A MORPHOMETRIC STUDY OF HERBST APPLIANCE TREATMENT

by

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Abstract

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The challenge of treating the skeletal Class II craniofacial composite is evidenced by the perplexing variety of orthopedic and orthodontic approaches available. The focus of the present study was to describe the treatment effects of a fixed functional appliance, the bonded acrylic splint Herbst, on a sample of 62 growing Class II individuals. The factor of compliance is eliminated and the short treatment time of 8 months reduces the likelihood that normal growth might be misinterpreted as treatment change. The counterpart analysis of Enlow was selected for radiographic evaluation, in order to provide an anatomic and morphogenic description of responsive and unresponsive regions. The results indicated that ten of the sixteen anatomic variables studied exhibited statistically significant changes in direction, magnitude or both, during the treatment interval. Dental effects were primarily responsible for the observed treatment outcome accompanied, to a lesser extent, by skeletal changes.

The Herbst appliance appears equally effective upon at least two different craniofacial composites (types A and B). In a high percentage of cases, type A individuals demonstrated treatment change resembling the compensations which characterize the type B untreated pattern. Post treatment evaluation of 25 of the treated cases demonstrated significant rebound tendencies in 6 of 16 variables. Dental changes appeared to be more stable than skeletal effects, and the highest relapse corresponded with those effects which tended to reverse the growth pattern observed in the control sample.

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INTRODUCTION

The Class II craniofacial pattern remains a common orthodontic challenge. Research efforts have attempted to characterize, identify and explain the complex factors underlying this malocclusion. This task is complicated because we have yet to completely understand the facial growth process and often gamble in our treatment approaches when appliance development proceeds at a rate exceeding our knowledge of the underlying problem. Decades of innovative treatment approaches have been offered with fluctuating popularity. With the refinement of orthognathic surgery, the use of functional appliances and the ever increasing knowledge and understanding of the growth and development process, it is hoped that the causes, descriptions and clinical solutions are gradually converging.

An addition to the Class II treatment repertoire is the bonded acrylic Herbst appliance. This device, non-removable and "functional" in design, lends itself to reliable investigation. Although use of the bonded Herbst appliance has been gaining in popularity, treatment results to date have been largely unreported in the orthodontic literature.

The purpose of the present study has been to evaluate the responses of Class II growing individuals

subsequent to an average of eight months of bonded Herbst appliance treatment.

The counterpart analysis of Enlow was utilized to provide an anatomic and morphogenic approach to treatment assessment. This technique has been used previously to describe the nature of structural imbalances and compensations underlying the skeletal Class II pattern (Enlow et al., 1971A, Whitney, 1983) and to provide a tool for a morphologic appraisal of treatment effects and stability.

LITERATURE REVIEW

I. The Class II Malocclusion

The Class II skeletal and dental composite remains the most frequent presentation in the American orthodontic practice and in many ways is also among the most challenging.

An abundance of literature is available representing variations on the theme of Class II correction. To complicate the scenario, studies by investigators (Wylie, 1947; Fisk et al., 1953; Sassouni, 1969, 1970; Moyers et al., 1980; McNamara, 1981) have revealed the Class II malocclusion to be not a single clinical entity but a broad spectrum of numerous combinations of dental and skeletal components. It has been concluded that abnormalities in both the horizontal and vertical development of the mandible were the most common components of the Class II malocclusion.

Enlow et al. (1971A) described two basic categories for Class II individuals: those with a protrusive maxillary A point compared with B point, as projected to the functional occlusal plane, and those with a protrusive mandibular B point relative to A point. They referred to these categories as Class II types A and B, respectively. Enlow documented essential differences among the skeletal and dental relationships characterizing these distinct craniofacial types. In a

more recent study (Enlow et al., 1985) type A and B composites were found to differ in response to Frankel appliance treatment, suggesting that predictability of treatment outcome could depend, in part, upon the pretreatment anatomic composite. The A type is the most frequent among the Class II group and demonstrates regional relationships contributing to an underlying tendency towards maxillary protrusion. The B type tends to be a less severe or even a non-maxillary protrusive composite with a underlying Class III disposition for many of the regional anatomic relationships.

In another study, Whitney (1983) observed that serial trends in the developing Class II individual worsened with age and that facial imbalances compounded.

The conscientious clinician strives to tailor each treatment plan to the needs of the individual. A better understanding of the development of the Class II pattern as well as the possibilities and limitations of a treatment method will help achieve more predictable results.

Esthetics, function and trauma prevention provide the rationale for treatment of the Class II malocclusion. In more severe cases where mandibular retrusion is obvious even to the untrained eye, psychosocial reasons for treatment are also valid. Psychologists, such as Schilder (Liggett, 1974), advise that, "the face is often

felt to be oneself. The face is one of the most important areas of the body in the development of a sense of personal identity. In the mind's illogical way, a fine face is believed to automatically bestow a fine character. Neurotic individuals in particular feel that their inadequacies are actually caused by their imperfect faces, and often seek plastic surgery as a way to resolve their personality difficulties. Society promotes and perpetuates a widespread striving for impossibly high standards of personal physical beauty."

Ancient physiognomists such as Lavater (Liggett, 1974), wrote textbooks full of advice on the implications of the character of facial features. Regarding the chin, he wrote:

> "I am, from numerous experiments, convinced that the projecting chin ever denotes something positive, and the retreating something negative. The presence or absence of strength in man is often signified by the chin. Flatness of chin bespeaks the cold and dry; smallness: fear."

These opinions have yet to be substantiated by adequate social-science documentation, but paradoxically, whether any true causal relationships exist between facial features and personality may not be as important as popular opinion. If people believe that facial features and temperament are related, even on a subconscious level, then their actions may be based on this feeling. It seems reasonable that if a person with a

recessive chin is treated as a weaker, less assertive person, then in time this could become a self-fulfilling prophecy.

Perhaps few professionals are as aware of society's demands for physical perfection as the orthodontist. Improvements in facial appearance must not be disregarded in correcting the Class II patient. Some past treatment methods failed to improve and could actually worsen facial appearance, since limited options have been available to morphogenetically treat the underdeveloped mandible.

The introduction of appliances which demonstrate potential for achieving changes in growth and morphology of skeletal parts has affected the way many clinicians are approaching skeletal Class II correction. Thousands of case reports laud the beneficial changes produced by "functional" appliances. The popularity of short training courses on this topic attest to the fact that these appliances have become widely used. Dramatic facial changes seldom seen with conventional fixed appliances are not only possible but also are fairly routine (Graber, 1985). Reasons for these treatment results, however, are still unclear, and the effects are not consistent from individual to individual. The situation becomes further obscured by attributing the changes merely to "condylar growth stimulation," which is

likely an oversimplification of a kinetic, multifactorial process. The fact remains, however, that sagittal change of a clinically significant magnitude is indeed achieved, and this result certainly warrants further study. Morphologic and morphogenic research aiming to clarify the treatment effects of, and response to these appliances is strongly called for at this time. The purpose of the present study has been to evaluate the treatment effects of one such device, the Herbst appliance, on a statistically significant sample of growing Class II patients. A special type of cephalometric approach was utilized to gain insight into the changes occurring within the craniofacial composite from an anatomic perspective. The counterpart analysis of Enlow was selected for this purpose.

II. Background Literature

The possibility of stimulating growth and achieving considerable changes in maxillary and mandibular morphology has been a time-honored objective of the orthodontist. Edward Angle (1907) believed that normalized adaptation of the craniofacial pattern could follow the clinical establishment of normal function. The advent of cephalometrics did not then support his theory, and as a result it became generally accepted that orthodontic treatment could influence only the dentoalveolar areas of the jaws (Brodie, 1940).

In the late 1950's and 1960's, studies emerged which began to support the possibility of changing the entire craniofacial complex (Klein, 1959; Weislander, 1963). At the same time, clinical results of functional orthopedics as practiced in Europe suggested that skeletal discrepancies might be corrected by intervention into the biologic process of facial growth (Korkhaus, 1960; Marshner and Harris, 1966).

The "functional appliance" has since been used in the correction of the Class II, Division 1 malocclusion with fluctuating popularity. This appliance can be described as any device which changes the position of the mandible to a Class I skeletal relationship with the maxilla, and concomitantly alters the functional soft tissue environment. Apart from effects on the dentoalveolar process, which are generally accepted, numerous studies report that mandibular displacement is accompanied by underlying changes in the craniofacial growth pattern, particularly affecting the mandible.

The literature reveals that the use of different such functional appliance treatment methods has widely varying results. One avenue to studying treatment response has been through experimental approaches. For the most part, these investigations report definite treatment reactions following therapy. Charlier et al. (1969) demonstrated stimulation of prechondroblastic

cells leading to growth augmentation of the condylar cartilage following hyperpropulsion of the mandible in young rats. In the same study, a causal relationship was found between intensity of condylar growth and amount of periosteal bone on the posterior border and postero-inferior border of the ramus. Studies most relevant to the clinician are those utilizing non-human primates, and experiments involving anterior displacement of the mandible have demonstrated various alterations in mandibular morphology. Stockli and Willert (1971) supported Charlier's findings, attributing observed changes to adaptation within the temporomandibular joint, namely the condylar cartilage. In addition they reported a high relapse resistance in the treated sample with no signs of histopathology. Others claimed that changes were limited to the gonial angle and/or alveolar structures (Hiniker and Ramfjord, 1966). To better describe the condylar response, a series of subsequent studies suggested that (1) increased lateral pterygoid muscle activity (Petrovic and Stutzman, 1975; McNamara, et al., 1975), or (2) tension on the meniscotemporal ligament (McNamara and Carlson, 1979; Petrovic and Stutzmann, 1977) might be responsible for the increased condylar activity. An additional area of study has been the glenoid fossa. In a very early report, Breitner (1930, cited in Elgoyhen, 1970), observed craniofacial

adaptation due, in part, to a mesial migration of the glenoid fossa. Zimmerman, however, (1971) has since shown that such a histologic picture can be observed in the normal remodeling process of the mandibulo-temporal complex.

Clinical research approaches have also been taken. Marshner and Harris (1966) considered total mandibular length and noted significantly higher growth in the treated groups. Bjork (1951), however, contends that any skeletal changes during this type of treatment may well be within the range of normal growth. Harvold (1971) concurred, concluding that treatment had no apparent effect on mandibular growth.

The weak correlation between animal research and clinical studies highlights the difficulties in drawing inferences between the two. Although animal studies generally demonstrated significant and consistent treatment responses, orthopedic results in human patients have not proven as predictable. Weislander (1984) suggested that timing of treatment, intensity, nature of forces applied and anchorage may be among the variables accounting for such differences. He cites one possible reason for the dramatic response seen in animal experiments as being the heavy forces used, which in relation to size and weight of the animal vastly exceeds those used in patients. According to Weislander, the

morphologic effects of orthopedic treatment may increase if proper anchorage is used at an early age and if the appliance is worn 24 hours per day.

It seems clear from the literature that further investigation will be required on both clinical and experimental levels before the orthodontist can select and consistently and effectively apply the use of a given functional appliance with informed confidence.

III. The Herbst Appliance

The Herbst appliance is a fixed, nonremovable mandibular protrusive-positioning device used in the treatment of Class II skeletal patterns where the mandible has been determined to be deficient. Research on removable functional appliances is problematic in that treatment effects can be greatly influenced by patient reliability. Because of the inherent compliance of the Herbst appliance, and relatively short treatment time of about 8 months, it was selected as the focus of this study.

The appliance was first introduced in 1905 by the German orthodontist Emil Herbst during an International Dental Congress in Berlin. Dr. Herbst was the first professor and chairman of an orthodontic department in Europe. He published a series of articles (Herbst, 1934) based on his experiences with the Retention-Scharnier (retention-hinge). The appliance can be described as an

artificial joint working between the mandible and maxilla. A bilateral telescoping mechanism attached to orthodontic bands sustains the mandible in an anterior position throughout all functions.

Herbst described several uses for this appliance:

1. as an artificial joint in cases of condylar resection;
2. for the retrognathic mandible;
3. correction of midline discrepancies;
4. relief of pain during healing of jaw fracture;
5. help against "night-crushing";
6. relief of "jaw cracking" in illnesses of the jaw.

Herbst maintained that a change in function and position of the mandible resulted in a reshaping of the condyle. As his rationale for this, he cited observations of the skull of a 60 year old woman.

> "As a result of her peculiar articulation - caused by the loss of many teeth - she was forced, by biting, to push one lower jaw so far to the left that the lower central of the right side touched the upper central of the left side. The consequence was that the two jaw hinges were used quite differently, so that the one processus condyloideus itself flattened out, but the other was forced to pointing itself more and more" (Herbst, 1934).

A contemporary of Edward Angle, Herbst believed that normal function resulted in normal tooth arrangement, and

that malocclusions could be improved through restoration of normal function.

> "The rearrangement of the lower jaws means an immediate change of the chewing function. These so suddenly created changes in the chewing organ and in the lower faceparty - or say we - in the region of the only movable bone of the human skull - now causes a change of the function of the lip pressure, cheek pressure and chewing muscle pressure, and with this a change in the effect of the tooth arrangement. So to speak, we are changing over to the natural healing process" (Herbst, 1934).

With the introduction of intermaxillary elastics in the United States and functional jaw orthopedics in Europe, orthodontists were then provided with other means for treating the Class II malocclusion. The Herbst technique was more or less forgotten until reintroduced by Hans Pancherz in 1979. Pancherz used the original Herbst design utilizing cemented molar and premolar bands but added additional anchorage when necessary through the use of soldered lingual bars. A one time edge-edge advancement was maintained for a treatment time of 6 to 8 months. Herbst had recommended retention of the correction with onlays, suggesting that cuspal interdigitation was critical in stability of the result. Pancherz preferred to retain with another functional appliance, such as an activator. The purpose of Pancherz' first study was to determine whether sagittal mandibular growth could be stimulated by treatment in

growing Class II children. He documented a clinically significant increase in mandibular growth by what he called a "24 hour bite jumping" effect upon the mandible. His cephalometric analysis revealed complete Class II correction in all cases due to equal contributions from skeletal and dental changes. He attributed a greater than normal mandibular length increase to condylar growth stimulation. Pancherz was also concerned that a change in mandibular position might be a result of forward posturing of the mandible. Temporomandibular joint radiographs were utilized to determine post-treatment condylar position in the glenoid fossa. In his 1982 study he reported an anterior condylar displacement not exceeding 0.3 mm in his treated sample. In a subsequent report, also in 1982, he examined vertical dentofacial changes in the same treated sample. A pronounced effect was seen on vertical posterior tooth position. As a result, an overbite was reduced, lower face height was increased and a clockwise rotation of the occlusal plane was seen to occur. Also four of 20 cases demonstrated marked rotation of the entire maxillary complex in a clockwise direction.

Several investigators have since modified the original Herbst design, primarily by changing the method by which the appliance is attached to the maxillary and mandibular dental arches. Replacing the use of bands by

Herbst and Pancherz, modifications have included the use of stainless steel crowns (Langford, 1981; Goodman and McKenna, 1985), the bonded acrylic splint (Howe and McNamara, 1983), a cast vitallium design (Weislander, 1984) and attachment of the telescoping mechanism directly to a continuous archwire (Smith, et al., 1986) (See Table I).

Anchorage modifications have included a partial banded design of the original, and full occlusal coverage with a total anchorage bonded acrylic appliance as used in the present study. (For further descriptions of appliance design and clinical management, see Howe and McNamara, 1983.)

IV. The Counterpart Analysis

The science of cephalometry was first introduced to the field of orthodontics by Broadbent in 1931. Cephalometric analysis evolved primarily as a response to the clinician's need for useful diagnostic and treatment planning criteria. Consequently, cephalometrics has become widely integrated into orthodontic research and firmly established as an educational and clinical tool. Useful procedures have been developed for the assessment of changes in dentofacial morphology, the study of abnormalities, and for the evaluation of orthodontic treatment results.

TABLE I

COMPARISON OF HERBST APPLIANCES AND CLINICAL APPLICATION

EUROPEAN DESIGN	U.S. DESIGN
Herbst 1934 Pancherz 1979	Howe, McNamara 1983
- bands - cemented	- full bonded occlusal splint
- partial or total anchorage	- total anchorage
- edge-edge advancement	- 3-4 mm advancement maximum
- one advancement only	- repeated as necessary at 2-3 month intervals
- 6-8 month treatment time	- 8 months + 3 months retention following final advancement
- retention with onlays (Herbst) retention with functional appliance i.e. activator (Pancherz)	
- no occlusal coverage	- full occlusal coverage

Most of the cephalometric analyses available today were derived at a time when significant clinical alterations of craniofacial structures were thought impossible. Due to the then existant limitations of the knowledge of craniofacial growth and development, the planes and angles used were rarely constructed with actual sites of growth and remodeling in mind. These analyses were more appropriate for describing the end result of the growth process than attempting to explain how the changes occurred.

In Enlow's counterpart procedure (Enlow et al., 1971A), various key anatomic parts within an individual are compared with respect to regional balance, or "goodness of fit." Boundaries for these counterparts are determined by the perimeters of the various major fields of growth, remodeling and displacement (Bhat and Enlow, 1985). Conventional cephalometric planes and angles are not relevant, and comparisons with population norms are not required. Dimension and alignment are given equal consideration in determining the architectural role of any given part. Equal incremental growth among counterparts will maintain a constant morphologic pattern. If proportionate growth and remodeling changes are not achieved, relative protrusions or retrusions of the parts occur. Effects are translated from region to region so that a given effect may be expressed in

locations quite remote from the actual source. The purpose of this analysis is to provide a means for determining the actual, underlying anatomic and morphogenic patterns present in any given craniofacial composite. In addition to identifying a given individual's growth pattern, the counterpart analysis helps to explain how such a pattern came about. For these reasons this cephalometric analysis was selected for the objectives of this study.

The constructs of this analysis correspond with the following growth fields:

1. the maxillary tuberosity
2. the mandibular condyle
3. the junction of the ramus and corpus
4. the anterior and posterior borders of the ramus
5. the anterior surfaces of the maxilla and mandible
6. the middle endocranial fossa
7. the occlusal plane
8. the sphenoethmoidal junction and lateral basicranial sutures

The PM (posterior maxillary) plane is a key component in this analysis. This base reference plane is utilized because it is essentially perpendicular to the neutral orbital axis (neutral line of vision) and, as

such, is consistent with the anatomically neutral position of the head. The PM plane also forms an anatomic boundary between the sets of counterparts (Table II).

A consideration which makes this procedure appropriate as an anatomic analysis is the use of planes and angles which coincide specifically with key growth and remodeling sites (Enlow, 1982). A meaningful appraisal of craniofacial pattern and treatment effects is made independent of the need for population comparison. Thus, specific morphologic reactions in a given individual can be determined.

As the real causative factors underlying structural imbalances become better understood, cephalometric analyses using actual anatomic and developmental relationships will become increasingly more relevant, and selection of more appropriate, effective treatment procedures for an individual patient can then become possible.

TABLE II

HORIZONTAL AND VERTICAL COUNTERPARTS

UTILIZED IN THE PRESENT STUDY

Horizontal Counterparts	1. Frontal lobes of the cerebrum 2. Anterior cranial fossae 3. Upper ethmomaxillary complex 4. Palate 5. Maxillary arch 6. Mandibular corpus
	1. Temporal lobes of the cerebrum 2. Middle endocranial fossae 3. Posterior oropharyngeal space 4. Ramus width
Vertical Counterparts	Ramus/middle endocranial fossae composite Posterior nasomaxillary complex

STATEMENT OF THESIS

The objective of this study is to evaluate specific anatomic and morphogenic changes in the Class II craniofacial composite following Herbst appliance treatment.

The objectives are:

1) to determine which particular anatomic parts and relationships are responsive to this treatment method and which are unaffected;
2) to determine whether different pre-treatment anatomic variations vary in response; and
3) to assess post-Herbst stability during subsequent orthodontic and retention phases.

MATERIALS AND METHODS

Treatment Sample

Lateral cephalometric radiographs were obtained from the patient files of three private orthodontic practitioners. The cases for this study were selected according to the following criteria:

1. At least an end-end molar or canine relationship;
2. Pre- and post-treatment radiographs available within 3 months of the onset and completion of Herbst appliance therapy;
3. All necessary landmarks readily identifiable;
4. No extraction of permanent teeth preceding or occurring during the treatment period;
5. No concurrent fixed appliance treatment;
6. All treated with the bonded acrylic Herbst appliance.

The treated sample included 33 males and 29 females for a total of 62 Class II cases. Three lateral cephalograms were requested for each treated case:

1. Pre-Herbst treatment (within 3 months before appliance delivery)
2. End of Herbst treatment (within 3 months following appliance removal)

3. Final treatment film (at least 6 months following completion of Herbst treatment)

Final treatment radiographs were available for 25 of the 62 cases studied. (See Table III for age averages and ranges). Treatment protocol involved an average treatment time of 8 months, with a range of 4-12 months between appliance delivery and removal. Patients were initially advanced 3-4 mm and subsequently re-advanced, if necessary, at 2-3 month intervals until the desired amount of mandibular repositioning was achieved. Patients were generally retained in the Herbst appliance 2-3 months following the final advancement.

Control Sample

The control sample was selected from the longitudinal records of the Bolton Study (CWRU, Cleveland, Ohio). Sixty-two Class II cases, matched by sex, age and dental classification were used. Specific criteria included:

1. At least an end-end molar or canine relationship
2. No extractions or congenitally missing teeth
3. No prior or concurrent orthodontic treatment
4. All necessary landmarks readily identifiable

TABLE III

AGE RANGES AND MEANS FOR TREATMENT AND CONTROL RADIOGRAPHS

Treatment Sample	Range in Years	Mean
T_1	7.4-17.8	12.5
T_2	8.2-18.8	13.4
T_3	10.0-20.0	14.9
Control Sample		
C_1	7.0-16.4	12.6
C_2	7.9-17.5	13.3
C_3	9.0-18.2	14.3

5. Sequential radiographs available in the required age ranges.

Three lateral cephalograms were used to represent each control case. Each radiograph was matched to within six months of its corresponding treatment radiograph (See Table III).

Technical Details

Tracings of all cephalograms were made on .003 matte acetate tracing paper using an England Eagle Turquoise 10 pencil with 2H drawing leads. Sufficient anatomic landmarks were traced to allow identification of 27 registration points (See Table IV, and Fig. 1). All tracings were done by the same investigator. Tracing error was assessed by retracing 15 headfilms subsequently compared to the initial tracings.

The tracings were analyzed using a computerized cephalometric technique. The facilities for the use of this program are housed in the Bolton Study and A.R. Jennings Computer Centers (CWRU). Each of the 27 points and a final standardization point, given x and y coordinates, were registered in sequence using a Summagraphics digitizing pad. The linear and angular measurements used in Enlow's Counterpart Analysis were then calculated by a suitably developed program (Behrents, 1984).

TABLE IV

POINTS USED FOR DIGITIZING CEPHALOMETRIC TRACINGS

1. Menton (Me)
2. B Point
3. Inferior Prosthion (IPr)
4. Incisal Edge of the Mandibular Central Incisor
5. Superior Prosthion (SPr)
6. A Point
7. Anterior Nasal Spine (ANS)
8. Most Posterior Occlusal Point of the Last Fully Erupted Maxillary and Mandibular Molars
9. Distal Surface of the Mandibular First Molar
10. Distal Surface of the Maxillary First Molar
11. Most Anterior Maxillary/Mandibular 1st Premolar Occlusal Contact
12. Cementoenamel Junction of the Last Fully Erupted Maxillary Molar
13. Anterior Border of Ramus (ARa)
14. Gonion (Go)
15. Posterior Border of Ramus (PRa)
16. Articulare (Ar)
17. Occipital Point (O)
18. Posterior Nasal Spine (PNS)
19. Inferior-most Point of the Pterygomaxillary Fissure
20. Foramen Rotundum in the Pterygomaxillary Fissure
21. Sphenoethmoidal Junction (SE)
22. Posterior Boundary of the Cribriform Plate

TABLE IV (cont.)

23. Orbitale (Or)

24. Anterior Boundary of the Cribriform Plate

25. Anterior-most Point of the Endocranial Surface of the Frontal Bone

26. Sella (S)

27. Nasion (Na)

Registration Point: Middle of the Ear Rod or Center of Internal Auditory Meatus

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

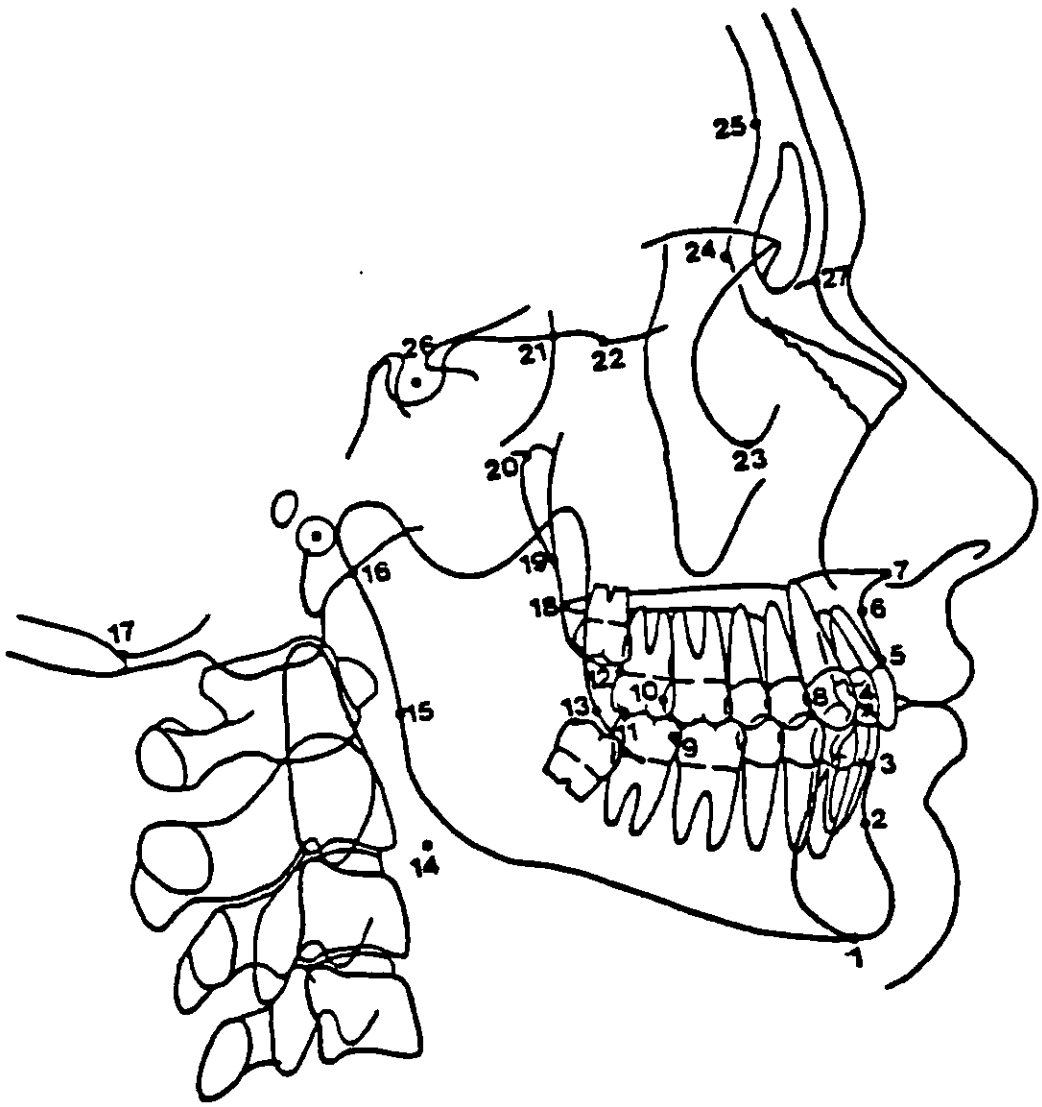

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TABLE V

THE SIXTEEN VARIABLES EVALUATED IN THIS STUDY

1. Aggregate cranial floor/maxilla and ramus/corpus horizontal dimensions at A and B points.
2. Middle cranial fossa (MCF) and posterior maxillary (PM) relative alignment.
3. Ramus alignment.
4. Ramus/MCF horizontal dimensions (skeletal).
5. Ramus/MCF horizontal dimensions (dental).
6. Maxillary/mandibular arches, skeletal dimensions, A point compared with B point.
7. Maxillary/mandibular arches, dental dimensions, A point compared with B point.
8. Maxillary/mandibular arches, skeletal dimensions, SPr compared with IPr.
9. Maxillary/mandibular arches, dental dimensions, SPr compared with IPr.
10. PM as compared with ramus/MCF vertical dimensions.
11. Corpus-occlusal alignment.
12. Gonial angle alignment.
13. Curve of Spee.
14. Palatal plane alignment.
15. Inferior maxillary plane.
16. Maxillary nerve/palatal plane alignment.

All radiographs were corrected for magnification and a final 6% magnification factor was used for all calculations. In the control sample, the object-to-film distance (midline-lateral: ML) was used to adjust the x/y coordinates of each x-ray to a standard 6% enlargement. The treatment radiographs, taken at an 8% enlargement, were corrected to the 6% factor by the computer program.

Entry of all data was performed by the same investigator. Accuracy of computer registration was checked by the repeated entry of 10 cases. Computer measurements were verified by statistical evaluation against those of the investigator for 10 cases.

Measurements

Sixteen variables were measured for each tracing at two time intervals, and are listed in Table V. An explanation of how each measurement was made accompanies Figures Two through 18. The millimetric measurements were made to the nearest 0.01 mm and given a qualitative value of (+) or (-) to indicate, respectively, a maxillary or mandibular protrusive effect for any one variable. Measured differences less than 0.5 mm were designated as "no change."

The three radiographs for each individual were labeled as follows:

T_1=Pre-treatment film C_1=First control film

T_2=End of treatment film C_2=Second control film

T_3=Post-treatment film C_3=Third control film

Net directional changes for each variable were determined between T_1 and T_2 (treatment interval); and T_2 and T_3 (post treatment interval). Similar assessments for the control variables were performed.

Statistical Methods

Data analysis was performed by two methods. A Statistical Package for the Social Sciences (SPSS-X) was utilized to generate frequency distributions for each variable in each of two time intervals. The sign test for statistical significance was applied to measure the preponderance of direction of change. A 0.01 level of significance was determined.

In addition, mean changes were calculated for each variable for the two time intervals examined in both the treatment and control groups. Standard deviations and confidence intervals were computed to evaluate the statistical significance of the magnitude of change for each variable.

Figure 2. All the points and planes used in the counterpart analysis are demonstrated in this diagram. The solid line represents the subject's own relationships while the dashed lines represent neutral positions. This diagram includes additions to the original construct and procedure presented by Enlow (1971).

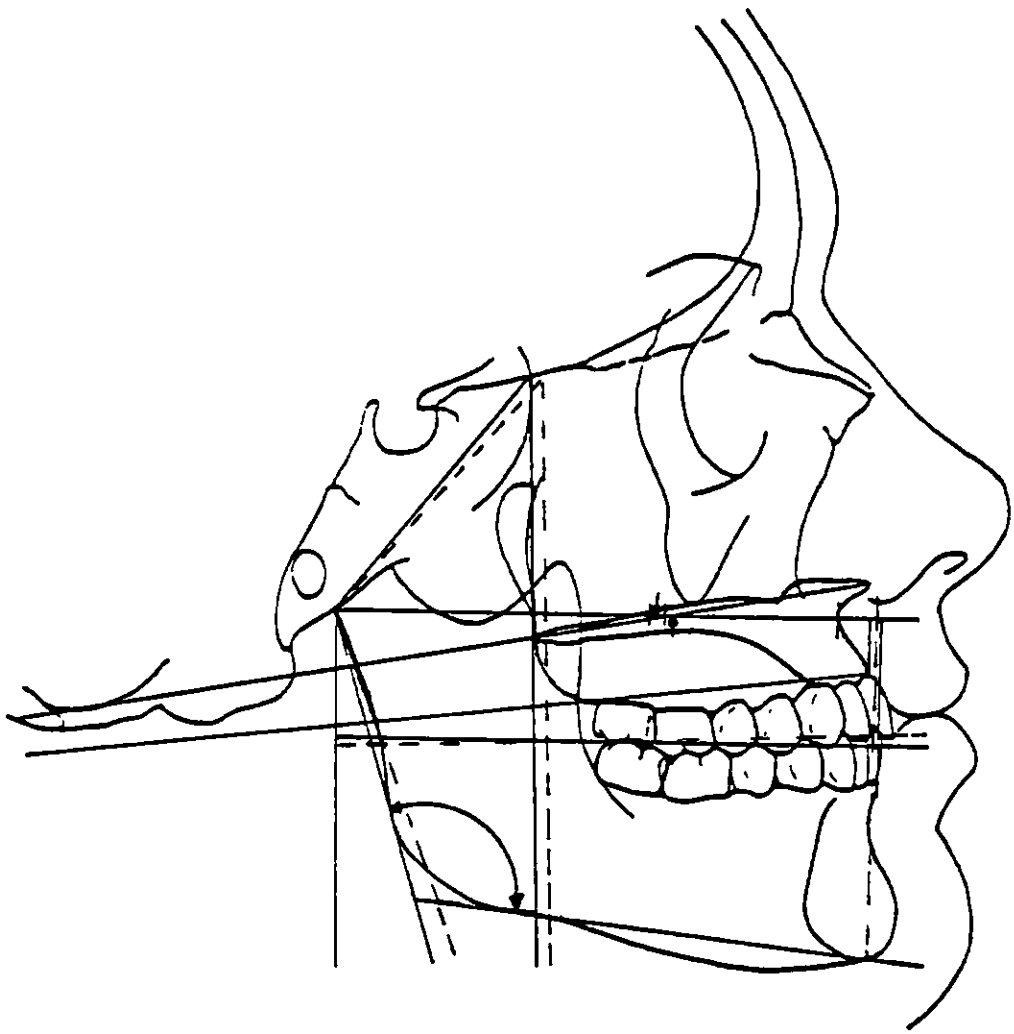


Figure 3. Aggregate cranial floor/maxilla and ramus/corpus horizontal dimensions at A and B points. This diagram demonstrates the comparison of lengths from Ar to A point and Ar to B point. The measurements are made in millimeters along REF. The lines from A point to REF and B point to REF are drawn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

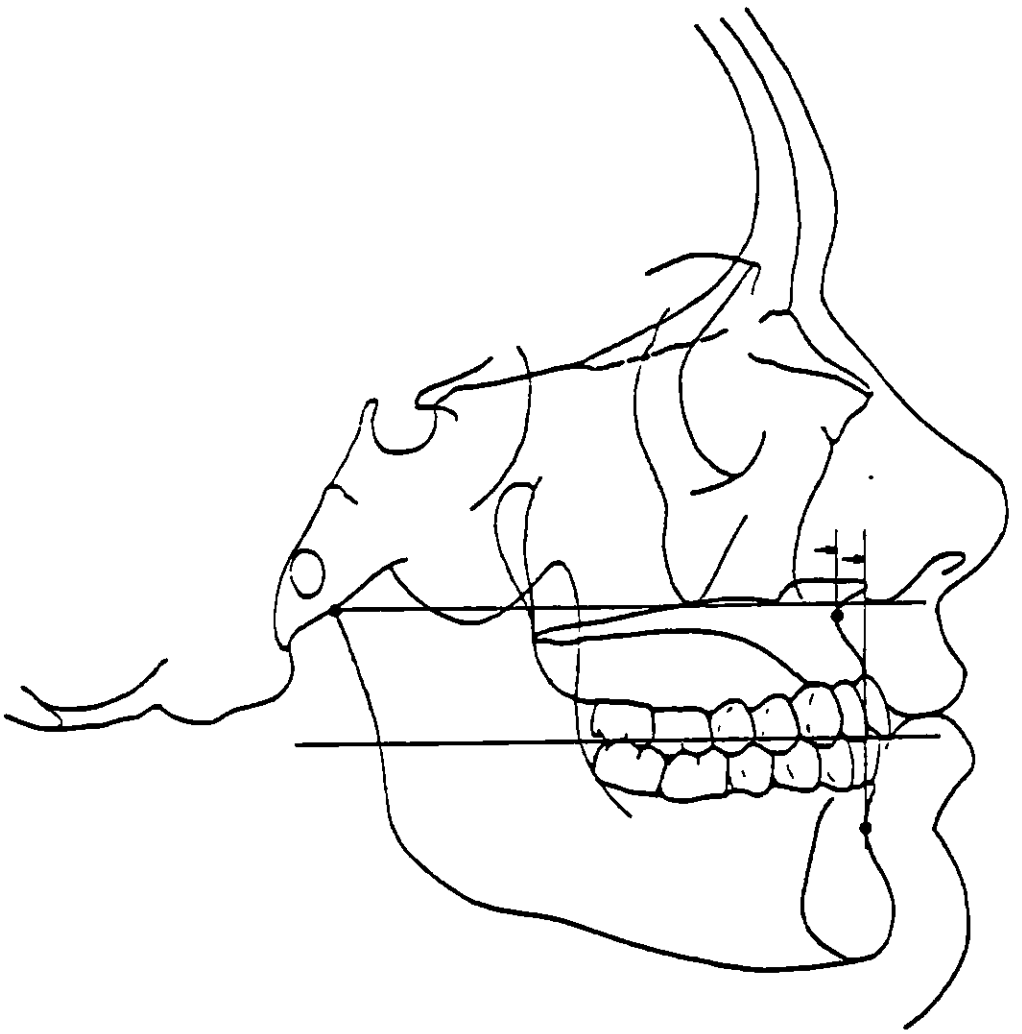


Figure 4. Middle cranial fossa (MCF) and posterior maxillary (PM) relative alignment. This diagram compares the neutral MCF/PM alignment (dashed line), which has an internal angle of 40.3° to the patient's MCF/PM alignment. The neutral MCF/PM alignment is drawn using a preconstructed template which has a 40.3° internal angle. The template is used by: (1) measuring the length of the MCF, and (2) transferring this length to the corresponding line on the template (with the vertex representing SE). (3) The tracing of the subject is placed over the template superimposing on AR and orienting the PM vertical of the patient and the neutral parallel to each other. (4) The neutral MCF/PM alignment is drawn 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.

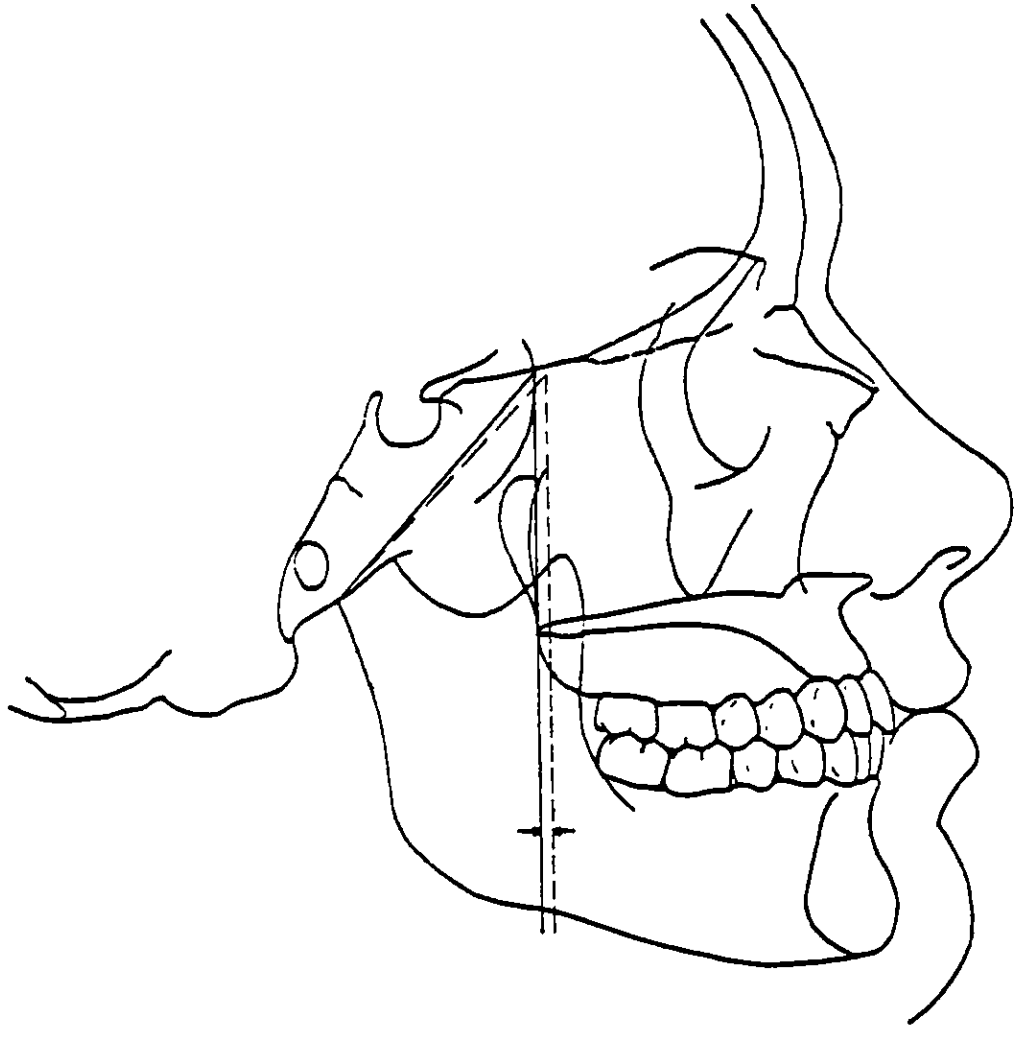


Figure 5. Ramus alignment. This diagram demonstrates the alignment of the subject's ramus plane and its relationship to the neutral ramus plane. A line from AR to Go represents the individual's ramus plane. The neutral ramus plane is represented by a line from Ar to the midpoint between AR and the neutral 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 positive number. If it is in front of NRa it is recorded as a negative number.

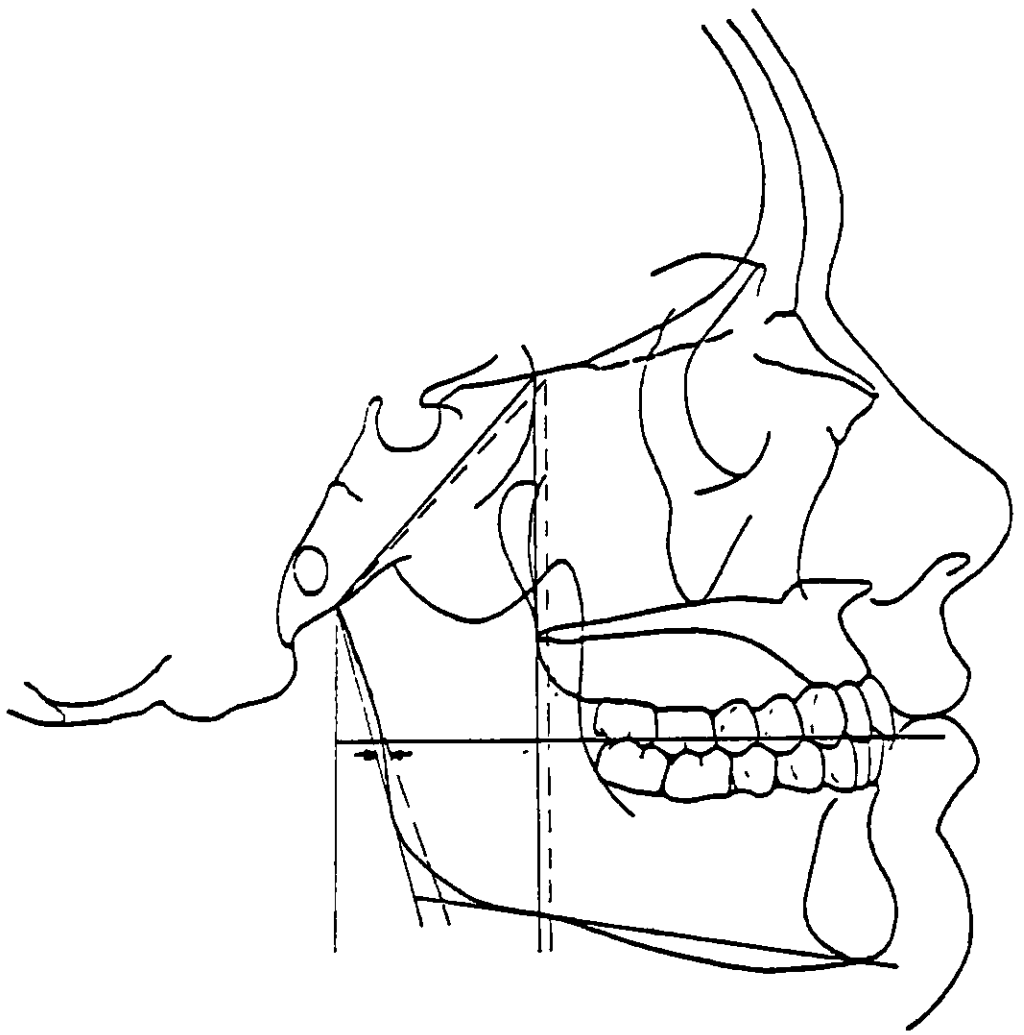


Figure 6. Ramus/MCF horizontal dimensions (skeletal). This diagram demonstrates the comparison of the horizontal dimensions of the middle cranial fossa (Ar to PM neutral) with the width of the ramus (Ar to ARa), and resultant effect on retrusive/protrusive placement of the maxilla and mandible. This measurement is made along REF is 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 is 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.

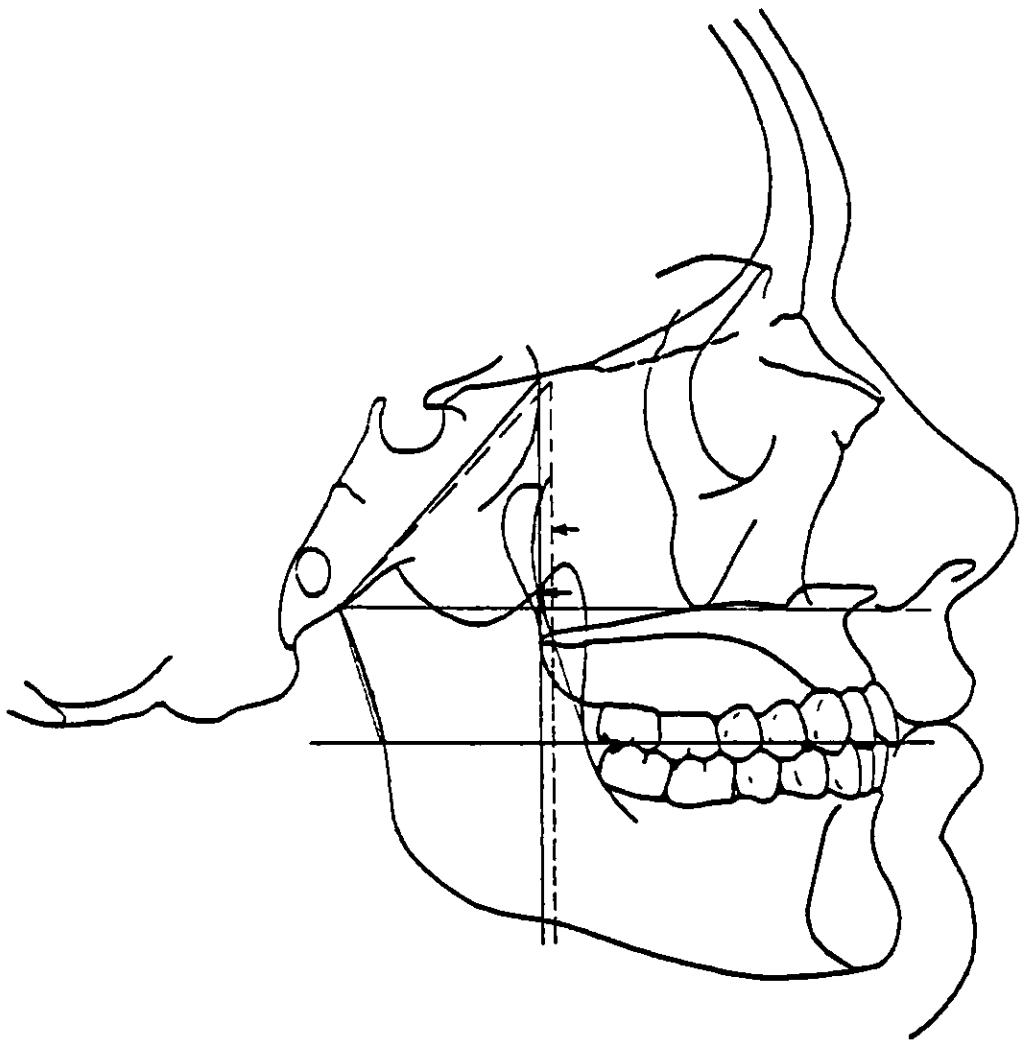


Figure 7. Ramus/MCF horizontal dimension (dental). The neutral positions of the molars are demonstrated with this measurement. The distal surfaces of the maxillary and mandibular first molars are indicated on REF by short vertical lines. The maxillary molar is corrected to its neutral position by adding or subtracting the distance betwen 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.

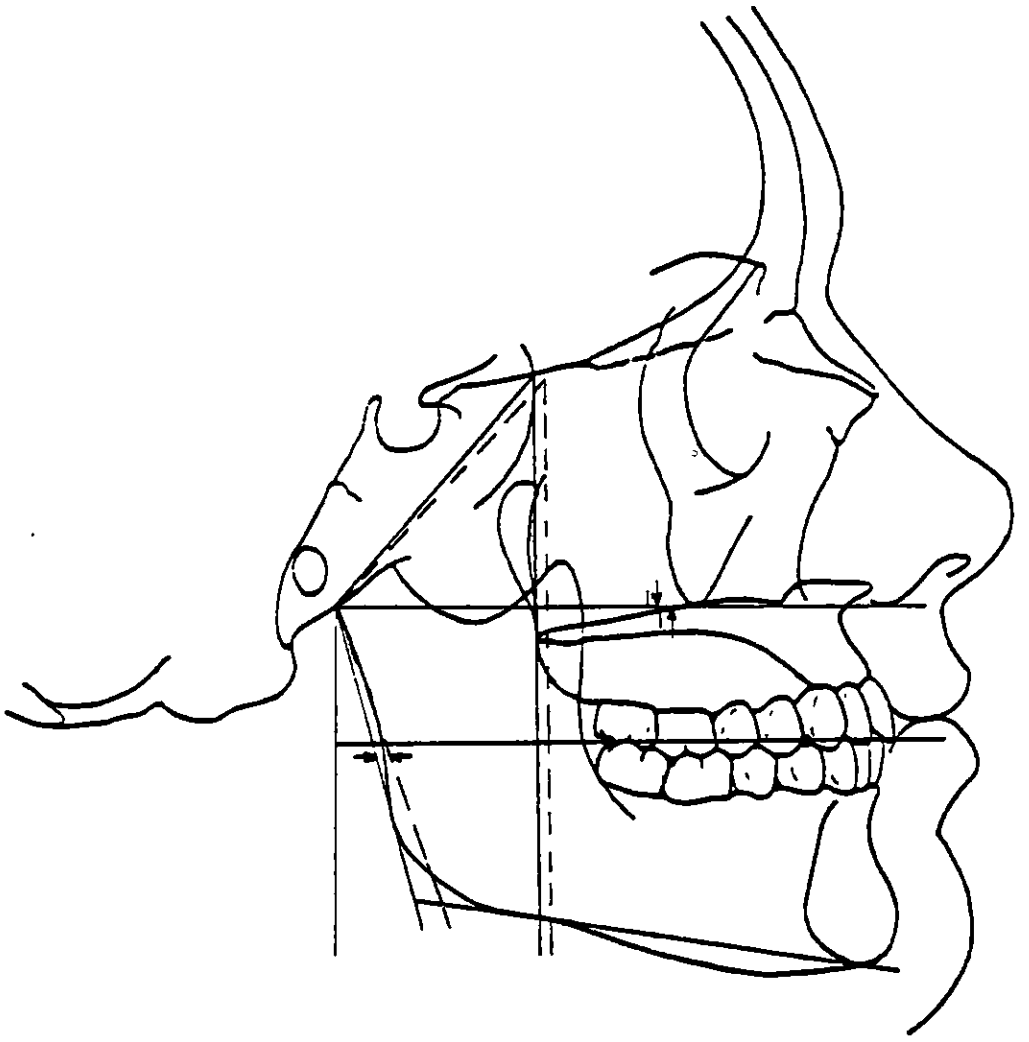


Figure 8. Maxillary/mandibular arches, skeletal dimensions, A point compared with B point. This diagram compares the length of the maxillary skeletal arch with the length of the mandibular skeletal arch. The maxillary skeletal arch is measured in millimeters from PM (solid line) along REF to A point. The mandibular skeletal arch is measured in millimeters from ARa where it intersects REF to B point along REF.

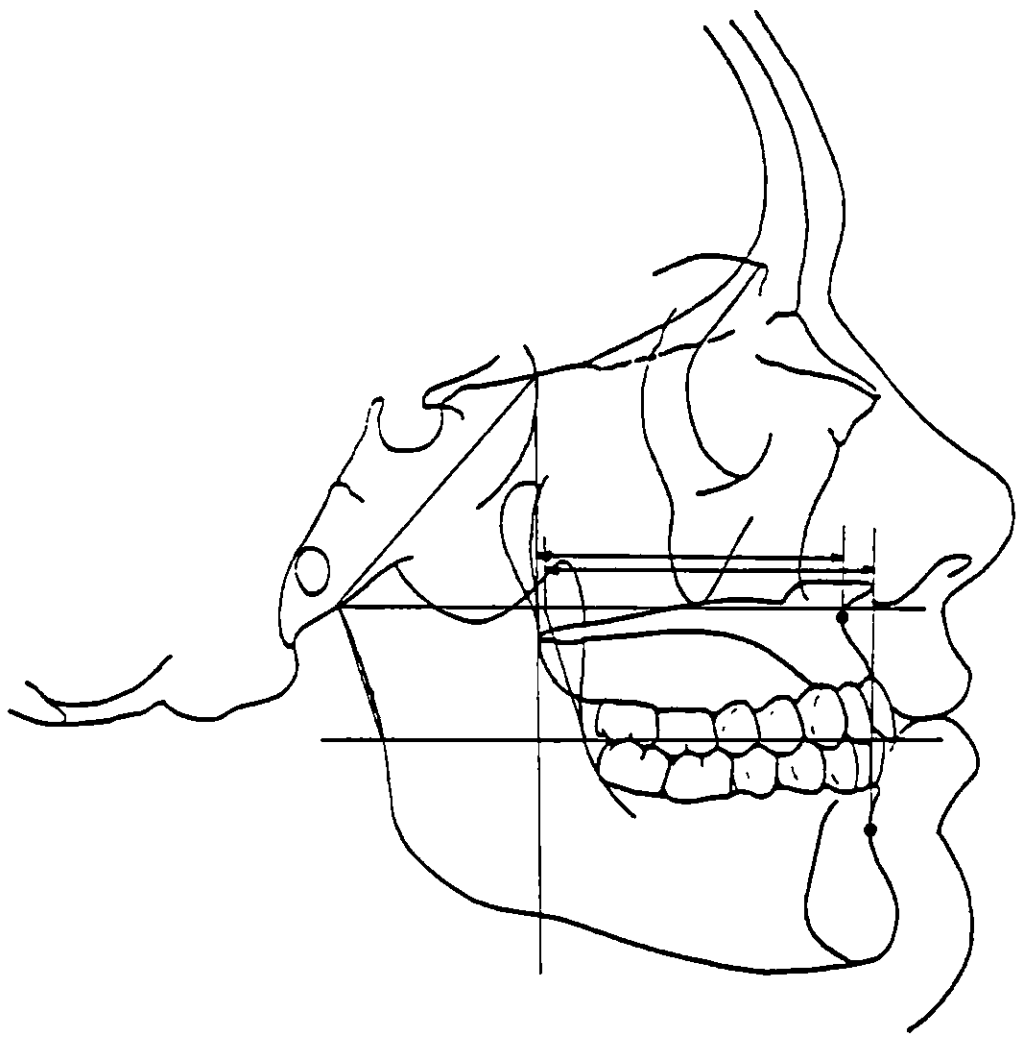


Figure 9. Maxillary/mandibular arches, dental dimensions, A point compared with B point. This is similar to the previous measurement except that the distances are measured to the distal surfaces of the first molars.

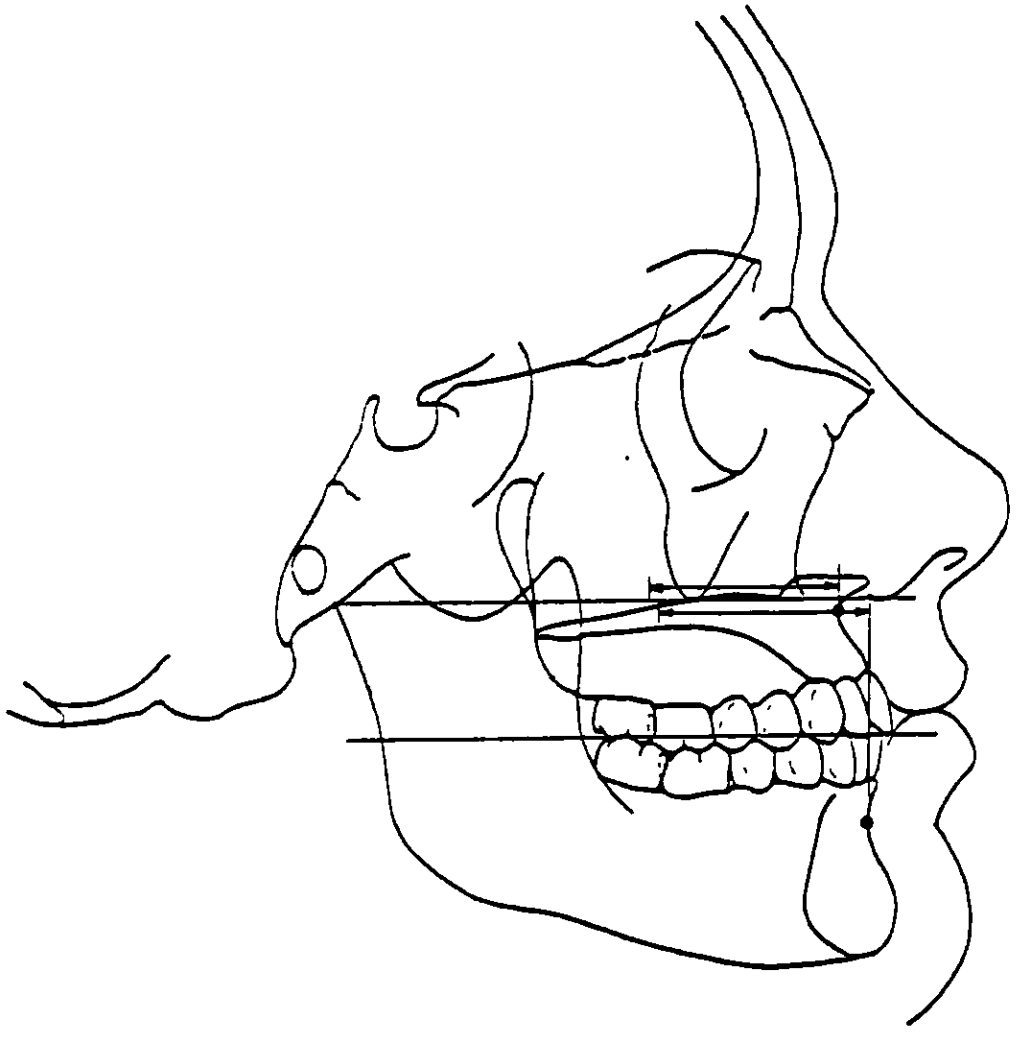


Figure 10. Maxillary/mandibular arches, skeletal dimensions, SPr compared with IPr. This comparison is identical to Figure 10 except that PM is measured to SPr and ARa is measured to IPr.

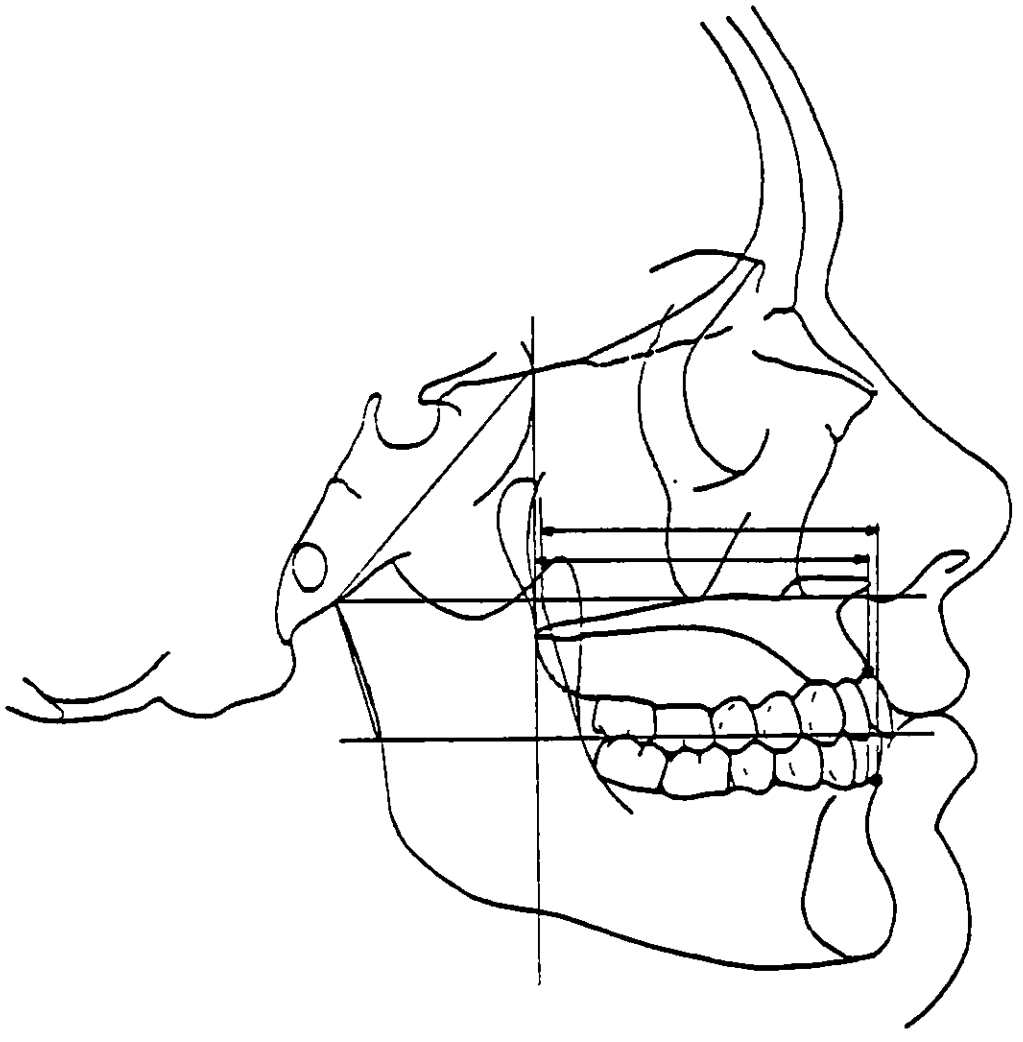


Figure 11. Maxillary/mandibular arches, dental dimensions, SPr compared with IPr. This measurement is identical to that in Figure 11 except that the distal of the maxillary first molar is measured to SPr and the distal of the mandibular first molar is measured to IPr.

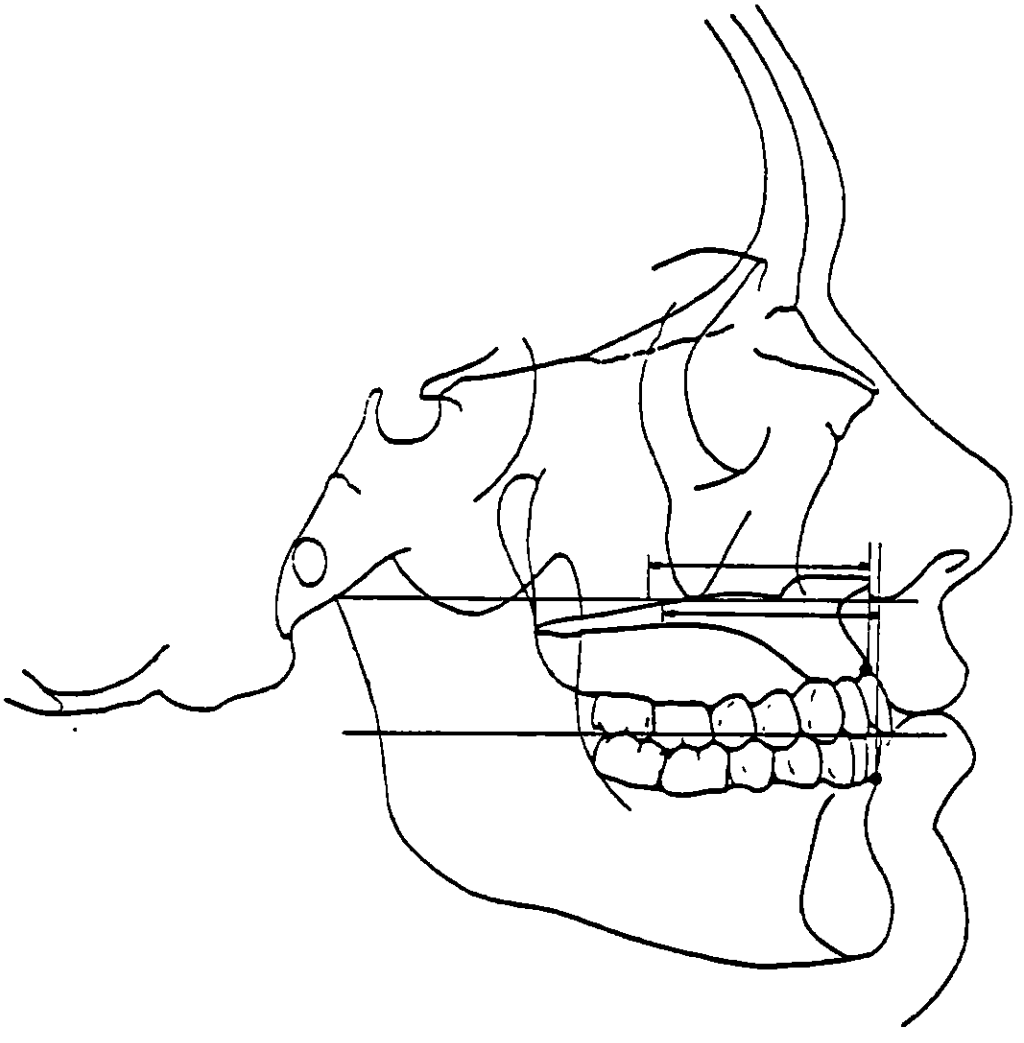


Figure 12. PM as compared with ramus/MCF vertical dimensions. The individual's relative posterior vertical nasomaxillary height is determined by this measurement. When the MCF rotates forward or backward, and the ramus rotates the same amount in the corresponding direction, no vertical disproportion in PM dimension has occurred relative to the composite vertical dimension of the middle cranial fossa and the ramus. The MCF rotation is determined by measuring the difference between PM and neutral PM along FOP. If PM is ahead of neutral PM, the MCF has a downward and forward rotation and is recorded as a positive value. If the PM is behind the neutral PM, the MCF has an upward and backward rotation and is recorded as a negative value. The ramus rotation is determined by measuring the difference between PRa and NRa along FOP. If PRa is ahead of NRa then the ramus has a forward rotation and is recorded as a negative value. If PRa is behind NRa then the ramus has a backwards rotation and is recorded as a positive value. Positive rotations of the MCF and the ramus will cause a "long" PM to occur. Negative rotations will cause a "short" PM to occur. (Ethnic variations and populations tendencies were not considered in this study.)

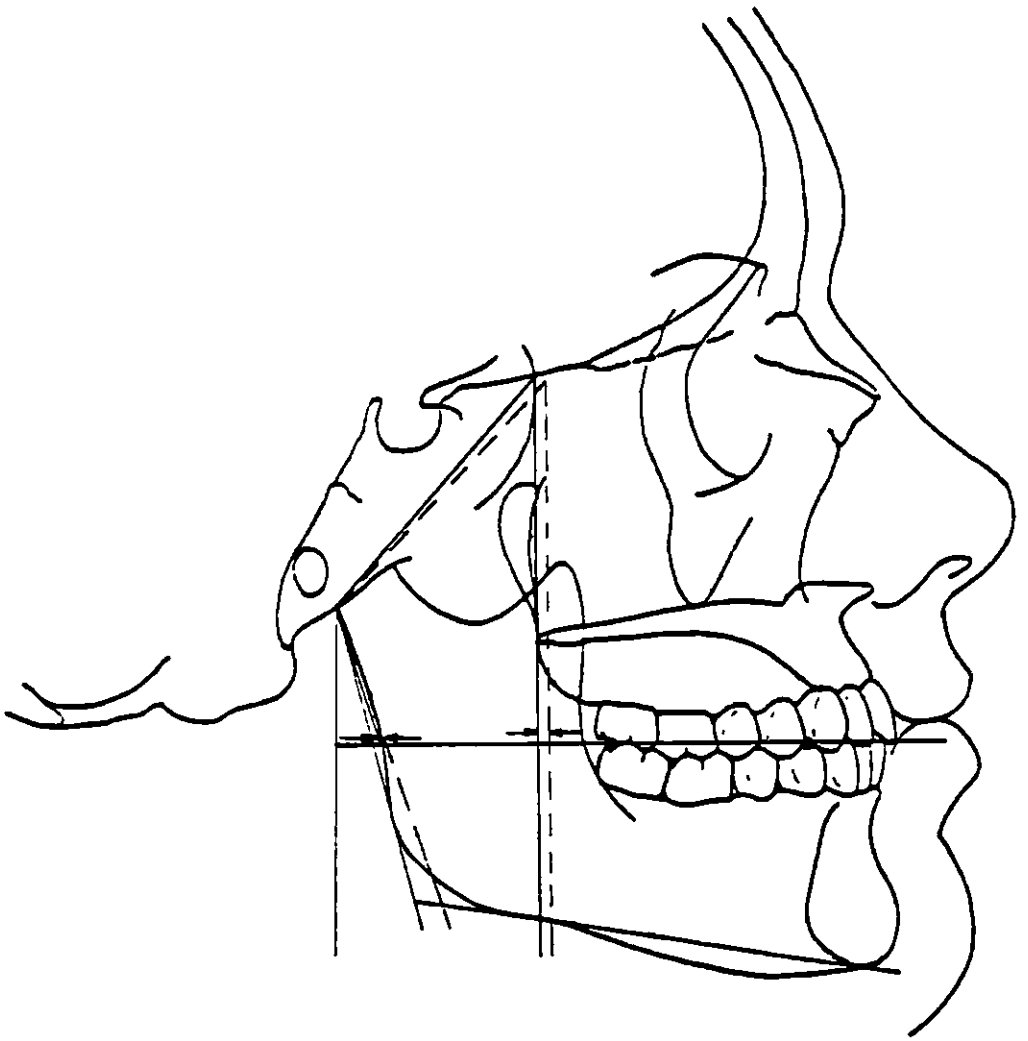


Figure 13. Corpus-occlusal alignment. This diagram demonstrates the extent of occlusal rotation as compared to the extent of ramus rotation. NOA acts as a reference line to determine the amount and direction of the occlusal rotation. NRa acts as a reference line to determine the amount of ramus rotation. 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. One arc is drawn from Ar, as the vertex crossing NOA and FOP. The distances between Ar to Go and Ar to NRa are measured at the points of intersection with the arc. If Ar to Go is behind NRa it is a positive number, if in front it is a negative number. The distance between FOP and NOA is measured at the point of intersection with the arc. If FOP is above NOA it is a positive number, if below it is a negative number. If FOP and Ar to Go have rotated equally in the same direction, the corpus/occlusal 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.

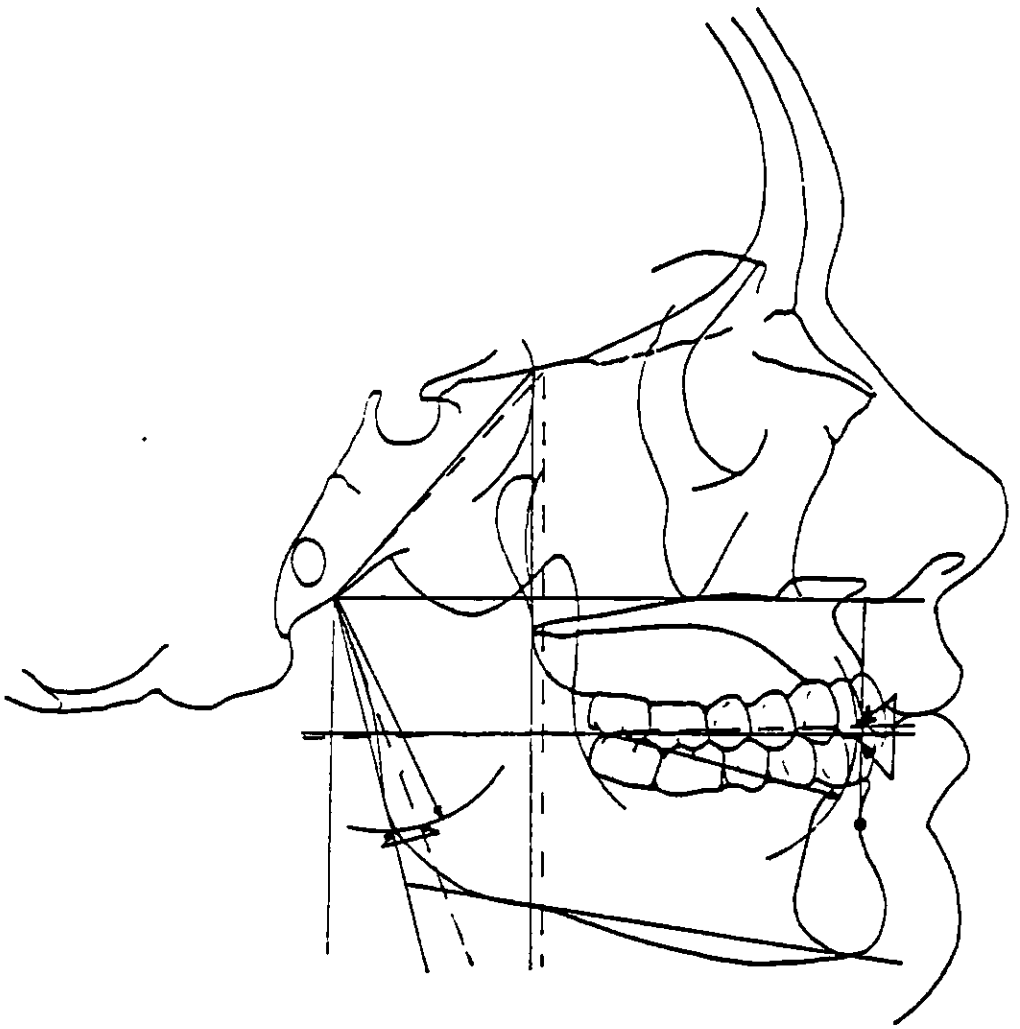


Figure 14. Gonial angle alignment. The mean gonial angle as presented in the Michigan Standard (Riolo, et al., 1975) is used as a neutral value, as indicated by a dashed line. The individual's mandibular plane is indicated by the line Me to Go. The measurement here is of two angles made in degrees. The neutral gonial angle and Ar to Go to Me.

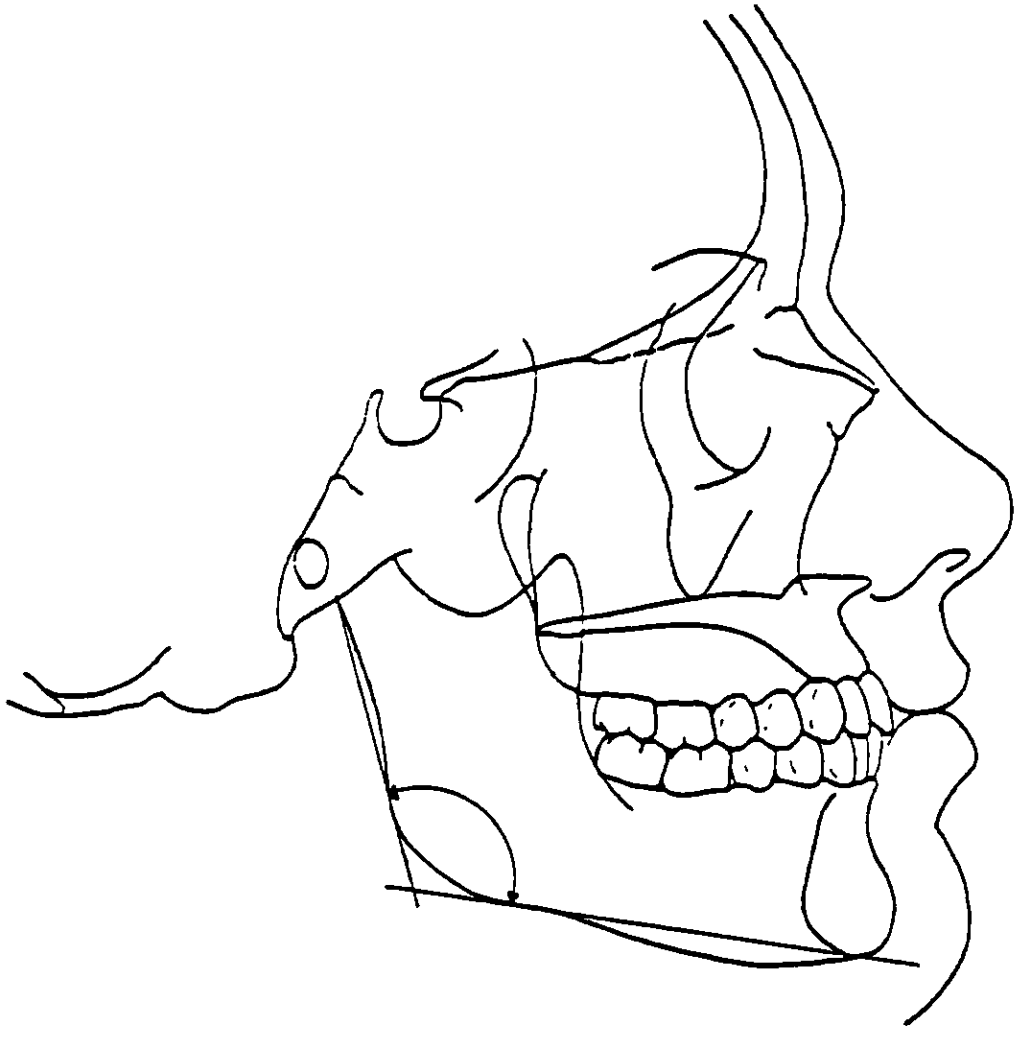


Figure 15. Curve of Spee. This is demonstrated by measuring the distance between the incisal edge of the mandibular central incisors and FOP. If the central incisors are above FOP it is a positive number, if below FOP it is a negative number.

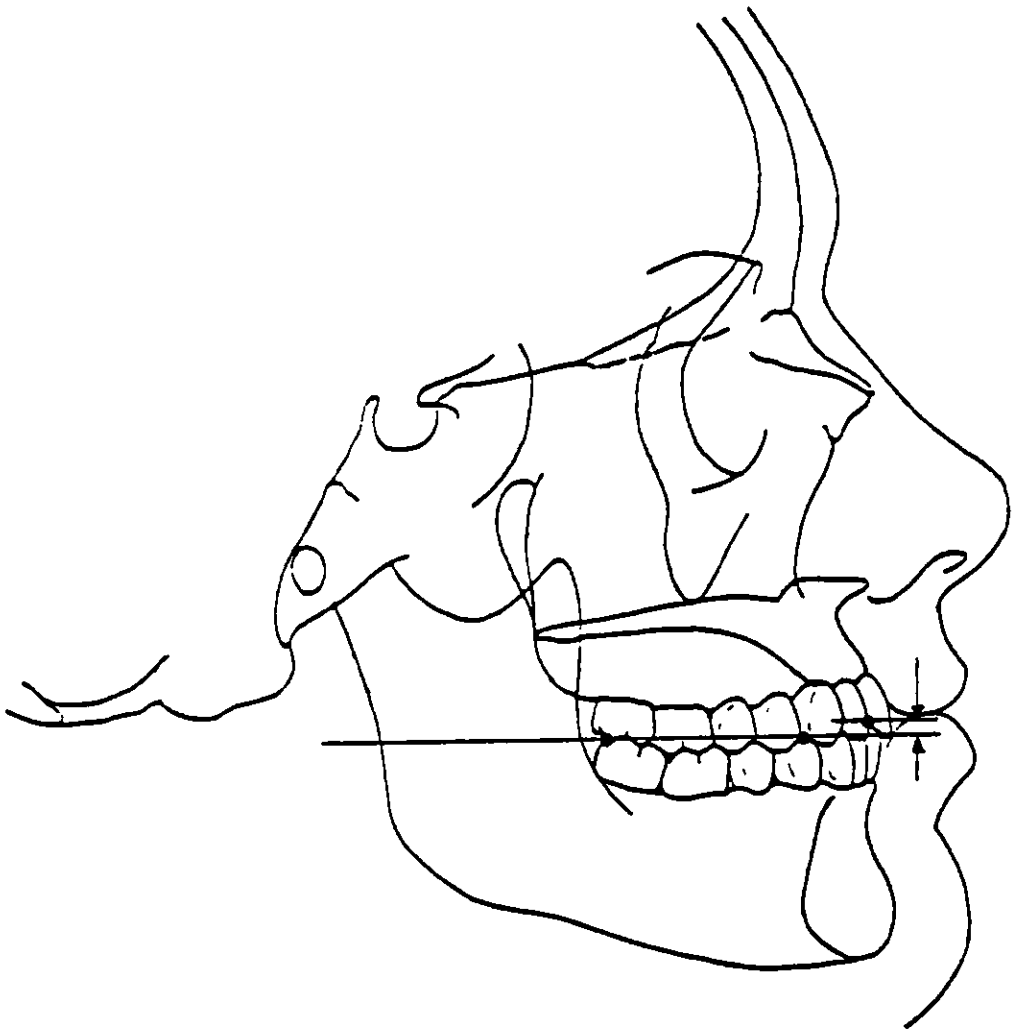


Figure 16. Palatal plane alignment. This diagram demonstrates the alignment between the palatal plane and the occipital fossa. The palatal plane is represented by a line from ANS through PNS. The distance between the plane and occipital point is measured. If the palatal plane is above O it is a negative number. If it is below O it is a positive number. Negative and positive values represent clockwise and counterclockwise rotations, respectively.

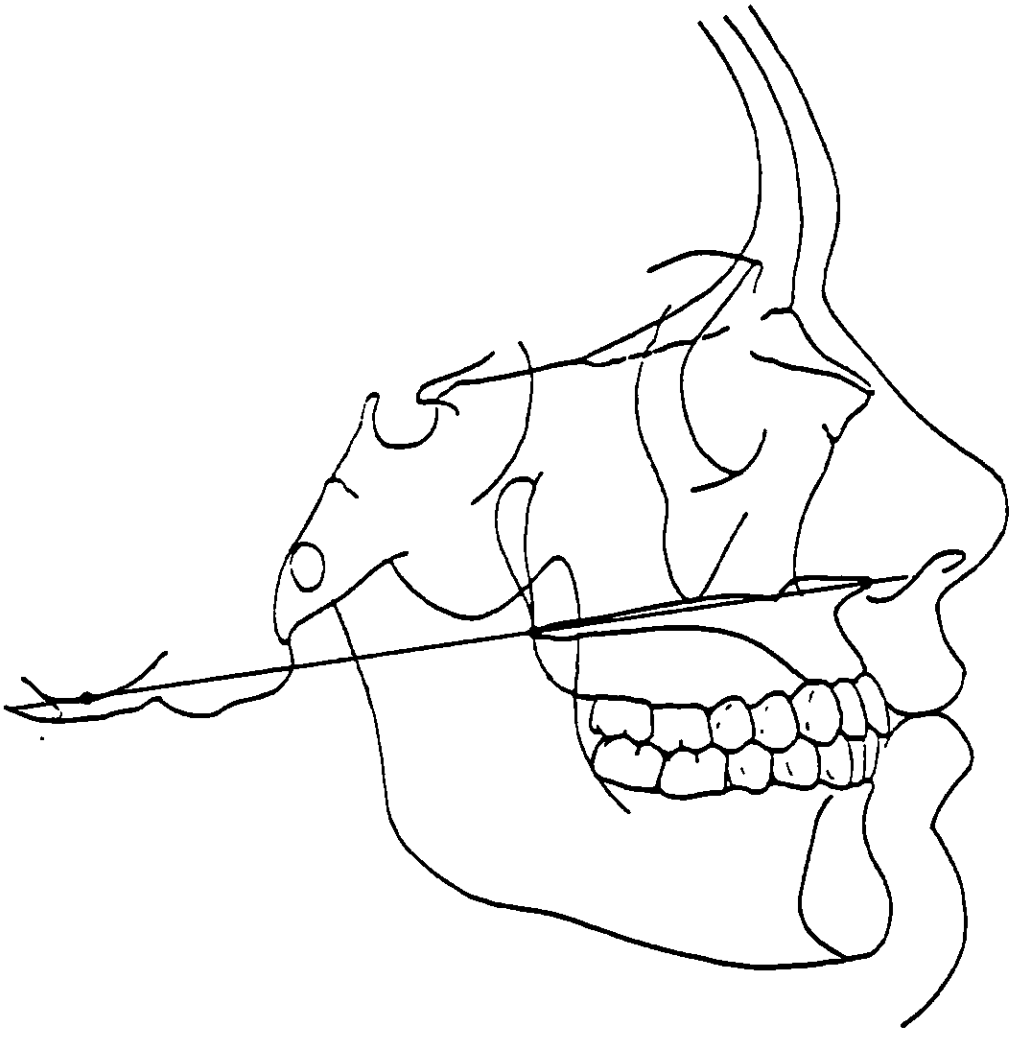


Figure 17. Inferior maxillary plane. This diagram demonstrates the alignment relationship between the inferior boundary of the nasomaxillary complex and the occipital fossa, theoretically representing the position establishing the inferior boundary for the nasomaxillary growth field. The line from SPr 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 negative number, if IMP is below O it is a positive number. Negative and positive values represent clockwise and counterclockwise rotation, respectively, of IMP in relation to O.

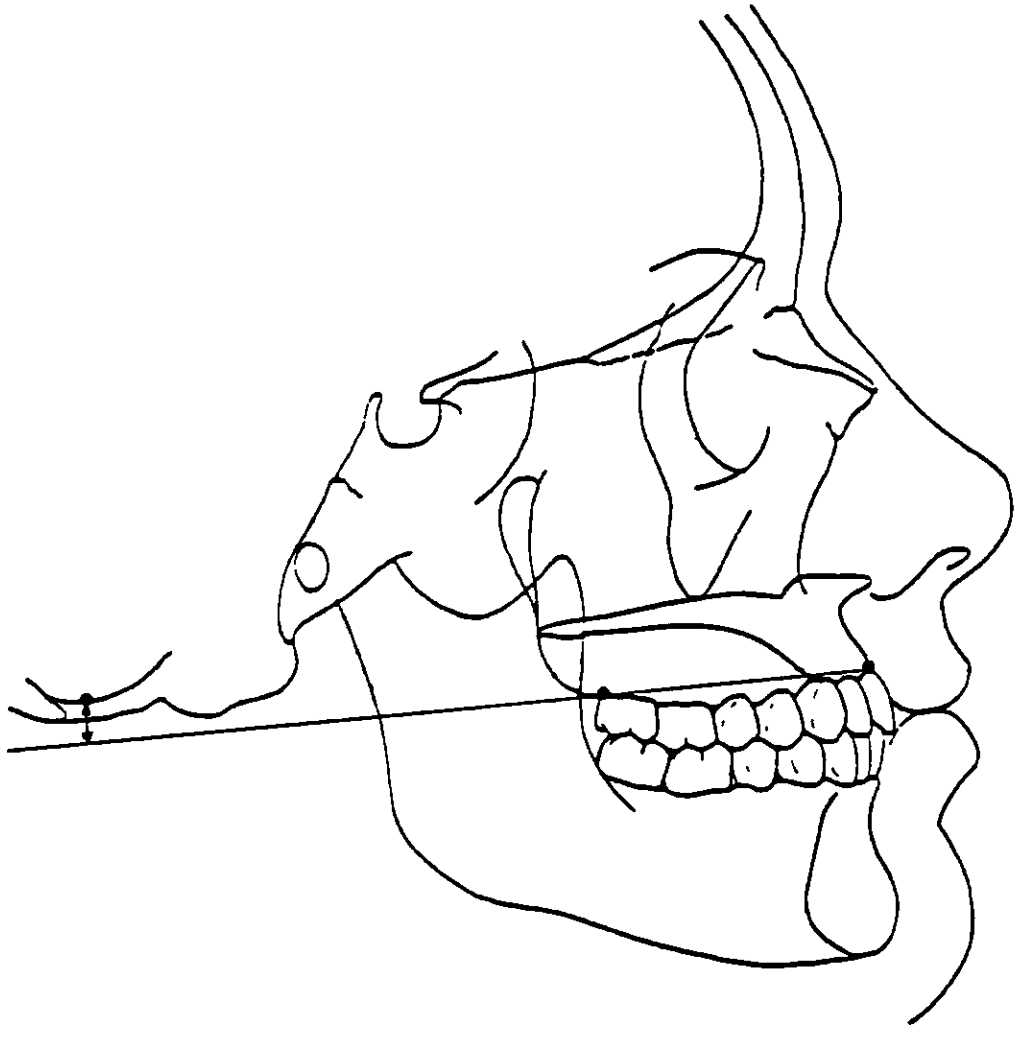
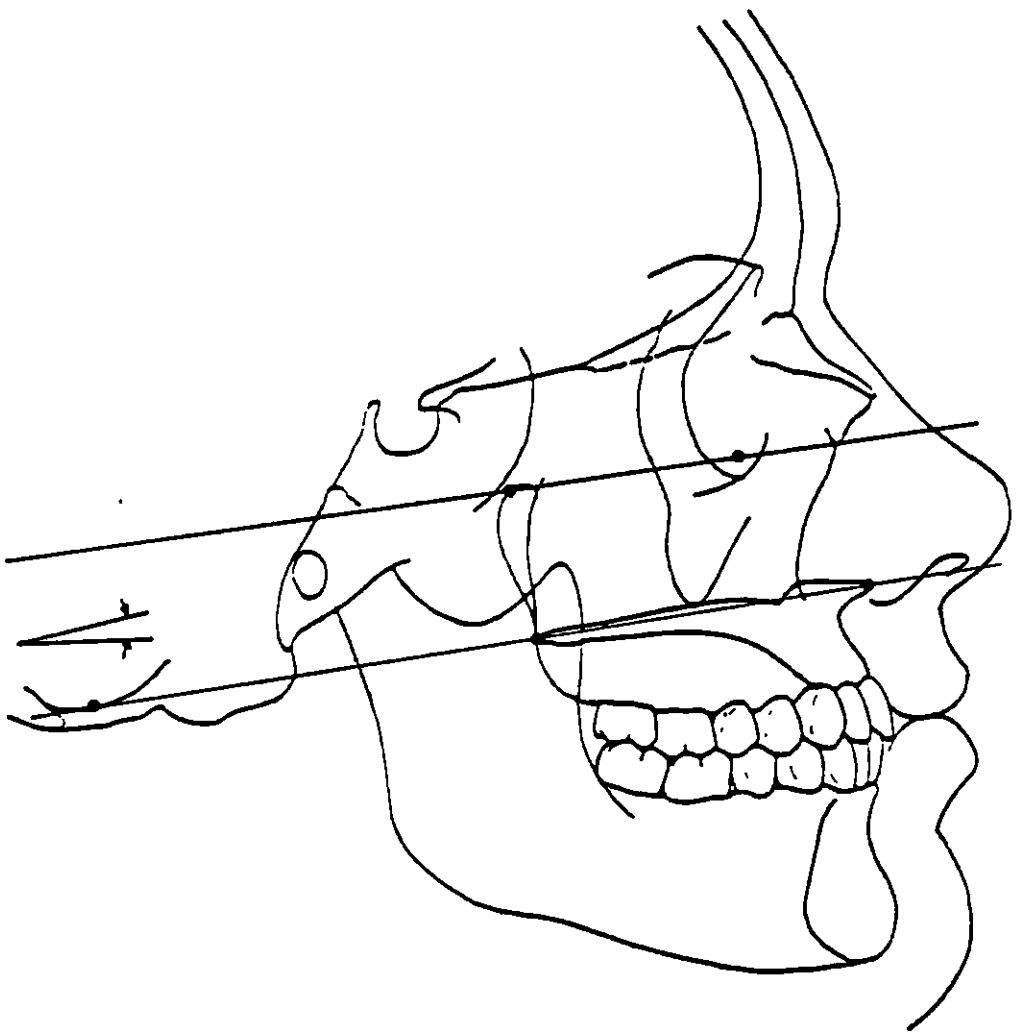


Figure 18. Maxillary nerve/palatal plane alignment. This diagram demonstrates the alignment relationship between the maxillary nerve and the palatal plane. The plane of the maxillary nerve is represented by a line from foramen rotundum in the pterygomaxillary fissure to a point 3 mm above orbitale (representing the course of the nerve prior to its downturn into the orbital floor). The palatal plane is determined as illustrated in Figure 17. An angular intersection is made between these two planes. If the angle is zero, the planes are in a neutral position. If the vertex of the angle is behind the subject, the angle is positive and indicates a clockwise rotational alignment of the palate. If the vertex is in front of the patient, the angle is negative and indicates a counterclockwise rotational alignment of the palate relative to the maxillary nerve.



RESULTS

Variable #1

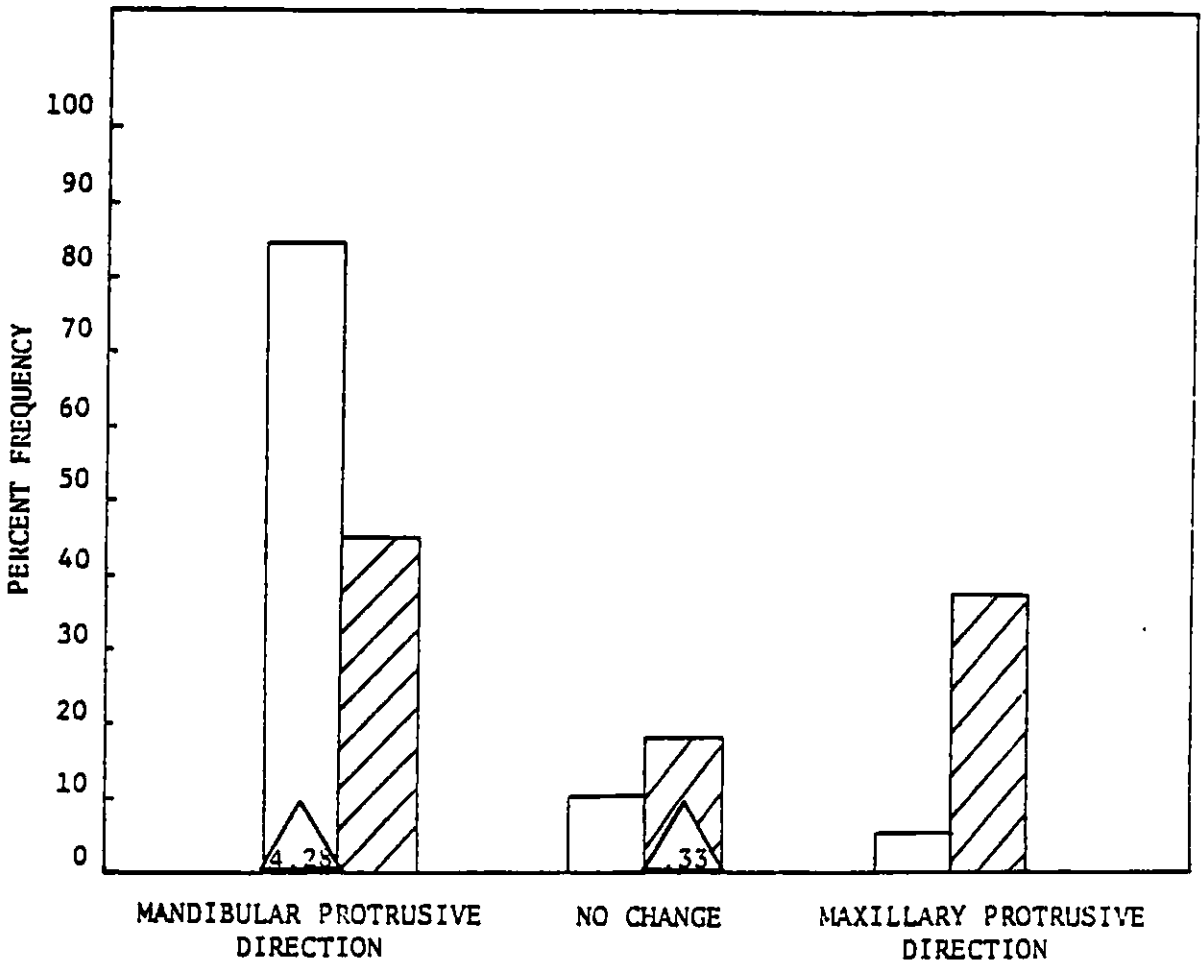
Aggregate cranial floor/maxilla relative to ramus/corpus horizontal dimension at A point and B point. The treatment sample demonstrated an increase in the cumulative composite dimension of the aggregate ramus/corpus relative to the cranial floor/maxilla horizontal dimensions, indicating a mandibular protrusive effect. Frequency analyses revealed that 84% of the treated sample demonstrated statistically significant changes ($p<0.01$) in the mandibular protrusive direction, with an average magnitude of 4.28 millimeters. No statistically significant changes were exhibited in the control sample in either direction or magnitude of change.

Post-treatment results demonstrated a trend towards rebound in a maxillary protrusive direction, the magnitude of which was determined to be statistically significant ($p<0.01$) with a mean value of 1.49 mm. No significant changes were exhibited by the control sample in either direction or magnitude of change (See Tables VI(A) and (B)).

TABLE VI(A)

VARIABLE #1 (T_2-T_1, C_2-C_1)

AGGREGATE CRANIAL FLOOR/MAXILLA AND RAMUS/CORPUS HORIZONTAL DIMENSIONS AT A POINT AND B POINT





= TREATMENT SAMPLE

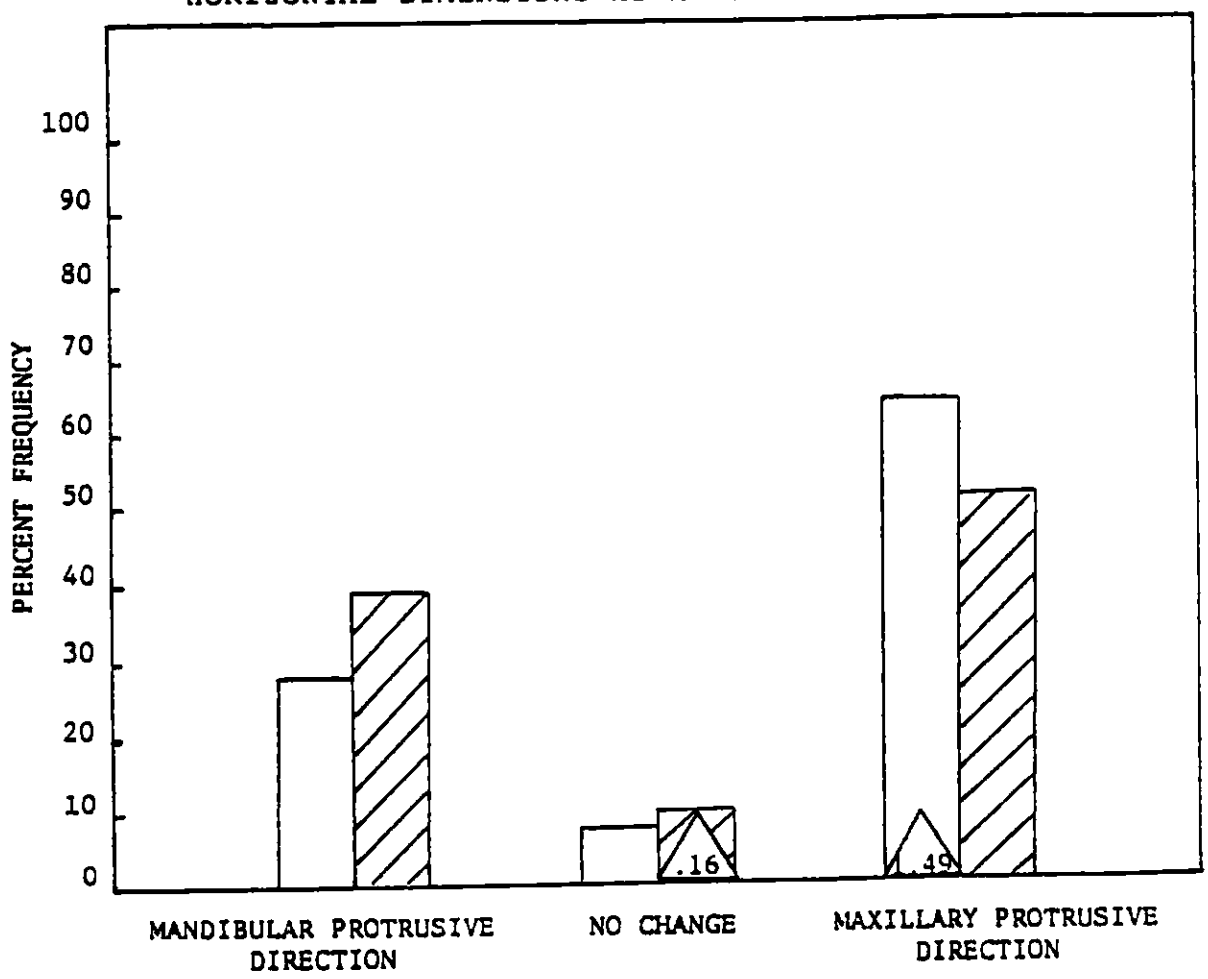
= CONTROL SAMPLE

= MEAN CHANGE (mm or degrees)

TABLE VI(B)

VARIABLE #1 (T_3-T_2, C_3-C_2)

AGGREGATE CRANIAL FLOOR/MAXILLA AND RAMUS/CORPUS HORIZONTAL DIMENSIONS AT A POINT AND B POINT



= TREATMENT SAMPLE

= CONTROL SAMPLE

= MEAN CHANGE (mm or degrees)

Variable #2

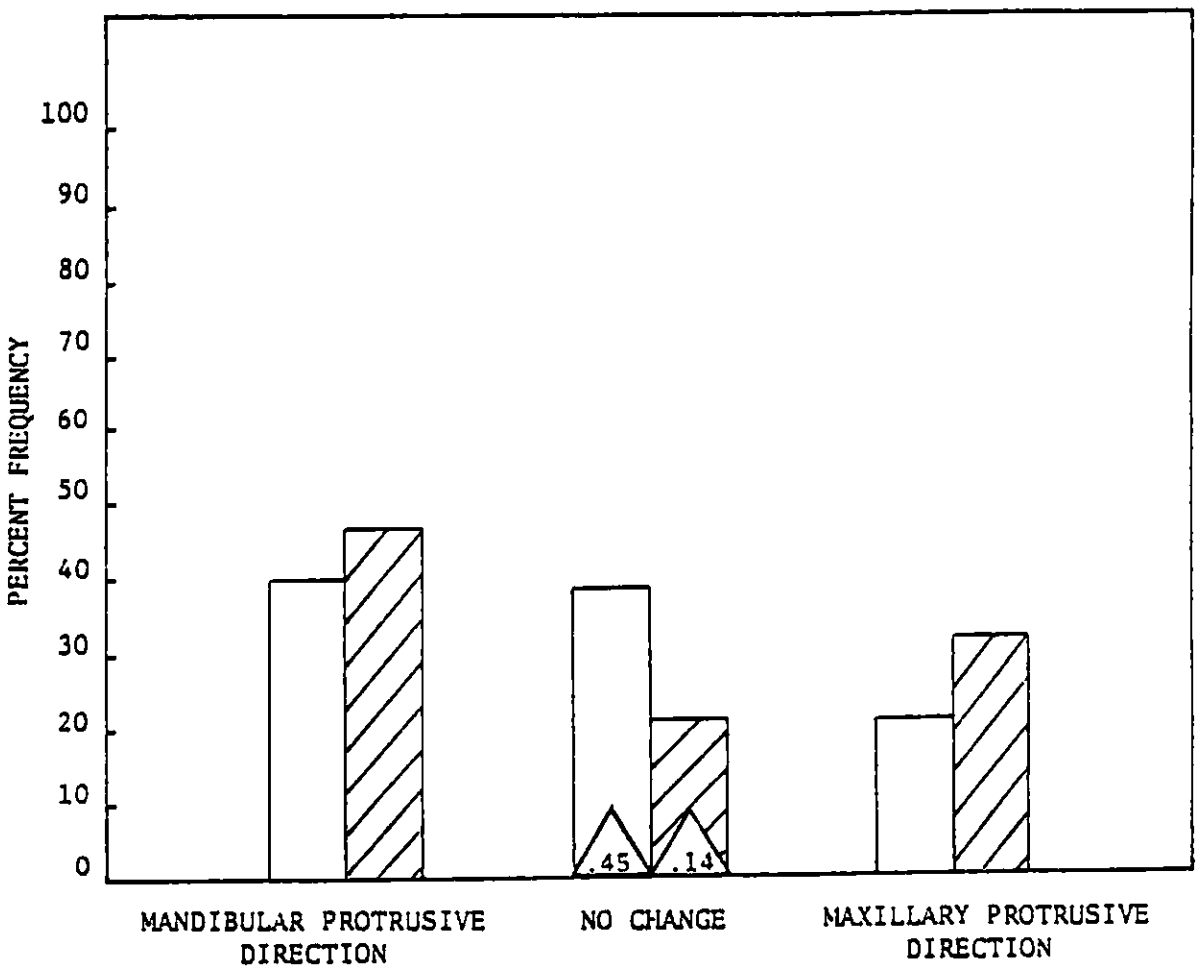
Middle cranial fossa (MCF) and posterior maxillary (PM) relative alignment. This relationship is compared to a population mean. No statistically significant changes in direction were demonstrated in either the treatment or control sample. The magnitude of each mean change was, however, significant for both treatment and control groups.

Post-treatment results demonstrated statistically nonsignificant changes in both direction and magnitude during the observed time period (See Tables VII(A) and (B)).

TABLE VII(A)

VARIABLE #2 (T_2-T_1, C_2-C_1)

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



= TREATMENT SAMPLE

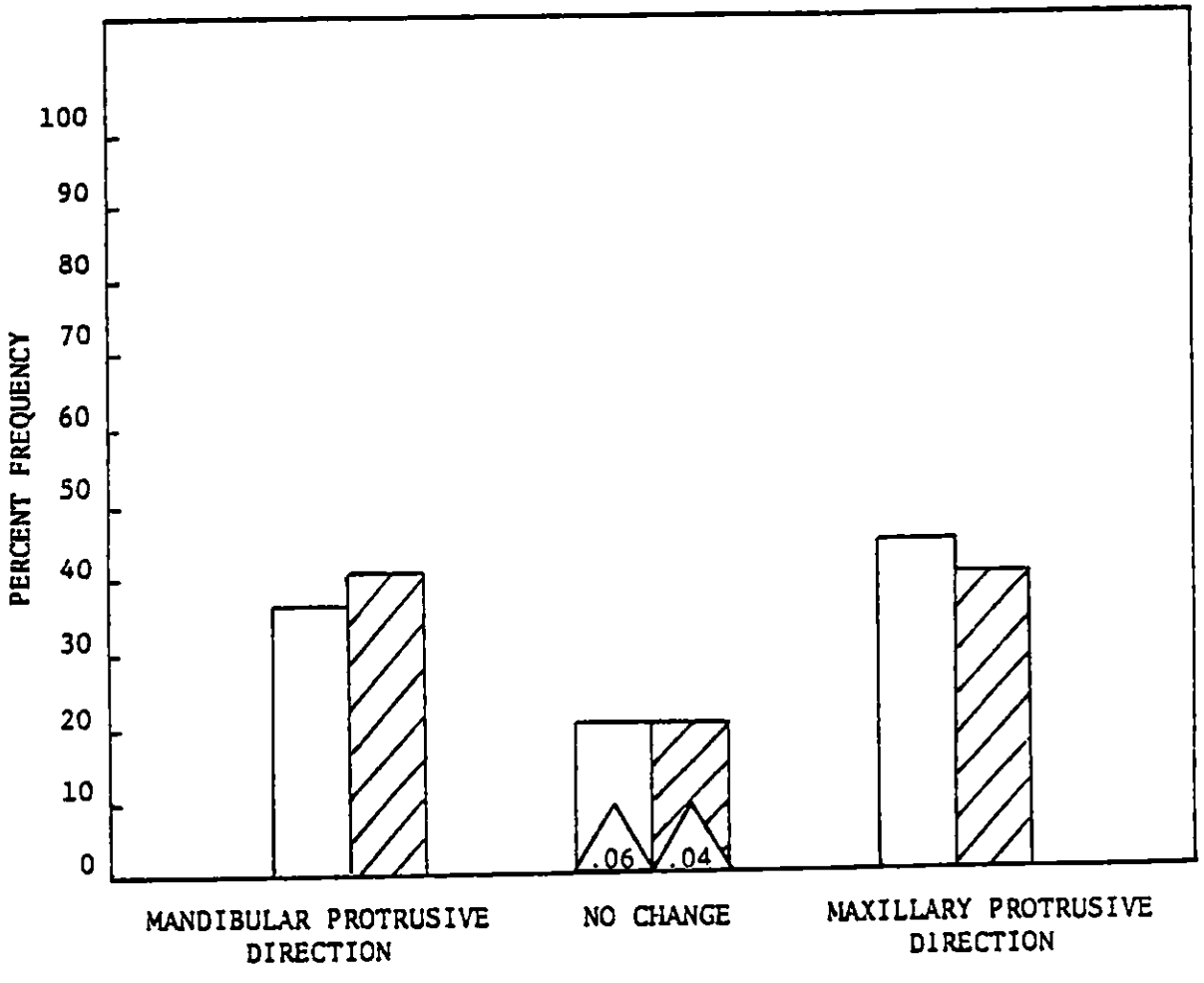
= CONTROL SAMPLE

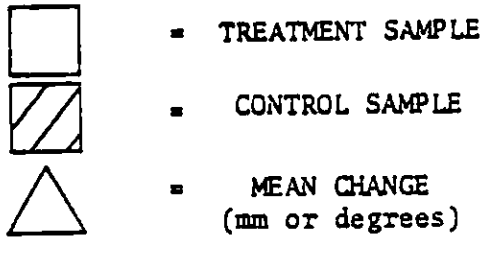
= MEAN CHANGE (mm or degrees)

TABLE VII(B)

VARIABLE #2 (T_3-T_2, C_3-C_2)

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





Variable #3

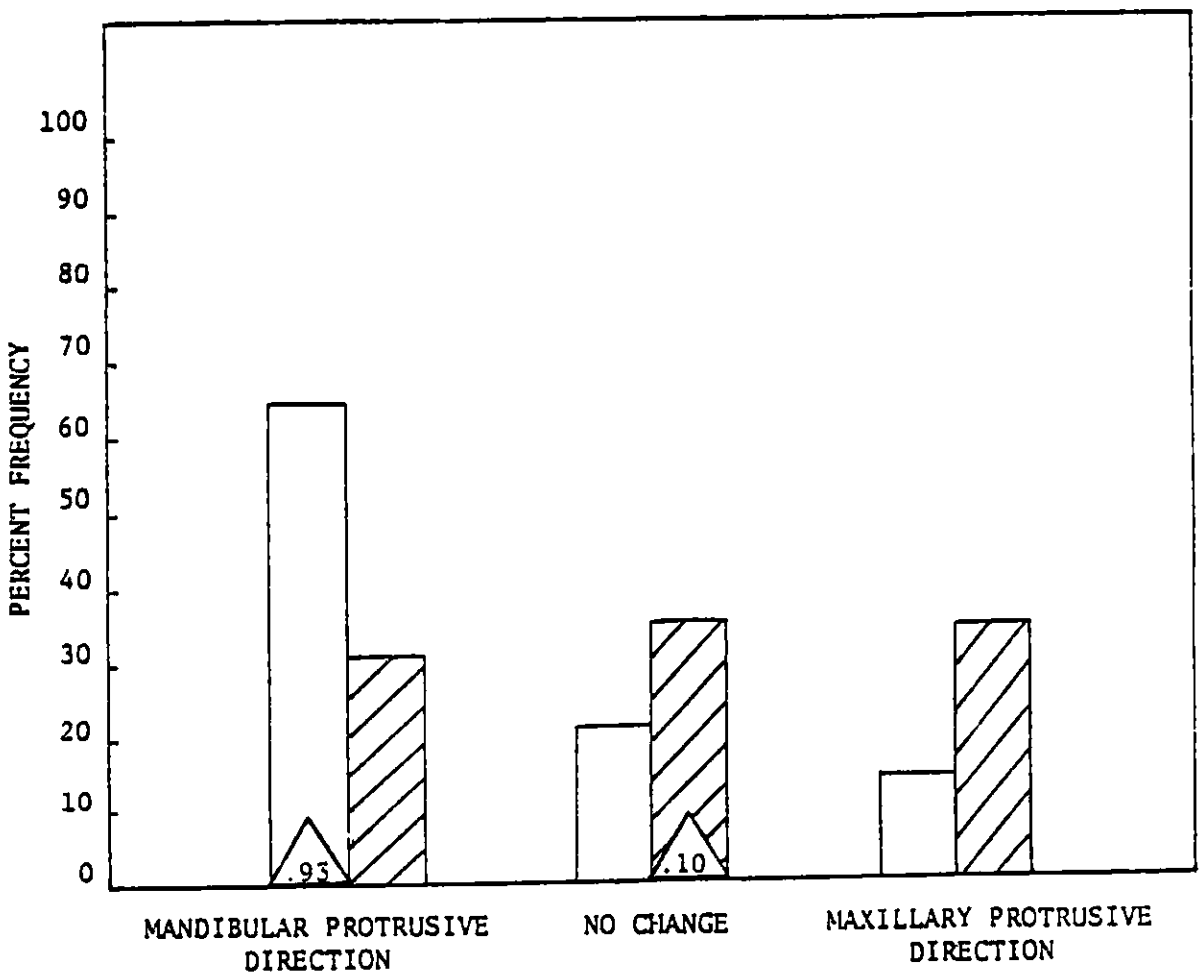
Ramus alignment. The alignment of the vertical ramus plane was unchanged in the control sample. The treatment sample exhibited a change in ramus alignment in an anterior direction which produced a mandibular protrusive effect in 65% of the group. The magnitude of this mean change was .93 millimeters and statistically significant.

The vertical ramus plane of the control sample remained unchanged during the second observation period. The treatment sample demonstrated a statistically significant reversal in ramus alignment during the post-treatment interval. The magnitude of this posterior rotation was statistically significant, averaged .96 millimeters and negated the treatment result (See Tables VIII(A) and (B)).

TABLE VIII(A)

VARIABLE #3 (T_2-T_1, C_2-C_1)

RAMUS ALIGNMENT



= TREATMENT SAMPLE

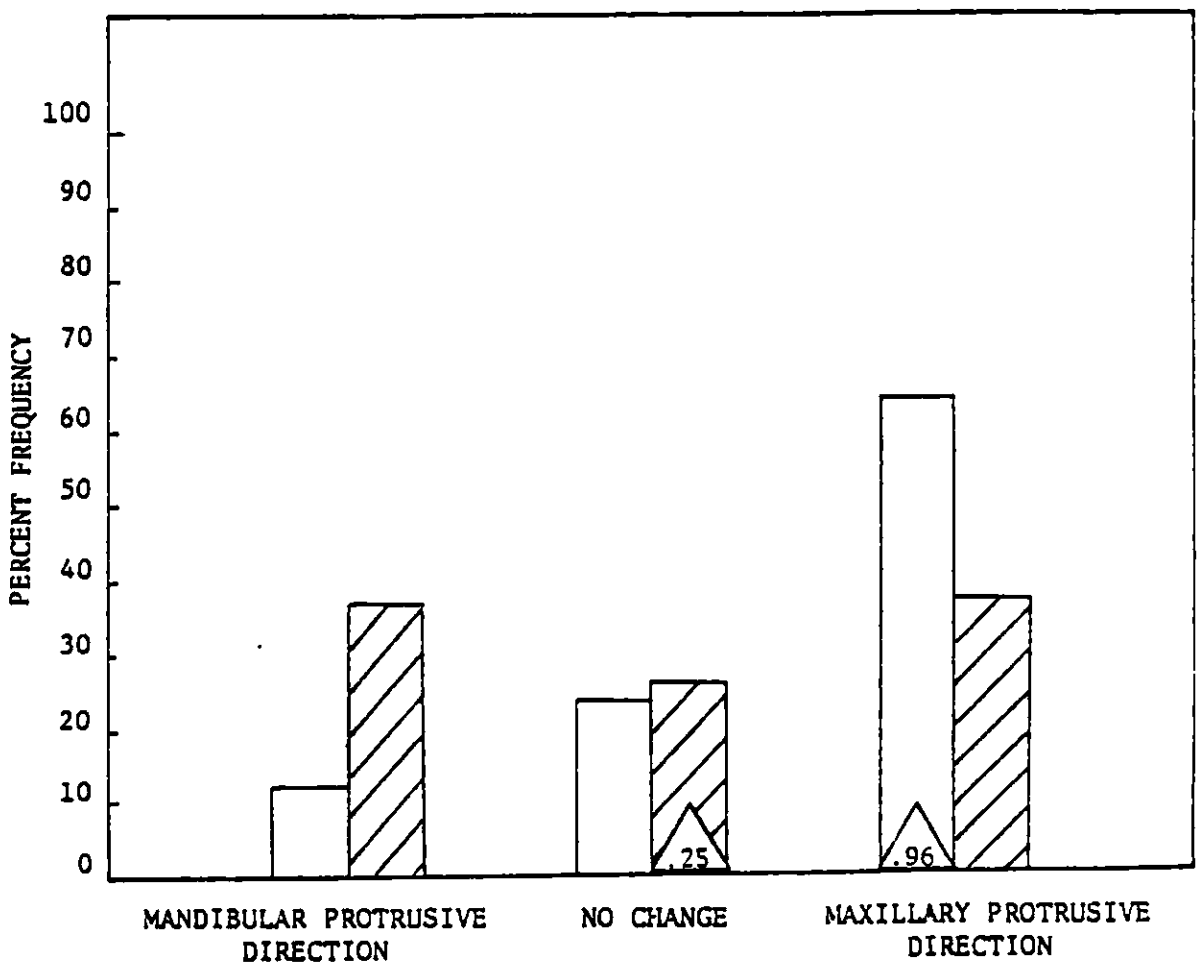
= CONTROL SAMPLE

= MEAN CHANGE (mm or degrees)

TABLE VIII(B)

VARIABLE #3 (T_3-T_2, C_3-C_2)

RAMUS ALIGNMENT



= TREATMENT SAMPLE

= CONTROL SAMPLE

= MEAN CHANGE (mm or degrees)

Variable #4

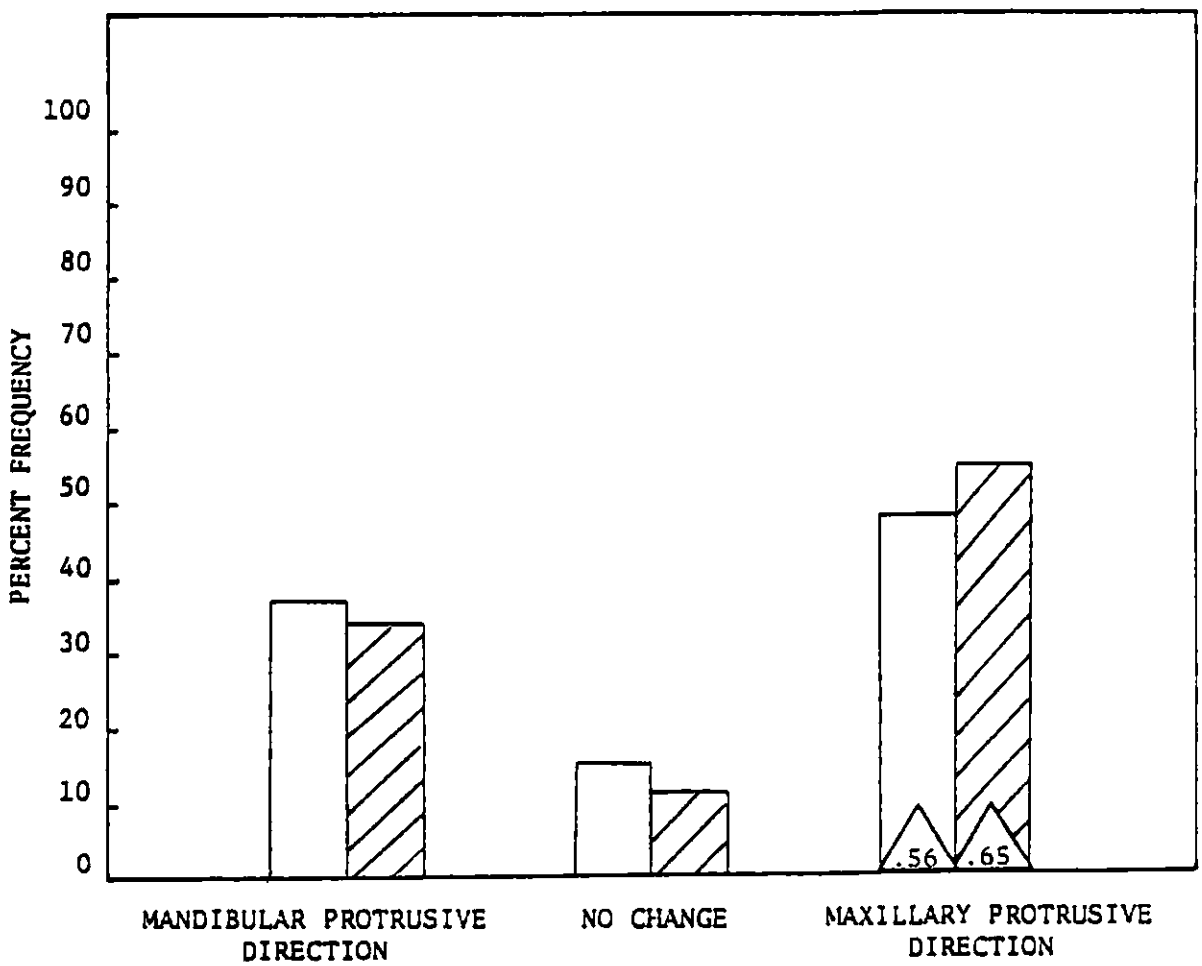
Ramus/MCF horizontal dimensions (skeletal). No significant differences in direction of change were observed in either group during the period examined. A trend was observed, however, for both groups demonstrating a decreased ramus width compared to the horizontal dimension of the MCF. The magnitude of the mean change of this relationship was found to be statistically significant in the control group with a value of .65 millimeters.

The post-treatment results demonstrated apparent stability of the changes seen in the first observation period. No statistically significant differences were observed in direction or magnitude for the treatment and control samples (See Tables IX(A) and (B)).

TABLE IX(A)

VARIABLE #4 (T_2-T_1, C_2-C_1)

RAMUS/MCF HORIZONTAL DIMENSION (SKELETAL)



= TREATMENT SAMPLE

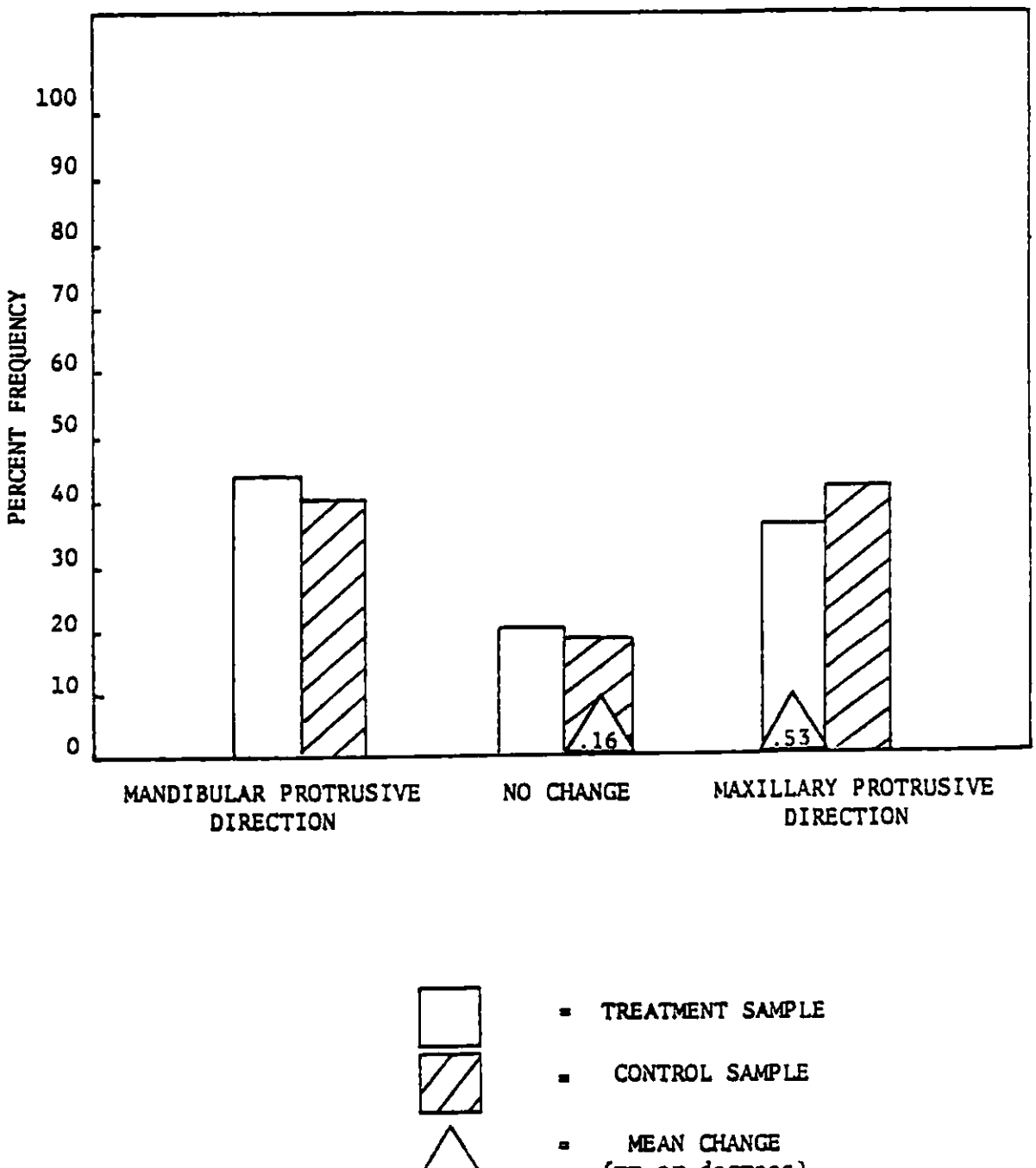
= CONTROL SAMPLE

= MEAN CHANGE (mm or degrees)

TABLE IX(B)

VARIABLE #4 (T_3-T_2, C_3-C_2)

RAMUS/MCF HORIZONTAL DIMENSION (SKELETAL)



Variable #5

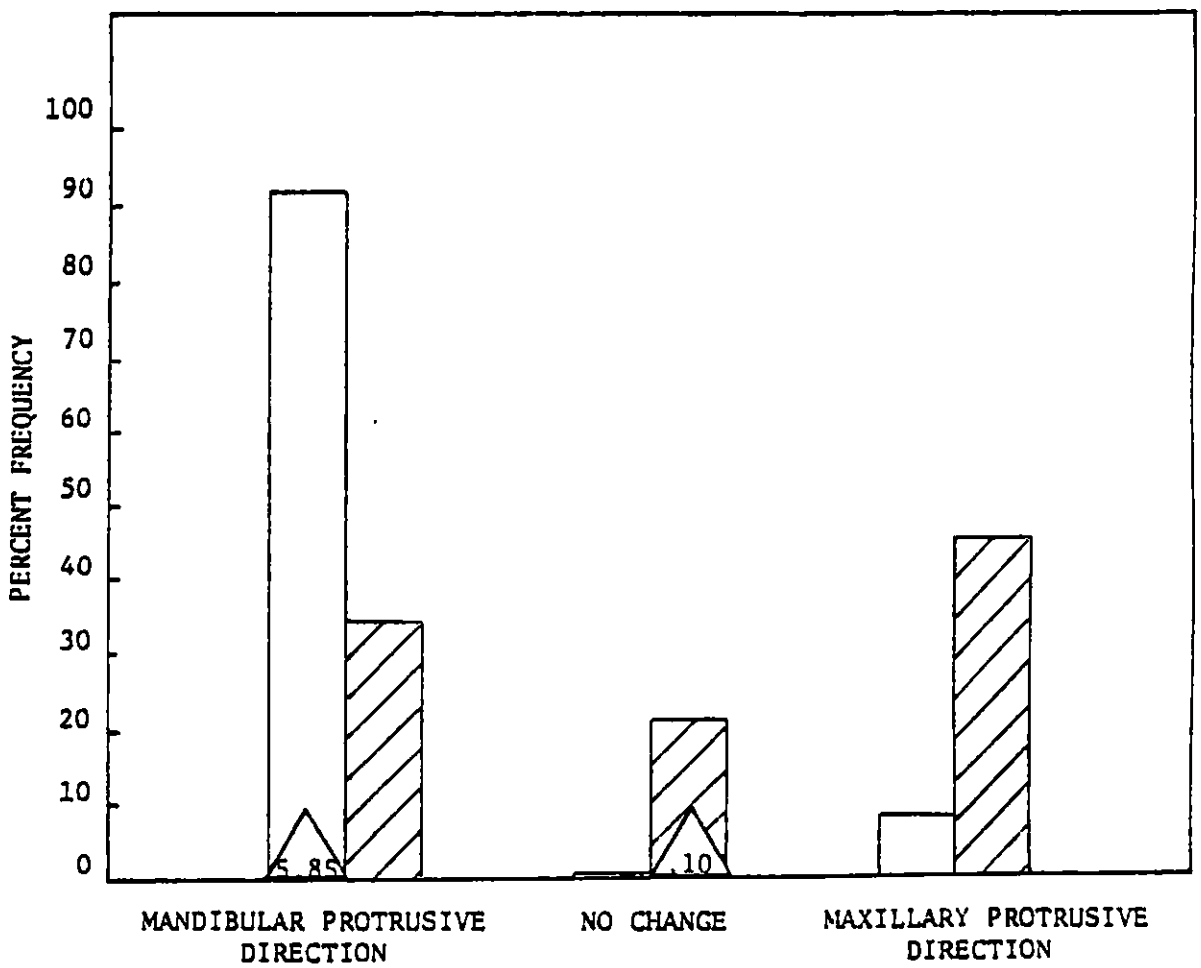
Ramus/MCF horizontal dimensions (dental). To determine this relationship, the positions of the mandibular and maxillary first molars are "neutralized" so as to disregard posterior skeletal rotational effects on tooth placement. Statistically significant changes were demonstrated in the treatment group. The neutral molar positions changed in the mandibular protrusive direction in 92% of the sample with a mean value of 2.85 millimeters. No statistically significant changes were observed in the control sample.

Post-treatment results demonstrated a reversal in direction of change for 64% of the treatment sample. This was statistically significant with a mean value of 2.20 millimeters of rebound observed. No statistically significant changes were demonstrated in the control sample during this period but the trend of directional change and magnitude were in a mandibular protrusive direction (See Tables X(A) and (B)).

TABLE X(A)

VARIABLE #5 (T_2-T_1, C_2-C_1)

RAMUS/MCF HORIZONTAL DIMENSION (DENTAL)



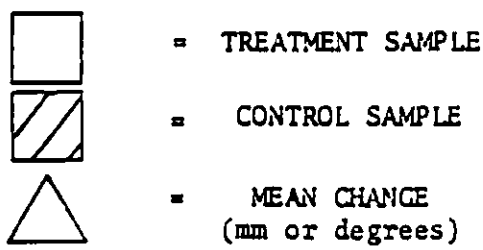
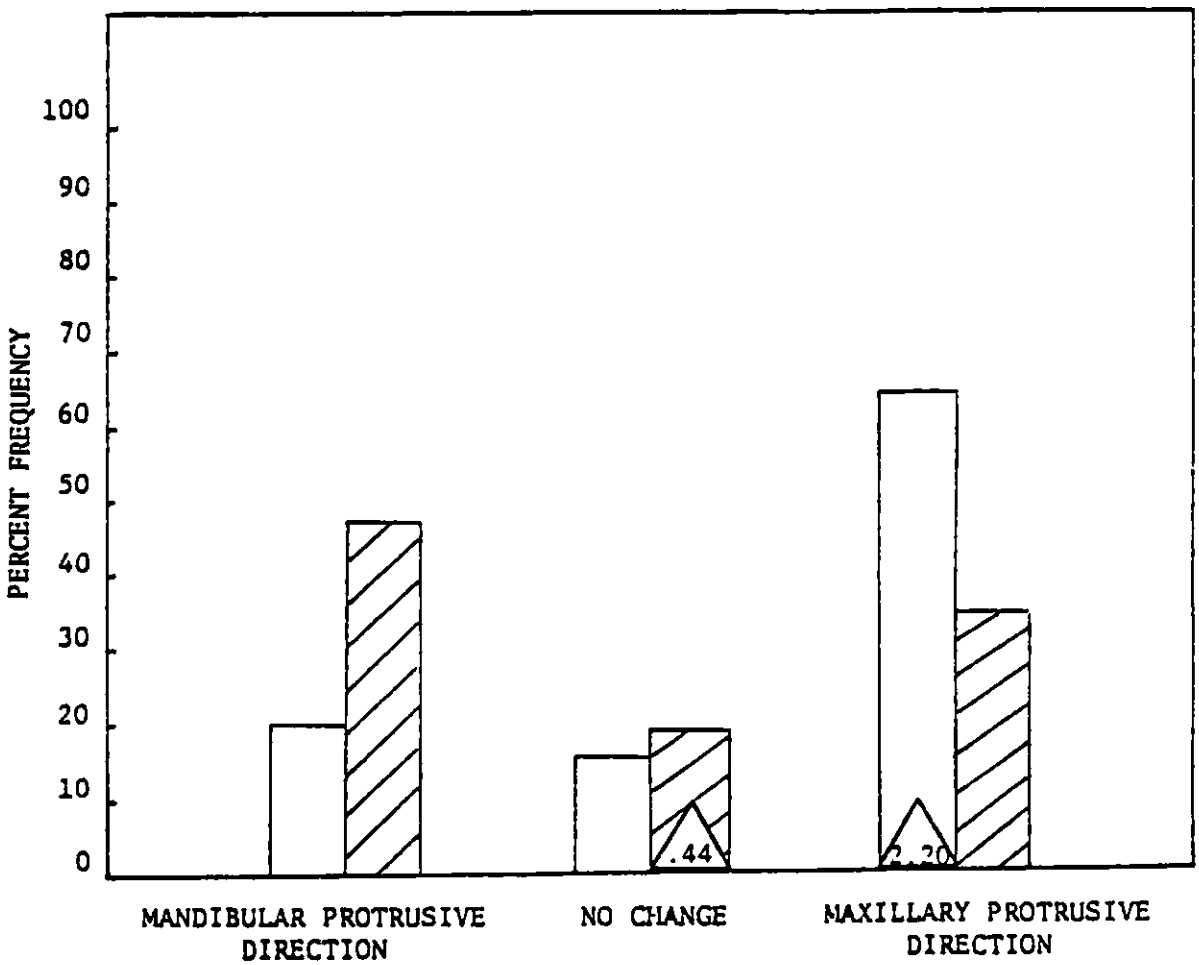


TABLE X(B)

VARIABLE #5 (T_3-T_2, C_3-C_2)

RAMUS/MCF HORIZONTAL DIMENSION (DENTAL)



= TREATMENT SAMPLE

= CONTROL SAMPLE

= MEAN CHANGE (mm or degrees)

Variable #6

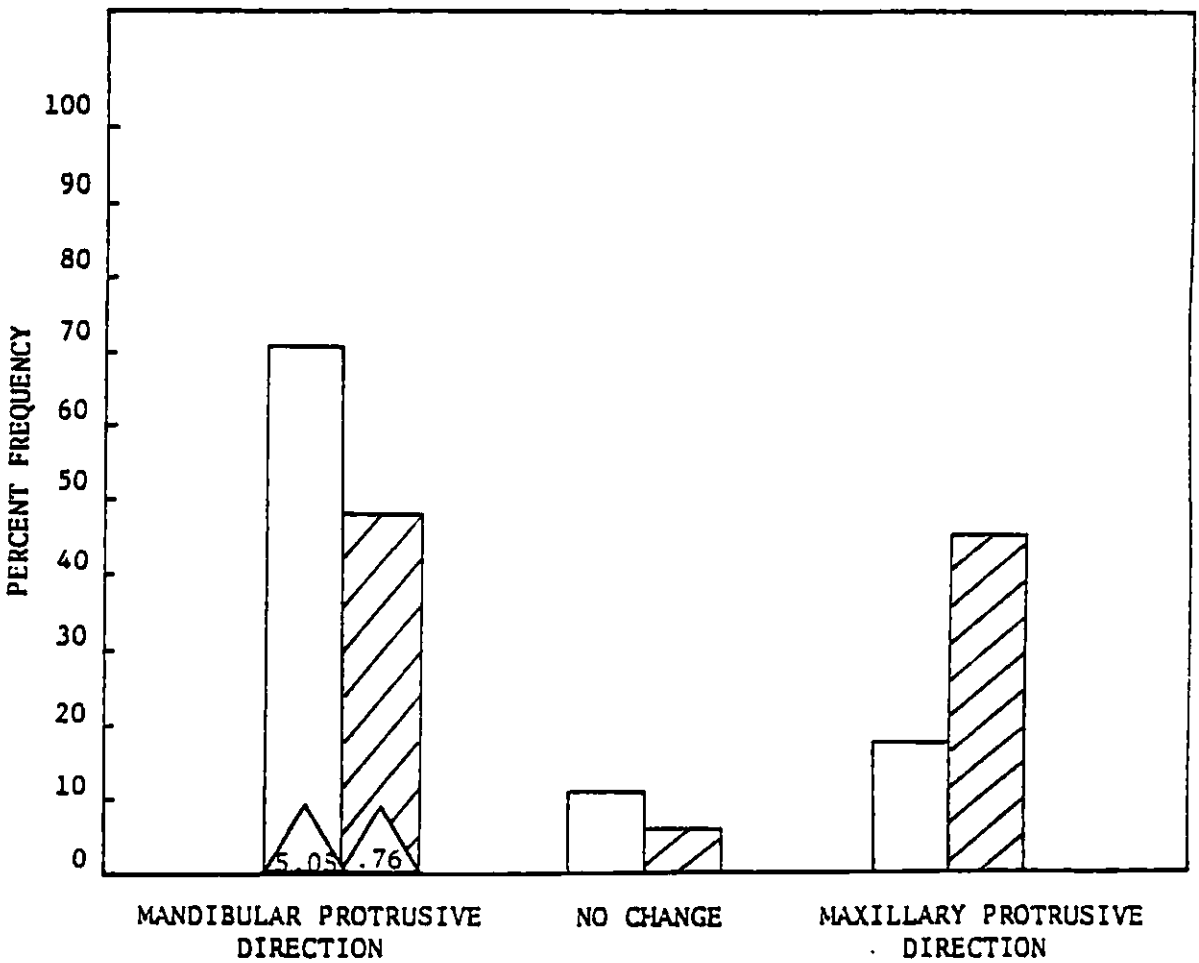
Maxillary/mandibular arches, skeletal dimensions, A point compared with B point. The treatment sample demonstrated a significant increase in mandibular arch dimension compared to maxillary arch in 71% of the group. The mean change was significant with a value of 5.05 millimeters. No significant differences were observed in the control sample during this time period examined.

No statistically significant changes were observed in either group during the post-treatment time interval. The treatment group did exhibit a trend towards rebound with a mean change of 1.10 millimeter in the maxillary protrusive direction (See Tables XI(A) and (B)).

TABLE XI(A)

VARIABLE #6 (T_2-T_1, C_2-C_1)

MAXILLARY/MANDIBULAR ARCHES, SKELETAL DIMENSIONS,
A POINT COMPARED WITH B POINT



= TREATMENT SAMPLE

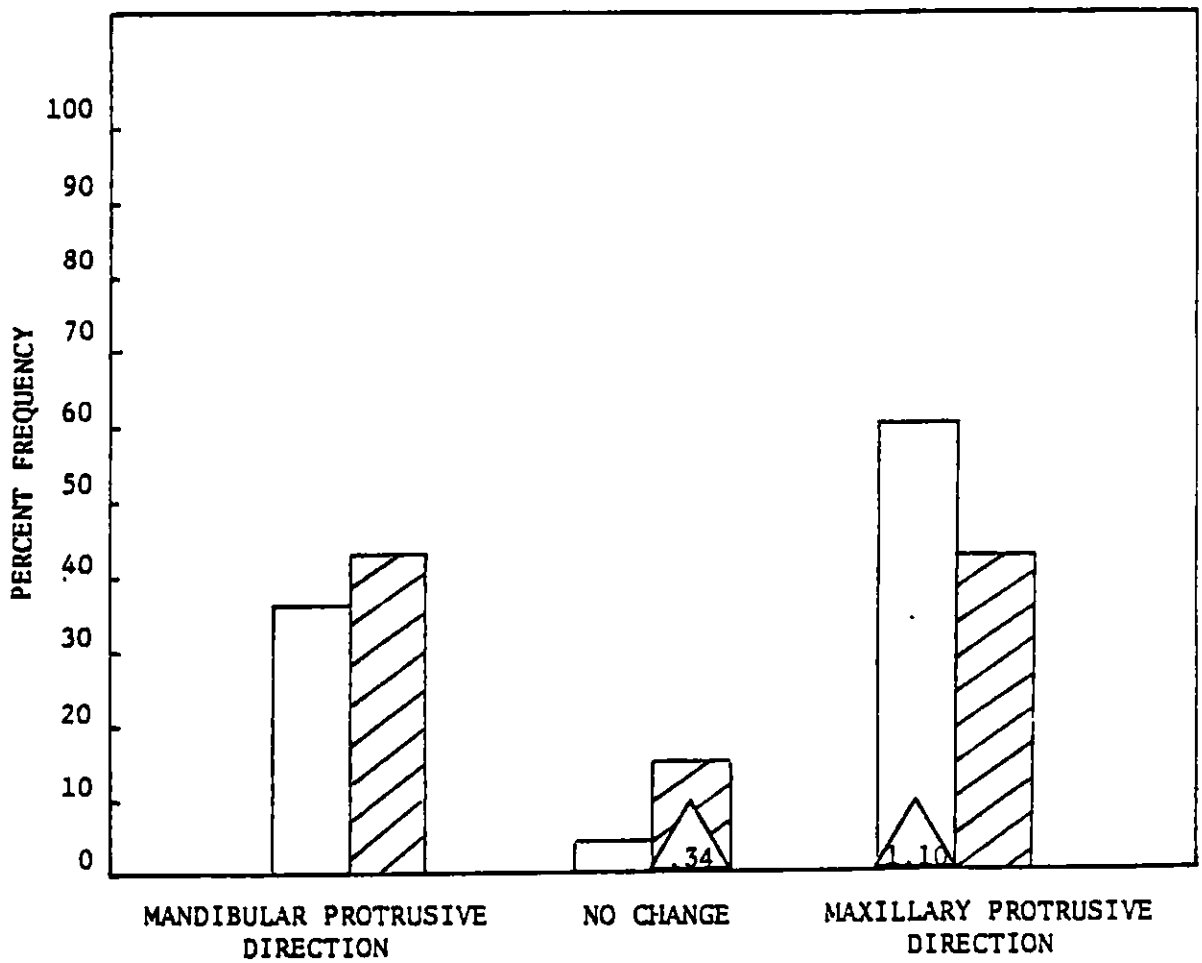
= CONTROL SAMPLE

= MEAN CHANGE (mm or degrees)

TABLE XI(B)

VARIABLE #6 (T_3-T_2, C_3-C_2)

MAXILLARY/MANDIBULAR ARCHES, SKELETAL DIMENSIONS,
A POINT COMPARED WITH B POINT



= TREATMENT SAMPLE

= CONTROL SAMPLE

= MEAN CHANGE (mm or degrees)

Variable #7

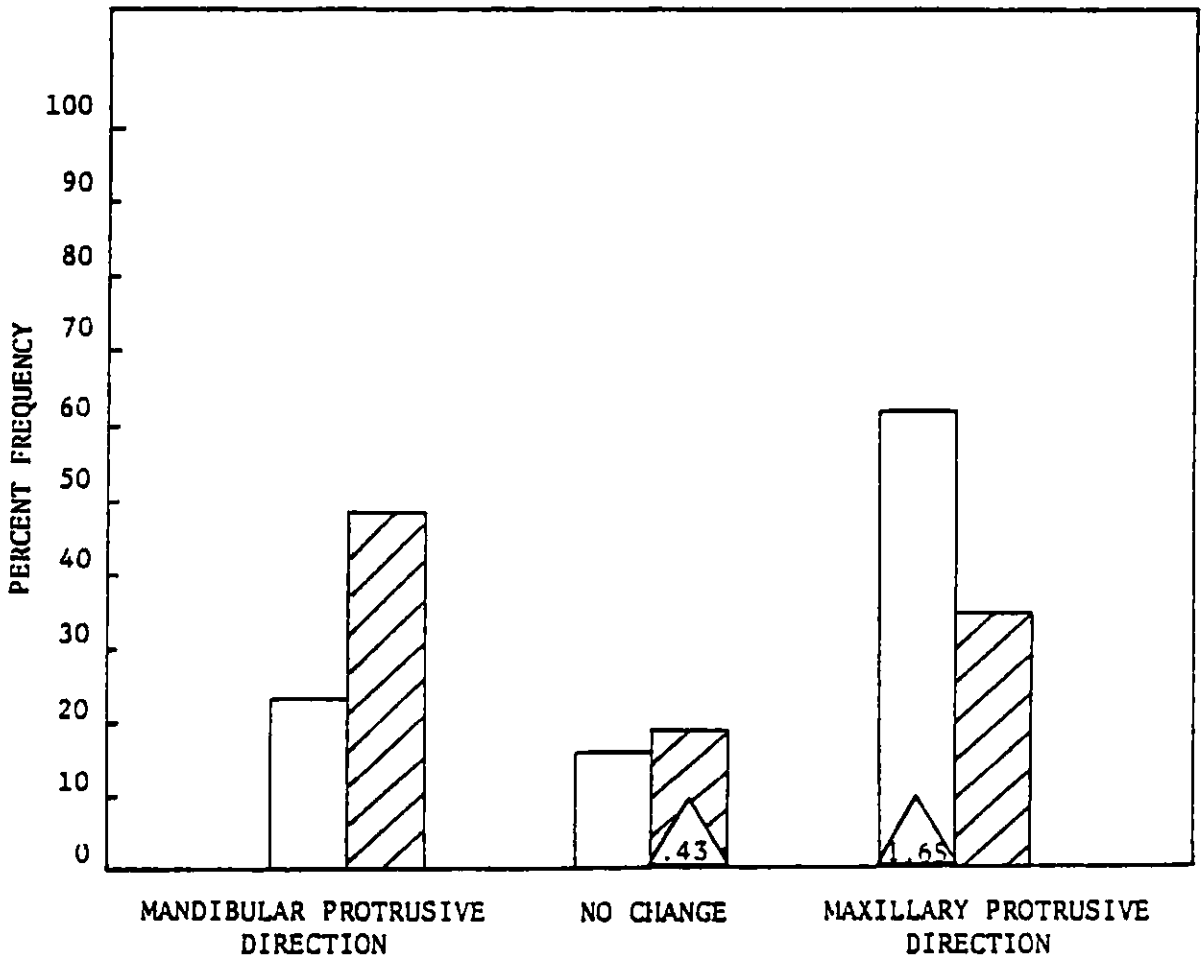
Maxillary/mandibular arches, dental dimensions, A point compared with B point. The treatment group demonstrated a significant shift in direction towards a relatively longer maxillary arch in 61% of the sample. The mean value for this change was 1.65 millimeters. No significant changes were observed in the control group for the same time period.

The treatment changes persisted during the post-treatment interval. No statistically significant changes were observed in either group (See Tables XII(A) and (B)).

TABLE XII(A)

VARIABLE #7 (T_2-T_1, C_2-C_1)

MAXILLARY/MANDIBULAR ARCHES, DENTAL DIMENSIONS,
A POINT COMPARED WITH B POINT



= TREATMENT SAMPLE

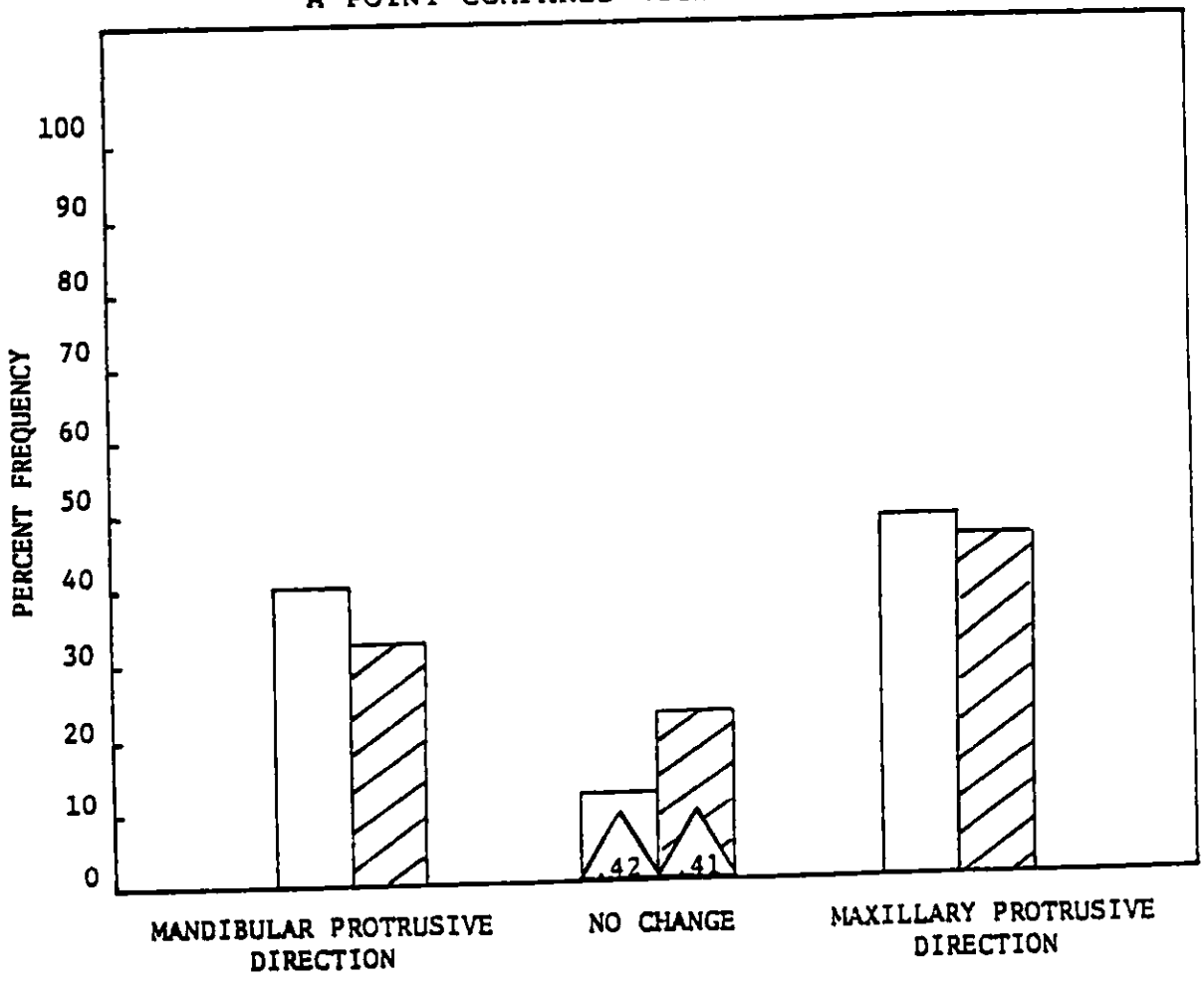
= CONTROL SAMPLE

= MEAN CHANGE
(mm or degrees)

TABLE XII(B)

VARIABLE #7 (T_3-T_1, C_3-C_2)

MAXILLARY/MANDIBULAR ARCHES, DENTAL DIMENSIONS,
A POINT COMPARED WITH B POINT



= TREATMENT SAMPLE

= CONTROL SAMPLE

= MEAN CHANGE
(mm or degrees)

Variable #8

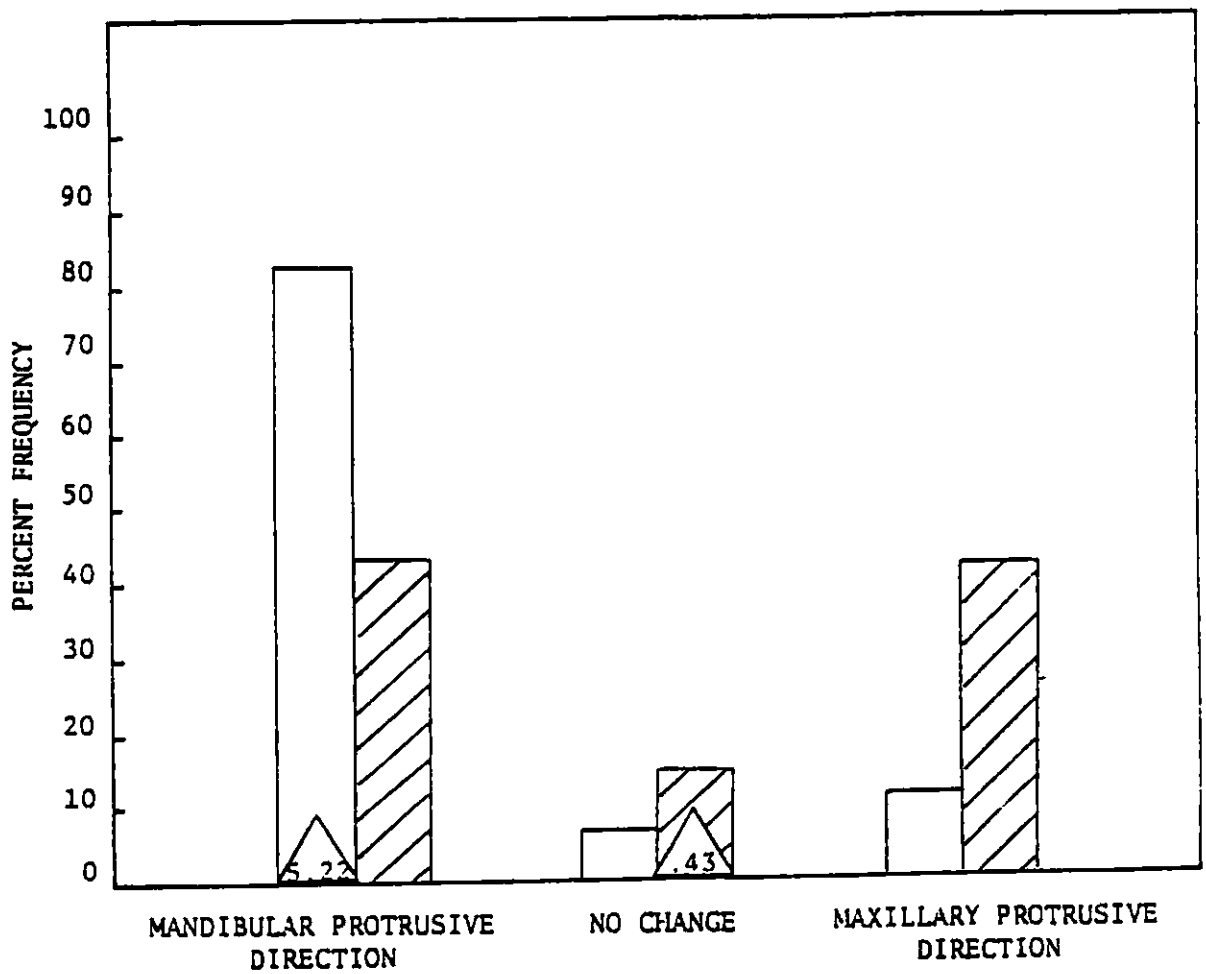
Maxillary/mandibular arches, skeletal dimensions, SPr compared with IPr. The change in horizontal mandibular arch length measured to IPr was greater compared to the maxillary arch in 81% of the sample. The mean change value was 5.22 millimeters and statistically significant. No significant changes were observed in the control sample during this time interval.

Post-treatment changes in the treatment group were not statistically significant. However, a mean rebound value of 1.24 mm was observed. No significant changes occurred in the control group during this period (See Tables XIII(A) and (B)).

TABLE XIII(A)

VARIABLE #8 (T_2-T_1, C_2-C_1)

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



= TREATMENT SAMPLE

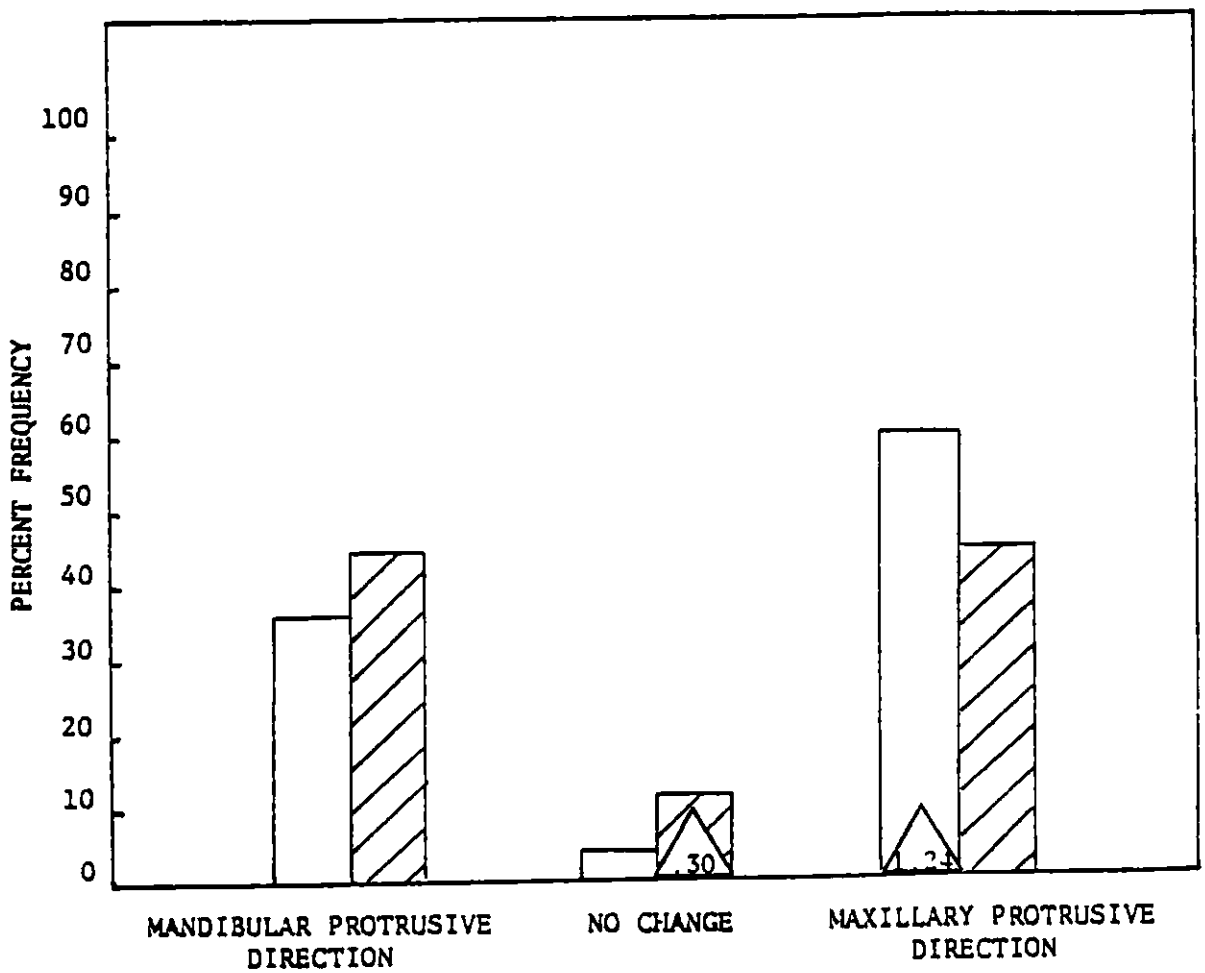
= CONTROL SAMPLE

= MEAN CHANGE (mm or degrees)

TABLE XIII(B)

VARIABLE #8 (T_3-T_2, C_3-C_2)

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



= TREATMENT SAMPLE

= CONTROL SAMPLE

= MEAN CHANGE (mm or degrees)

Variable #9

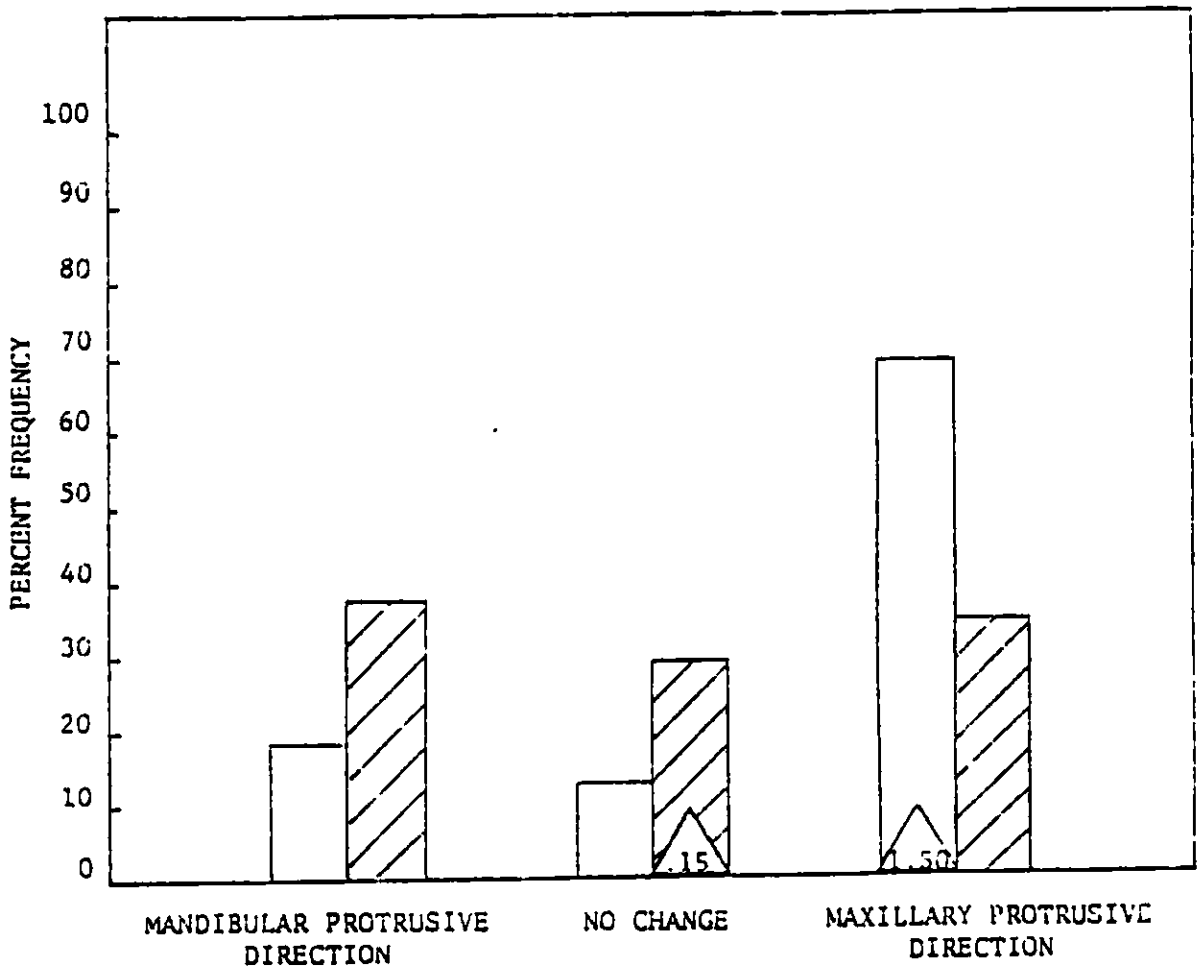
Maxillary/mandibular arches, dental dimensions, SPr compared with IPr. Statistically significant differences were observed in the treatment sample for both direction and magnitude of change. An increase in maxillary dental arch length was demonstrated compared with the mandibular arch in 69% of the sample with a mean change value of 1.5 millimeters.

No statistically significant changes were observed in either group during the post-treatment observation period. A 20% change in direction and a tendency toward relapse with a mean value of .49 millimeters in the mandibular protrusive direction was observed in the treatment sample (See Tables XIV(A) and (B)).

TABLE XIV(A)

VARIABLE #9 (T_2-T_1, C_2-C_1)

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



= TREATMENT SAMPLE

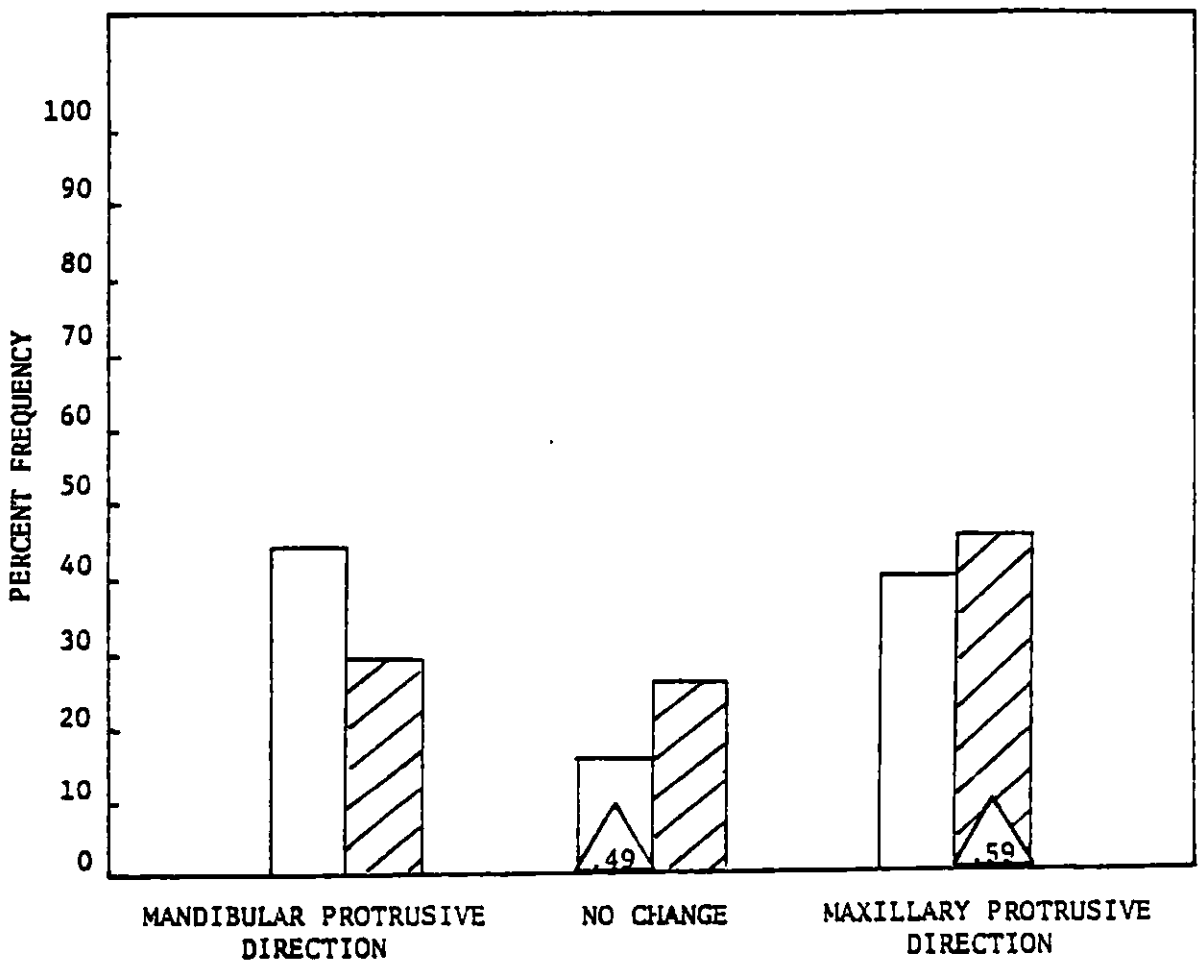
= CONTROL SAMPLE

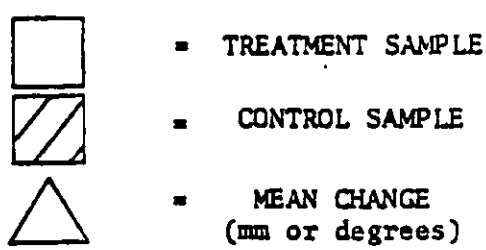
= MEAN CHANGE (mm or degrees)

TABLE XIV(B)

VARIABLE #9 (T_3-T_2, C_3-C_2)

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





Variable #10

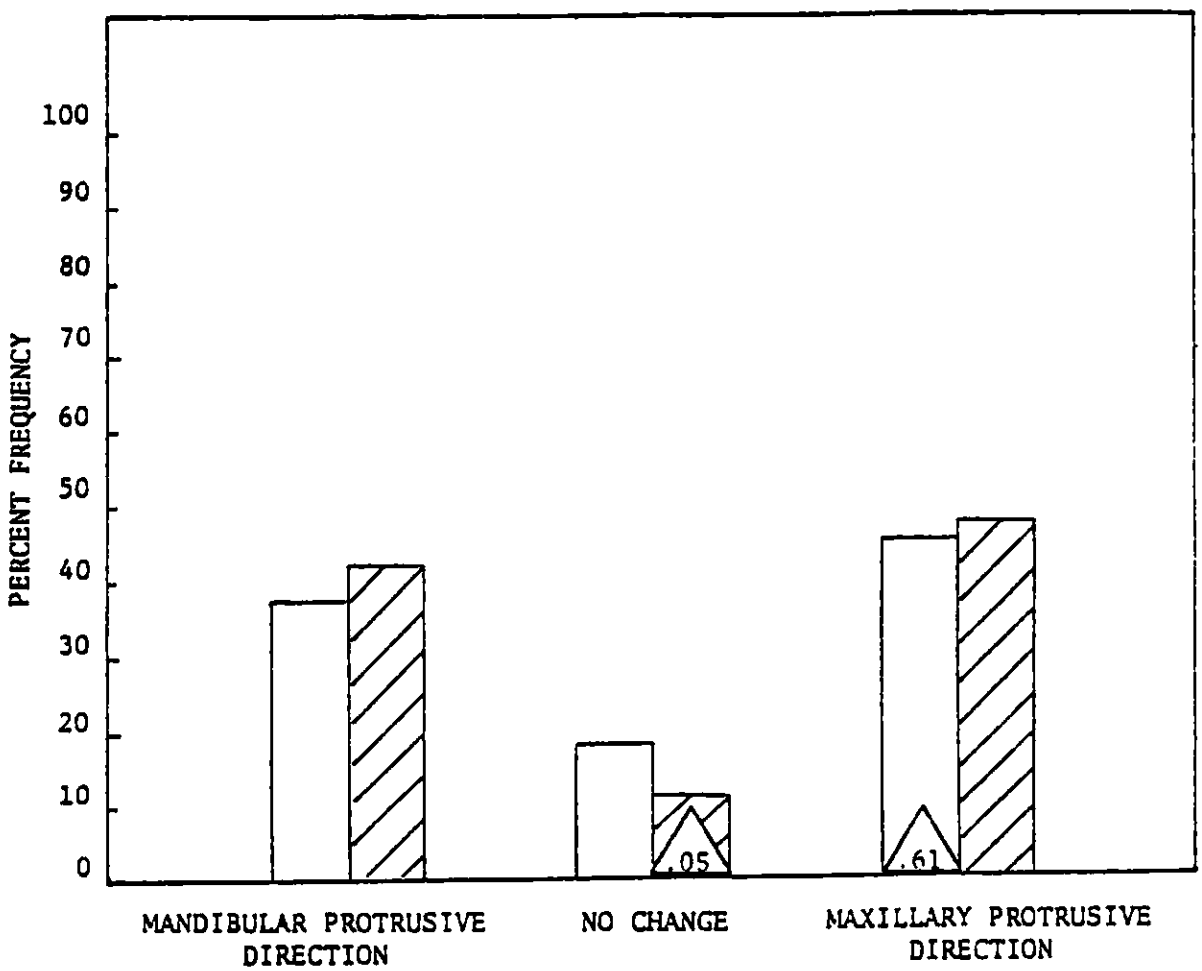
PM as compared with ramus/MCF vertical dimensions. In examining the mean change in the relative vertical length of the PM, the tendency was to become slightly longer, resulting in a maxillary protrusive effect (due to the rotational effect on the mandible) with a mean value of .61 millimeters. The changes in both groups, however, did not attain statistical significance for either direction or magnitude of change.

No significant differences for either group were observed during the post-treatment time interval (See Tables XV(A) and (B)).

TABLE XV(A)

VARIABLE #10 (T_2-T_1, C_2-C_1)

PM AS COMPARED WITH RAMUS/MCF VERTICAL DIMENSIONS



= TREATMENT SAMPLE

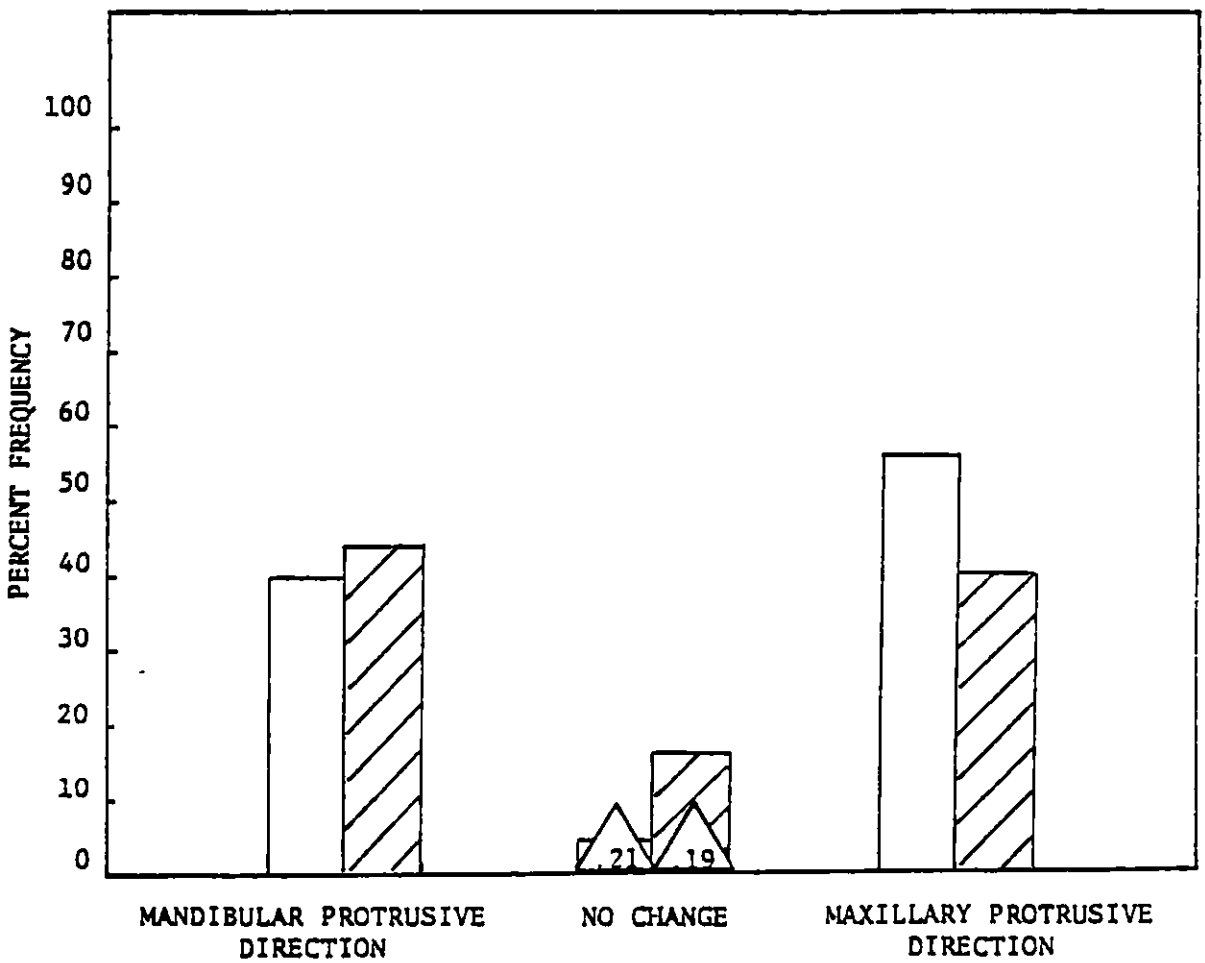
= CONTROL SAMPLE

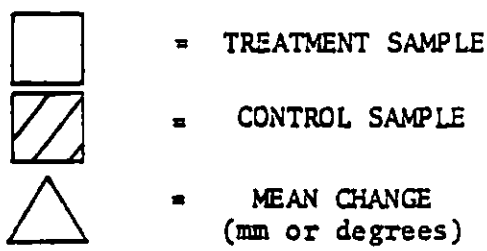
= MEAN CHANGE (mm or degrees)

TABLE XV(B)

VARIABLE #10 (T_3-T_2, C_3-C_2)

PM AS COMPARED WITH RAMUS/MCF VERTICAL DIMENSIONS





Variable #11

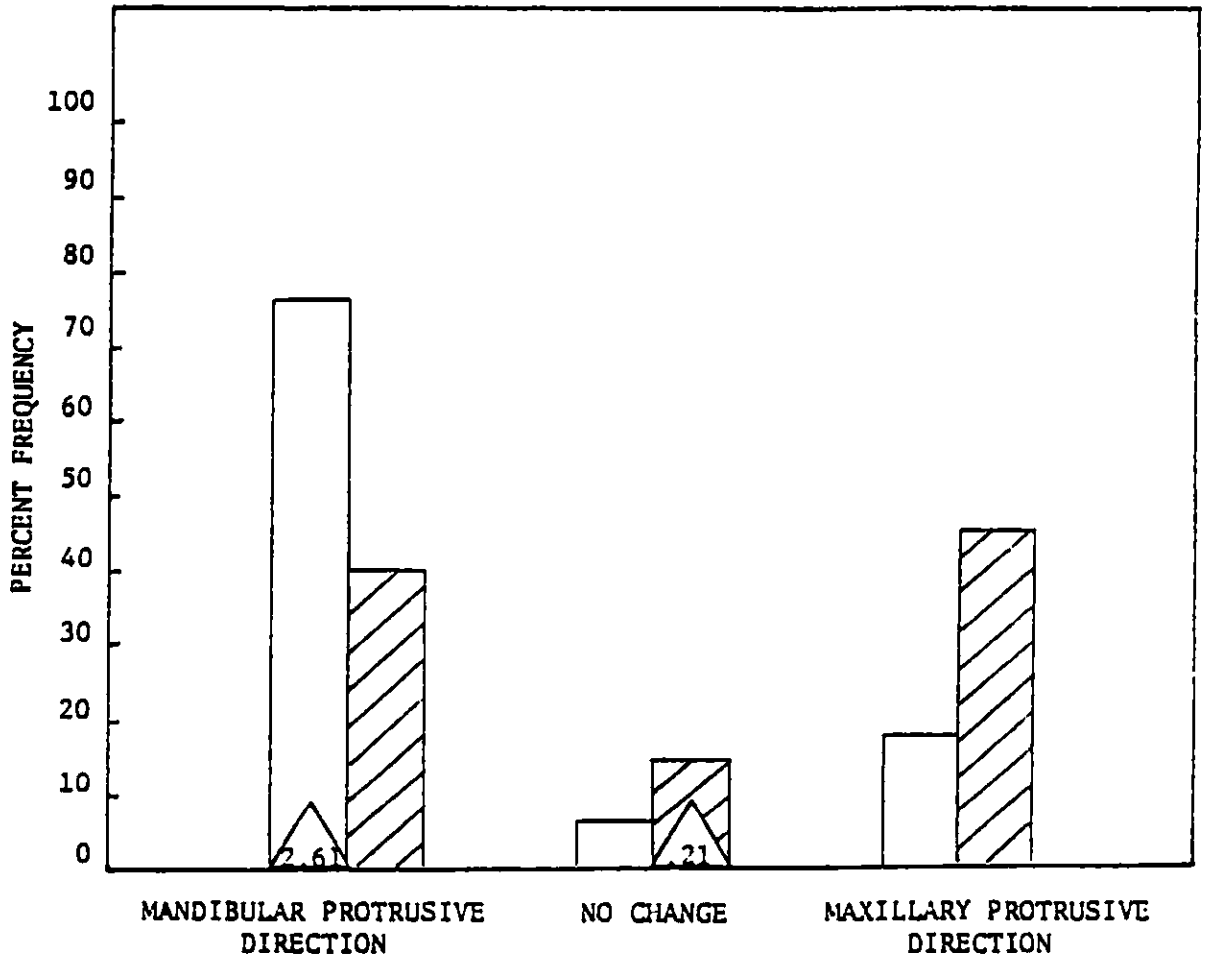
Corpus/occlusal alignment. In comparison with ramus rotation, the corpus/occlusal rotation in the treatment sample significantly increased the mandibular protrusive effect by a mean change of 2.61 mm through a downward corpus/occlusal rotation. Also, a statistically significant difference in direction of change was observed in 76% of the treatment group favoring mandibular protrusion. No significant differences were observed in the control sample during this time period.

In the treatment sample, a statistically significant reversal was observed resulting in complete rebound of the treatment change. No significant changes were observed in the control sample (See Tables XVI(A) and (B)).

TABLE XVI(A)

VARIABLE #11 (T_2-T_1, C_2-C_1)

CORPUS/OCCLUSAL ALIGNMENT



= TREATMENT SAMPLE

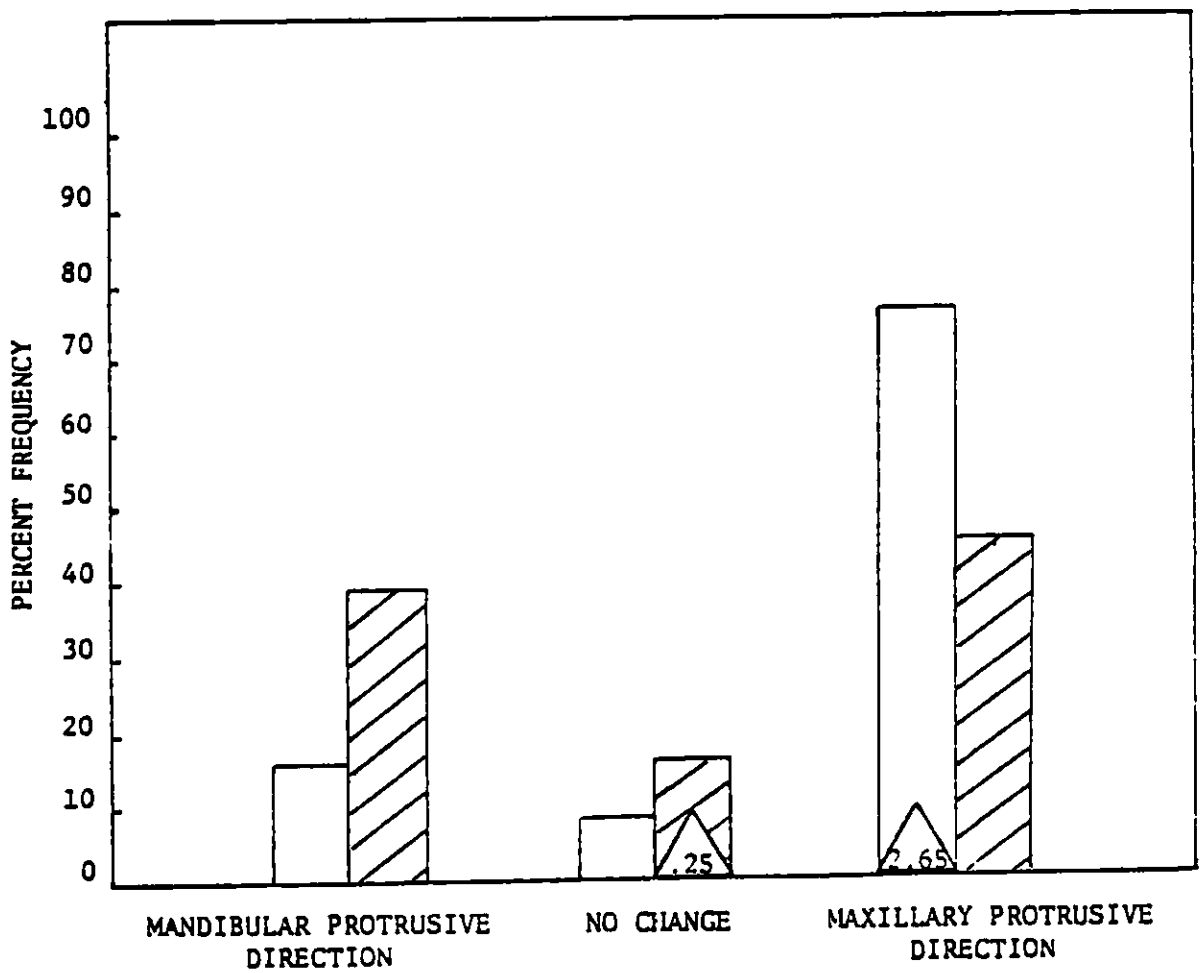
= CONTROL SAMPLE

= MEAN CHANGE (mm or degrees)

TABLE XVI(B)

VARIABLE #11 (T_3-T_2, C_3-C_2)

CORPUS/OCCLUSAL ALIGNMENT



= TREATMENT SAMPLE

= CONTROL SAMPLE

= MEAN CHANGE (mm or degrees)

Variable #12

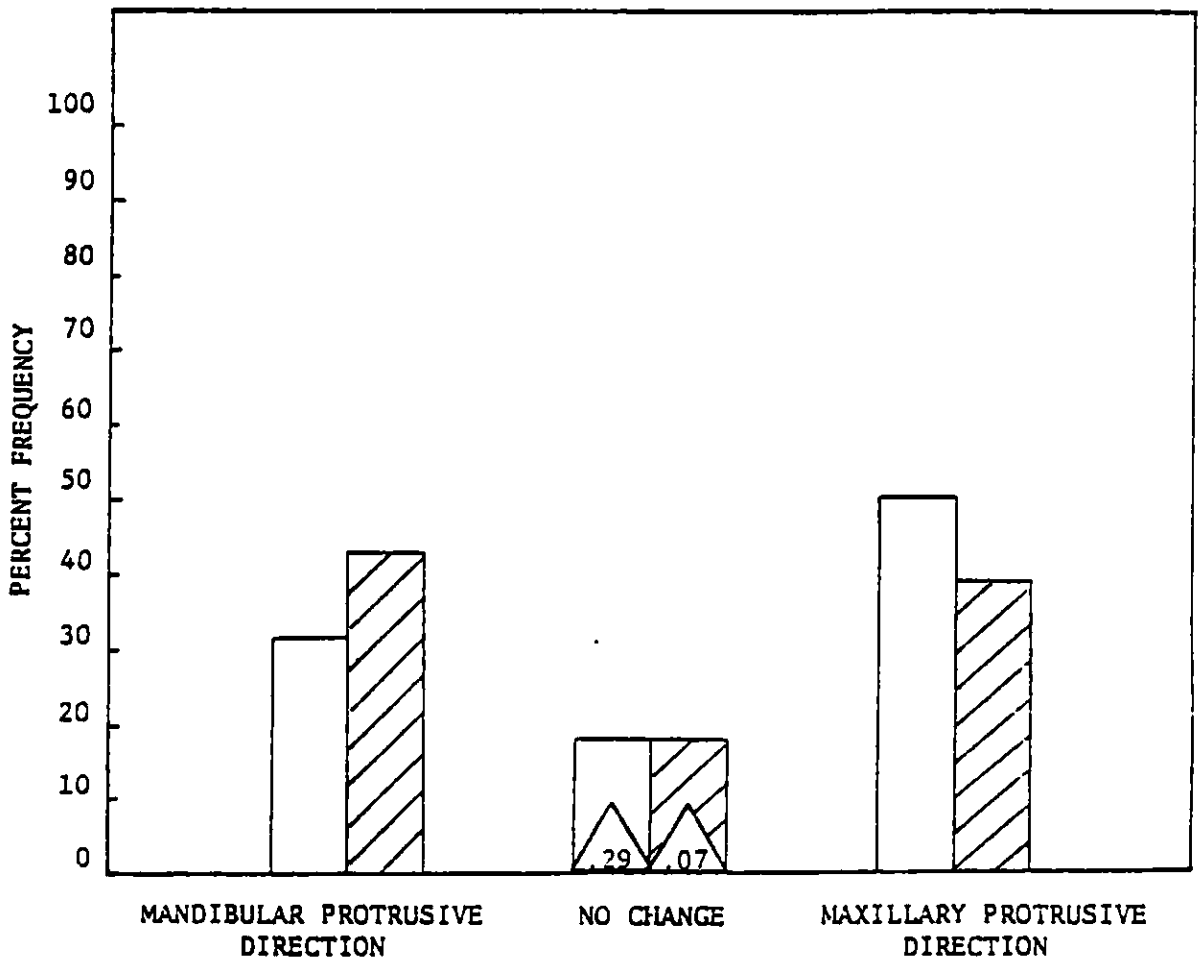
Gonial angle alignment. No statistically significant differences were demonstrated for either the treatment or control groups.

Post-treatment evaluation demonstrated significant trends in direction of change favoring mandibular protrusion in both treatment and control sample. The results demonstrated a significant opening of the angle with a mean value of 2 degrees in the treatment sample and .54 degrees in the control sample which was not significant statistically (See Tables XVII(A) and (B)).

TABLE XVII(A)

VARIABLE #12 (T_2-T_1, C_2-C_1)

GONIAL ANGLE ALIGNMENT



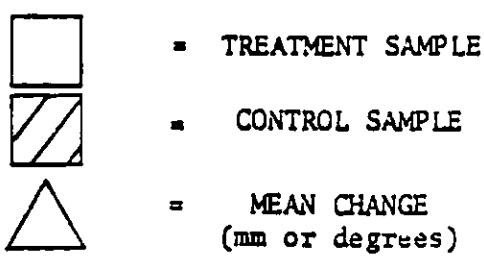
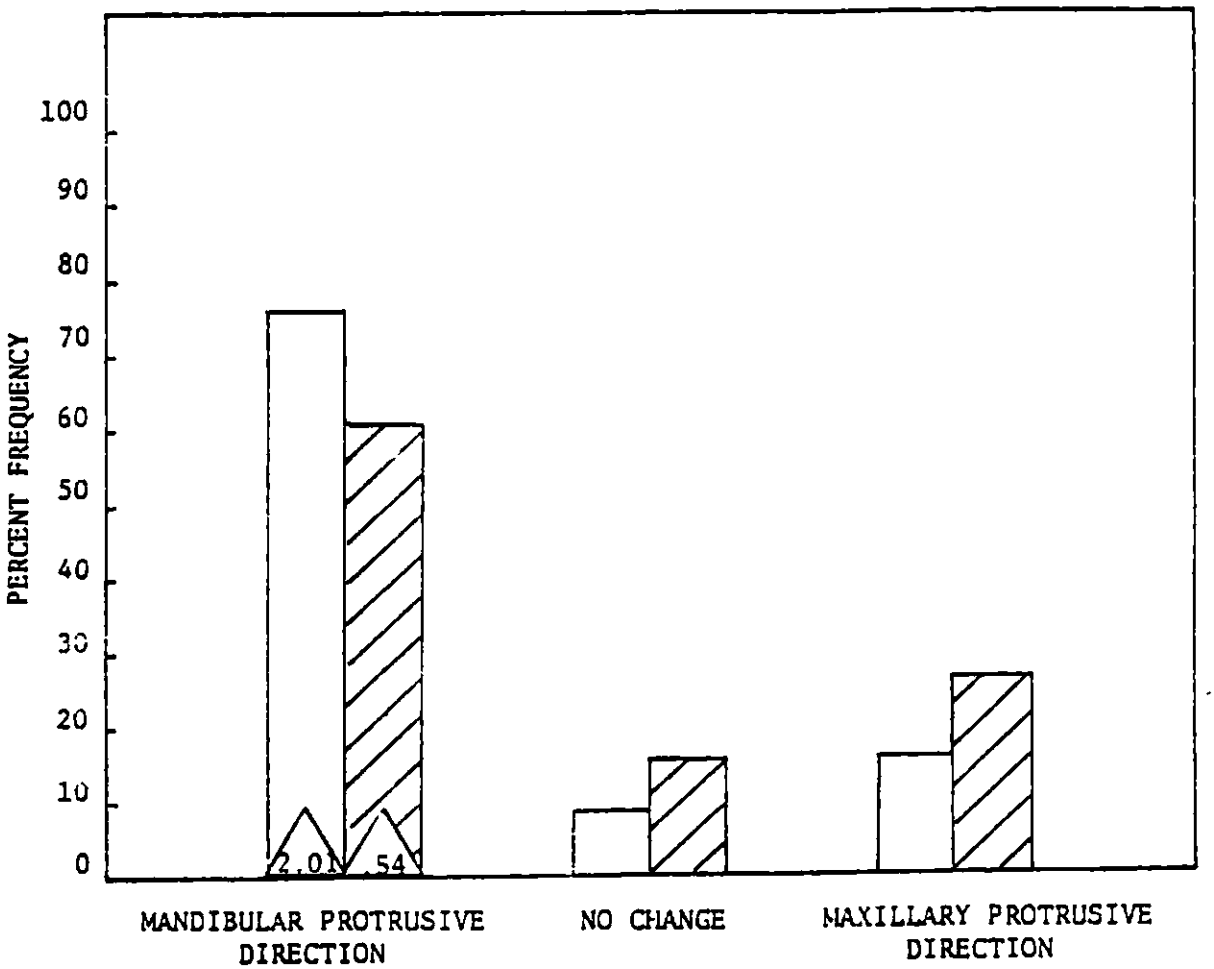


TABLE XVII(B)

VARIABLE #12 (T_3-T_2, C_3-C_2)

GONIAL ANGLE ALIGNMENT



= TREATMENT SAMPLE

= CONTROL SAMPLE

= MEAN CHANGE (mm or degrees)

Variable #13

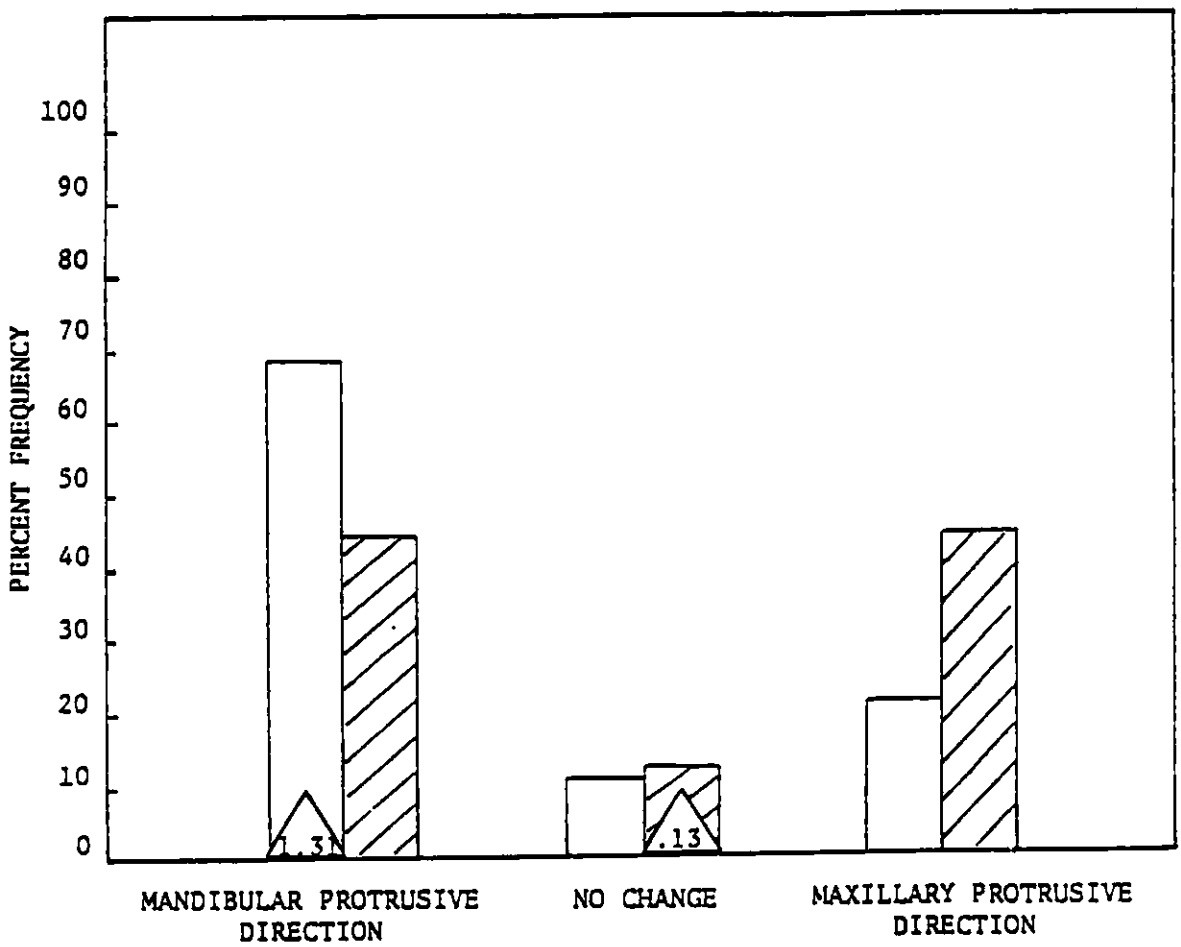
Curve of Spee. The results indicate that the Curve of Spee tended to flatten in 68% of the treatment sample, producing a mandibular protrusive effect. The mean change for this effect was 1.31 millimeters. No significant changes were apparent in the control sample.

Post-treatment results demonstrated that the treatment changes were sustained throughout this observation period, with no significant differences in either direction or magnitude of change in the treatment and control samples (See Tables XVIII(A) and (B)).

TABLE XVIII(A)

VARIABLE #13 (T_2-T_1, C_2-C_1)

CURVE OF SPEE



= TREATMENT SAMPLE

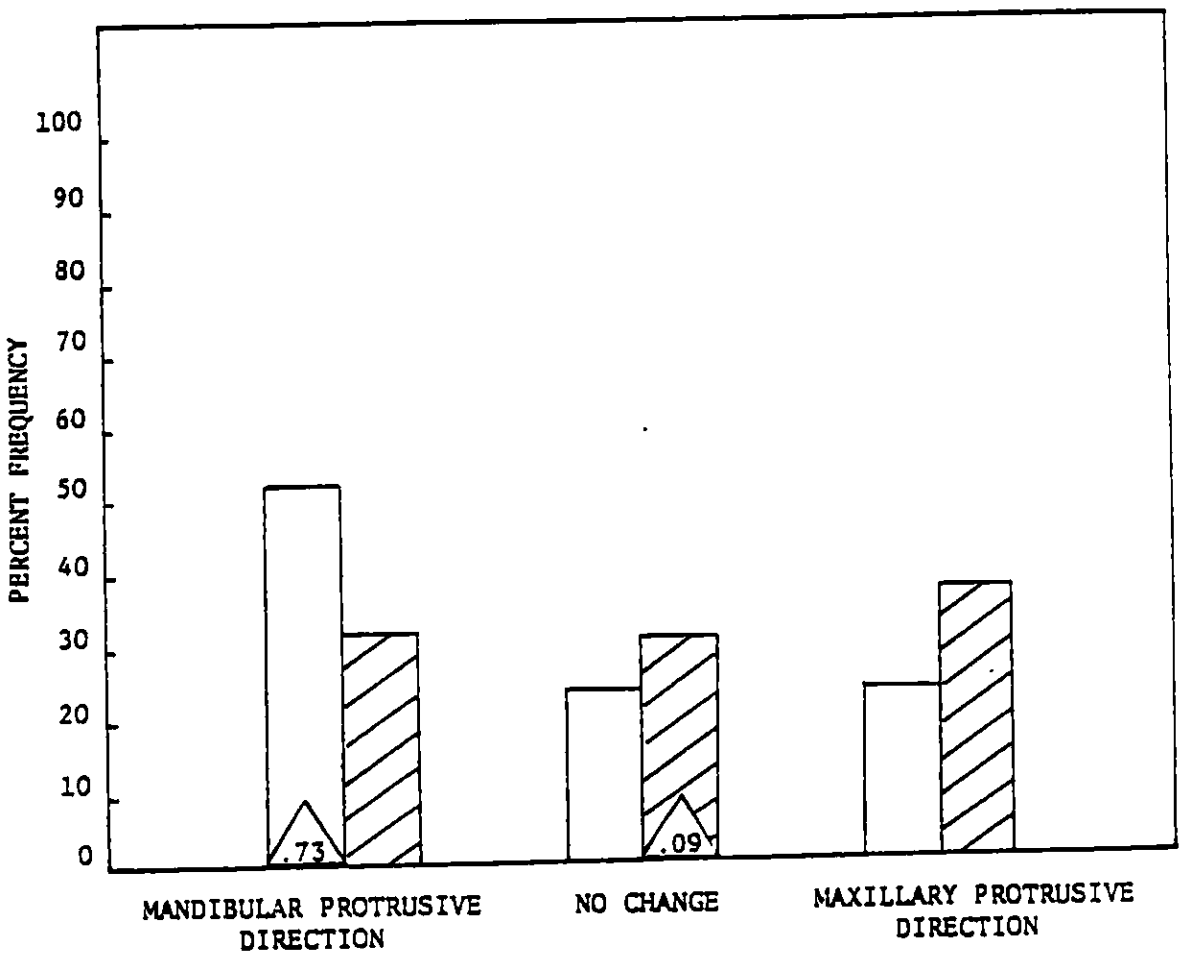
= CONTROL SAMPLE

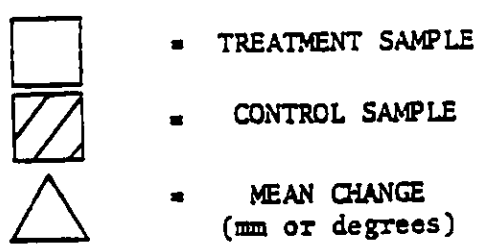
= MEAN CHANGE (mm or degrees)

TABLE XVIII(B)

VARIABLE #13 (T_3-T_2, C_3-C_2)

CURVE OF SPEE





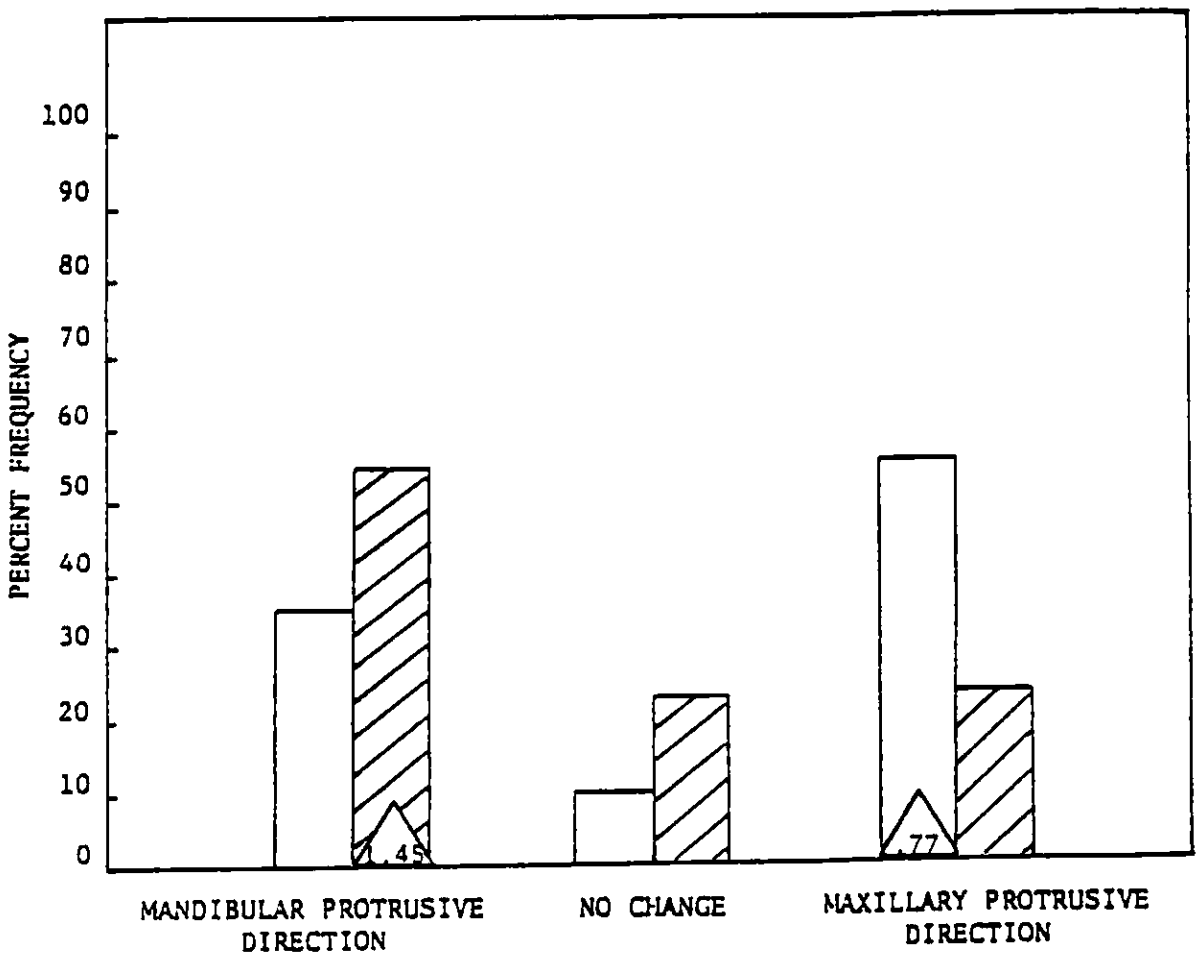
Variable #14

Palatal plane alignment. In the control sample, a significant tendency was demonstrated for a palatal plane rotation in a clockwise direction producing a mandibular protrusive effect with a mean value of 1.45 mm distance from occipital point. No statistically significant changes were demonstrated in the treatment group, however, the trend was in the opposite direction with an occurrence of a counterclockwise rotation of the palatal plane.

No significant changes in either sample were observed during the post-treatment time interval (See Tables XIX(A) and (B)).

TABLE XIX(A)
VARIABLE #14 (T_2-T_1, C_2-C_1)

PALATAL PLANE ALIGNMENT



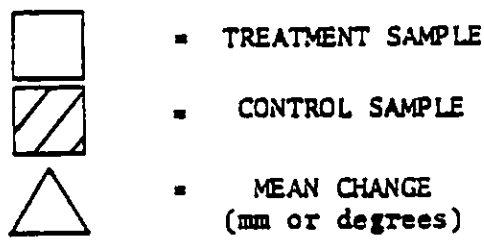
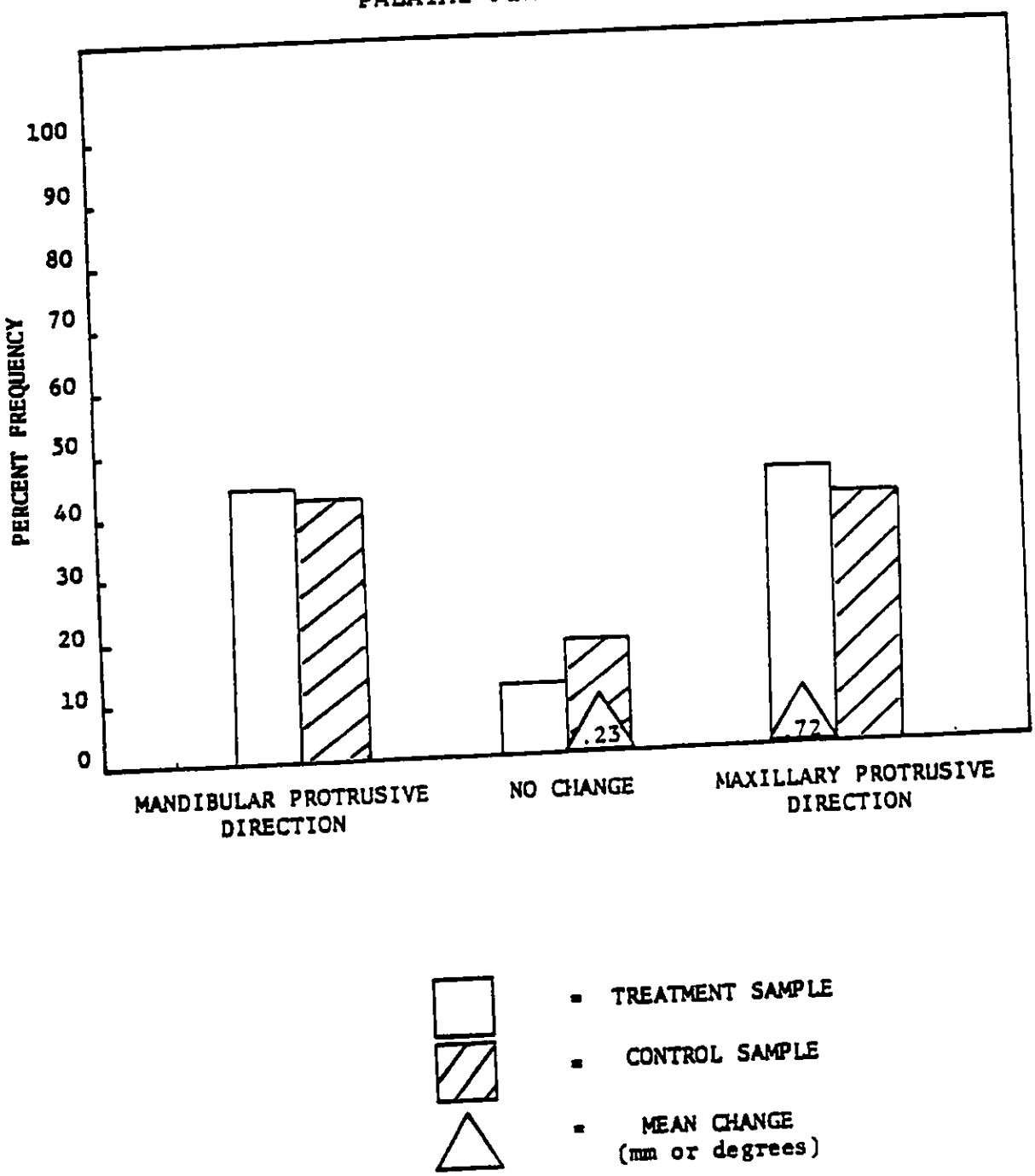


TABLE XIX(B)

VARIABLE #14 (T_3-T_2, C_3-C_2)

PALATAL PLANE ALIGNMENT



Variable #15

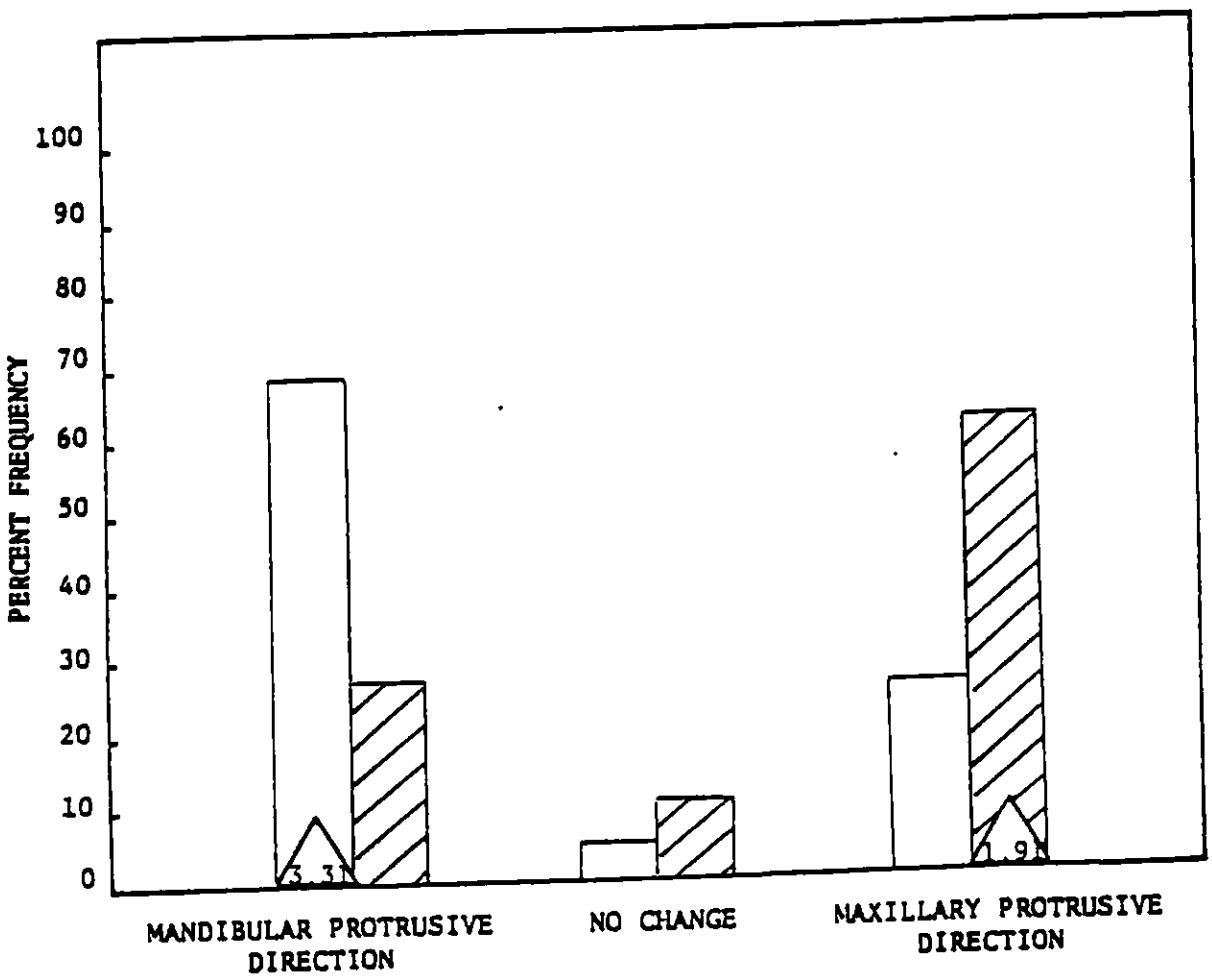
Inferior maxillary plane alignment. The treatment and control samples demonstrated changes which were statistically significant and opposite in direction and effect. The control group IMP rotated in a counter-clockwise direction producing a maxillary protrusive effect with a mean change value of 1.91 millimeters. The treatment group IMP rotated in a clockwise direction, contributing to mandibular protrusion in 69% of the sample with a mean change value of 3.31 millimeters.

Post-treatment changes occurred in both groups. In the control group, further significant rotation of the IMP in a counterclockwise direction maintained and added to the maxillary protrusive effect. In the treatment group, however, the counterclockwise IMP rotation resulted in a maxillary protrusion of 4.22 millimeters. This reversal in rotational direction exceeded and therefore negated the treatment change (See Tables XX(A) and (B)).

TABLE XX(A)

VARIABLE #15 (T_2-T_1, C_2-C_1)

INFERIOR MAXILLARY PLANE ALIGNMENT



= TREATMENT SAMPLE

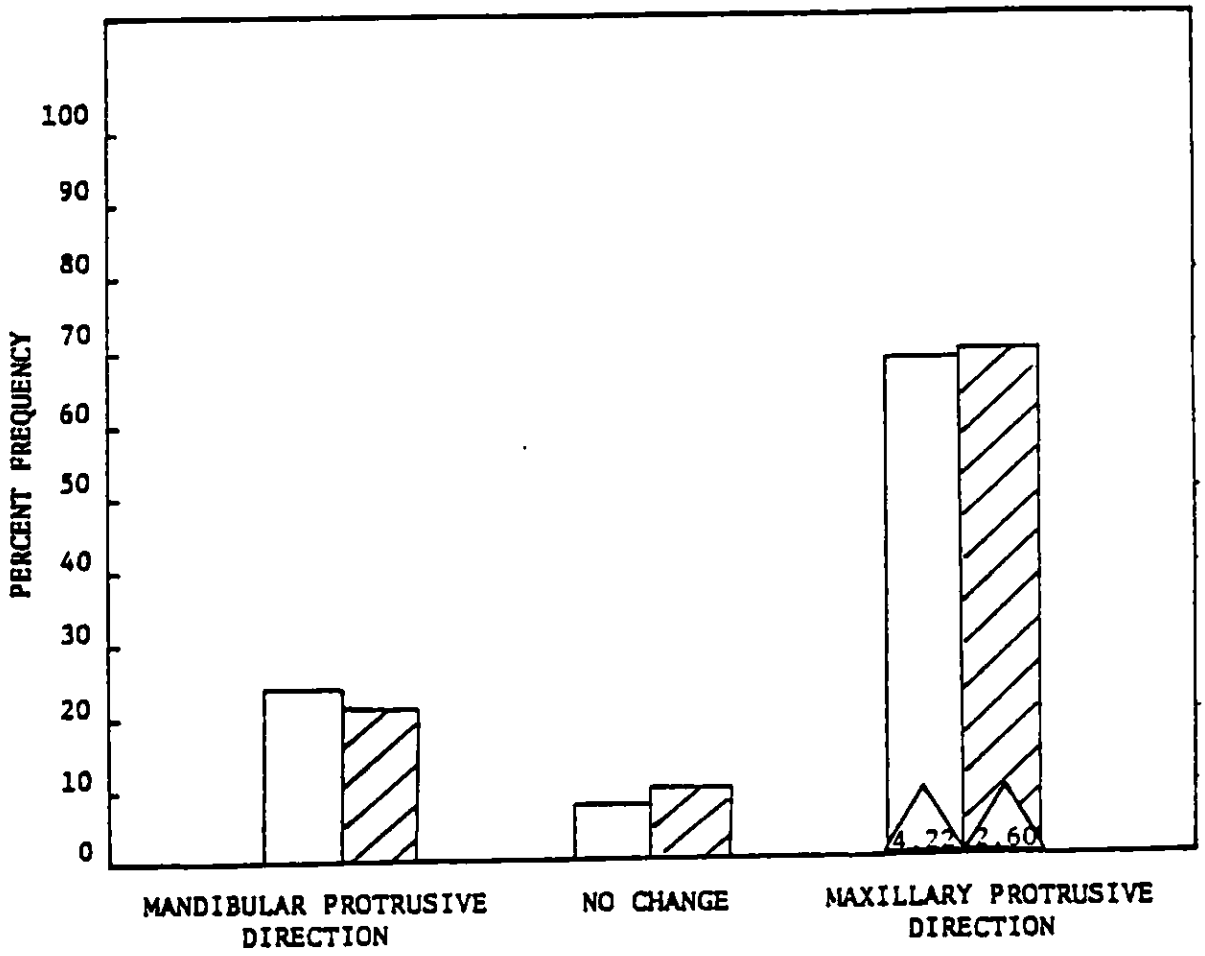
= CONTROL SAMPLE.

= MEAN CHANGE (mm or degrees)

TABLE XX(B)

VARIABLE #15 (T_3-T_2, C_3-C_2)

INFERIOR MAXILLARY PLANE ALIGNMENT



= TREATMENT SAMPLE

= CONTROL SAMPLE

= MEAN CHANGE (mm or degrees)

Variable #16

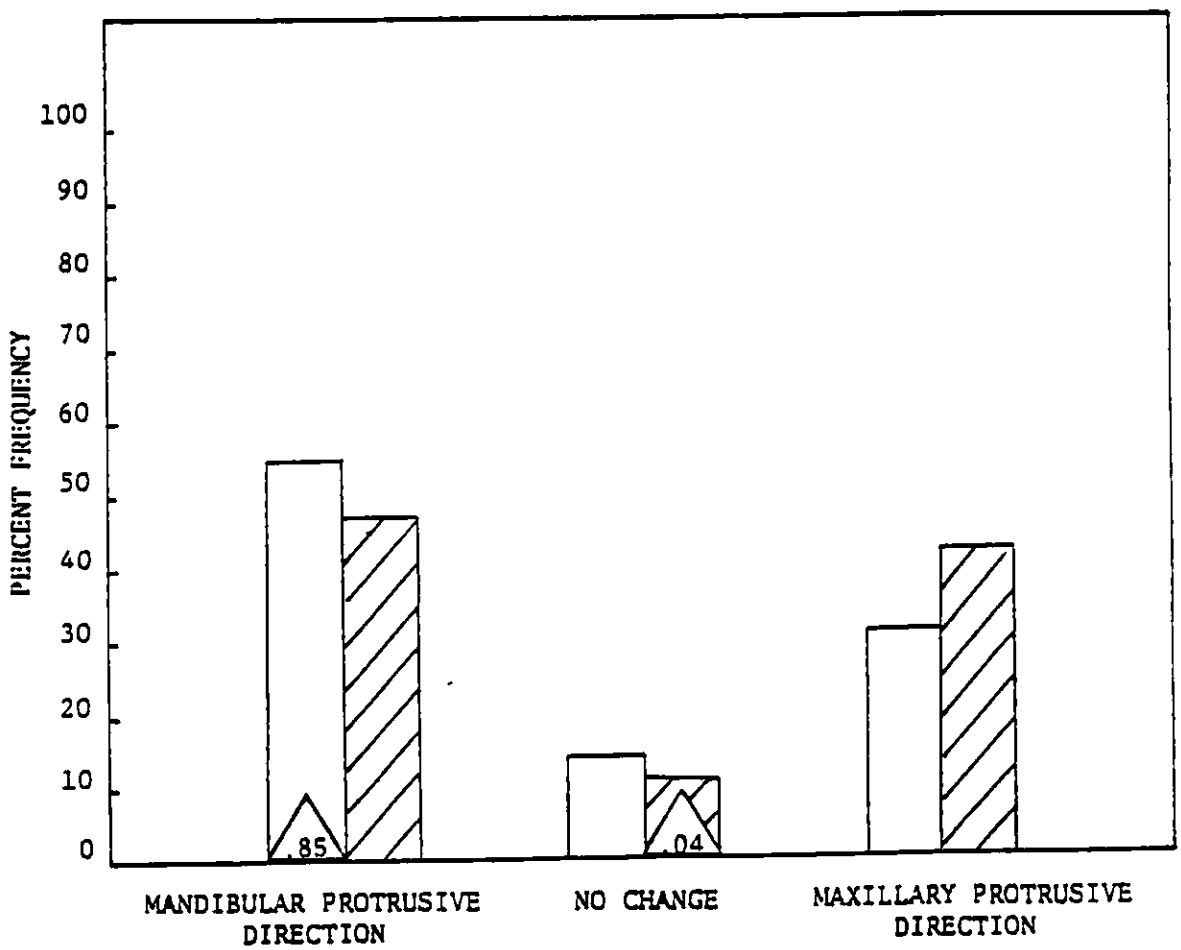
Maxillary nerve/palatal plane alignment. No significant changes were observed in the treatment or the control samples during this time interval. A slight tendency toward counterclockwise rotation of the palatal plane relative to the inferior maxillary nerve contributed a small increase of mandibular protrusion in the treatment sample.

Very little deviation occurred during the post-treatment time interval. No significant differences in direction or magnitude of change were observed in either group (See Tables XXI(A) and (B)).

TABLE XXI(A)

VARIABLE #16 (T_2-T_1, C_2-C_1)

PLANE OF THE MAXILLARY NERVE



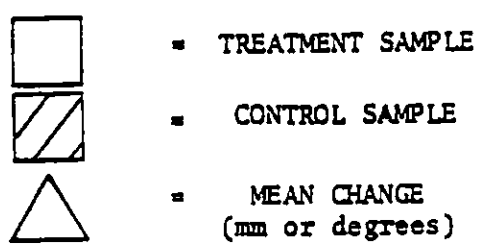
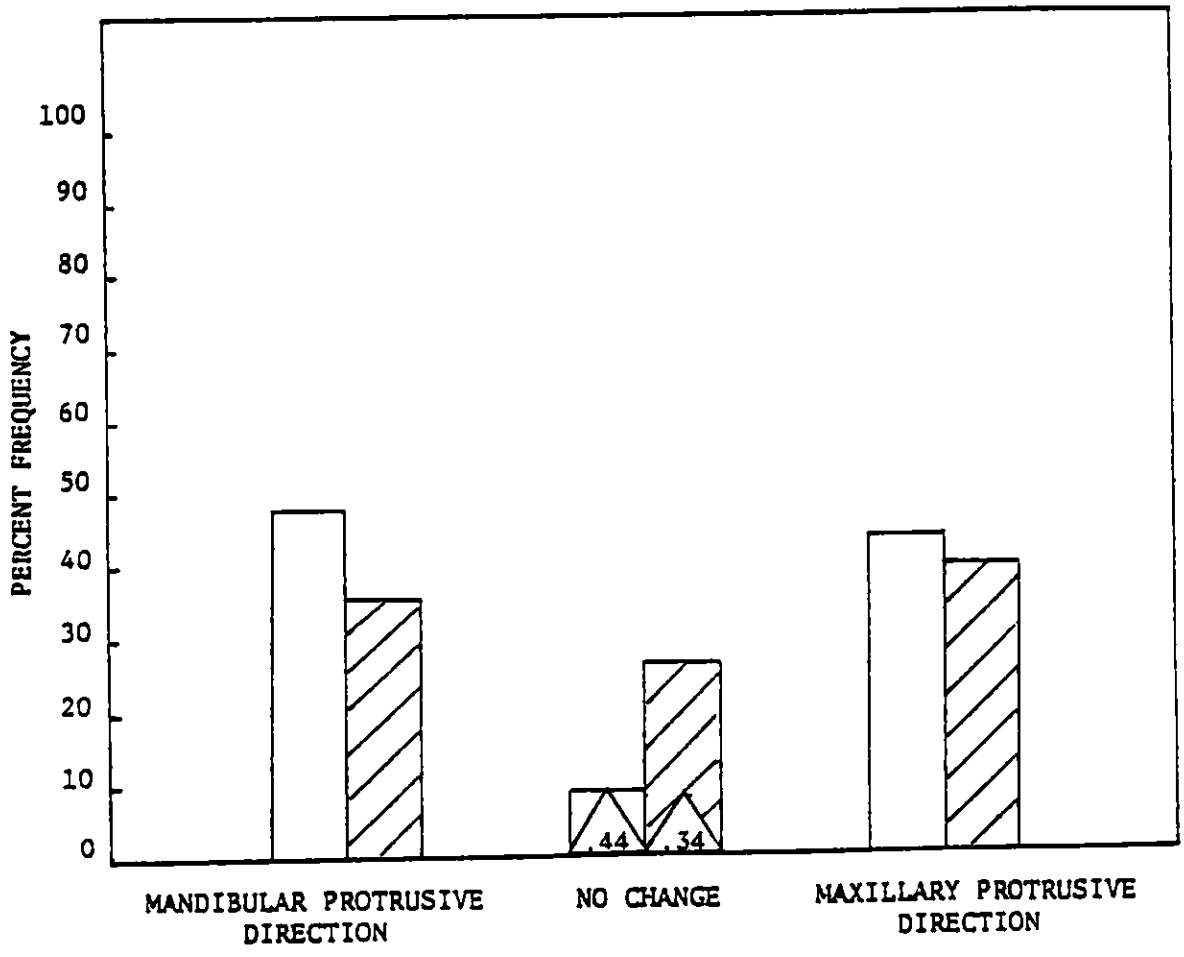


TABLE XXI(B)

VARIABLE #16 (T_3-T_2, C_3-C_2)

PLANE OF THE MAXILLARY NERVE



= TREATMENT SAMPLE

= CONTROL SAMPLE

= MEAN CHANGE (mm or degrees)

TABLE XXII

FREQUENCY DISTRIBUTION FOR DIRECTION

OF CHANGE

TREATMENT SAMPLE (T_2-T_1)

Variable	Mandibular Protrusion N	%	No Change N	%	Maxillary Protrusion N	%	Sign Test for Statistical Significance
1 Ar-A, Ar-B	52	84	7	11	3	5	p<.01
2 MCF AL	25	40	24	39	13	21	NS
3 RAMAL	40	65	13	21	9	14	p<.01
4 RMCF/SK	23	37	9	15	30	48	NS
5 RMCF/D	57	92	0	0	5	8	p<.01
6 MX/MD AB/SK	44	71	7	11	11	18	p<.01
7 MX/MD AB/D	14	23	10	16	38	61	p<.01
8 MX/MD SPr/IPr SK	51	82	4	7	7	11	p<.01
9 MX/MD SPr/IPr DENT	11	18	8	13	43	69	p<.01
10 PM VERT	23	37	11	18	28	45	NS
11 C-O ALIGN	47	76	4	6	11	18	p<.01
12 GONIAL <	20	32	11	18	31	50	NS
13 CSPEE-INC	42	68	7	11	13	21	p<.01
14 PAL PL AL	22	35	6	10	34	55	NS
15 INF MX PL	43	69	3	5	16	26	p<.01
16 MX N/PPL	34	55	9	14	19	31	NS

TABLE XXIII

FREQUENCY DISTRIBUTION FOR DIRECTION OF CHANGE

CONTROL SAMPLE (C_2-C_1)

Variable	Mandibular Protrusion N	%	No Change N	%	Maxillary Protrusion N	%	Sign Test for Statistical Significance
1 Ar-A, Ar-B	28	45	11	18	23	37	NS
2 MCF AL	29	47	13	21	20	32	NS
3 RAMAL	19	31	22	35	21	34	NS
4 RMCF/SK	21	34	7	11	34	55	NS
5 RMCF/D	21	34	13	21	28	45	NS
6 MX/MD AB/SK	30	48	4	6	28	45	NS
7 MX/MD AB/D	30	48	11	18	21	34	NS
8 MX/MD SPr/IPr SK	27	43	9	15	26	42	NS
9 MX/MD SPr/IPr DENT	23	37	18	29	21	34	NS
10 PM VERT	26	42	7	11	29	47	NS
11 C-O ALIGN	25	40	9	15	28	45	NS
12 GONIAL <	27	43	11	18	24	39	NS
13 CSPEE-INC	27	44	8	12	27	44	NS
14 PAL PL AL	34	54	14	23	14	23	$p<.01$
15 INF MX PL	17	27	7	11	38	62	$p<.01$
16 MX N/PPL	29	47	7	11	26	42	NS

TABLE XXIV

FREQUENCY DISTRIBUTION FOR DIRECTION OF CHANGE

TREATMENT SAMPLE (T_3-T_2)

Variable	Mandibular Protrusion		No Change		Maxillary Protrusion		Sign Test for Statistical Significance
	N	%	N	%	N	%	
1 Ar-A, Ar-B	7	28	2	8	16	64	NS
2 MCF AL	9	36	5	20	11	44	NS
3 RAMAL	3	12	6	24	16	64	p<.01
4 RMCF/SK	11	44	5	20	9	36	NS
5 RMCF/D	5	20	4	16	16	64	p<.05
6 MX/MD AB/SK	9	36	1	4	15	60	NS
7 MX/MD AB/D	10	40	3	12	12	48	NS
8 MX/MD SPr/IPr SK	9	36	1	4	15	60	NS
9 MX/MD SPr/IPr DENT	11	44	4	16	10	40	NS
10 PM VERT	10	40	1	4	14	56	NS
11 C-O ALIGN	4	16	2	8	19	76	p<.01
12 GONIAL <	19	76	2	8	4	16	p<.01
13 CSPEE-INC	13	52	6	24	6	24	NS
14 PAL PL AL	11	44	3	12	11	44	NS
15 INF MX PL	6	24	2	8	17	68	p<.05
16 MX N/PPL	12	48	2	8	11	44	NS

TABLE XXV

FREQUENCY DISTRIBUTION FOR DIRECTION OF CHANGE

CONTROL SAMPLE (C_3-C_2)

Variable	Mandibular Protrusion N	%	No Change N	%	Maxillary Protrusion N	%	Sign Test for Statistical Significance
1 Ar-A, Ar-B	24	39	6	10	32	51	NS
2 MCF AL	25	40	12	20	25	40	NS
3 RAMAL	23	37	16	26	23	37	NS
4 RMCF/SK	25	40	11	18	26	42	NS
5 RMCF/D	29	47	12	19	21	34	NS
6 MX/MD AB/SK	27	43	9	15	26	42	NS
7 MX/MD AB/D	20	32	14	23	28	45	NS
8 MX/MD SPr/IPr SK	27	44	8	12	27	44	NS
9 MX/MD SPr/IPr DENT	18	29	16	26	28	45	NS
10 PM VERT	27	44	10	16	25	40	NS
11 C-O ALIGN	24	39	10	16	28	45	NS
12 GONIAL <	38	61	8	13	16	26	$p<.01$
13 CSPEE-INC	20	32	19	31	23	37	NS
14 PAL PL AL	26	42	11	18	25	40	NS
15 INF MX PL	13	21	6	10	43	69	$p<.01$
16 MX N/PPL	22	35	16	26	24	39	NS

TABLE XXVI

95% CONFIDENCE INTERVALS FOR

THE MEANS OF THE MEASURED VARIABLES

TREATMENT SAMPLE (T_2-T_1)

Variable	$\bar{X}$	SD	Confidence Interval	Statistical Significance
1	-4.276	3.892	-3.29 to -5.26	yes
2	-0.446	1.694	-0.02 to -0.88	yes
3	-0.925	1.521	-0.54 to -1.31	yes
4	0.556	3.056	1.33 to -0.22	no
5	-5.845	4.351	-4.74 to -6.95	yes
6	-5.048	5.941	-3.54 to -6.56	yes
7	1.648	3.320	2.49 to 0.81	yes
8	-5.215	4.865	-3.98 to -6.45	yes
9	1.502	2.158	2.05 to 0.95	yes
10	0.606	3.699	1.55 to -0.33	no
11	-2.610	4.333	-1.51 to -3.71	yes
12	0.286	2.986	1.05 to -0.47	no
13	-1.306	2.814	-0.59 to -2.02	yes
14	0.770	5.015	0.5 to -2.04	no
15	-3.310	7.864	-5.30 to -1.32	yes
16	-0.853	3.256	-0.023 to -1.68	yes

TABLE XXVII

95% CONFIDENCE INTERVALS FOR

THE MEANS OF THE MEASURED VARIABLES

CONTROL SAMPLE (C_2-C_1)

Variable	$\bar{X}$	SD	Confidence Interval	Statistical Significance
1	-0.327	2.846	0.39 to -0.99	no
2	-0.138	1.810	-0.32 to -0.59	no
3	0.104	2.554	0.753 to -0.54	no
4	0.647	2.378	1.25 to 0.04	yes
5	0.097	2.897	0.83 to -0.64	no
6	-0.763	5.064	0.53 to -2.05	no
7	-0.429	2.651	0.24 to -1.11	no
8	-0.429	3.768	0.53 to -1.39	no
9	-0.154	1.573	0.25 to -0.55	no
10	0.054	2.307	0.64 to -0.53	no
11	-0.205	2.810	0.51 to -0.92	no
12	-0.067	2.819	0.65 to -0.78	no
13	-0.126	2.185	0.43 to -0.68	no
14	-1.450	3.496	-2.34 to -0.56	yes
15	1.91	5.029	0.63 to 1.28	yes
16	-0.041	3.066	0.82 to -0.74	no

TABLE XXVIII

95% CONFIDENCE INTERVALS FOR

THE MEANS OF THE MEASURED VARIABLES

TREATMENT SAMPLE (T_3-T_2)

Variable	$\bar{X}$	SD	Confidence Interval	Statistical Significance
1	1.494	2.850	2.87 to 0.11	yes
2	0.064	1.943	0.86 to -0.74	no
3	0.995	1.459	1.71 to 0.29	yes
4	0.534	3.225	1.86 to -0.80	no
5	2.196	4.180	3.93 to 0.47	yes
6	1.099	5.811	3.50 to -1.30	no
7	-0.417	3.210	1.14 to -1.98	no
8	1.238	5.016	3.31 to -0.83	no
9	-0.490	2.442	0.52 to -1.50	no
10	-0.210	2.909	0.99 to -1.41	no
11	2.653	3.615	4.14 to 1.16	yes
12	-2.008	2.454	-0.96 to -3.06	yes
13	-0.726	2.019	0.26 to -1.71	no
14	0.720	6.115	1.80 to -3.24	no
15	4.223	8.271	0.81 to 7.63	yes
16	-0.435	3.935	1.48 to -2.36	no

TABLE XXIX

95% CONFIDENCE INTERVALS FOR

THE MEANS OF THE MEASURED VARIABLES

CONTROL SAMPLE (C_3-C_2)

Variable	$\bar{X}$	SD	Confidence Interval	Statistical Significance
1	0.160	3.010	0.92 to -0.60	no
2	-0.044	1.708	0.39 to -0.47	no
3	-0.253	2.197	0.31 to -0.81	no
4	0.160	2.081	0.69 to -0.37	no
5	-0.439	2.380	0.16 to -1.04	no
6	0.335	4.988	1.61 to -0.94	no
7	0.408	2.630	1.08 to -0.26	no
8	0.296	3.595	2.10 to -0.150	no
9	0.592	2.058	1.62 to -0.44	no
10	0.189	2.372	0.79 to -0.41	no
11	0.252	2.994	1.75 to -1.25	no
12	-0.542	2.796	0.17 to -1.25	no
13	0.090	1.873	1.03 to -0.85	no
14	-0.230	3.378	2.15 to -1.46	no
15	2.604	5.155	1.29 to 3.91	yes
16	0.340	2.367	0.94 to -0.26	no

TABLE XXX

MEANS AND STANDARD DEVIATIONS OF MEASURED VARIABLES

TREATMENT SAMPLE

Variable		T_1 Pre Treatment	T_2 End of Treatment	T_3 Post Treatment	T_2-T_1 Treatment Change	T_3-T_2 Post Treatment Change
1	X	0.63	-3.64	-2.21	-4.28	1.49
	S.D.	3.72	3.26	3.08	3.89	2.85
2	X	1.07	0.63	1.07	-0.45	0.06
	S.D.	2.46	2.92	1.97	1.69	1.94
3	X	2.29	1.37	2.05	-0.93	0.96
	S.D.	1.74	1.64	1.57	1.52	1.46
4	X	- 0.41	0.15	1.03	0.56	0.53
	S.D.	3.06	3.26	3.18	3.06	3.23
5	X	- 2.75	-8.60	-5.49	-5.85	2.20
	S.D.	3.44	4.45	2.82	4.35	4.18
6	X	- 1.51	-6.56	-6.11	-5.05	1.10
	S.D.	5.72	5.44	5.41	5.94	5.81
7	X	- 0.32	1.33	0.08	1.65	-0.42
	S.D.	3.26	2.86	3.06	3.32	3.21
8	X	2.02	-3.20	-2.48	-5.22	1.24
	S.D.	5.15	4.62	4.33	4.87	5.02
9	X	3.14	4.64	3.39	1.50	-0.49
	S.D.	1.98	2.25	2.09	2.16	2.44
10	X	1.67	2.28	1.08	0.61	-0.21
	S.D.	2.82	4.45	2.57	3.70	2.91
11	X	0.74	-1.87	0.20	-2.61	2.65
	S.D.	3.60	3.69	2.99	4.33	3.62
12	X	-3.23	-2.94	-4.62	0.29	-2.01
	S.D.	5.99	6.73	4.81	2.99	2.45
13	X	3.70	2.39	2.31	-1.31	-0.73
	S.D.	2.11	2.10	1.52	2.81	2.02
14	X	-6.45	-5.68	-6.16	-0.77	0.72
	S.D.	7.67	8.02	8.86	5.02	6.12
15	X	6.19	2.88	6.63	-3.31	-4.22
	S.D.	8.13	8.23	7.23	7.86	8.27
16	X	4.67	3.82	3.56	-0.85	-0.44
	S.D.	3.74	3.27	2.74	3.26	3.94

TABLE XXXI

MEANS AND STANDARD DEVIATIONS OF MEASURED VARIABLES

CONTROL SAMPLE

Variable		C_1 Pre Treatment	C_2 End of Treatment	C_3 Post Treatment	C_2-C_1 Treatment Change	C_3-C_2 Post Treatment Change
1	X	-0.56	-0.89	-0.73	-0.33	0.16
	S.D.	3.78	3.80	3.60	2.85	3.01
2	X	-0.67	-0.81	-0.85	-0.14	-0.04
	S.D.	2.97	2.96	3.06	1.81	1.71
3	X	2.29	2.39	2.14	0.10	-0.25
	S.D.	2.20	2.88	2.21	2.55	2.19
4	X	0.75	1.39	1.50	0.65	0.16
	S.D.	3.03	3.01	3.11	2.38	2.08
5	X	-0.64	-0.54	-0.98	0.10	-0.44
	S.D.	3.95	3.91	3.78	2.89	2.38
6	X	-1.68	-2.45	-2.11	-0.76	0.34
	S.D.	5.88	6.86	6.17	5.06	4.99
7	X	-1.40	-1.83	-1.42	-0.43	0.41
	S.D.	3.61	3.62	3.43	2.65	2.63
8	X	1.61	1.18	1.48	-0.43	0.30
	S.D.	4.67	5.60	4.94	3.77	3.59
9	X	1.95	1.79	2.38	-0.15	0.59
	S.D.	2.13	2.33	2.33	1.57	2.06
10	X	3.13	3.18	3.37	0.05	0.19
	S.D.	3.13	3.23	3.35	2.31	2.37
11	X	1.61	1.40	1.65	-0.21	0.25
	S.D.	4.39	4.24	4.53	2.81	2.99
12	X	-4.43	-4.49	-5.04	-0.07	-0.54
	S.D.	7.38	8.00	8.10	2.82	2.79
13	X	3.83	3.70	3.79	-0.13	0.09
	S.D.	2.09	1.96	2.19	2.19	1.87
14	X	-3.85	-5.29	-5.53	1.45	0.23
	S.D.	7.39	6.52	6.45	3.50	3.38
15	X	3.29	5.21	7.81	-1.91	-2.60
	S.D.	8.78	8.51	9.38	5.03	5.16
16	X	4.13	4.09	4.43	-0.04	0.34
	S.D.	2.91	3.02	2.73	3.07	2.37

TABLE XXXII

TREATMENT RESPONSES OF TYPE A AND TYPE B CLASS II COMPOSITES

	Class II Type A			Class II Type B		
	N	Mandibular Protrusive	Maxillary Protrusive	N	Mandibular Protrusive	Maxillary Protrusive
Treatment	39	37	2	23	21	2
Control	26	17	9	36	15	21

TABLE XXXIII

TYPE CONVERSION AS DETERMINED BY A/B AGGREGATE

	A —> A	A —> B	B —> B	B —> A
Treatment	5/39=13%	34/39=87%	22/23=96%	1/23=4%
Control	14/26=54%	12/26=46%	22/36=61%	14/36=39%

DISCUSSION

In evaluating what is described as treatment change, other factors are undoubtedly playing a role in the observed outcome. The Herbst appliance is one additional environmental influence upon the collage of functional, genetic and neurophysiologic events ongoing in the growing individual.

According to the description by Whitney (1983) of serial evaluation of the Class II pattern, one would expect the untreated individual to exhibit changes which tend to worsen the expression of the underlying Class II discrepancy with time. The Class II sample in Whitney's study demonstrated relative constancy of middle cranial fossa alignment, a relatively short posterior nasomaxilla until the age of 16, a constant backward alignment of the ramus, accompanied by a progressive closure of the gonial angle and an increased curve of Spee. These last three features have been discussed by Enlow (1982) as normal growth findings for the untreated Class II pattern. In addition to this, Whitney found that the maxillary-to-mandibular discrepancy tended to increase over time. The control group in the present study demonstrated few changes in the variables examined, but identifiable trends were consistent with the conclusions of Enlow and Whitney. Two areas changed notably in the untreated sample. The palatal plane alignment was observed to

rotate in a clockwise direction with respect to occipital point in a significant percent of the sample. The palatal plane relationship to the maxillary nerve remained constant. Also the control group demonstrated a strong tendency for a counterclockwise rotation of the inferior maxillary plane, perhaps reflecting the development of an excessive posterior nasomaxillary dimension.

The cumulative effects of the aggregate of changed anatomic conditions during treatment indicate that directional changes favoring mandibular protrusion occurred in a high percentage of the treatment sample. This is consistent with results reported in the literature for the European Herbst design. Three explanations for the observed sagittal changes were offered by Weislander (1984). He suggested that stimulation of growth of the mandibular condyles, a change in mandibular morphology and an anteroinferior change in condylar position with a possible anterior translation of the glenoid fossae may all be contributing factors.

The scope of the present study does not include assessment of the condylar response to this treatment modality, but is appropriate for studying certain changes in morphology. Prior to undertaking this study, due consideration was given to the possibility that the

appliance might create a dual bite situation which would not allow for proper application of the counterpart principle. To test for anteroinferior positional changes of articulare, suggestive of dual bite, a template was constructed from each of the initial treatment radiographs. This template incorporated articulare, sella and a perpendicular distance to PM vertical. The template was superimposed over the end-of-treatment radiograph. Differences in linear measurements did not exceed 1.0 mm in any treatment or control case. Weislander (1984) reported the occurrence of a double radiographic contour of the fossa outline in 19 of his 33 cases, indicating a possible anterior transformation of the fossa. No increase was observed in the supracondylar space, however. In a smaller Pancherz sample (1985) no change in radiographic condylar position was observed.

The morphologic adaptations occurring throughout the craniofacial complex during Herbst appliance treatment was a major focus of this study. The potential tracing error, point registration error and computer versus human measurement error was recognized and determined to be less than 2% following repeated trials of each.

Skeletal Changes

The middle cranial fossa alignment was relatively constant but demonstrated a trend towards backward alignment in about 40% of the treatment sample. The

control group demonstrated adverse changes in this alignment to a greater extent. In the treatment sample, an anterior direction of ramus alignment was observed. This lengthens the horizontal expression of the ramus and shortens its vertical expression.

Normally, the ramus is observed to upright during growth and development to accommodate vertical elongation of the nasomaxillary complex. During treatment, however, an anatomic effect occurred which contributed to the clinically desirable result of mandibular protrusion, and which reversed the formerly established growth pattern. Because of this reversal, it is possible that the treatment effect might be more prone to relapse or that continued growth would erase the benefits gained.

The relative horizontal dimensions of the middle cranial fossa and ramus remained constant in both groups throughout the period evaluated. This might be interpreted in a number of ways. The normal mechanism of mandibular growth as described by Enlow (1975) reveals a histologic pattern which demonstrates resorptive remodeling of the anterior border of the ramus and bone deposition remodeling at the posterior border. If these remodeling processes proceed at a comparable rate, the ramus will progressively remodel posteriorly while maintaining the same width. If an imbalance is introduced, such as a short corpus or functional

appliance therapy, this region is morphogenically capable of serving to compensate. In the former situation, often encountered in a Class II type A, the ramus may be wider than its counterpart and provides a more anteriorly positioned mandibular corpus and dental arch. Similarly, when a mandibular protrusive device such as a functional regulator is introduced, a new imbalance suddenly demands corpus lengthening. In a recent study by Enlow et al. (1985) functional regulator treatment was found to be associated with a narrowing of the mandibular ramus width, in conjunction with corpus lengthening. Ramus narrowing occurred to a greater extent in the control than in the treatment group following Herbst treatment. It may be possible that the remodeling processes are offset by the increased horizontal ramus dimension due to a more anterior ramus alignment in treated subjects, thus precluding excessive mandibular protrusion that could be caused by the appliance.

At least two possibilities can be considered for the relative increase in mandibular bony arch length. An actual lengthening of the corpus may be occurring through accelerated remodeling accompanied, perhaps, by some restriction of maxillary skeletal growth through a headgear effect of the appliance. With sufficient anchorage, it would seem feasible to influence the basal growth potential or direction of the maxilla as a

reciprocal effect of the protrusive mechanics of the telescoping arch assembly. Other studies (Pancherz, 1985; Weislander, 1984) have reported changes in overall mandibular length from condylion to gnathion which averaged three times that seen in the control group. By combining the results from the horizontal ramus dimensions with the relative arch length comparisons, it appears that the increased mandibular horizontal dimension is occurring to a greater extent in the corpus of the mandible. Contributions from condylar remodeling or maxillary retrusion are likely involved, but cannot be adequately evaluated in this study.

In addition to the significant anterior ramus alignment, a downward rotation of the corpus/occlusal alignment occurred, providing an additional mandibular protrusive effect. The gonial angle remained constant for the most part, exhibiting a slight tendency towards closure. It is likely, then, that the occlusal plane is rotating in a clockwise manner and that the corpus to ramus relationship is relatively unchanged. The occlusal plane rotation was accompanied by a similar rotation of the inferior maxillary plane. This finding was observed by DiPalma (1982) in evaluation of the effects of the functional regulator. To compensate for this relative shortening of the posterior maxilla, the ramus rotates anteriorly, displacing the corpus in the same direction.

These events are a reversal of the observations of the control group during the same time interval. The palatal plane alignment was also reversed as compared with the control. In the Class II control, the palatal plane tended to rotate in a clockwise direction, contributing to the existing mandibular protrusion. In the treated sample, the palatal plane demonstrated a tendency to remain constant or to rotate counterclockwise.

In summary, the skeletal counterparts of the treatment sample responded in the following manner: the middle cranial fossa rotated slightly backwards and the PM vertical dimension remained fairly constant as compared with the ramus/MCF vertical dimension. The inferior boundary of the nasomaxillary complex rotated in a clockwise direction and a relatively shorter posterior vertical dimension resulted, accompanied by an anterior rotation of the mandible. The palatal plane remained constant, suggesting an inhibition of a tendency to rotate in a clockwise direction as seen in the controls. The corpus/ramus relationship remained constant as demonstrated by an unchanged gonial angle. These skeletal changes produced effects which are, for the most part, mandibular protrusive in direction and consistent with clinical goals in that respect.

It is interesting to note that these treatment changes are consistent with many of the functional,

operative compensatory mechanisms observed in the untreated Class II, type B craniofacial composite. This type of Class II is characterized by B point being positioned anterior to A point with respect to the occlusal plane. The middle cranial fossa and ramus alignments are less markedly maxillary protrusive. The PM vertical dimension tends to be relatively shorter, and the ramus/MCF horizontal dimensions, both skeletally and dentally relate to a relatively longer mandibular corpus. Finally, the corpus/occlusal alignment of the untreated type B Class II tends to exhibit a downward rotation relative to the ramus, whereas the untreated A type demonstrates the opposite. These features closely resemble the responses in the A type observed during the treatment interval of this study.

The pretreatment sample consisted of 38 type A and 23 type B Class II individuals. The results of a recent study by Enlow et al. (1985) suggested that A and B types respond differently to functional regulator treatment. It was found that type A individuals more predictably exhibited a mandibular protrusive response as an outcome of treatment than did the type B patients. A similar research question was addressed as part of the present study. The results indicate, however, that both A and B types responded with equal predictability at a greater than 95% confidence level. (See Table XXXII).

Further evaluation of the type A versus the type B response revealed that following treatment, 87% of the pre-treatment type A Class II individuals came to resemble the type B Class II composite in conjunction with treatment, not only by assessment of the A/B aggregate change but also in regional craniofacial anatomic adaptations. Pre-treatment type B individuals remained so, with only one patient reversing to exhibit type A features following treatment. No significant trends were observed in the control group for B-to-A or A-to-B conversions.

Dental Changes

Dental changes achieved with the European design Herbst appliance are well documented. Pancherz (1985, 1982A, 1982B, 1979) reported that six months of treatment resulted in Class I or overcorrected molar relationships; overjet averaging 3.0 mm and overbite 2.5 mm in his sample of 22 treated cases. He attributed the treatment result to equal skeletal and dental contributions.

The aim of the present study was not to verify final molar and incisor relationships but to evaluate the relative dental directions and magnitudes of change possible during the treatment time. All five dental variables were found to contribute significantly to the Herbst treatment result.

The design of the bonded acrylic Herbst utilized in this study maintains a fairly static distance between the lower first molar and lower incisors, as would be expected as all teeth are within an occlusal coverage splint. In the upper arch, however, the anterior six teeth are not incorporated in the splint design. This does allow independent movement of the anterior and posterior dental segments.

The capacity for distalization of the upper posterior segments has been reported (Pancherz, 1985; Weislander, 1984) and was evident in this study as seen in the counterpart measurements which incorporate the maxillary first molar. The distance between Ar and upper molar is decreasing with an accompanying increase between A point or SPr and the upper first molar. As discussed earlier, the maxillary skeletal arch length had not increased and may have been actually inhibited from full lengthening. Significantly, the treatment changes are mostly as a result of intra-arch dental unit distalization. Since extractions were not performed, the molar distalization may well be violating the space available for the succeeding molars. Clinical consideration might be appropriate in evaluating the pretreatment tooth/arch discrepancy in order to avoid potential root injury or impaction of second or third molars. In addition, since the maxillary arch length is

not remodeling at a pace commensurate with distal tooth movement, the resultant infringement of the posterior maxillary boundary may be building in relapse potential following treatment if the anatomic counterparts, such as the pharyngeal space, attempt to reassert themselves.

Closer inspection of changes within the mandibular arch as compared to the same within the maxillary arch reveals that a significant increase in the measurement from Ar to the lower first molar occurred. This reflects a combination of actual horizontal mandibular skeletal arch lengthening and any mesial migration of the lower molar as a result of anchorage loss and lower incisor flaring, as compared to the relative shortening of this dimension in the maxillary arch.

The measurement from the ramus/corpus junction to the lower first molar indicated that some of the increase in arch length occurred in this region. The first molar to B point was found to be constant, within the confines of appliance design. This also indicated that actual anchorage loss was minimal. A small increase in length from lower molar to IPr demonstrates that an equivalent amount of lower incisor flaring did occur. This, accompanied by the horizontal lengthening of the mandible, probably contributed to the significant flattening of the curve of Spee.

The occlusal plane rotation will be discussed as both a skeletal and dental change, because vertical adjustments of tooth position may have influenced this rotation as well as skeletal factors. Pancherz (1985) observed that his appliance design resulted in intrusion of mandibular incisor and maxillary molars accompanied by eruption of premolars and mandibular molars. The European design allows eruption of individual teeth to occur more freely since occlusal coverage is not present. Within a splint design, any vertical positional dental changes would seem to involve more of an "en masse" rotation around a fulcrum. A clockwise occlusal plane rotation was observed in this study. Since clinical results include reduction of anterior overbite at end of treatment (Weislander, 1984), differential amounts of inferior/superior vertical tooth movement would be anticipated. One example to account for this bite opening effect would be a relatively greater intrusion of the mandibular incisors than the extent of drift inferiorly of the exterior maxillary teeth, or that the mandibular molars drift superiorly to a greater extent than the maxillary molars become intruded. Perhaps these events are happening simultaneously.

In summary, both dental and skeletal effects contributed to the treatment outcome. The dental changes were primarily responsible for the observed treatment

results and were accompanied by significant skeletal responses.

Rebound Tendencies

It is reasonable to assume that some anatomic structures and relationships are more resistant than others to permanency of changes imposed upon their existing growth patterns. Rebound or relapse could be considered a function of this resistance to change or an intrinsic morphogenic attempt to return to a balanced state.

Post-treatment radiographs were available for 25 of the 62 treated cases. These radiographs represent the end of orthodontic treatment including fixed appliances, when appropriate. Orthopedic forces were not used as part of the post-Herbst orthodontic finishing. Of the sixteen variables examined, six were found to rebound to a significant extent. These variables were: A/B aggregate, ramus alignment, ramus/MCF horizontal dental dimensions, the corpus/occlusal alignment, gonial angle, and inferior maxillary plane. These variables represent treatment effects which created directional changes opposite to the pattern normally seen in an untreated Class II. One of the six variables is a dental measurement and reflects a rebound of one third of the treatment change in about two thirds of the treatment sample. This rebound may be the result of the mesial

return of the maxillary molar distalization previously discussed. Without extraction of posterior teeth, this rebound may not be surprising as the natural eruption process of the succeeding molars unfolds.

Skeletal patterns are established fairly early in growth and development and perhaps attempting to arrest or redirect skeletal growth at the adolescent age is already too late. Complete rebound of the treatment response was evident for ramus alignment, corpus/occlusal alignment and inferior maxillary plane alignment. Thus, the rotational changes appear more resistant to alteration in growth pattern than the horizontal changes. These three variables are also important from the standpoint that the treatment imposed changes which reversed the existing growth plan. For example, during the untreated facial growth process the ramus normally becomes more backwardly aligned (upright) to accommodate a vertically increasing nasomaxillary complex. The Herbst appliance served to only temporarily reverse this tendency, so that the mandibular protrusive clinical result was only transient.

In the control group of this study, the inferior maxillary plane was observed to rotate in a counterclockwise direction. The Herbst treatment response reversed this rotation. Following treatment, the counterclockwise rotation again asserted itself

resulting in rebound which exceeded the pretreatment baseline value.

Finally, the gonial angle, which is normally observed to close with time, remained constant with only a slight tendency to close during Herbst treatment. The post-treatment growth changes accompanied by fixed orthodontic appliance treatment, however, resulted in a significant increase in the gonial angle measurement. Likewise, the control group also exhibited a significant gonial angle increase, demonstrating the continuation of that tendency observed during the first time interval.

Dental changes appeared to be more stable than skeletal changes following treatment. Perhaps this is a reflection of the relative ease of creating adequate retention appliances for the teeth. Retaining a skeletal alteration is difficult due, in part, to the relative inaccessibility of the parts requiring stabilization. Pancherz (1985) and Weislander (1984) among others recommend retention of the skeletal treatment change with activator wear. This may be sufficient to prevent horizontal changes from relapse, but may not be sufficient for maintaining rotational treatment effects. Also, with a removable activator, patient compliance then becomes critical in maintaining the treatment result, and an activator is probably less convenient to wear than a simple retainer. The additional disadvantage of

activator retention is that the clinician may need to postpone the fixed appliance treatment, usually indicated following Herbst treatment, due to the difficulty involved in using fixed and removable appliances simultaneously. The rebound observed could also be explained by the fact that most of these individuals underwent fixed appliance therapy during the post-treatment time interval. The orthodontist might have unknowingly applied orthodontic mechanics which served to reverse the treatment effects achieved. An adverse sequela was observed in the opening of the gonial angle which, when accompanied by the rebound of the ramus in a backward direction, exaggerates the loss of the treatment effect.

Enlow (1982) suggested that, "if one could locate positions of functional, morphologic balance and then place all components into such relationships, then relapse would presumably be precluded or minimized." When rebound is not observed, as in the remaining ten variables examined, then several possibilities exist. Sufficient observation time may not have elapsed, since rebound probably occurs at different rates and times in different regions. Our measurement devices or techniques may not be sensitive enough to detect such changes, or relapse may be occurring in the third dimension which lateral cephalometric radiographs cannot assess. Of

course the possibility exists that an actual growth redirection was achieved and is being maintained, or that treatment accentuated a growth process already underway.

In order to preserve the treatment changes which contribute to mandibular protrusion, they must first be identified. The aggregate changes at A and B points summarize the cumulative treatment effects and the subsequent stability or rebound. Seventy-five percent of the 25 cases evaluated for stability demonstrated cumulative relapse of about one-third of the treatment change. This may imply that exceeding treatment goals through overcorrection might be considered. An expanded study utilizing a larger sample would be appropriate at this time. In addition, evaluation of stability as it relates to Class II type would be of interest. Although both A and B types responded to Herbst treatment, if B types are already partially compensated prior to treatment, then further attempts to achieve mandibular protrusive changes may result in recognition of limitations later expressed as greater rebound. If treatment effects can change a B type to a "super B" type and rebound does not occur, further growth may well result in an undesirable prognathic profile. It is apparent that answers to these hypothetical situations would have a profound effect on orthodontic diagnosis and treatment planning.

SUMMARY AND CONCLUSIONS

The Class II craniofacial pattern represents a broad spectrum of numerous dental and skeletal combinations which continue to challenge the clinician's expertise and command of basic biological knowledge. The focus of this study was to evaluate the treatment effects of a nonremovable functional appliance, the acrylic bonded Herbst, on a sample of 62 growing Class II individuals.

The objectives were to determine which anatomic parts were responsive to this treatment and which were unaffected. In addition, pre-treatment composite presentation was studied to assess variability in response among type A and type B individuals. Finally, an attempt was made to localize and describe areas sensitive to relapse during the post-Herbst interval.

The treatment sample and matched control group each consisted of 33 males and 29 females spanning an average age range of 12.5 to 14.9 years. Three radiographs for each individual were analyzed using the counterpart analysis of Enlow. This anatomic method is useful in determining morphologic and morphogenic relationships among regions within a given person without the need for conventional cephalometric planes and angles. Both frequency percentage distributions and mean changes were determined for 16 variables over two time intervals.

Levels of significance using the sign test and confidence intervals were calculated.

The results of the study may be summarized by the following conclusions:

1. The controls were representative of normal serial changes for the Class II pattern as reported in previous studies. Two areas did undergo notable change in this untreated sample: the palatal plane demonstrated a tendency for clockwise rotation, while the inferior maxillary plane rotated in a counterclockwise direction.
2. The cumulative effects of the aggregate of changes in the composite of the anatomic relationships evaluated indicated that directional changes favoring mandibular protrusion occurred in a high percentage of the treatment sample. Both skeletal and dental treatment effects contributed to this result. The dental changes were primarily responsible for the observed treatment result, and were accompanied, secondarily, by significant skeletal compensation. Of the 16 variables evaluated, 10 were found to be statistically significant at the $p<.01$ level for direction of change.
3. Skeletal changes contributing to a mandibular protrusive effect include a slight backward and

upwardly inclined middle cranial fossa accompanied by a more anteriorly aligned ramus. The inferior maxillary plane rotated in a clockwise manner which resulted in a relatively shorter posterior maxillary vertical dimension. The gonial angle remained constant but a significant downward rotation of the corpus/occlusal alignment as compared to the ramus was observed. The mandibular skeletal arch lengthened significantly with respect to the maxillary arch and appeared to be remodeling to the greatest extent in the region of the corpus. This effect may have been increased by the restriction of maxillary skeletal growth.

4. Dental changes observed included a distalization of maxillary molars. Mesial movement of the mandibular molars was a reflection of mandibular lengthening since minimal anchorage loss was observed, yet significant correction of molar position resulted. The curve of Spee tended to flatten, partially as a result of some extent of lower incisor flaring. The occlusal plane rotation probably resulted from a change in vertical position of the teeth, such as movement of the maxillary and mandibular molars in a superior direction while the mandibular incisors were intruded relative to the maxillary incisors. The resultant effect was to open the bite in the

vertical dimension and to produce a mandibular protrusion in the horizontal dimension.

5. Class II type A and type B responded to treatment with equal predictability at a greater than 95% confidence level. In addition, 87% of the pretreatment type A individuals resembled type B following treatment. Pretreatment B types tended to remain so. No significant trends were observed for A-B conversion in the control group.

6. Dental treatment effects exhibited less rebound tendency than did the skeletal changes. The maxillary molars, however, did relapse significantly from distalized positions. The skeletal changes demonstrating the most rebound were those which were rotational in nature, especially if the direction of rotation reversed the pattern as would be expected in untreated control comparisons. The relapse observed could reflect either an unsuccessful attempt to influence the normal growth pattern, or that the post-Herbst orthodontic mechanics used in the fixed appliance phase may have altered the treatment effects in an adverse way.

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APPENDIX I

DEFINITIONS OF ANATOMIC LANDMARKS

Points	Definition
A	A Point: the deepest point on the labial premaxillary surface between the anterior nasal spine and superior prosthion.
ANS	Anterior nasal spine: the tip of the spinous process of the maxilla forming the most anterior projection of the bony floor of the nasal cavity.
Ar	Bjork's Articulare: the point of intersection of the external (inferior) surface of the basicranium and the posterior margin of the condylar neck.
ARa	Anterior border of ramus: the point of intersection of the anterior margin of the ramus with the functional occlusal plane.
B	B point: the deepest point on the anterior surface of the symphyseal outline of the mandible between infradentale (inferior prosthion) and pogonion.
Go	Constructed gonion: the intersection of lines tangent to the posterior border of the ramus and inferior border of the mandible.
IPr	Inferior prosthion: the point of contact of the alveolar process between the mandibular central incisors.
Me	Menton: the most inferior point on the symphysis of the mandible.
O	Occipital point: the inferior-most point on the endocranial surface of the occipital fossa.
Or	Orbitale: the lowest point on the inferior margin of the orbit.
PNS	Posterior nasal spine: the tip of the spinous process formed by the most posterior projection of the junction of the palatine bones in the midline of the roof of the oral cavity.

DEFINITIONS OF ANATOMIC LANDMARKS, continued

Points	Definition
PRa	Posterior border of ramus: the point of intersection of the posterior edge of the ramus with the functional occlusal plane.
SE	Sphenoethmoidal junction: intersection of the averaged image of the right and left shadows of the great wings of the spenoid with the floor of the anterior cranial fossa.
SPr	Superior prosthion: the point of contact of the alveolar process between the maxillary central incisors.

APPENDIX II

DEFINITIONS OF CEPHALOMETRIC PLANES

Line	Definition
Ar to Go	A line from Ar to constructed Go used to determine the alignment of the ramus.
ARa	Anterior ramus plane, a line from the intersection of FOP and the anterior border of the ramus drawn parallel to PRa up to REF.
FOP	Functional occlusal plane, a line from the most posterior occlusal contact point of the last fully erupted maxillary and mandibular molars to the most anterior maxillary-mandibular first premolar occlusal 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 plane, represented by a line from SE to Ar.
NOA	Neutral occlusal axis, a line perpendicular to PM through the most posterior occlusal contact point of the last fully erupted maxillary and mandibular molars.
NRa	Neutral ramus alignment, a line from Ar to a point midway between Ar and neutral PM line at the level of gonion.
PM	PM vertical, a line from SE through the averaged inferior-most point of the pterygomaxillary fissures.
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).

DEFINITIONS OF CEPHALOMETRIC PLANES, II, continued

Line	Definition
PRa	Posterior ramus plane, from Ar to the posterior margin of the ramus where it intersects FOP.
REF	Reference line, a line parallel to FOP from Ar anteriorly.