mandibular corpus in an upward direction relative to the ramus, as demonstrated by the change in corpus/occlusal alignment. The occlusal plane alignment has also rotated in the same direction. Some of the decrease in gonial angle, however, may also be due to resorption of the lower anterior border of the corpus due to pressure from the appliance.

Group III, treated with the vertical pull chin cup, in addition to cervical headgear and fixed intraoral appliances demonstrated an increased gonial angle with treatment. This tendency also increased after therapy. It is probable that the cervical headgear and intraoral therapy have components of force that counteract that of the vertical pull chin cup. It is also probable that the detrimental effects of the cervical headgear were also reduced. Such coordination of treatment planning was referred to earlier by Subtelny and Sakuda (1964), and Sassouni and Nanda (1964).

The average gonial angle opening in Group V, the functional regulator treatment group, was 1.111 degrees. Some gonial angle divergence should be expected in that the appliance requires the teeth to be apart for its use. This increase in gonial angle is also reflected in the rotation of the mandibular

corpus in a downward direction relative to the ramus, as demonstrated by the change in corpus/occlusal alignment.

Therefore, due to these significant differences in the effect on mandibular morphology and subsequent rotational relationships between counterparts between Groups II and V, it is apparent the vertical pull chin cup and the functional regulator affect the mandible and its counterparts differently. When the hyperdivergent pattern results mainly in an aberrant mandibular morphology with a Class III tendency a vertical pull chin cup may be preferred. In this manner the shape of the mandible may be improved and the Class III tendency reduced. When the hyperdivergent pattern results less in a mandibular dysmorphology, where the mandible has not compensated to a great degree and the tendency is toward a Class II skeletal pattern the functional regulator may be preferable. In this manner, the Class II tendency will be reduced and the shape of the mandible will not change greatly as it compensated due to the change in the functional environment.

The control group, in general, exhibited only mild changes with growth in the time period examined. These generally resembled the growth trend that the population in this part of the world exhibits. Most variables favored a slight maxillary protrusion, slight mandibular retrusion, a slightly long PM vertical, and very good dental relations.

The adult sample also exhibited small changes if any for most variables. Most changes observed could very well be within tracing error. It would be reasonable to assume that most observed changes were dentoalveolar in nature and had very little effect on the positional relationships of the skeletal parts.

All of the constructs of the counterpart analysis that measured to or from the first molars produced variable comparative results. This is due to the fact in the treatment groups different treatment factors influenced the positions of the teeth. In Group II extractions were performed before vertical pull chin cup therapy, but the same teeth were not extracted from case to case. In Group III no extractions were performed. However, cervical pull headgear and tandem arch therapy influenced the position of the first molars to varying degrees. In Group V, some cases involved extractions and some did not. Therefore, no conclusions can be made concerning comparative dental effects of the three treatment procedures.

In Groups II, III, and IV, post-retention cephalograms were available allowing rebound to be determined. Rebound was consistently observed for five variables; 1) Curve of Spee; 2) lower anterior facial height; 3) plane of the maxillary nerve; 4) maxillary/mandibular arches, dental dimensions, SPr compared with IPr; and 5) vertical anterior maxillary plane alignment. When the treatment effect would increase the Curve of Spee, if

rebound occurred it would be to decrease the Curve of Spee. If the lower anterior facial height was decreased by the vertical pull chin cup, as in Group II, the rebound would be to increase this dimension. Never did this dimension decrease after treatment if the change during treatment was to increase anterior vertical dimension. The palatal plane, if tipped relative to the maxillary nerve during treatment, always returned to its original relationship with the maxillary nerve. SPr moved back from the vertical anterior maxillary plane in all three groups with treatment. After treatment, the tendency was for SPr to move anteriorly towards the vertical anterior maxillary plane. It is reasonable to assume that some anatomical relationships are more resistant than others to a change in their existing direction of growth and that rebound is a function of how resistant the existing anatomic relationship is to change and of the magnitude of the treatment change. Accordingly, there were four variables where rebound was consistently not present; 1) maxillary/mandibular arches, skeletal dimensions, SPr compared with IPr; 2) Ramus/MCF horizontal dimensions (skeletal); 3) inferior maxillary plane; and 4) gonial angle alignment. With all four variables the change after treatment continued the change before treatment. Four possibilities exist for this to occur. Either the treatment had no effect and the post-treatment changes were a continuation of the changes during treatment, or the effect of treatment only

moderately inhibited the "normal" change that would take place without treatment only to continue uninhibited after treatment. Also, treatment could have accentuated the change that would have normally taken place or actually redirected the growth change that would take place after treatment due to the influence during treatment. In general, relapse was much more prevalent for Group III (vertical pull chin cup and orthodontic treatment) than for Group II (vertical pull chin cup only). Most of the changes in skeletal relationships for Group II were less in magnitude compared to Group III and were less likely to relapse. Relapse for Group V (functional regulator treatment) could not be evaluated.

SUMMARY AND CONCLUSIONS

Treatment of the hyperdivergent skeletal pattern and management of the associated vertical and horizontal dysplasias have plagued the orthodontic profession to the present. There is ample reason to assume that skeletal morphology can be altered through the use of either direct force in an attempt to change form directly or through changing the functional environment in which the skeletal components reside. This study was an attempt to examine two of these methods, vertical pull chin cup therapy and functional regulator therapy, and to describe the changes that take place during treatment, and to describe any significant differences that occurred between these methods during the treatment time. Also studied were the rebound tendencies that occurred with vertical pull chin cup therapy and the treatment effects on the adult skeletal open bite pattern.

This study involved 73 subjects divided into five groups:

1. untreated "normal" individuals;
2. individuals with hyperdivergent skeletal patterns treated with vertical pull chin cups only;
3. individuals with hyperdivergent skeletal patterns treated with vertical pull chin cups, cervical headgear, and fixed intraoral appliances;
4. adult individuals with hyperdivergent skeletal patterns treated with vertical pull chin cup therapy, cervical pull headgear, and fixed intraoral appliances;

5. individuals with hyperdivergent skeletal patterns treated with the functional regulator.

Treatment effects were assessed utilizing the counterpart analysis. This analysis is intended for the evaluation of the dimensions and alignment of actual anatomic counterparts, in contrast to conventional cephalometric planes and angles. The planes described in the counterpart analysis correspond with the key fields and sites of growth and remodeling that naturally occur in the individual.

An analysis of variance and Tukey's test were used to test for significant statistical differences among the measurements indicating the change that occurred during the various treatments.

The results of the study may be summarized:

1. There is a statistically significant difference between the treatment changes that took place between the vertical pull chin cup and the functional regulator treatment.

2. Significant treatment effects of functional regulator therapy include a decrease in the forward alignment of the MCF relative to the PM vertical, a clockwise rotation of the inferior maxillary plane, a forward rotation of the ramus plane, a downward alignment rotation of the corpus of the mandible relative to the ramus, a clockwise rotation of the functional occlusal plane. The resultant effect is to close the bite in the vertical dimension and to produce a mandibular protrusion in the horizontal dimension.

3. Significant treatment effects of vertical pull chin cup therapy include a forward alignment of the MCF relative to the PM vertical, a counterclockwise rotation of the inferior maxillary plane, a posterior rotation of the ramus plane, an upward alignment rotation of the

corpus of the mandible relative to the ramus, a counterclockwise rotation of the functional occlusal plane. The resultant effect is to close the bite in the vertical dimension and to produce a mandibular retrusive effect in the horizontal dimension.

4. From the above factors, vertical pull chin cup therapy was recommended for skeletal open bites that have Class III skeletal patterns, which could benefit from its mandibular retrusive effect. Functional regulator therapy was recommended for skeletal open bite patterns that have Class II tendencies which could benefit from the its mandibular protrusive effect.

5. Cervical pull headgear and orthodontic treatment during vertical pull chin cup therapy produce a greater counterclockwise rotation of the inferior maxillary plane and thus compromised the effect of the vertical pull chin cup.

6. Vertical pull chin cup therapy has very little effect in changing the morphology or anatomic positional relations in adult patients.

7. No definite pattern was observed to account for the amount and extent of rebound that occurred.

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