A LONGITUDINAL STUDY ON THE EFFECTS OF SERIAL EXTRACTION USING THE COUNTERPART ANALYSIS

Abstract

by

DERYA U. YUKSEL

The focus of the present study was to describe the treatment effects of serial extraction procedures on a sample of 35 growing Angle Class I individuals. The counterpart analysis of Enlow and some additional cephalometric measurements were selected for radiographic evaluation in order to provide an anatomic and morphogenic description of responsive or unresponsive parts. There were 4 anatomical features that seemed to identify with the treatment sample before any treatment had begun. The results indicated that one of the 18 variables indicated significant change in direction, while 15 of the 27 variables indicated significant magnitude of change. The significant results were skeletal as well as dental changes which occurred mostly during the second time interval T_3-T_2 after the extraction of four first bicuspids. The skeletal changes were mainly in the horizontal dimension. The two variables in the counterpart analysis that indicated any vertical change were the curve of Spee and the inferior boundary of the nasomaxillary complex. The

dental changes indicated mesial drift of the dental arches which was found to be greater in the lower arch and also greater than in the control group. The skeletal changes were supported by similar dental changes in the horizontal dimension which indicated a relative increase in the mandibular bony and dental arches. The maxillary and mandibular incisors becoming more recumbent, with an increased curve of Spee, explained the increase of overbite observed in the treated group at the end of serial extraction procedures.

In addition to the counterpart analysis, another 9 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 Figure 21.

The three radiographs for each individual were labeled as follows:

T_1 = Pre-treatment film	C_1 = First control film
T_2 = During treatment film	C_2 = Second control film
T_3 = End of treatment film	C_3 = Third control film

For the 18 variables, net directional changes were determined for each variable between T_1 and T_2; and T_2 and T_3. Similar assessments for the control variables were performed.

Statistical Methods

Data analysis was performed by two methods.

Pearson's chi-square test was utilized to generate frequency distributions for each variable in each of two time intervals and to compare the two groups for any directional change.

In addition, analysis of variance and covariance with repeated measures was calculated for 27 variables for the two time intervals to compare the control and treated groups. Mean changes, standard deviations were computed to evaluate the statistical significance of the magnitude of change for each variable. For the variables with statistically significant interaction of time with group, t-tests were done in order to compare treated and control groups at $time_1$, $time_2$ and $time_3$.

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7673 7-73

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Submitted in partial fulfillment of the requirements
for the Degree of Master of Science in Dentistry

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May, 1987

DEDICATED TO

My parents, Mediha and Orhan Yuksel who have given me their unlimited love, support and wisdom throughout my entire career, who have guided my life and have helped me achieve my dreams and aspirations.

My sisters, Deniz and Demet whose special friendship and love have always been a source of inspiration.

ACKNOWLEDGEMENTS

A study of this kind can only be completed with the unselfish efforts of many. The author wishes to express her sincere gratitude to those who made possible the culmination of this project.

To Dr. Donald H. Enlow, Chairman, Department of Orthodontics for his excellent and unique course in Cranio-Facial Growth and Development, and his invaluable guidance in the preparation of this study.

To Dr. B. Douglas Amberman for his helpful advice, time and sincere interest.

To Dr. B Holly Broadbent Jr. for his helpful suggestions and for graciously offering the use of the materials and facilities of the Bolton Study.

To Dr. Gary Wolf for his genuine interest, sincerity and willingness to help.

To Dr. Howard Kossoff and Dr. Charles Schwarz for generously contributing radiographs.

To Dr. Donna McClish for her statistical expertise and her assistance.

To M. Jean Kee, my typist for her skill in the preparation of this manuscript and for helping me to meet the deadlines.

To all of my instructors, for their interest, time, encouragement and expertise during these two years.

To my classmates Michael Kim, Craig Kishiyama, Joe Petrone, Shiang-Su Shiao and Ioannis Triantafyllou whose friendship made

those two years fun and unforgettable. I wish you success in your future endeavors.

To my best friends Ann Cipriani and Sedef Dincman whose friendship I will always remember. Thanks for being there when I most needed you. I will miss you both a lot.

To my family, whose continued love and encouragement helped me to achieve my goals.

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INTRODUCTION

Serial extraction has been defined in the literature as the extraction of deciduous and permanent dental units for the purpose of harmonizing the amount of tooth material with the space available in the dental arches.

Instead of serial extraction, the terms of "guidance of eruption" and "guidance of occlusion" were preferred respectively by Hotz (1947) and Dale (1976).

The interception and prevention of malocclusions have been among the goals of the dental profession since the Eighteenth Century. Serial extraction is consistent with this goal as a method for intercepting certain malocclusions at an early age and preventing them from becoming more severe. The rationale for serial extraction in modern orthodontics was first defined by Kjellgren in 1929, and since then the value of the procedure has become widely recognized and studied.

Serial extraction was initially proposed as a method for reducing the severity of a malocclusion with little or no mechanical intervention. With time, it was found that the results were rarely ideal, and serial extraction was subsequently used in conjunction with fixed orthodontic appliances. Serial extraction procedures, although simple in theory, require thoughtful case selection and close supervision.

The purpose of this study is to evaluate the craniofacial growth responses of Angle Class I individuals subsequent to serial extraction therapy. The counterpart analysis of Enlow (1971) was utilized to provide an anatomic and morphogenic approach to treatment assessment.

LITERATURE REVIEW

The first reference to the removal of deciduous teeth to allow more favorable alignment of permanent teeth was made by a Frenchman, Robert Bunon in 1743. He suggested the removal of deciduous teeth to provide a comfortable place for the permanent teeth. Bunon wrote that it would be better to:

> "...sacrifice the deciduous canine teeth to the incisors and the small molars (premolars) for the permanent canines ...than to have the entire set of teeth poorly arranged ill at ease...".

Bourdet in 1757 mentioned that when there is not enough space for the permanent cuspids and they start to erupt forward, a premolar should be removed in order to allow the cuspid to drift distally into its proper position. He also suggested the removal of the premolar on the opposite side in order to maintain the symmetry of the dental arch.

In 1814 Joseph Fox also advocated early extraction procedures. Two reasons, he stated for the crowding of permanent teeth were overretention of the deciduous teeth and a tooth size-to-arch length discrepancy.

In 1855 Harris mentioned that the longer the irregularity exists the more difficult will be its correction. If this irregularity is due to arch length deficiency, then permanent teeth should be removed to achieve a proper alignment.

Later, Angle's (1907) expansionist philosophy had a retarding effect on the use of extraction procedures. He believed that bone would grow in response to functional demand and that the jaws could be stimulated by orthodontic manipulation to attain a size sufficient to contain a full complement of teeth. He advocated that normal occlusion and normal facial features could only be achieved when all the permanent teeth were present.

On the other hand, Case in 1907 recommended extraction to achieve good stability and esthetics. In 1921, he commented that:

> "one of the greatest errors in this teaching (that of Angle) is that whatever the irregularity or the facial deformity, the main and indispensable object in the practice of orthodontics is to place the dentures in normal occlusion".

Growth and development of the face began to receive more attention with the advent of the roentographic cephalometer by Broadbent in 1928. Brodie and Broadbent agreed that the morphogenic pattern of the face was predetermined and that once the pattern was established early in development, it did not seem to change later during growth.

In 1947, Kjellgren proposed the name "serial extraction" for a procedure consisting of "one or more extractions of deciduous teeth in the mixed dentitions, with the purpose of forming the most favorable possible situation for the extraction of the permanent dentition where the intended final reduction of dental units is carried out".

His observation was based on crowded dentitions with early resorption and loss of deciduous canines that allowed spontaneous alignment of incisors. He also found that extraction of the first deciduous molars and first premolars prior to the eruption of the canines allowed a favorable shifting of the canines.

The timing for extractions proposed by Kjellgren is as follows:

a) Extraction of the deciduous canines when the lateral incisors are half-erupted at about the age of nine years.

b) Extraction of the deciduous first molars about one year later.

c) Extraction of the first premolars when they are almost completely erupted and when the canines are about one-half erupted.

He also suggested different extractions for different malocclusions. In Cl.II malocclusions, he would extract only the maxillary first premolars; in bimaxillary protrusion cases, the four first premolars; and in Cl.III malocclusions, only the mandibular first premolars.

Also in 1947, Hotz from Switzerland described a similar procedure that he preferred calling "guidance of eruption". His goal was to avoid the need for active orthodontic treatment or to reduce it to a minimum. He presented some variations of Kjellgren's serial extraction procedure.

> "The probable sequence of eruption must be evaluated before the first premolars are extracted. In its simplest form, we have the sequence of canines before second premolars or second premolars before canines. If the second premolar erupts before the canine, the first premolar

> serves as space maintainer and should not be extracted before eruption of the second premolar. In some cases the space has to be maintained after extraction by means of a simple plate which can be used as a bite plate and for better alignment of the incisors if necessary. If the canine erupts before the second premolar, the first premolar must be extracted early, often before eruption. In the mandible, because of a more favorable size ratio between deciduous and permanent teeth, the extraction of premolars can often be avoided, and in some cases the extraction of an incisor is indicated."

Nance in 1947 found that there was no increase in arch length between the right and left first permanent molars, but usually a decrease of 3.4 millimeters in the mandible (1.7 millimeters per side) and 1.8 millimeters in the maxilla (0.9 millimeters per side). This space is lost during the transition from the deciduous to the permanent dentition due to the fact that the deciduous molars and canines are wider than the permanent premolars and canines. Nance felt that, this leeway space could not be used for repositioning of teeth since it is necessary for the transition from deciduous to permanent dentition.

Subsequent to these studies from abroad, orthodontists such as Terwilliger, Dewel and Lloyd in the United states began to advocate serial removal of teeth in patients with severe arch length discrepancies.

The clinical observations supporting serial extraction were as follows:

a) Some individuals have a discrepancy between tooth material and the arch length that doesn't improve with growth (Dewel).

b) There is no increase in arch length subsequent to eruption of the permanent first molars and iatrogenically produced arch length is not stable (Nance).

c) Early removal of teeth allows physiologic, unassisted movement of adjacent teeth into more favorable positions (Lloyd).

Indications for serial extraction were based largely on the presence of crowding in the early mixed dentition, and the evaluation of the results was assessed from clinical observation.

In 1950, Moorrees examined records of children taken from the deciduous through the permanent dentitions. He attempted to correlate measurements of mesiodistal crown diameters, arch length, available space and overbite in the deciduous dentition with corresponding measurements in the permanent dentition. The final occlusion was seen as a result of the interaction of various dental characteristics, all of which could either aggravate or compensate for a discrepancy of tooth size or arch length.

Later on, Dewel noted that evidence of arch length deficiency is confirmed by a characteristically thin labial plate of alveolar bone in the mandibular incisor region. He also noted that, cephalometrically, the typical Cl.I serial extraction case presents a facial pattern best described as flat or straight. The incisors would be upright and fall on the Na-Pog, facial plane. Serial extraction seems to be the logical answer for inadequate structural growth mesial to the first permanent molars after their eruption and the eruption of the incisors.

Treatment according to Dewel consisted of three stages, with intervals of 6 months to one year between extractions. The stages were:

a) Premature extraction of the deciduous canines to leave enough space for the permanent lateral incisors to erupt in even alignment over basal bone;

b) Subsequent extraction of the first deciduous molars which will allow the first premolars to erupt early;

c) the final extraction of the first premolars to make it possible for the permanent canines to erupt in a favorable direction.

The above sequence should be used when one can see from intraoral X-rays that the first premolars are erupting ahead of the permanent canines. When the permanent canines are erupting first, then the deciduous first molars are then removed initially.

In 1956, Lloyd divided the procedure into two adjustment periods:

a) period of incisor adjustment in which all four deciduous canines are removed after the eruption of maxillary lateral incisors.

b) period of canine adjustment which is dependent upon the sequence of eruption of canine and first premolars as determined by x-rays.

According to Lloyd, about one year after the removal of the deciduous canines, the first deciduous molars exfoliate if the premolars are erupting ahead of the canines. The first premolars are extracted after they erupt. Secondly, if permanent canines and first premolars are erupting at the same time, the first deciduous molars are removed to let the first premolars erupt prior to their extraction. And finally, if the first premolars are slower to erupt than permanent canines, the first deciduous molars are removed and the first premolars are enucleated. An alternate plan is to extract the first deciduous molars which would allow the permanent canines and the first premolars to erupt. The next step would be the removal of the first premolars. In this case, a soldered lingual arch appliance from one mandibular permanent first molar to another should be used.

In 1962, Grøn examined the prediction of tooth eruption. She found that there was a significant correlation between eruption and root development. She concluded that generally permanent teeth erupt when their root formation is about three-quarters complete.

Also in 1962, Fanning examined the effect of extraction of deciduous molars on the formation and eruption of their successors. She observed that the rate of formation of the premolar did not change after the extraction of its deciduous precursor. An immediate spurt occurred in the eruption of the premolar following extraction of the deciduous molar, regardless of its stage of development and the age of the child.

Fanning reports that the extraction of a deciduous molar at a later period when the premolar was well along root formation and actively erupting, accelerated the movement and the early eruption of the premolar. For optimum results in serial extraction procedures, a deciduous tooth should be removed at a time when the permanent successor will erupt without delay.

In 1963, Moorrees, Fanning and Grøn discussed indications and timing of serial extraction procedures based on dental development. They showed that the indications for serial extraction are more complicated than just a comparison of tooth sizes in deciduous and permanent dentitions. The wide variation in changes in arch size and in the leeway space showed incisor crowding to be an unreliable basis for predicting a favorable or an unfavorable outcome of dental development.

These authors also suggested that early extraction of the deciduous canines could lead to early eruption of the permanent canines which might then cause impaction of the first premolars. Therefore, they sometimes suggested the extraction of the first deciduous molars to encourage the early eruption of the first premolars.

Heath in 1961 published a clinical evaluation of serial extraction procedures and arrived at very similar conclusions.

Mayne (1969) stated that:

> "Constant reappraisal of molar relationship, mandibular growth, intercanine arch growth as well as individual tooth positions often alters the original treatment plan. The clinician must be aware of normal changes in the face form with maturation."

In 1963, Tweed emphasized the fact that growth trends must be classified prior to the beginning of appliance treatment. In his preorthodontic guidance program, he proposed to remove all four erupting first premolars, along with all four deciduous canines. This must be done at least 4 to 6 months prior to the eruption of the canines, which usually migrate distally and erupt into good positions. He also observed that this step is usually followed by a lingual tipping of the mandibular incisors. He felt this self-correction saved seven to nine months of treatment and led to a better position and inclination of the mandibular incisors.

Once Tweed's diagnosis shows a total arch length discrepancy and the patient is between 7 years 6 months and 6 years 6 months, serial extraction procedures are initiated as follows:

1) At approximately 8 years, all four deciduous first molars are extracted. The deciduous canines are retained to retard the eruption of the permanent canines.

2) Four to 10 months after the extraction of the first deciduous molars, the first premolars will erupt but are not extracted until the crowns come through the alveolar bone.

3) When the premolars crowns are erupted, extract all deciduous canines and first premolars. If the deciduous canines have been lost or extracted then the first premolars should be enucleated.

In 1967, Dewel stated that one of the undesirable side effects of serial extraction was the deepening of the bite. He felt that, the presence of teeth contributes to growth and the absence of teeth detracts from growth. Vertical as well as horizontal growth depend on normal proximal and occlusal function which will maintain arch length, normal overbite and overjet. He also pointed out that the lower incisor position constitutes one of the most critical areas in a cephalometric discrepancy analysis.

Penman in 1969 did a cephalometric study on serial extraction, and the significant findings were as follows:

1) The ANB angle was reduced.

2) The angle of convexity was reduced.

3) The maxillary and mandibular incisors tipped lingually.

4) The interincisal angle was increased.

5) The overbite was increased.

6) The maxillary and mandibular permanent canines erupted occluso-distally.

7) The maxillary and mandibular molars moved mesially.

8) The direction of growth in the maxilla and in the mandible was not affected.

In 1970, Sanin reported the following changes that occurred after the removal of the first premolars:

1) The unerupted canines began their distal migration into the extraction spaces.

2) The irregularities of the mandibular incisors began their self-correction as they tipped lingually.

3) The overbite increased.

4) The second premolars usually erupted with varying degrees of mesial inclination.

He also observed that, in patients treated with only serial extraction with good occlusal results, several occlusal characteristics were common, such as Cl.I molar relationship, overjet smaller than 3.5 mm, and overbite about 50% or less.

Wagers, in 1976, mentioned some of the advantages of corrective mixed dentition procedures as follows:

1) Developing psychological disturbances were allayed.

2) The teeth were protected from accidental harm.

3) Perverted muscular habits changed and seldom persisted.

4) Facial complex growth, would develop better in its proper correlation to adjacent structures after early treatment. His clinical judgement was that the face developed better and esthetically improved after early corrective orthodontic treatment.

5) In discrepancy cases, early treatment could provide a better eruptive path for the teeth.

6) Posttreatment stability was increased.

7) Early treatment allowed orthodontic appliances to be removed earlier in the permanent dentition.

8) Patients at earlier age were more easily manageable.

Dale (1976) calls his serial extraction procedure "guidance of occlusion". He also pointed out some of the ideal conditions for him where guidance of occlusion procedure could be indicated. Some of those conditions listed below are in accord with other authors' conclusions, such as:

1) There must be a true, severe, hereditary tooth-size jaw-size discrepancy.

2) Presence of a mesial step mixed dentition developing into a Cl.I permanent relationship.

3) Minimal overbite and overjet.

4) The facial pattern should be orthognathic or slightly dental-alveolar protrusive.

Serial extraction procedures are based on the fact that arch length does not increase mesial to permanent first molars and there is a leeway space of 1.3 mm in the maxilla and 3.1 mm in the mandible (Moyers).

Schwarz and McDaniel (1977) studied longitudinal records of fifteen children with Cl.I molar and sixteen with Cl.II molar occlusion treated with serial extraction. They concluded that:

1) The change in lower incisor position was not predictable.

2) Canines which may have been impacted or blocked out, erupted into space formerly occupied by first premolars.

The results of their study confirmed previous reports that serial extraction in itself, does not constitute a logical end point in treatment. Usually, a period of full appliance therapy must follow to correct axial inclinations, rotations, close extraction spaces and level the plane of occlusion.

Rabine (1978) stated that the movement of the canines and the anterior teeth mimicked those of stage I in Begg treatment which he called "Stage A". The objectives of Stage A were the following:

1) Uninhibited occlusal development.

2) unravelling of the anterior teeth, permitting the lower anterior teeth to assume a position of functional balance on the basal bone.

3) Finally, limited appliance therapy.

An understanding of the influence of serial extraction on growth and development of the face is of great importance. Wong (1957) and Jacobs (1959) suggested that serial extraction procedures may retard growth. But later on, Smollen (1965) and Whitney (1965) concluded that serial extraction in Cl.I malocclusions showed no evidence of growth retardation.

Ringenberg (1967,1978) summarized the results of some controlled longitudinal studies of serial extraction and also concluded that there was no evidence of growth retardation.

Garfinkle (1980) studied the effect of deciduous tooth extraction in the late mixed dentition on the eruption of succadaneous teeth in 10 Macaca Nemestrina. Regardless of sex, upper or lower arch, chronologic or dental age, all first premolars on the experimental side erupted before those on the control side.

Odenrick and Trocmé (1985) compared the facial morphology of children subjected to serial extraction with a normal control group. Significant differences were found between the facial, dentoalveolar and dental morphology of children with severe crowding and those without crowding. The lengths of the maxilla and the mandible were significantly shorter in the serial extraction group. The mandibular plane was also steeper. Maxillary arch width and depth were smaller as well as the mandibular intercanine distance. The upper and lower incisors were found to be significantly wider in the serial extraction group.

The planes and angles used in most of the cephalometric analyses were rarely constructed with actual sites of growth and remodeling in mind. They were more appropriate for describing the end result than attempting to explain how the changes occurred.

In the present study, Enlow's counterpart analysis was used (Enlow _et al_., 1971A). In the counterpart analysis various key anatomic parts within an individual are compared with respect to regional balance. The boundaries for the counterparts are determined by the perimeters of the various major fields of growth, remodeling and displacement (Bhat and Enlow, 1985). Dimension and alignment are given equal consideration in determining the architectural role of any given part. Equal increments of growth among counterparts will maintain a constant morphologic pattern. If growth and remodeling changes are not proportionate then relative protrusions and retrusions of the parts will occur. The effects will then be translated from region to region so that a given effect may be expressed in locations quite distant from the actual source. This analysis provides 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, this analysis also helps to explain how such a pattern came about.

The growth fields in this analysis are as follows:

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 perpendicular to the neutral orbital axis (neutral line of vision) and is consistent with the anatomically neutral position of the head. The PM plane also forms an anatomic boundary between the sets of counterparts (Table I).

As mentioned above, the planes and angles used in the counterpart analysis coincide specifically with key growth and remodeling sites (Enlow, 1982). Cephalometric analyses using actual anatomic and developmental relationships are increasingly more relevant.

TABLE I

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 purpose of this study is to evaluate the skeletal and dental changes in Angle Cl.I individuals following serial extraction procedures using the counterpart analysis and additional cephalometric measurements.

The objectives are:

1) to determine what are the combination of anatomic features that seem to identify with cases treated with serial extraction before the treatment had begun;
2) to determine which particular anatomic parts and relationships respond or do not respond to this treatment;
3) to determine whether the changes are skeletal, dental or both.

MATERIALS AND METHODS

Treatment Sample

Lateral cephalometric radiographs were obtained from the patient files of two private orthodontic practitioners. Patient selection was based on the following criteria:

1. Angle Cl.I molar relationship;
2. Serial lateral cephalometric radiographs available for each patient at the following stages;
   a) initial cephalogram taken during the mixed dentition, before the loss of deciduous first molars;
   b) immediately prior to the extraction of first premolars.
   c) After the extraction of first premolars.
3. All necessary landmarks readily identifiable;
4. No missing teeth;
5. No concurrent fixed appliance treatment;
6. All treated with serial extraction procedure.

The treated sample included 17 males and 18 females for a total of 35 Class I cases. The mean time interval between the first and second radiograph is twelve months, and two years between the second and third radiographs.

Control Sample

The control sample was selected from the longitudinal records of the Bolton Study (Case Western Reserve University, Cleveland, Ohio). Thirty-five Angle Class I cases, matched by sex and age were used. Specific criteria included:

1. Angle Class I molar relationship;
2. No extractions or congenitally missing teeth;
3. No prior or concurrent orthodontic treatment;
4. All necessary landmarks readily identifiable;
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 seven months of its corresponding treatment radiograph (see table II).

Technical Details

Tracing of all cephalograms were made on .003 matte acetate tracing paper using a Pentel P250 pencil with 0.5 mm drawing leads. Sufficient anatomic landmarks were traced to allow identification of 27 registration points (see Table III and Figure 1). Points 22 and 24 were not included in any of the measured variables. Their identification was found to be not as precise as on dry skulls. All tracings were done by the same investigator. Tracing error was assessed by retracing 30 headfilms which were subsequently compared to the initial tracings. The t-test demonstrated no statistically significant results for any of the variables.

The tracings were analyzed using a computerized cephalometric technique. The facilities for the use of this program are located in the Bolton Study and A.R. Jennings Computer Centers (Case Western

TABLE II

AGE RANGES AND MEANS FOR
TREATMENT AND CONTROL RADIOGRAPHS

Treatment Sample	Range in Years	Mean
T1	7.9 - 11.11	9.4
T2	8.9 - 12.10	10.4
T3	9.10 - 16.0	12.4
Control Sample		
C1	7.11 - 12.0	9.0
C2	8.11 - 13.0	10.2
C3	10.0 - 16.0	12.1

TABLE III

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 Prostion (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 First 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
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

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


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Reserve University). 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).

All radiographs were corrected for magnification and a final 6% magnification factor was used for all calculations. All treated and control radiographs 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 30 radiographs. Then, computer measurements were verified by statistical evaluation against those of the investigator for 30 cases. Once again, the t-test demonstrated no statistically significant results for any of the variables.

Measurements

For the counterpart analysis, eighteen variables were measured for each tracing at two time intervals and are listed in Table IV. The explanations of how each measurement was made accompanies Figures 2 through 20. The millimetric measurements were made to the nearest 0.01 mm and given a qualitative value of (+) or (-). The latter was done to indicate respectively, a maxillary or mandibular protrusive effect for any one variable. Measured differences less than 0.5 mm were noted as "no change".

TABLE IV

THE EIGHTEEN VARIABLES EVALUATED IN THIS STUDY

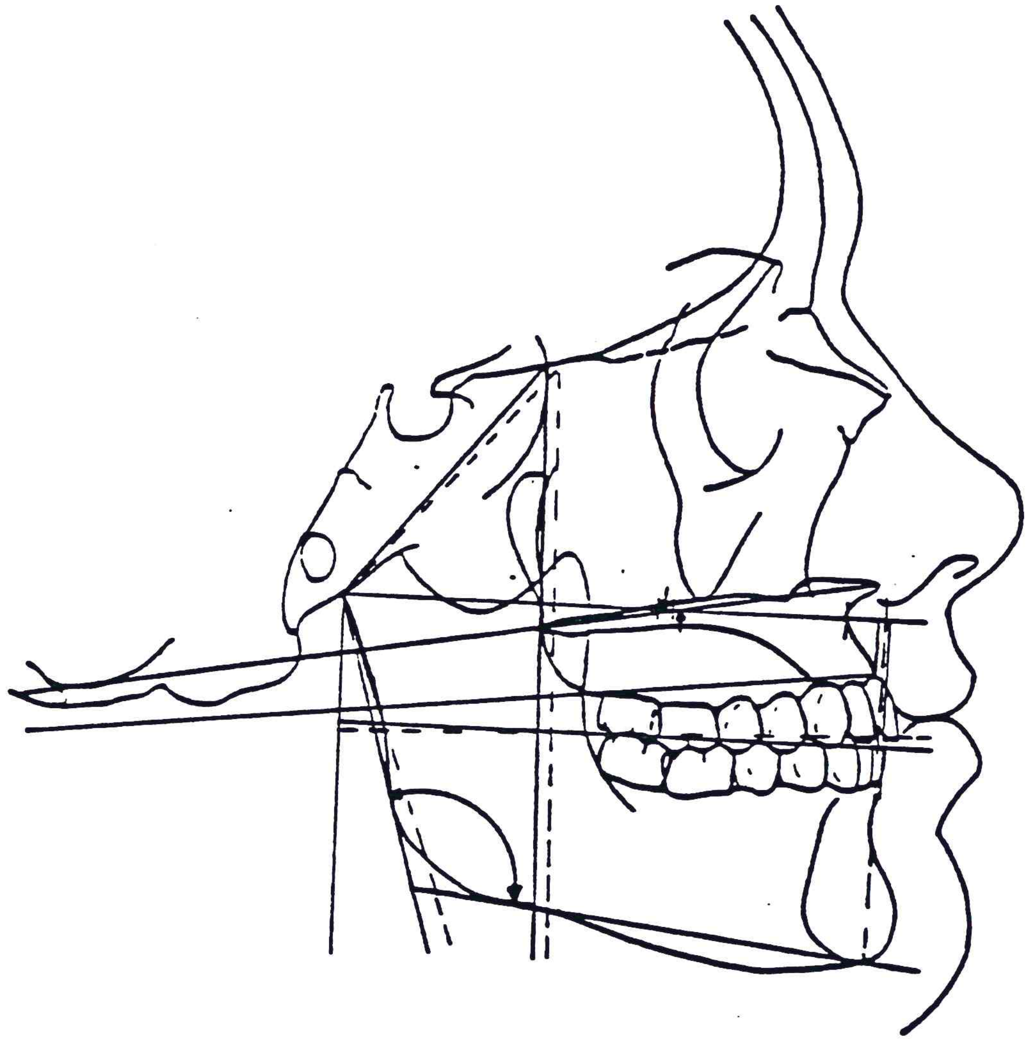
1. Aggregate cranial floor/maxilla and ramus/corpus horizontal dimensions at A and B points.
2. Aggregate cranial floor/maxilla and ramus/corpus horizontal dimensions at SPr and IPr.
3. Middle cranial fossa (MCF) and posterior maxillary (PM) relative alignment.
4. Ramus alignment.
5. Ramus/MCF horizontal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

TABLE V

ADDITIONAL NINE VARIABLES MEASURED IN THIS STUDY

1. U1 - A Pog = Upper central incisor to A Pogonion line measured in mm.
2. L1 - A Pog = Lower central incisor to A Pogonion line measured in mm.
3. Y axis to SN = Angle between Nasion - Sella - Gnathion.
4. OP to SN = Occlusal plane to Sella - Nasion.
5. U1 - L1 = Interincisal angle.
6. OB = Overbite measured in millimeters between the upper and lower incisal edges perpendicular to the functional occlusal plane.
7. ANB = Angle between A point - Nasion - B point.
8. U1 - SN = Angle between the long axis of the upper central incisor and Sella - Nasion line.
9. L1 - MP: Angle between the long axis of the lower central incisor and the lower border of the mandible.

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).



<u>Figure 3.</u> <u>Aggregate cranial floor/maxilla and ramus/corpus horizontal dimensions at A and B points.</u> 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.

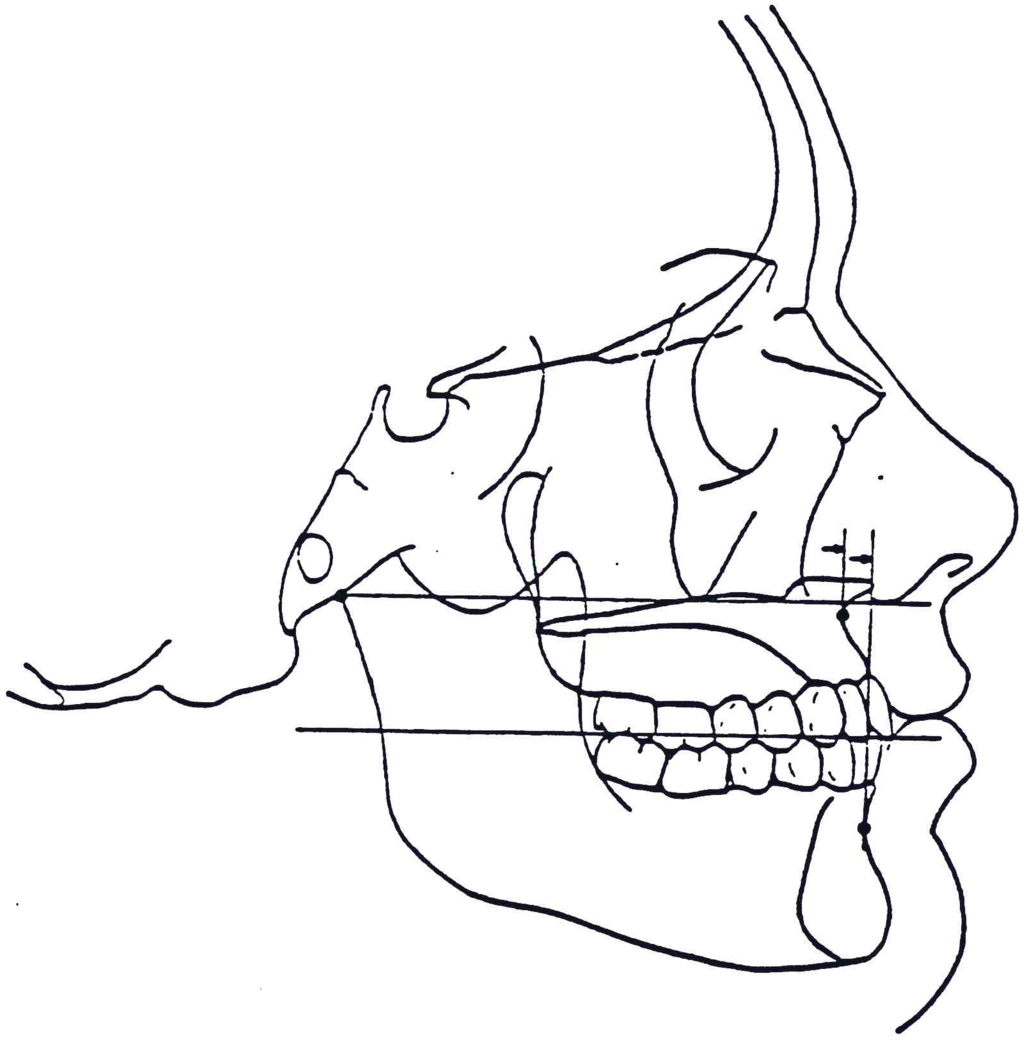


Figure 4. Aggregate cranial floor/maxilla and ramus/corpus horizontal dimensions at SPr and IPr. This diagram demonstrates the comparison of lengths from Ar to SPr and Ar to IPr. The measurements are made in millimeters along REF. The lines from SPr to REF and IPr to REF are drawn perpendicular to REF.

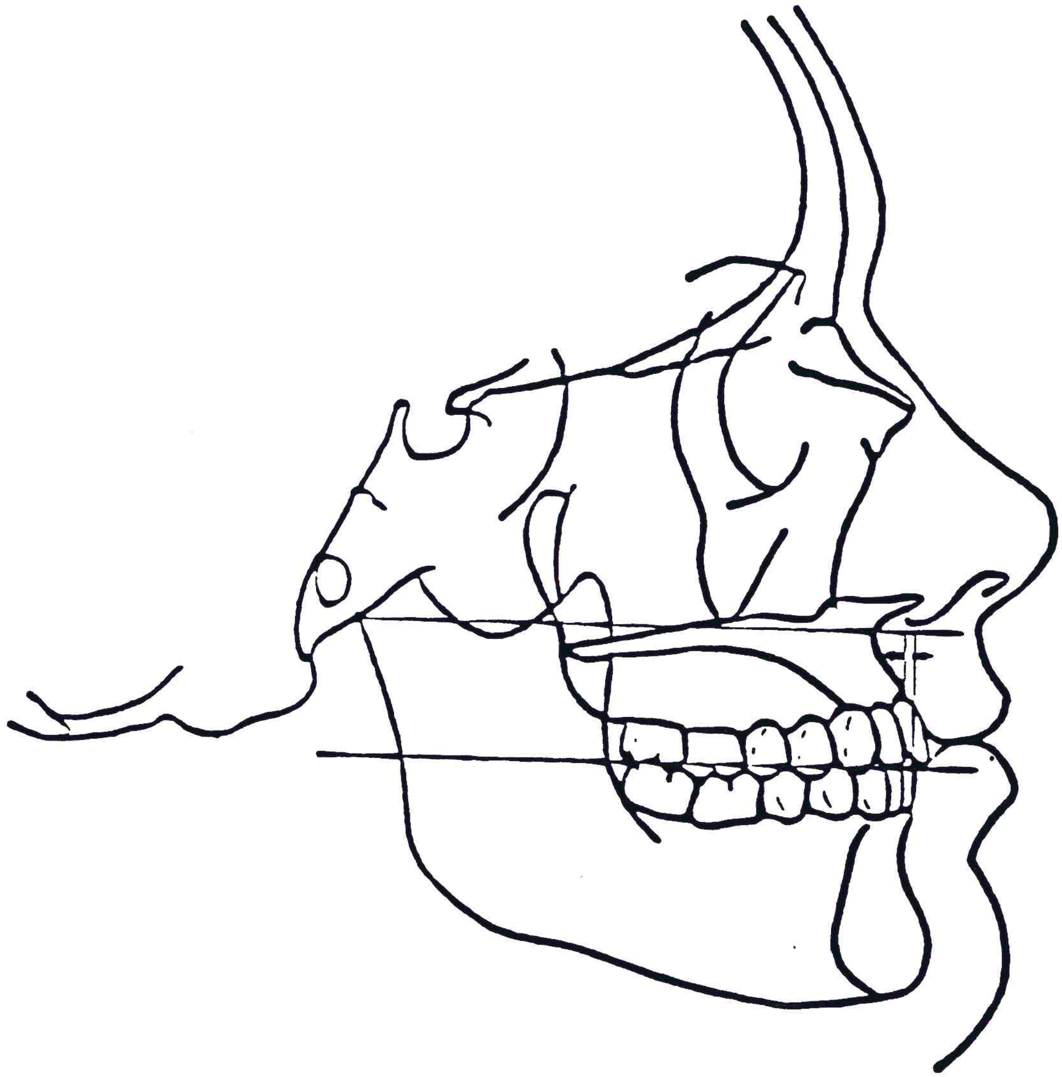


Figure 5. Middle cranial fossa (MCF) and posterior maxillary (PM) relative alignment. This diagram compares the neutral MCF/PM alignment (dashed line), which has an internal angle of 40.3° to the patient's MCF/PM alignment. The neutral MCF/PM alignment is drawn using a preconstructed template which has 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.

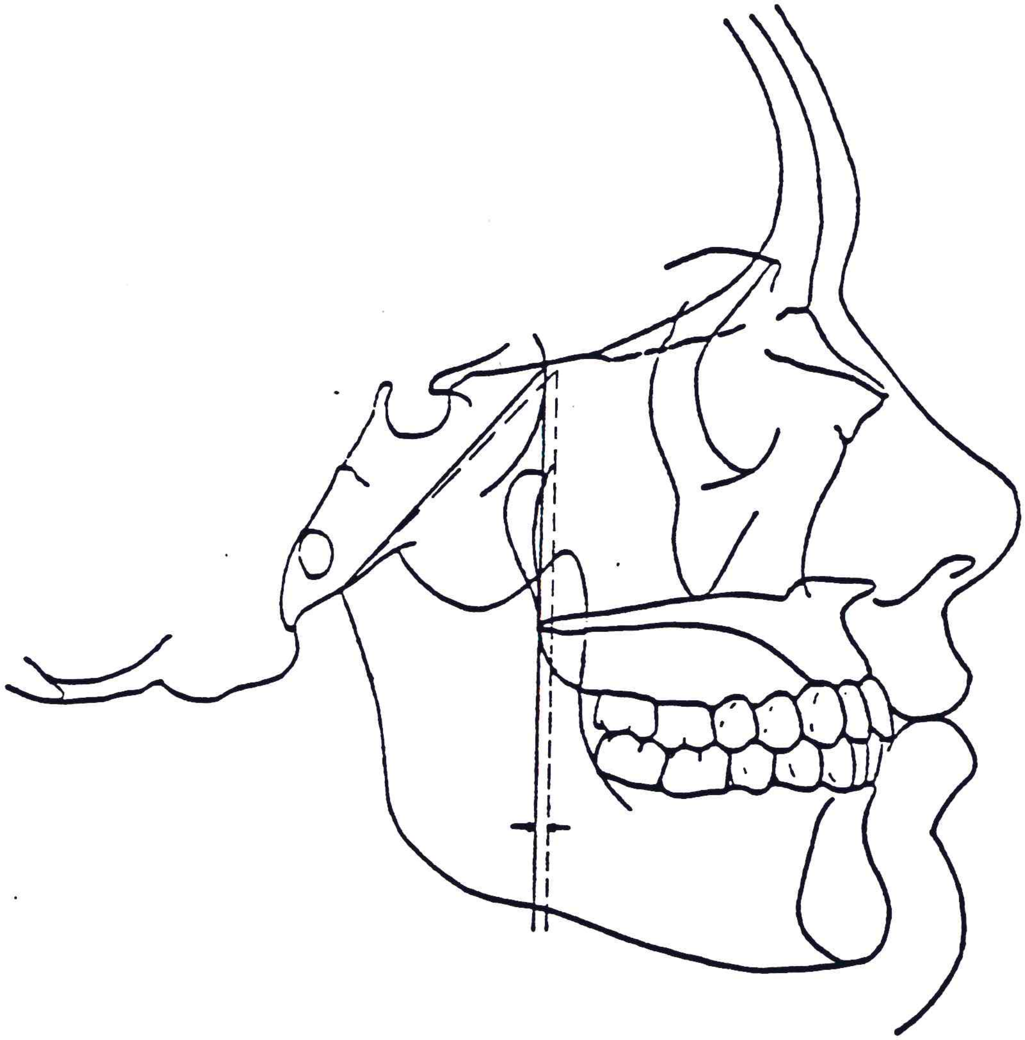


Figure 6. Ramus alignment. This diagram demonstrates the alignment of the subject's ramus plane and its relationship to the neutral ramus plane. A line from Ar to Go represents the individual's ramus plane. The neutral ramus plane is represented by a line from Ar to the midpoint between Ar and the neutral PM vertical at the level of Go. The comparison of their alignment effects on retrusive/protrusive placement of the mandible is made along FOP. This 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.

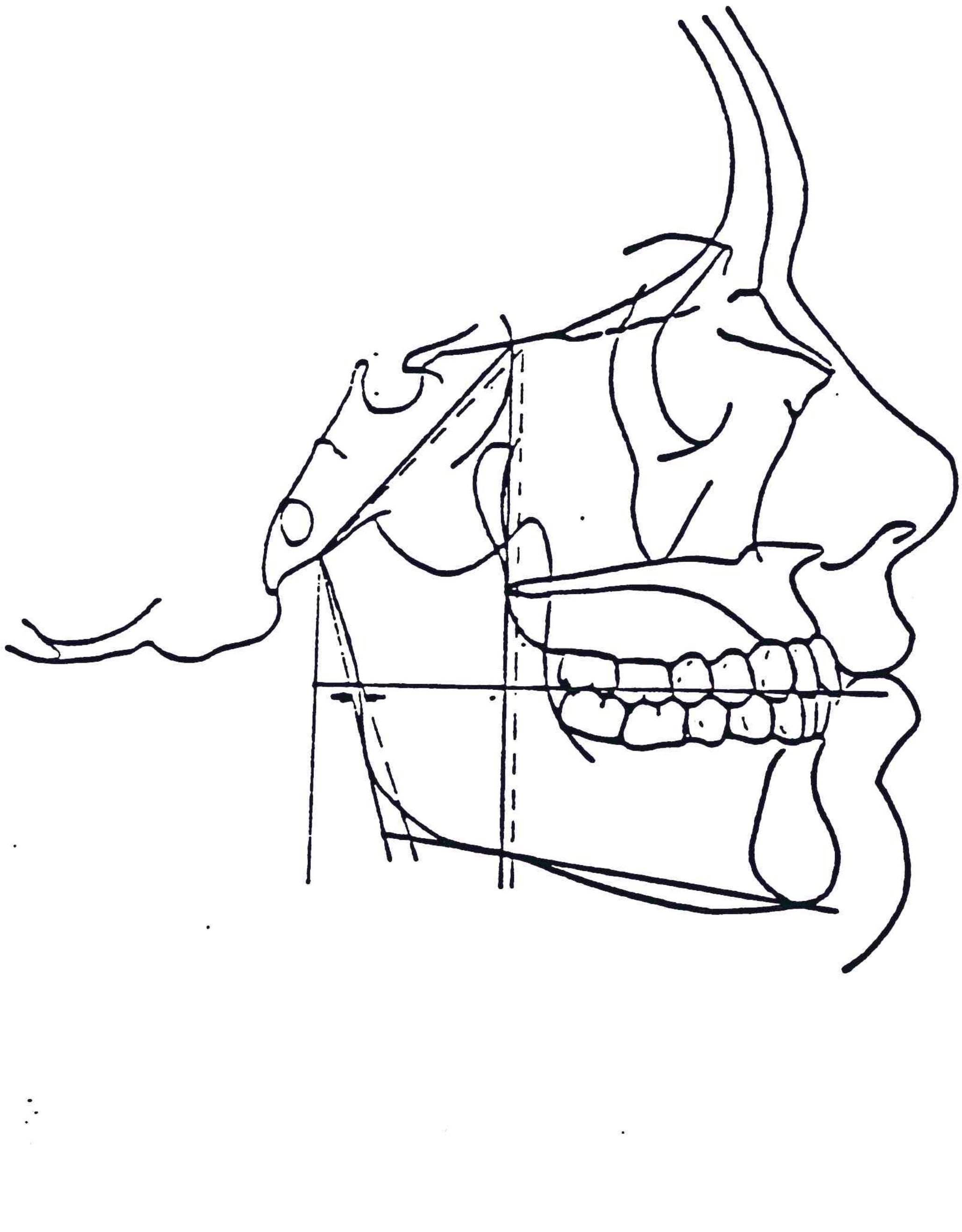


Figure 7. Ramus/MCF horizontal dimensions (skeletal). This diagram demonstrates the comparison of the horizontal dimensions of the middle cranial fossa (Ar to PM neutral) with the width of the ramus (Ar to ARa), and resultant effect on retrusive/protrusive placement of the maxilla and mandible. This measurement is made along REF in millimeters. The line PRa is drawn from Ar to FOP where it intersects the posterior border of the ramus. A line parallel to PRa is drawn from the anterior border of the ramus where it intersects FOP up to REF. The line indicates ARa. The distance from Ar to ARa and Ar to PM neutral are now measured along REF.

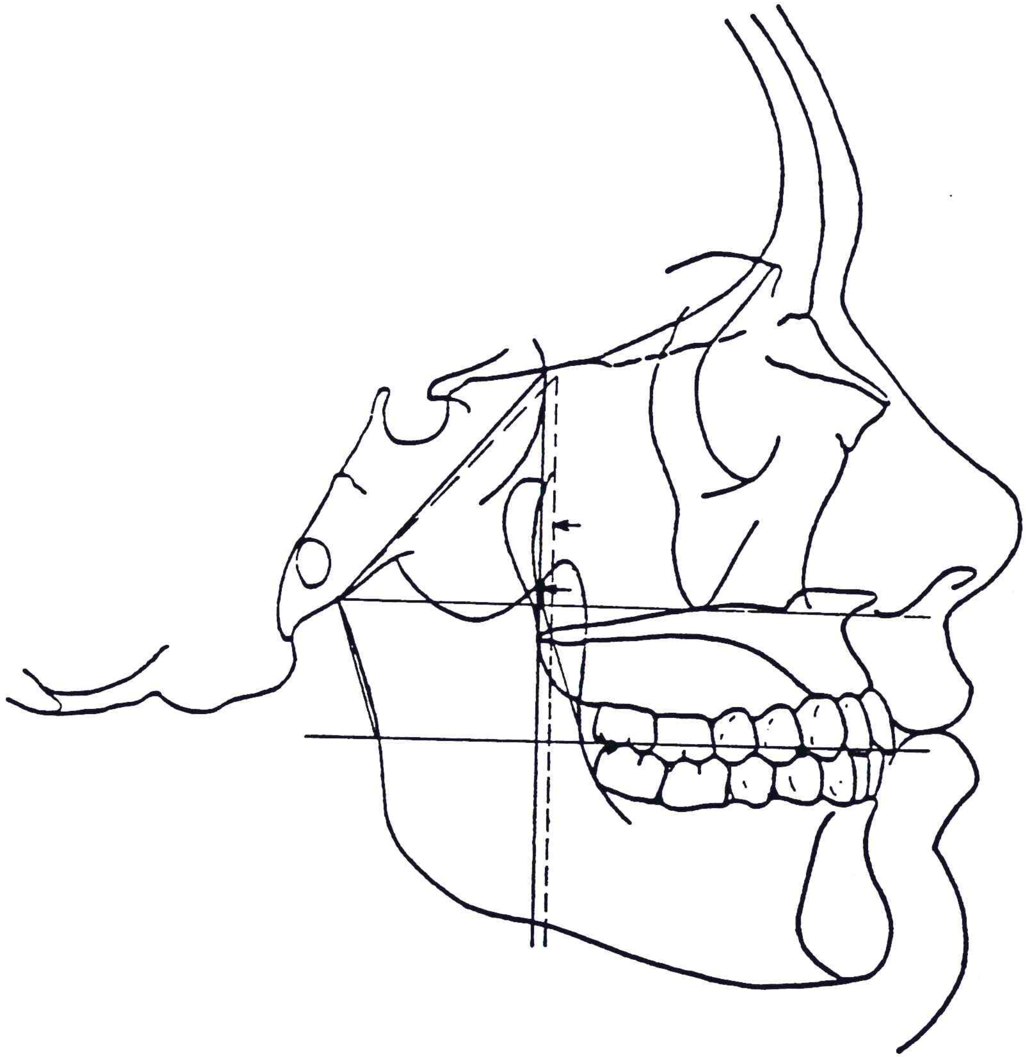


Figure 8. Ramus/MCF horizontal dimension (dental). The neutral positions of the molars are demonstrated with this measurement. The distal surfaces of the maxillary and mandibular first molars are indicated on REF by short vertical lines. The maxillary molar is corrected to its neutral position by adding or subtracting the distance between PM and neutral PM. When the MCF/PM rotation is forward (PM is in front of neutral PM) the correction is made by subtracting the PM-PM neutral difference from the Ar to maxillary molar length along 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.

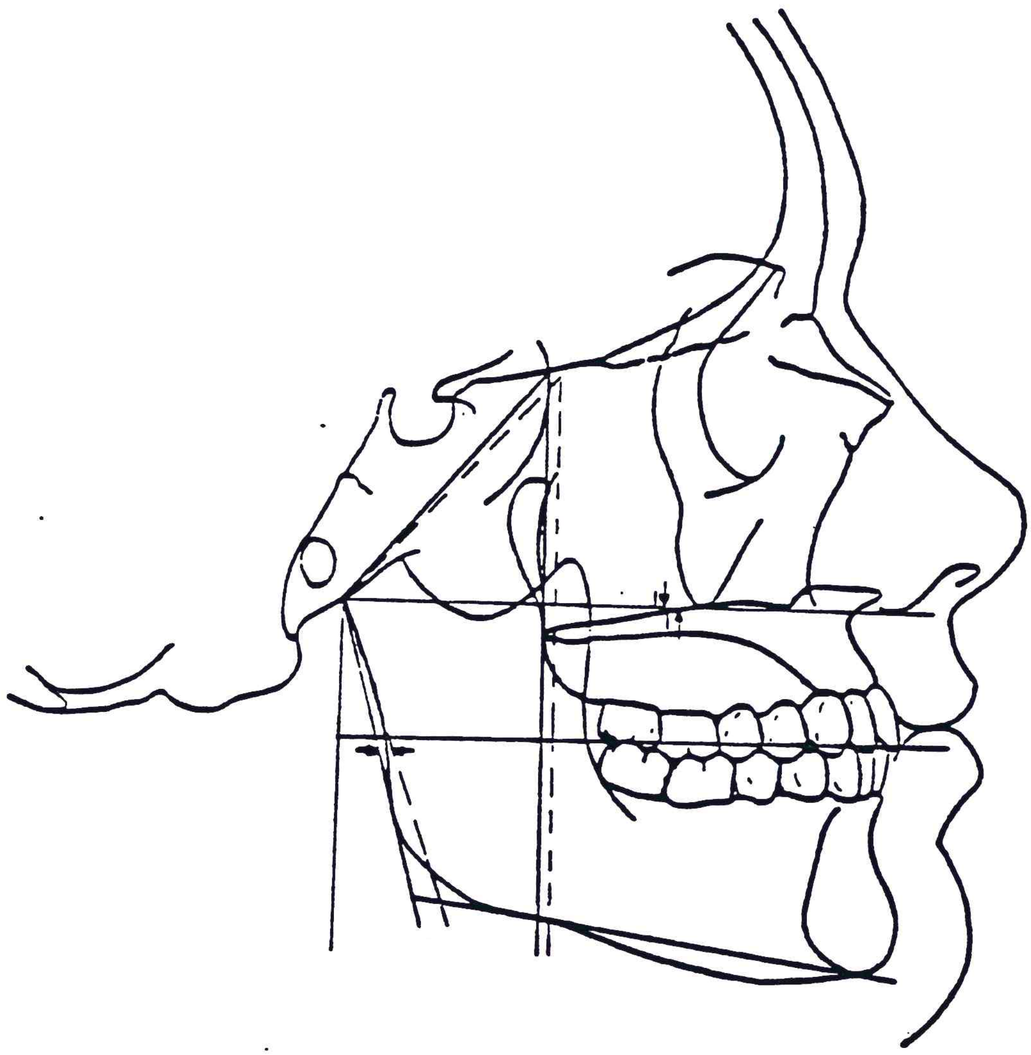


Figure 9. Molar positions (composite). Short vertical lines along REF indicate the distal surfaces of the maxillary and mandibular first molars. The measurement is made in millimeters along REF from Ar to the short vertical lines.

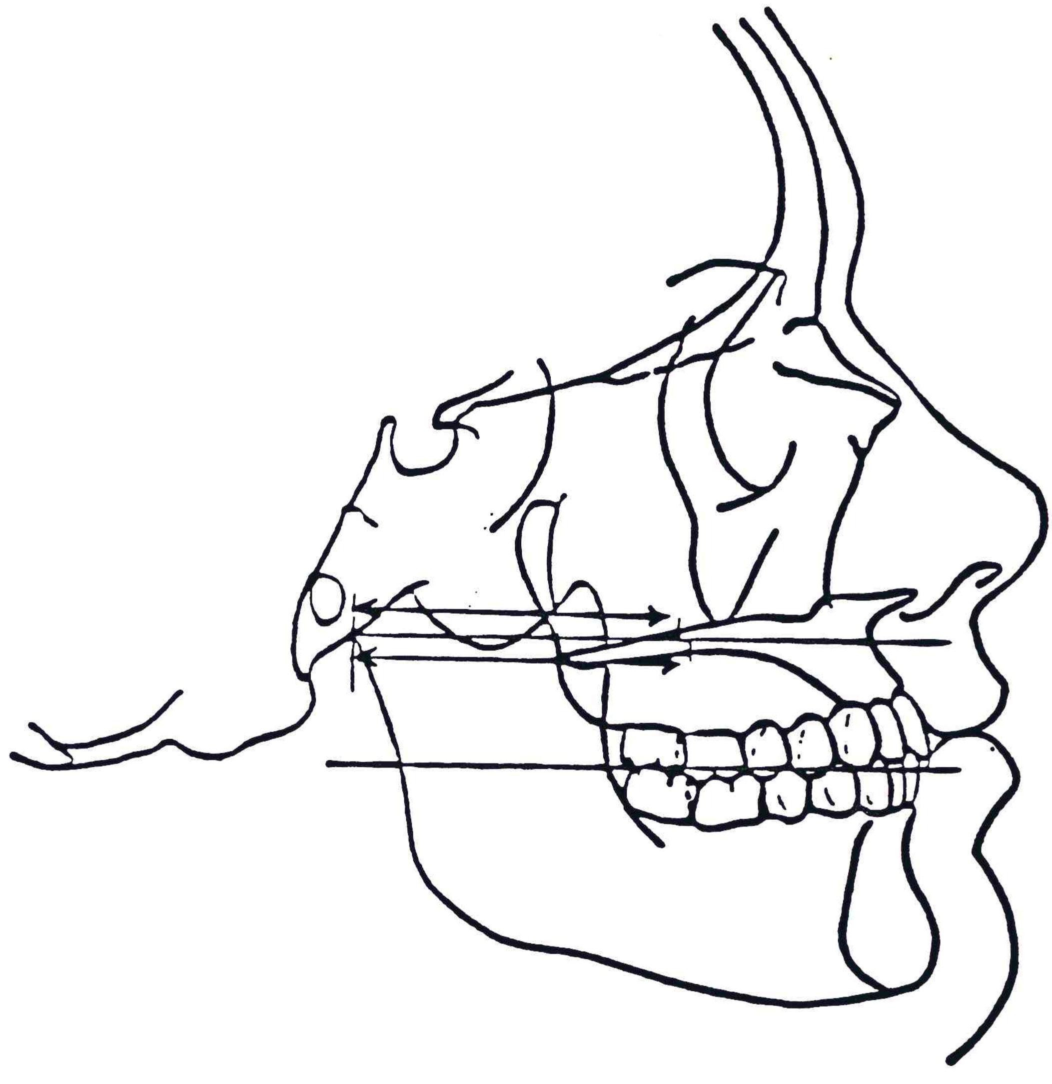


Figure 10. Maxillary/mandibular arches, skeletal dimensions, A point compared with B point. This diagram compares the length of the maxillary skeletal arch with the length of the mandibular skeletal arch. The maxillary skeletal arch is measured in millimeters from PM (solid line) along REF to A point. The mandibular skeletal arch is measured in millimeters from ARa where it intersects REF to B point along REF.

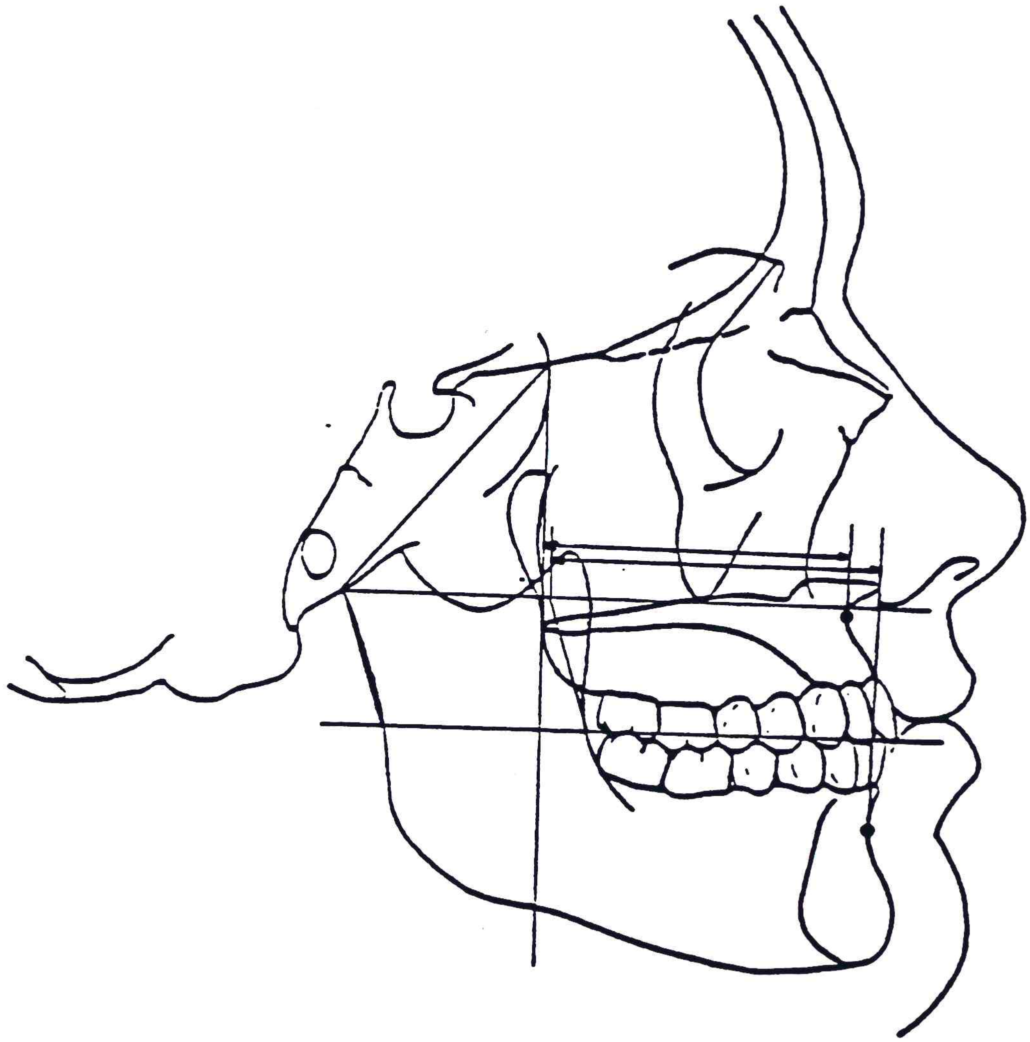


Figure 11. Maxillary/Mandibular arches, dental dimensions, A point compared with B point. This is similar to the previous measurement except that the distances are measured to the distal surfaces of the first molars.

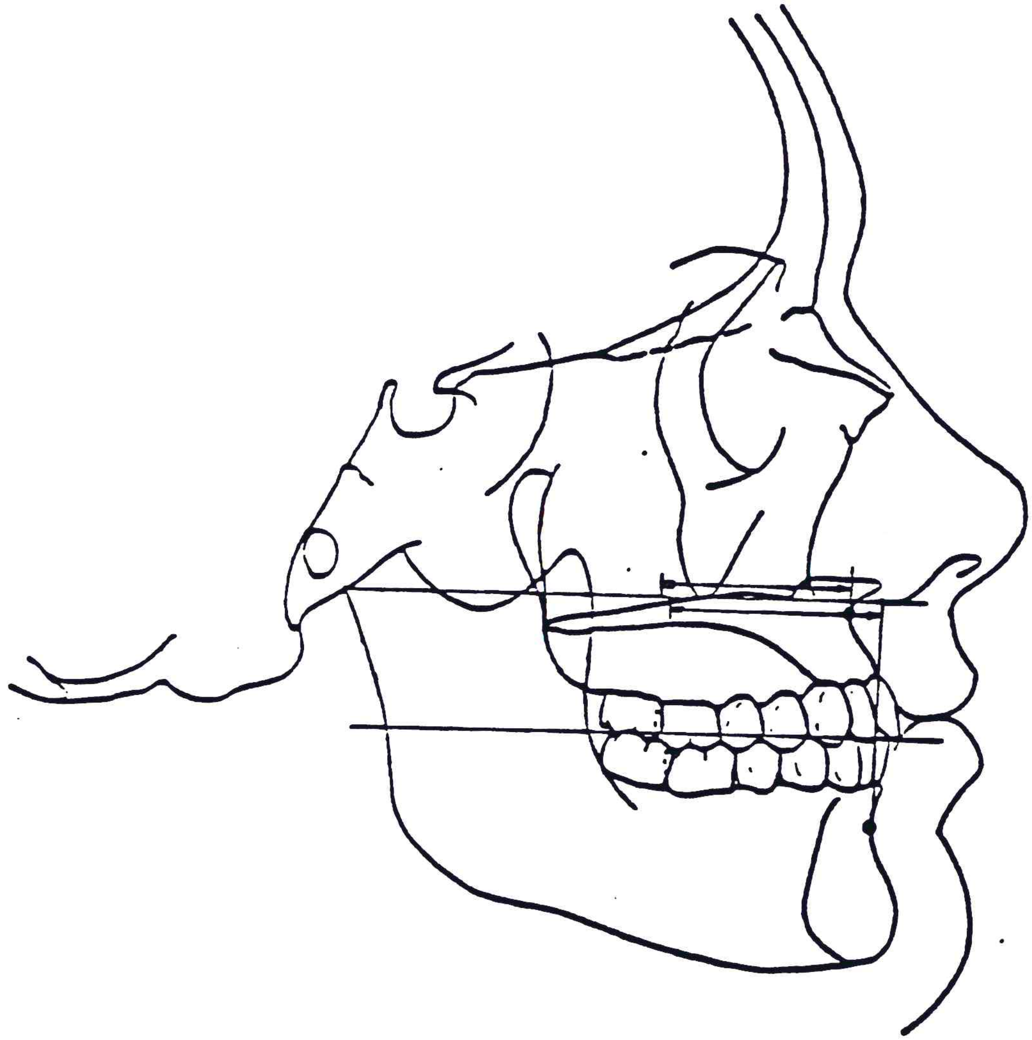


Figure 12. Maxillary/mandibular arches, skeletal dimensions, SPr compared with IPr. This comparison is identical to Figure 10 except that PM is measured to SPr and ARa is measured to IPr.

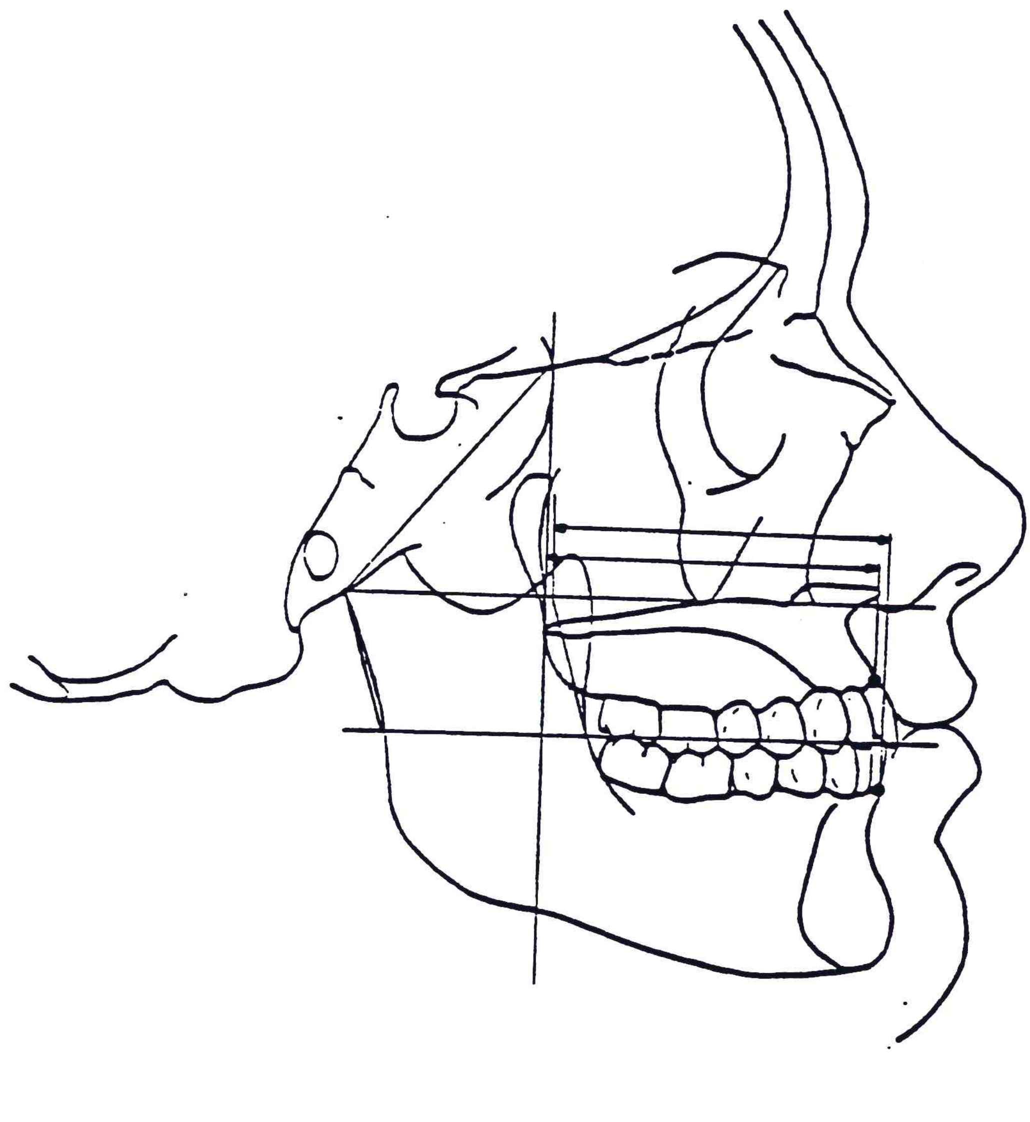


Figure 13. Maxillary/mandibular arches, dental dimensions, SPr compared with IPr. This measurement is identical to that in Figure 11 except that the distal of the maxillary first molar is measured to SPr and the distal of the mandibular first molar is measured to IPr.

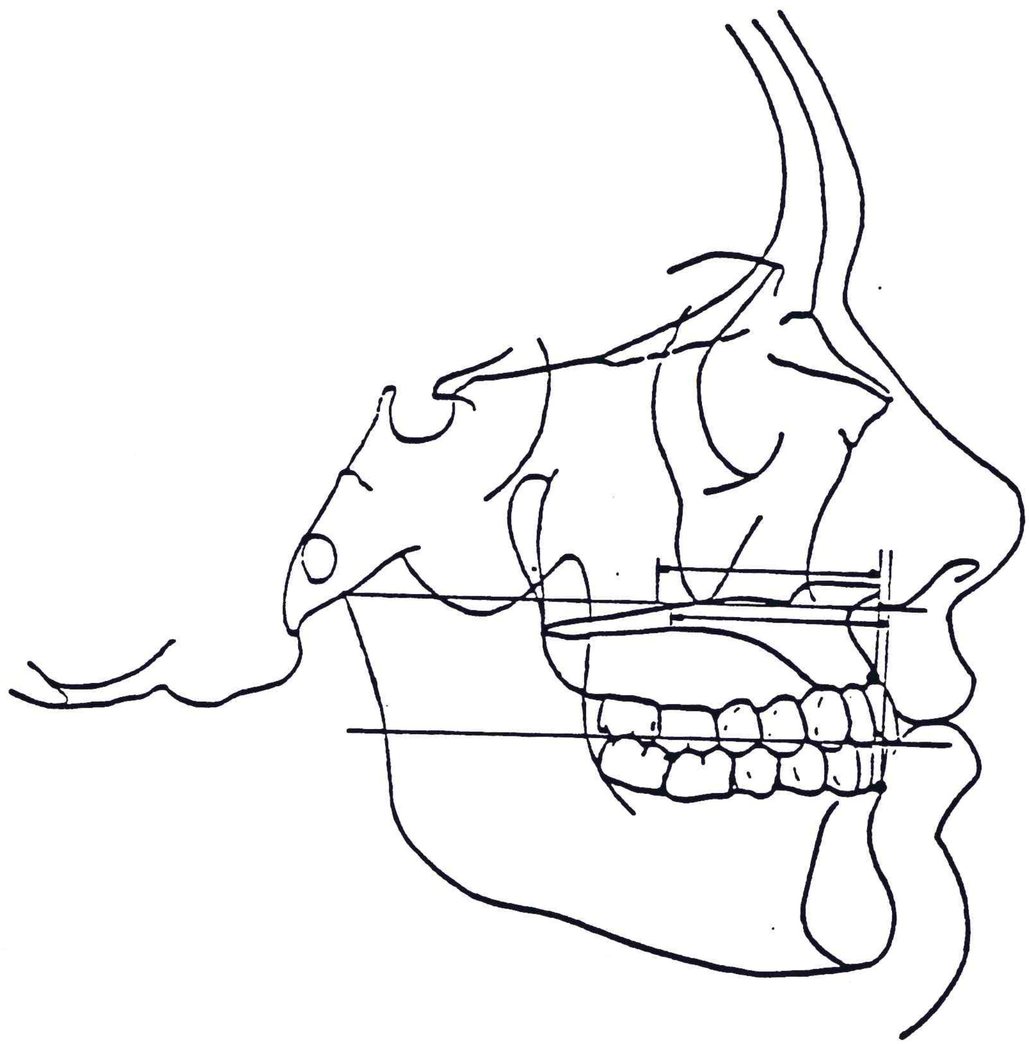


Figure 14. PM as compared with ramus/MCF vertical dimensions. The individual's relative posterior vertical naso-maxillary height is determined by this measurement. When the MCF rotates forward or backward, and the ramus rotates the same amount in the corresponding direction, no vertical disproportion 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.)

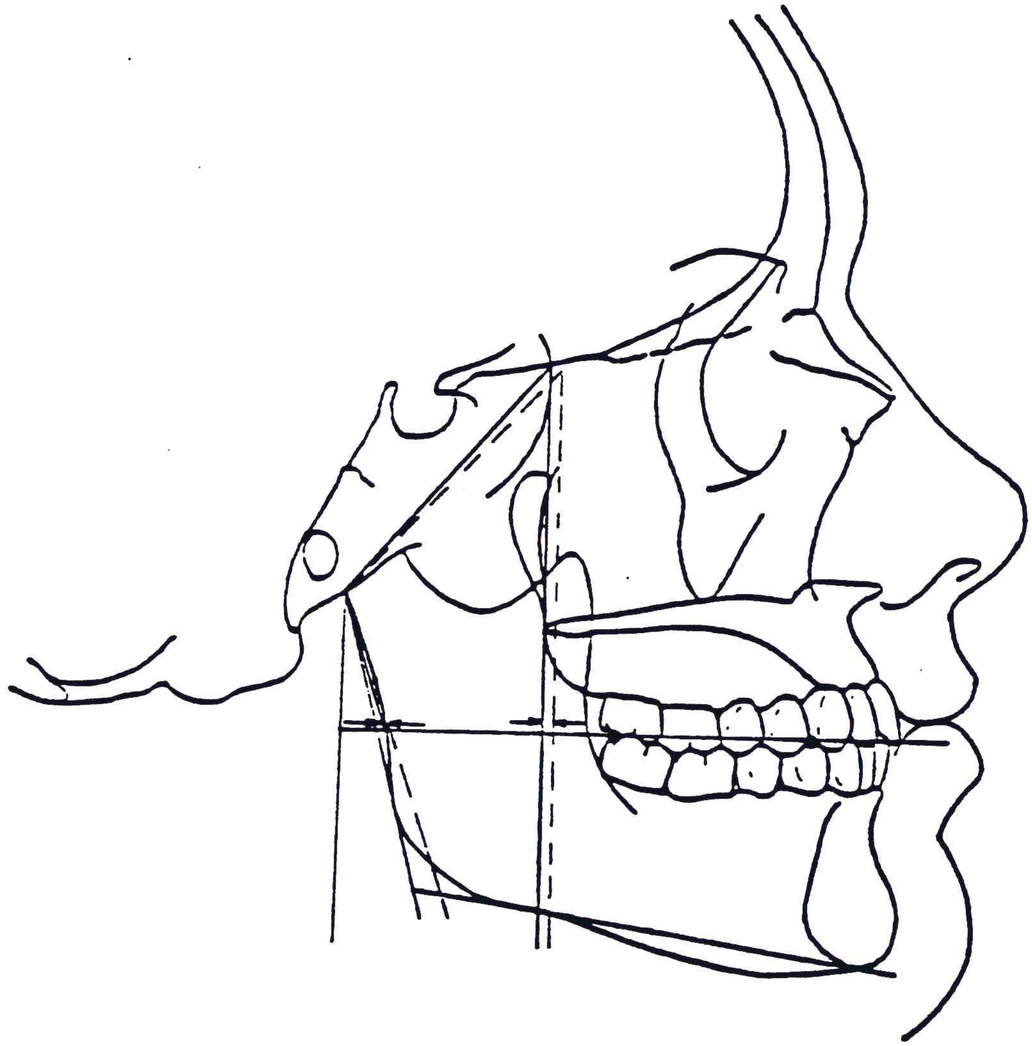


Figure 15. Corpus-occlusal alignment. This diagram demonstrates the extent of occlusal rotation as compared to the extent of ramus rotation. NOA acts as a reference line to determine the amount and direction of the occlusal rotation. NRa acts as a reference line to determine the amount of ramus rotation. 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 arch 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.

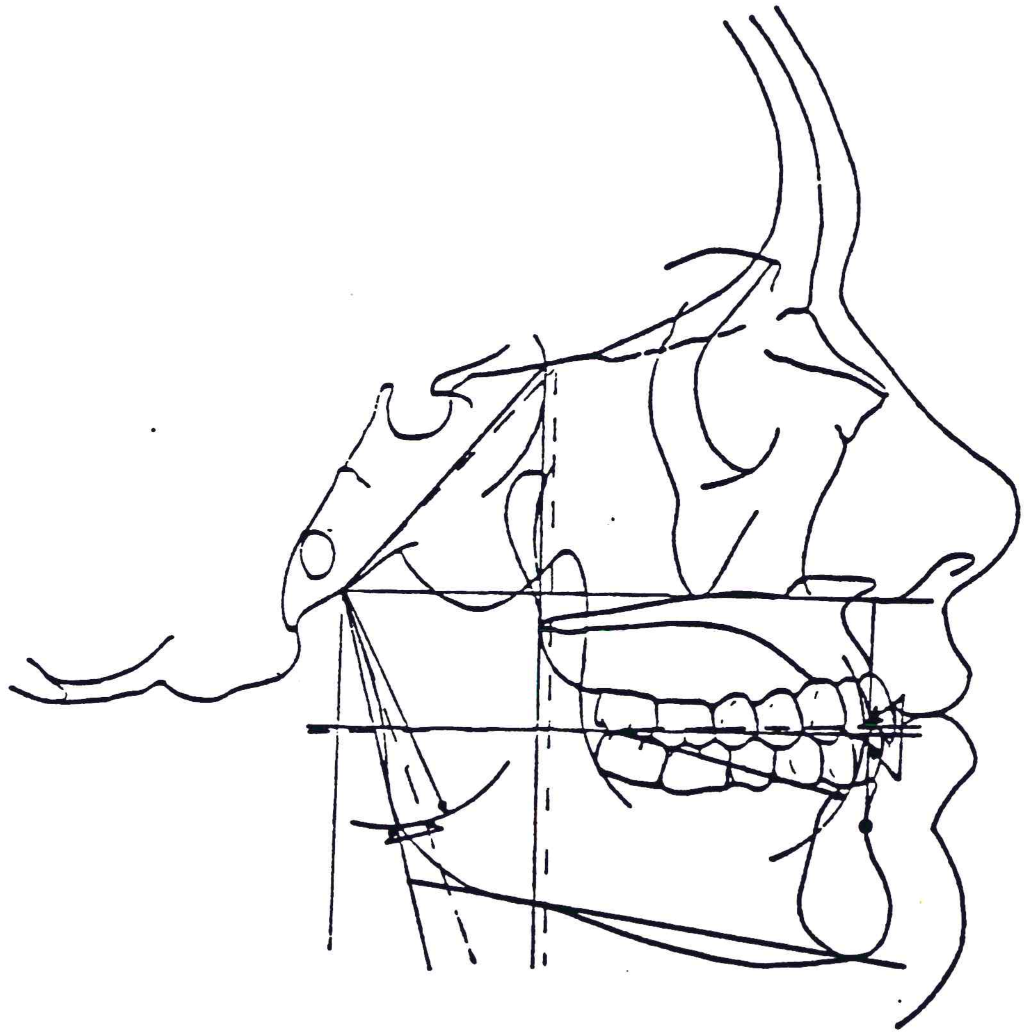


Figure 16. Gonial angle alignment. The mean gonial angle as presented in the Michigan Standard (Riolo, et al., 1975) is used as a neutral value, as indicated by a dashed line. The individual's mandibular plane is indicated by the line Me to Go. The measurement here is of two angles made in degrees. The neutral gonial angle and Ar to Go to Me.

<u>Figure 17</u>. <u>Curve of Spee</u>. 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.

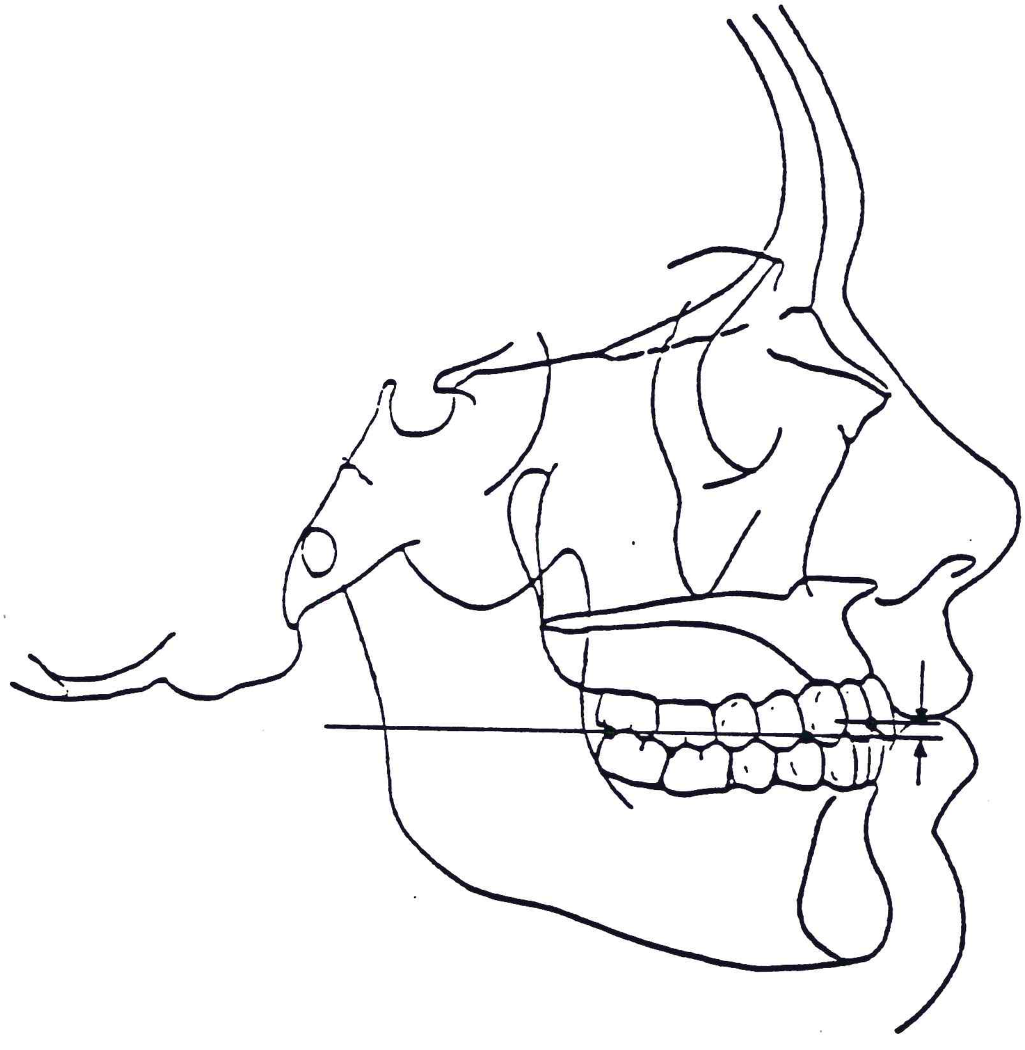


Figure 18. Palatal plane alignment. This diagram demonstrates the alignment between the palatal plane and the occipital fossa. The palatal plane is represented by a line from ANS through PNS. The distance between the plane and occipital point is measured. If the palatal plane is above 0 it is a negative number. If it is below 0 it is a positive number. Negative and positive values represent clockwise and counterclockwise rotations, respectively.

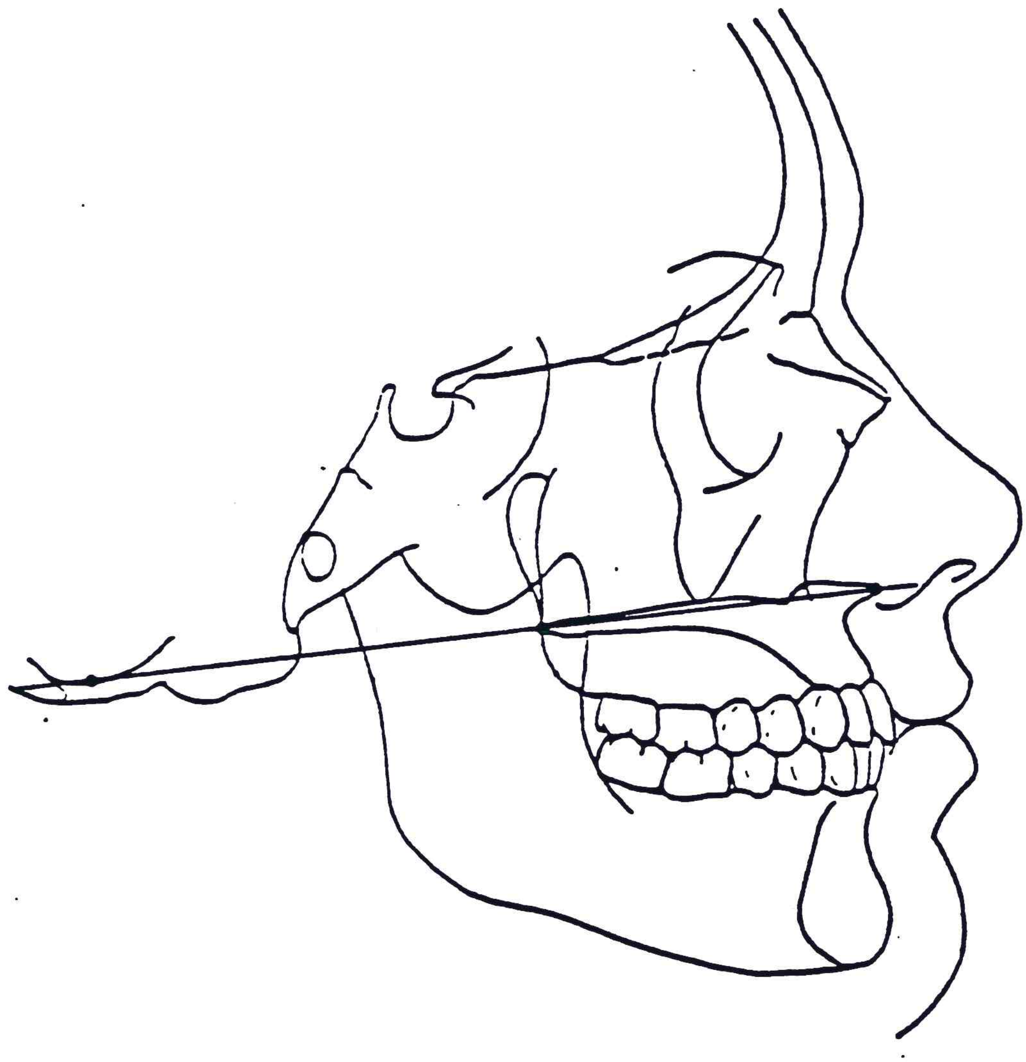


Figure 19. Inferior maxillary plane. This diagram demonstrates the alignment relationship between the inferior boundary of the nasomaxillary complex and the occipital fossa, theoretically representing the position establishing the inferior boundary for the nasomaxillary growth field. The line from SPr through the cemento-enamel 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.

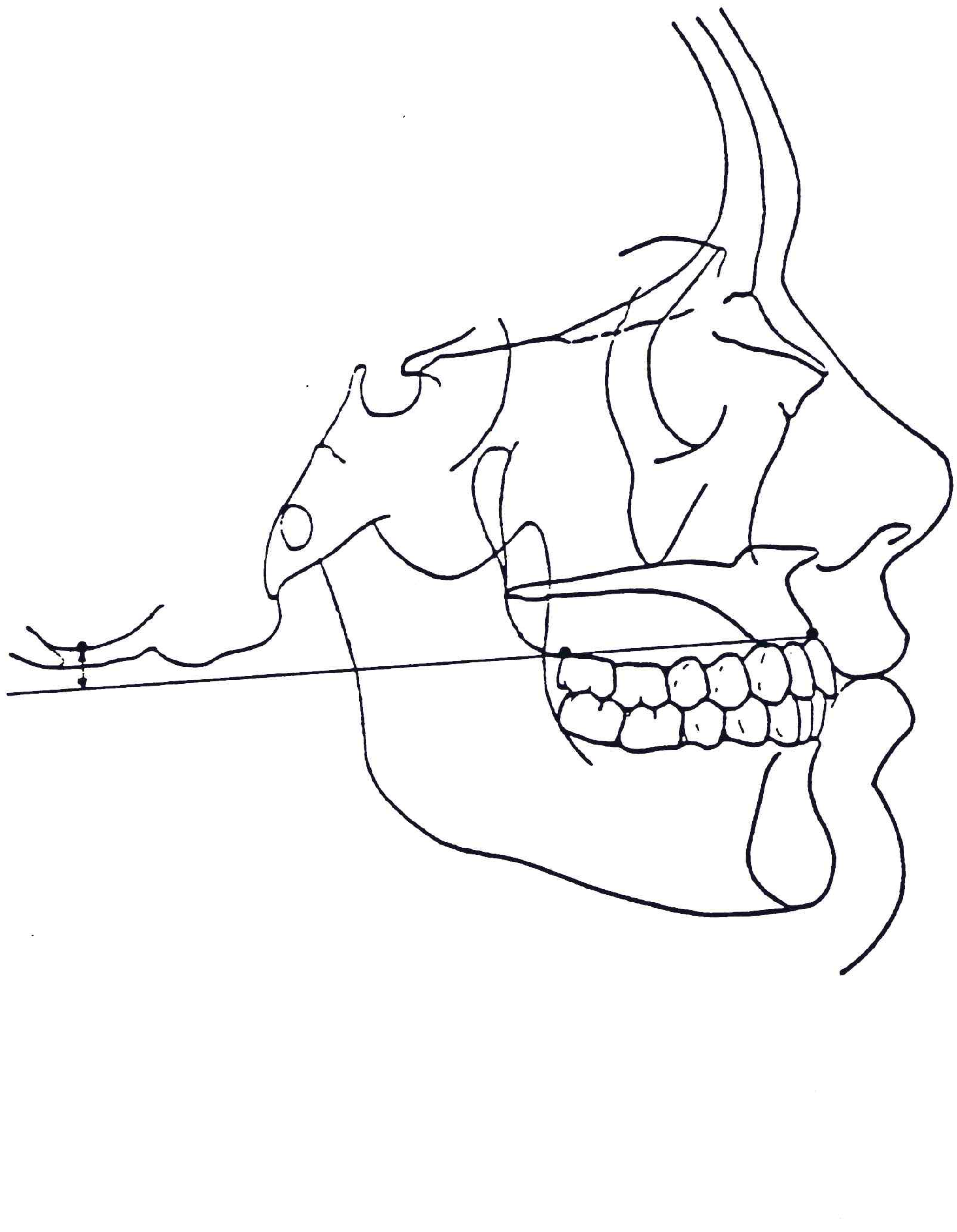


Figure 20. Maxillary nerve/palatal plane alignment. This diagram demonstrates the alignment relationship between the maxillary nerve and the palatal plane. The plane of the maxillary nerve is represented by a line from foramen rotundum in the pterygomaxillary fissure to a point 3 mm above orbitale (representing the course of the nerve prior to its downturn into the orbital floor). The palatal plane is determined as illustrated in Figure 18. An angular intersection is made between these two planes. If the angle is zero, the planes are in a neutral position. If the vertex of the angle is behind the subject, the angle is positive and indicates a clockwise rotational alignment of the palate. If the vertex is in front of the patient, the angle is negative and indicates a counterclockwise rotational alignment of the palate relative to the maxillary nerve.

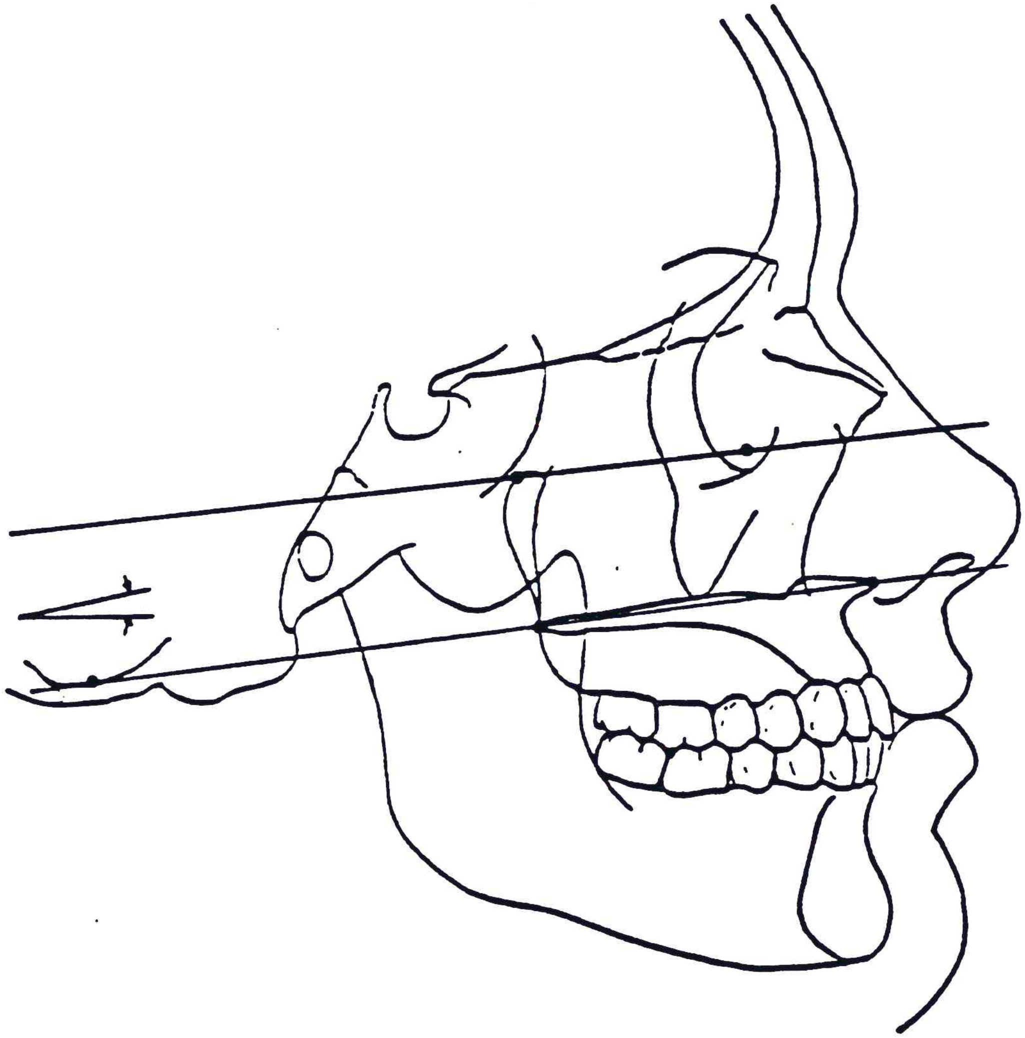
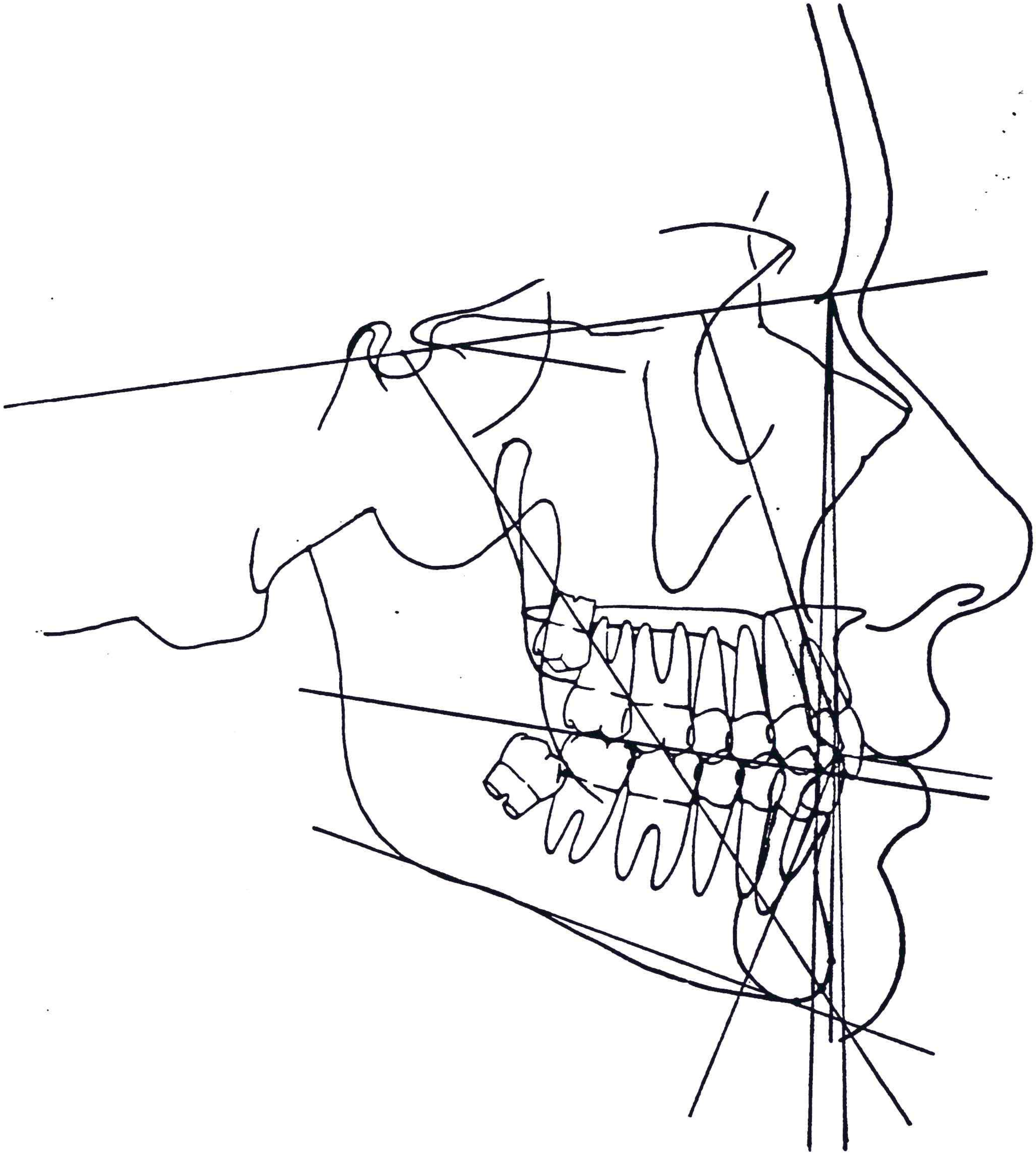


Figure 21. All the points and planes used to determine the additional nine variables are demonstrated in this diagram.

1: U1-APog.
2: L1-APog.
3: Y axis to SN.
4: OP to SN.
5: U1-L1.
6: OB.
7: ANB.
8: U1-SN.
9: L1-MP.



RESULTS

Variable #1

Aggregate Cranial Floor/Maxilla Relative to Ramus/Corpus Horizontal Dimension at A Point and B Point.

The frequency distribution for direction of change when treated group was compared with control group demonstrated no statistically significant changes ($p > .05$) in either direction for the two time intervals (Tables XIX and XX).

Analysis of variance and covariance with repeated measures indicated an interaction of time with group which was statistically significant ($p < .01$) (Table XXII).

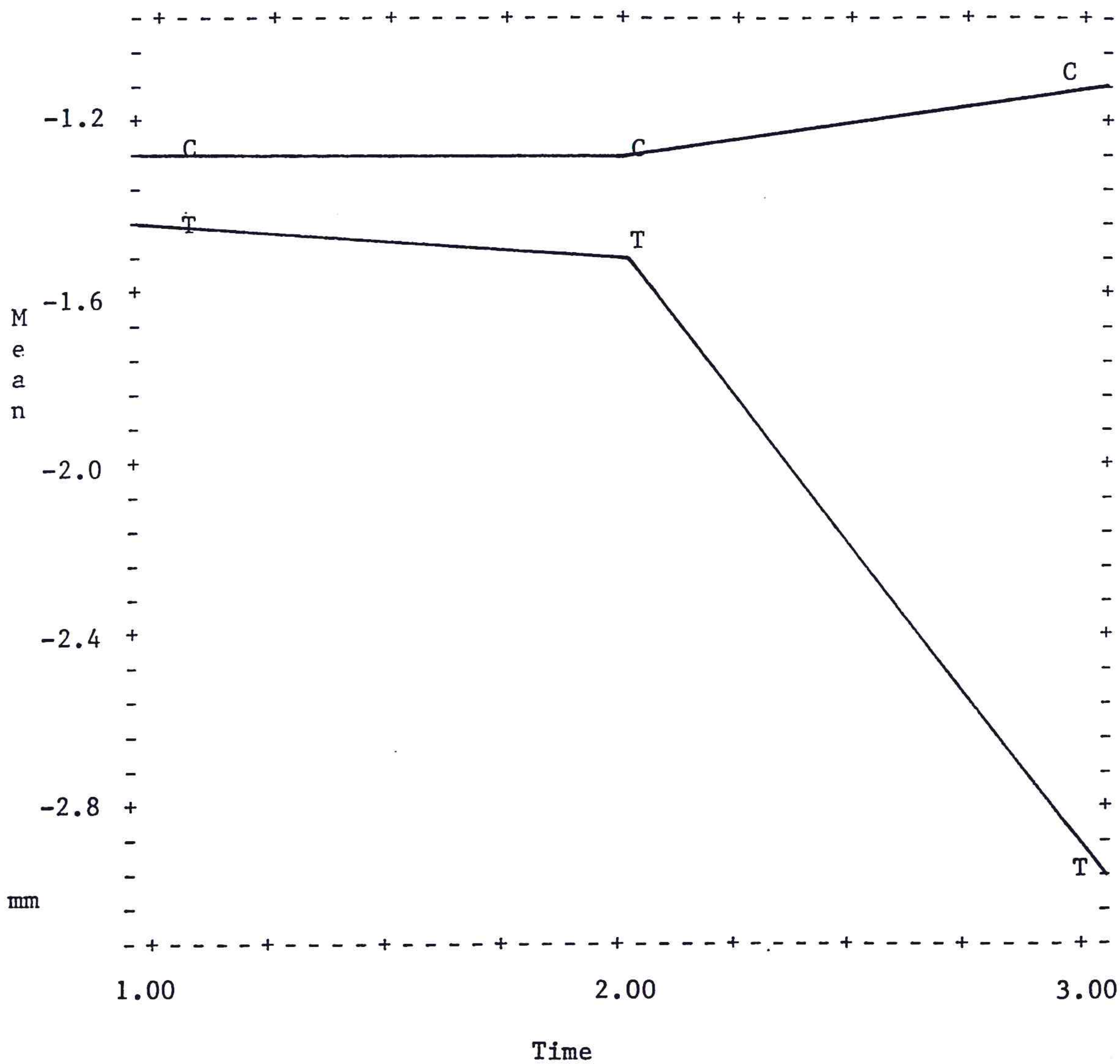
Because of the interaction of time with group, t test was done for time 1, time 2 and time 3. The t test indicated a statistically significant result at time 3 with $p < .01$ (Table XXIII).

A plot of mean values against time illustrates that the profiles of treated and control groups were similar to each other at the first time interval T_2-T_1.

But at the second time interval T_3-T_2, the control group demonstrates an increase in the mean value of 0.18 mm while the treated group demonstrates a decrease in the mean value of 1.41 mm (see Tables VI and XXI).

TABLE VI

Variable #1: Ar.A, Ar.B.



GROUP = Treated, SYMBOL = T
GROUP = Control, SYMBOL = C

Variable #2

Aggregate Cranial Floor/Maxilla Relative to Ramus/Corpus Horizontal Dimension at SPr and IPr.

The frequency distribution for direction of change when treated group was compared with control group indicated no statistically significant changes ($p > .05$) in either direction for the two time intervals (Tables XIX and XX).

The analysis of variance and covariance with repeated measures demonstrated no statistical significance for group, time and interaction (Table XXII).

Variable #3

Middle Cranial Fossa (MCF) and Posterior Maxillary (PM) Relative Alignment.

No statistically significant changes in direction were demonstrated when the treated group was compared to the control group for two different time intervals (Tables XIX and XX).

The analysis of variance and covariance with repeated measures also indicated no statistical significant results for group, time and interaction P values (Table XXII).

Variable #4

Ramus Alignment

The frequency distribution for directional change in the vertical ramus plane between treated and control groups at two time intervals indicated statistically not significant results (Tables XIX and XX).

There was also no significant magnitude of change for the vertical ramus plane demonstrated by the analysis of variance and covariance with repeated measures (Table XXII).

Variable #5

Ramus/MCF Horizontal Dimensions (Skeletal).

The frequency distribution for directional change when treated and control groups were compared indicated no significant changes in either direction for the two time intervals (Tables XIX and XX).

The analysis of variance and covariance demonstrated no significant results for group and interaction of group with time. Only time factor was found to be statistically significant (Table XXII).

Variable #6

Ramus/MCF Horizontal Dimensions (Dental).

The frequency distribution for directional change when treated and control groups were compared demonstrated no significant changes in either direction for the two time intervals (Tables XIX and XX).

Meanwhile, the analysis of variance and covariance with repeated measures demonstrated statistically significant p values at .05 level for group and time. The treated group indicated a decrease in the mean values of 0.5 mm at T_2-T_1 and another decrease of 0.2 mm at T_3-T_2 while the control group had an increase of 0.3 mm at T_2-T_1 and a decrease of 0.7 mm at T_3-T_2 (Tables XXI and XXII).

Variable #7

Molar Positions (Composite).

The frequency distribution for direction of change when both groups were compared demonstrated no statistically significant changes ($p > .05$) in either direction for the two time intervals (Tables XIX and XX).

The analysis of variance and covariance indicated statistically significant p values at .01 level for group and time. The treated group demonstrated a decrease in the mean values of 0.17 mm during T_2-T_1 time interval and 0.24 mm during T_3-T_2 time interval. While the control group had a decrease in the mean values of only 0.02 for T_2-T_1, and 0.22 for T_3-T_2 time interval (Tables XXI and XXII).

Variable #8

Maxillary/Mandibular Arches, Skeletal Dimensions, A Point Compared With B Point.

The frequency distribution for directional change when the two groups were compared to each other demonstrated no statistically significant changes ($p > .05$) in either direction for the two time intervals (Tables XIX and XX).

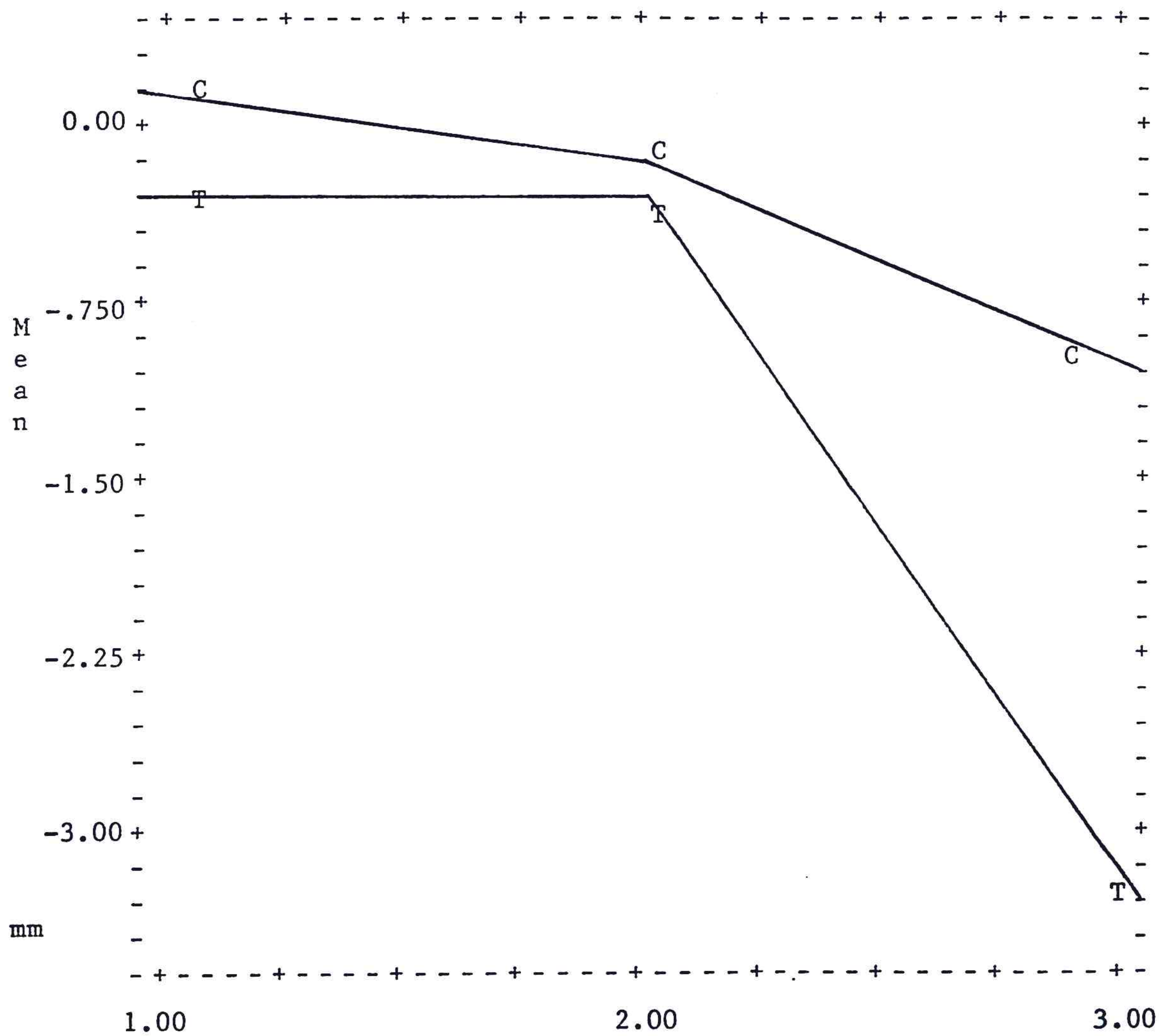
Meanwhile, analysis of variance and covariance with repeated measures indicated the interaction of time with group, and the time itself to be statistically significant (Table XXII).

Because of the interaction of time with group, t-test was done for $time_1$, $time_2$ and $time_3$ respectively. The t-test indicated a statistically significant result at $time_3$ at .05 level (Table XXIII).

A plot of mean values against time illustrates that the profiles of treated and control groups are similar to each other during the first time interval T_2-T_1. During this first time interval, the treated group has only 0.03 mm mean value change while the control group has a decrease in the mean value of 0.04 mm. But at the second time interval T_3-T_2, the treated group indicates a decrease of 3.09 mm while the control group has a decrease of only 0.88 mm of mean value change (Tables VII and XXI).

TABLE VII

Variable #8: MX/MD AB/Sk



GROUP = Treated, SYMBOL = T
GROUP = Control, SYMBOL = C

Variable #9

Maxillary/Mandibular Arches, Dental Dimensions, A Point Compared With B Point.

The frequency distribution for directional change when the groups were compared with each other indicated no statistically significant changes ($p > .05$) in either direction for the two time intervals (Tables XIX and XX).

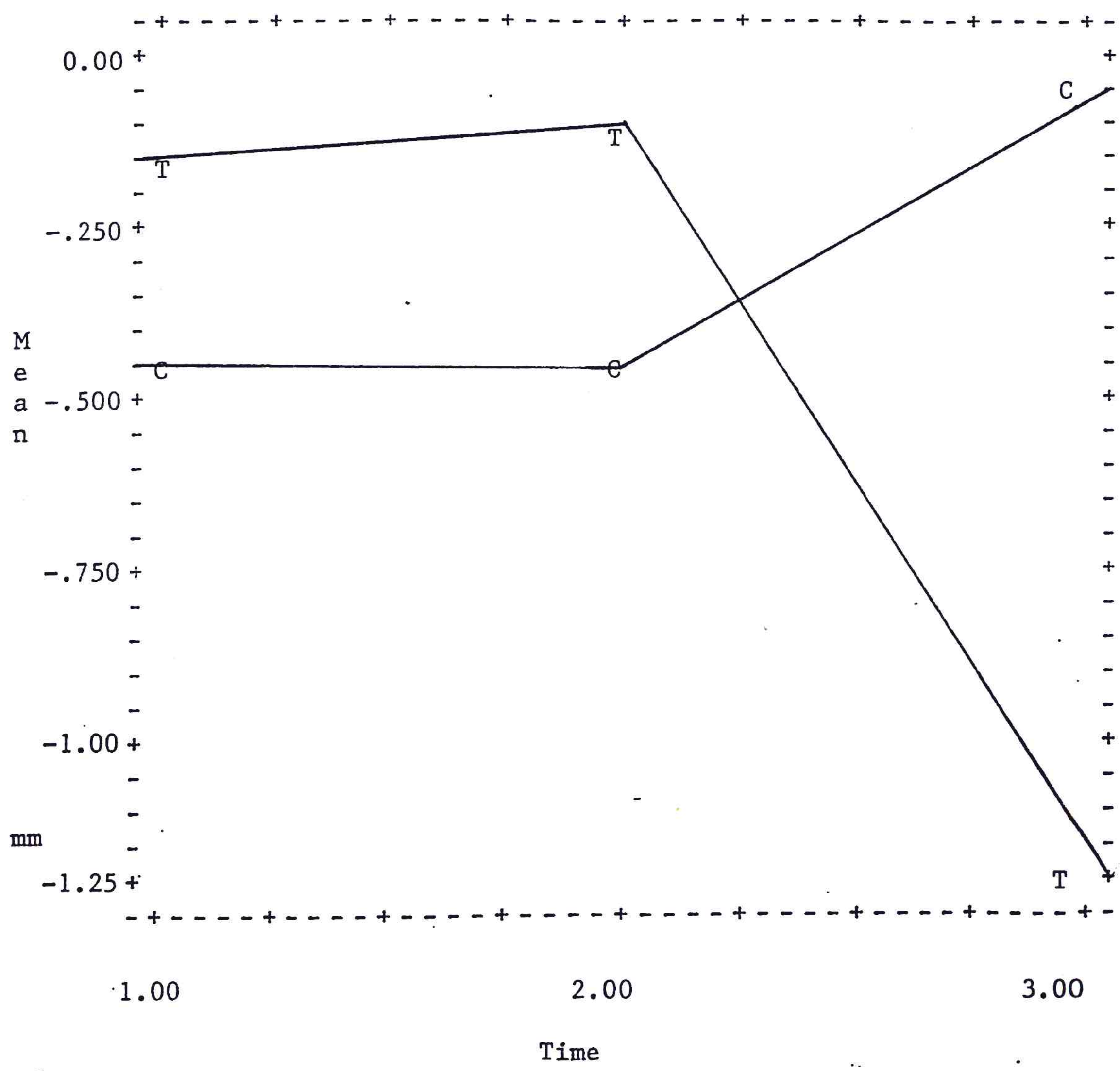
Analysis of variance and covariance with repeated measures indicated an interaction of time with group which was statistically significant at .01 level (Table XXII).

Because of the interaction of time with group, t test was done for $time_1$, $time_2$ and $time_3$ respectively. The t-test indicated that only $time_3$ was close to be statistically significant with a p value of .07 (Table XXIII).

A plot of mean values against time illustrates that the profiles of treated and control groups are quite similar during the first time interval T_2-T_1. The mean value change for the treated group during T_2-T_1 is an increase of 0.09 mm, meanwhile the control group has a decrease of 0.05 mm. During the second time interval T_3-T_2, while the treated group's mean value is decreasing considerably about 1.16 mm, the control group's mean value is increasing about 0.41 mm (Tables VIII and XXI).

TABLE VIII

Variable #9: MX/MD AB/D



GROUP = Treated, SYMBOL = T
GROUP = Control, SYMBOL = C

Variable #10

Maxillary/Mandibular Arches, Skeletal Dimensions, SPr Compared With IPr.

The frequency distribution for direction of change when treated group was compared with control group demonstrated no statistically significant changes ($p > .05$) in either direction for the two time intervals (Tables XIX and XX).

The analysis of variance and covariance also demonstrated no significant results for group and interaction of group with time. Only the time factor was found to be statistically significant (Table XXII).

Variable #11

Maxillary/Mandibular Arches, Dental Dimensions, Measured at SPr and IPr.

The frequency distribution for directional change in the maxillary and mandibular dental arches, did not indicate any statistically significant results when both groups were compared at two different time intervals (Tables XIX and XX).

There was also no significant magnitude of change in the dental arches demonstrated by the analysis of variance and covariance with repeated measures (Table XXII).

Variable #12

PM as Compared With Ramus/MCF Vertical Dimensions.

The frequency distribution for directional change when both groups were compared indicated no significant changes in either direction for the two intervals (Tables XIX and XX).

The relative vertical length of the PM had no significant magnitude of change demonstrated by the analysis of variance and covariance with repeated measures. Only the time factor was found to be statistically significant (Table XXII).

Variable #13

Corpus-Occlusal Alignment

The frequency distribution for directional change when both groups were compared to each other indicated no statistically significant result for the first time interval T_2-T_1 (Table XIX).

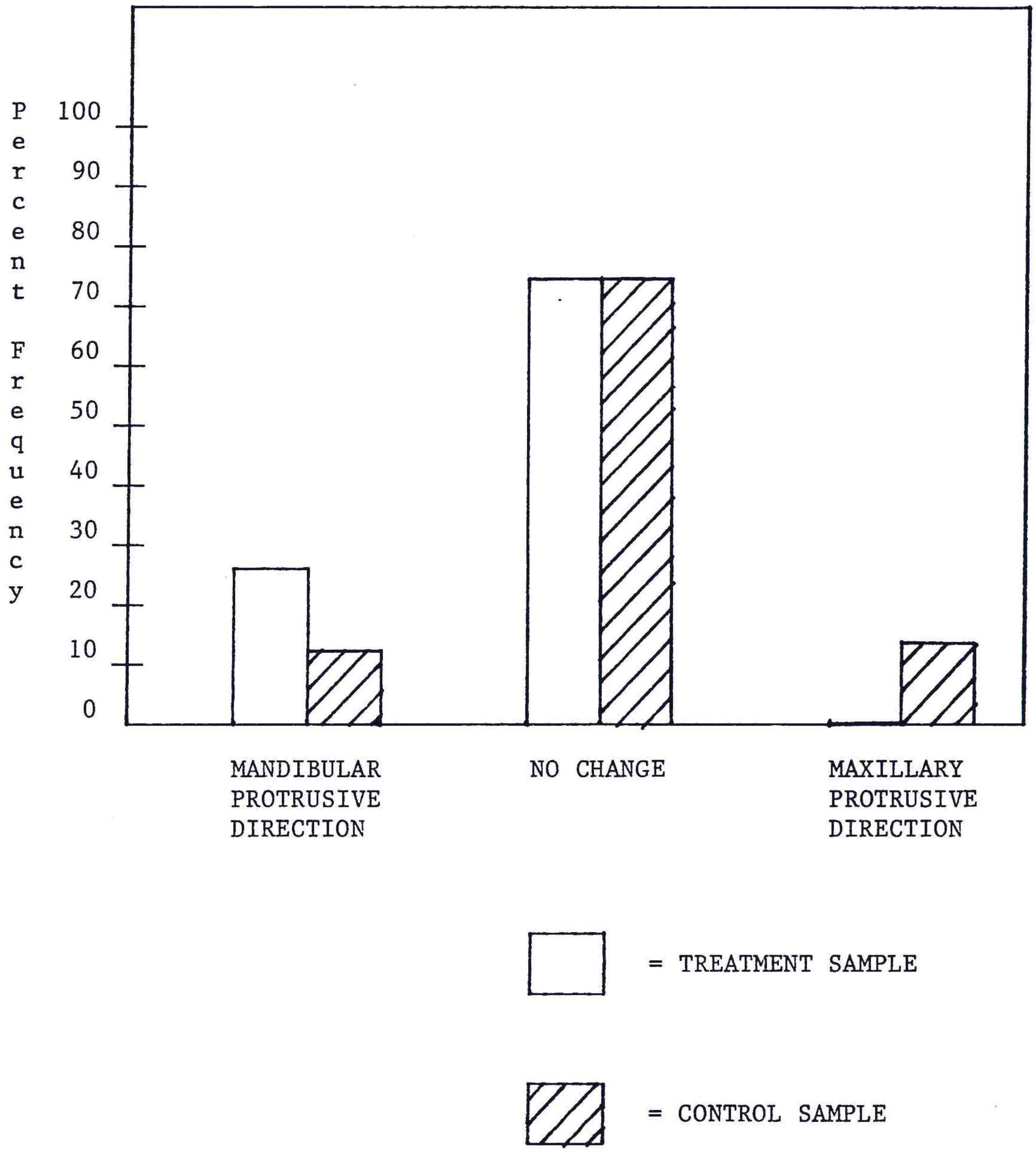
For the second time interval, the frequency distribution for directional change when the groups were compared to each other did indicate a statistically significant result at .05 level with a mandibular protrusive effect. Although, this variable being the only significant result among 36 tested variables, this finding could have occurred by chance alone (Tables IX and XX).

There was no significant magnitude of change for the corpus/occlusal alignment demonstrated by the analysis of variance and covariance with repeated measures (Table XXII).

TABLE IX

Variable #13: $(T_3\text{-}T_2,\ C_3\text{-}C_2)$

CORPUS/OCCLUSAL ALIGNMENT



Variable #14

Gonial Angle Alignment.

The gonial angle alignment had no directional change in either direction demonstrated by the frequency distribution for the two time intervals (Tables XIX and XX).

The analysis of variance and covariance with repeated measures indicated no significant magnitude of change for the gonial angle alignment (Table XXII).

Variable #15

Curve of Spee

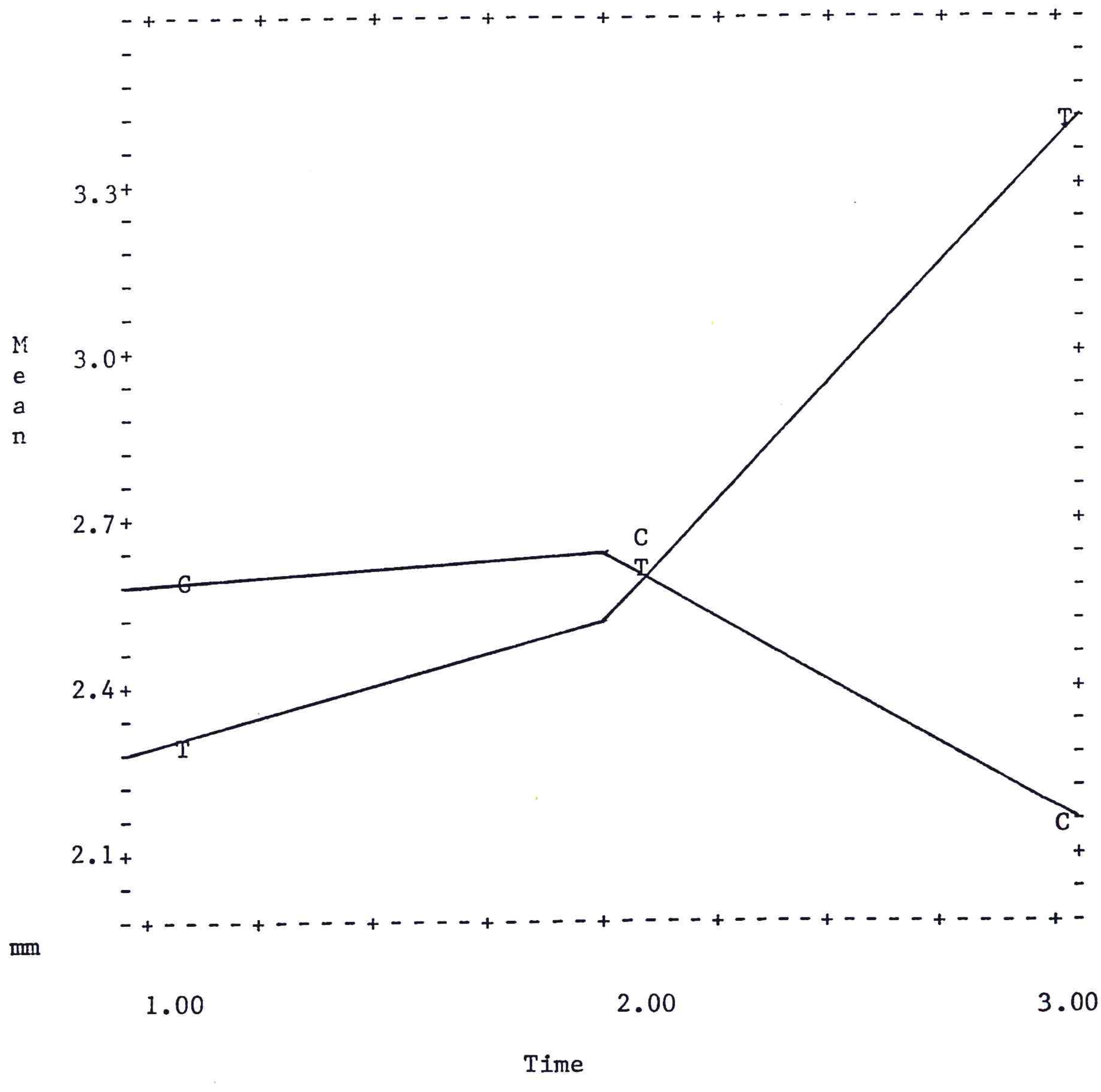
The curve of Spee had no directional change in either direction demonstrated by the frequency distribution for the two time intervals (Tables XIX and XX).

Meanwhile, analysis of variance and covariance with repeated measures indicated a significant interaction of time with group at .01 level (Table XXII). The t-test indicated a statistically significant result at $time_3$ with $p < .01$ (Table XXIII).

A plot of mean values against time illustrates the magnitude of change, during the first time interval T_2-T_1, as an increase of 0.36 mm for the treated group and 0.12 mm for the control group. The mean magnitude of change, during the second time interval T_3-T_2, is an increase of 0.79 mm for treated group and a decrease of 0.54 mm for control group (Tables X and XXI).

TABLE X

Variable #15: CSPEE INC



GROUP = Treated, SYMBOL = T
GROUP = Control, SYMBOL = C

Variable #16

Palatal Plane Alignment.

The frequency distribution for directional change when both groups were compared to each other demonstrated no statistically significant changes ($p > .05$) in either direction for the two time intervals (Tables XIX and XX).

There was also no significant magnitude of change demonstrated by the analysis of variance and covariance for the two time intervals (Table XXII).

Variable #17

Inferior Maxillary Plane.

The inferior maxillary plane had no directional change in either direction demonstrated by the frequency distribution for the two time intervals (Tables XIX and XX).

The analysis of variance and covariance with repeated measures indicated a significant magnitude of change when both groups were compared to each other. The mean change during the first time interval for the treated group was a decrease of 1.25 mm and the control group had also a decrease of 0.85 mm. The second time interval, the treated group had an increase of 1.17 mm while the control group kept decreasing about 0.21 mm (Tables XXI and XX).

Variable #18

Maxillary Nerve/Palatal Plane Alignment.

The frequency distribution for directional change demonstrated no significant results when treated and control groups were compared to each other for the two time intervals T_2-T_1 and T_3-T_2 (Tables XIX and XX).

There was also no significant results for magnitude of change demonstrated by the analysis of variance and covariance with repeated measures (Table XXII).

Variable #19

Upper Incisor to A.Pog Line.

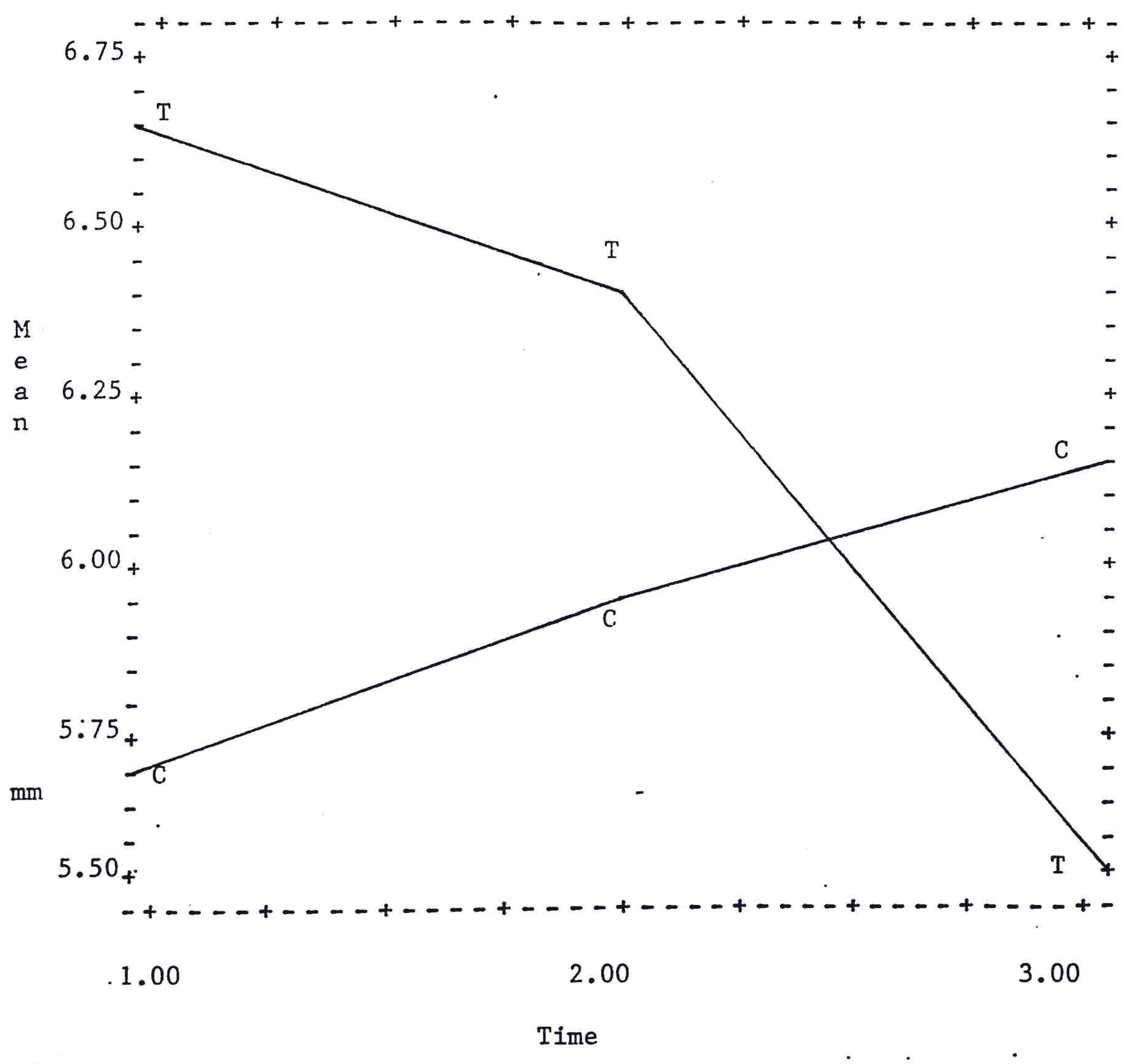
There was a significant magnitude of change for this variable, demonstrated by the interaction of group with time at .01 level (Table XXII).

Because of the interaction of time with group, t-test was done for $time_1$, $time_2$ and $time_3$ respectively. The t-test indicated that only $time_1$ was close to be statistically significant with a p value of .06. This would point out the fact that the mean inclination of upper incisors to A.Pog line was quite different in two groups (Table XXIII).

A plot of mean values against time illustrates that the inclination of upper incisors in the treated group is decreasing considerably while it's increasing in the control group. The mean change during the first time interval T_2-T_1 for treated group is a decrease of 0.21 mm while it's an increase of 0.24 mm for control group. During the second time interval T_3-T_2, it's another decrease of 0.86 mm for treated and an increase of another 0.22 mm for control group (Tables XI and XXI).

TABLE XI

Variable #19: U1.APog



GROUP = Treated, SYMBOL = T
GROUP = Control, SYMBOL = C

Variable #20

Lower Incisor to A.Pog Line.

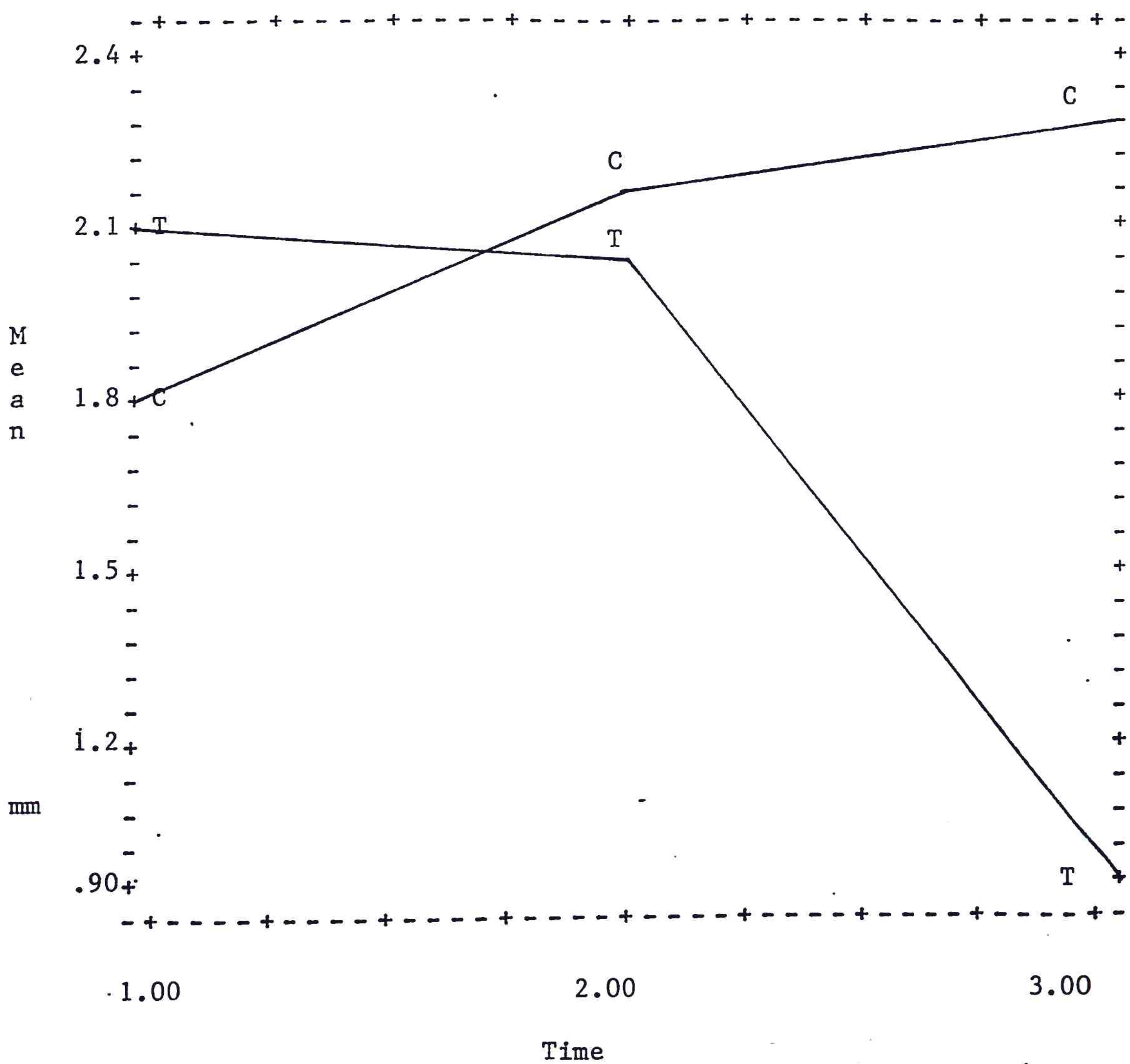
There was a significant magnitude of change for this variable, demonstrated by the interaction of time with group at .01 level (Table XXII).

Because of the interaction of time with group, the t-test was used for $time_1$, $time_2$ and $time_3$ respectively. The t-test indicated that only $time_3$ was significant at .01 level (Table XXIII).

A plot of mean values against time illustrates that the inclination of lower incisors to A.Pog line is decreasing considerably in the treated group while it's increasing in the control one (Table XII). The mean change during the first time interval T_2-T_1 for treated group is a decrease of 0.06 mm while it's an increase of 0.32 mm in the control group. During the second time interval T_3-T_2, there is another decrease of 1.08 mm for treated and another increase of 0.16 mm for control group (Table XXI).

TABLE XII

Variable #20: L1.APog



GROUP = Treated, SYMBOL = T
GROUP = Control, SYMBOL = C

Variable #21

Y Axis to SN.

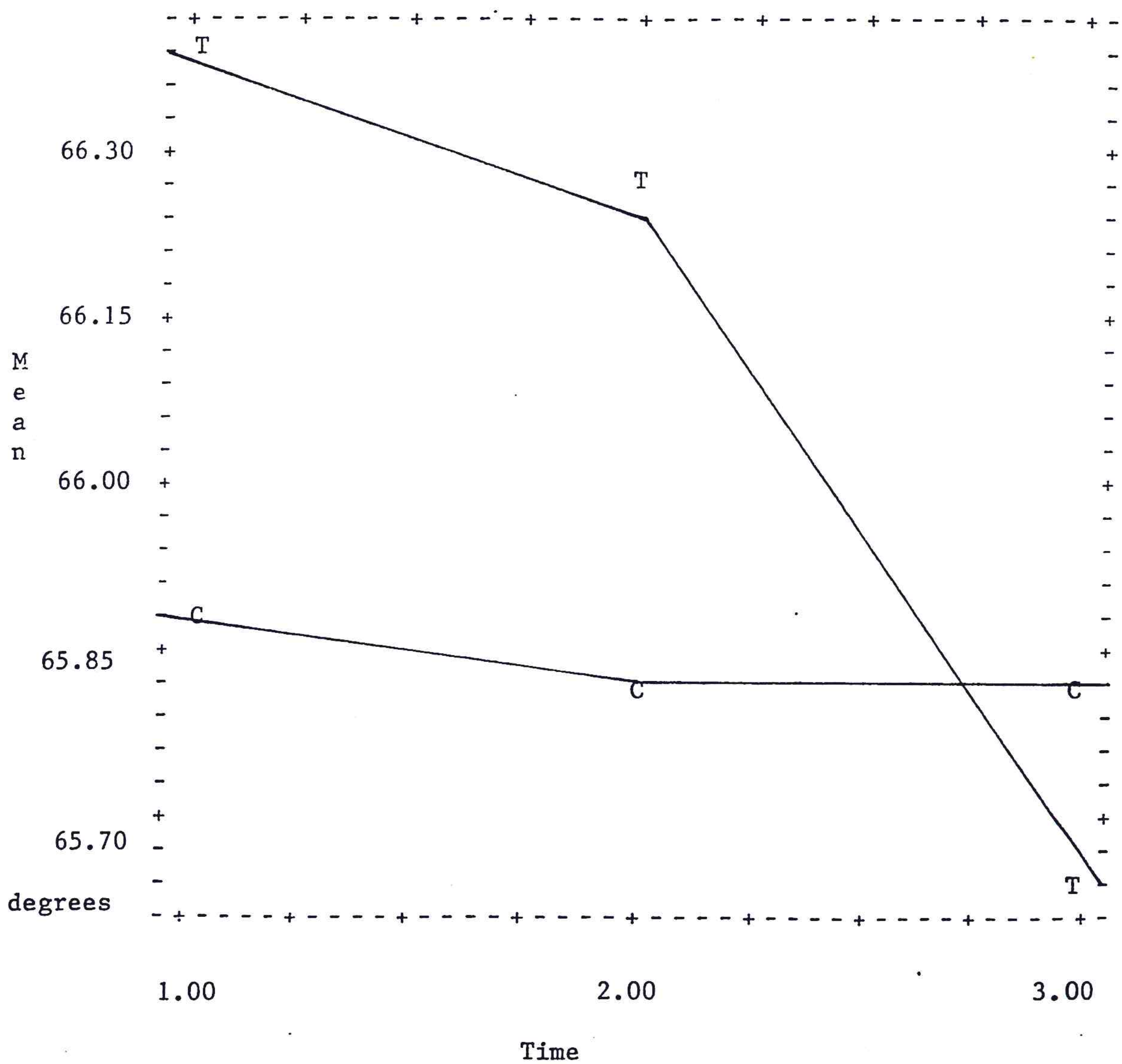
The analysis of variance and covariance with repeated measures indicated a significant interaction of time with group with a p value of .02 (Table XXII).

The t-test was performed for $time_1$, $time_2$ and $time_3$ respectively, But the t-test indicated no statistically significant results (Table XXIII).

A plot of mean values against time illustrates how during the first time interval, there is a decrease of 0.16 degrees for the treated group and 0.07 for the control group. During the second time interval, the treated group indicates another decrease of 0.58 degrees while the control group has an increase of only 0.01 degrees (Tables XIII and XXI).

TABLE XIII

Variable #21: Y axis to SN



GROUP = Treated, SYMBOL = T
GROUP = Treated, SYMBOL = C

Variable #22

Occlusal Plane to SN.

The occlusal plane to Sella-Nasion line did not show any significant magnitude of change demonstrated by the analysis of variance and covariance with repeated measures (Table XXII).

Variable #23

The Interincisal Angle.

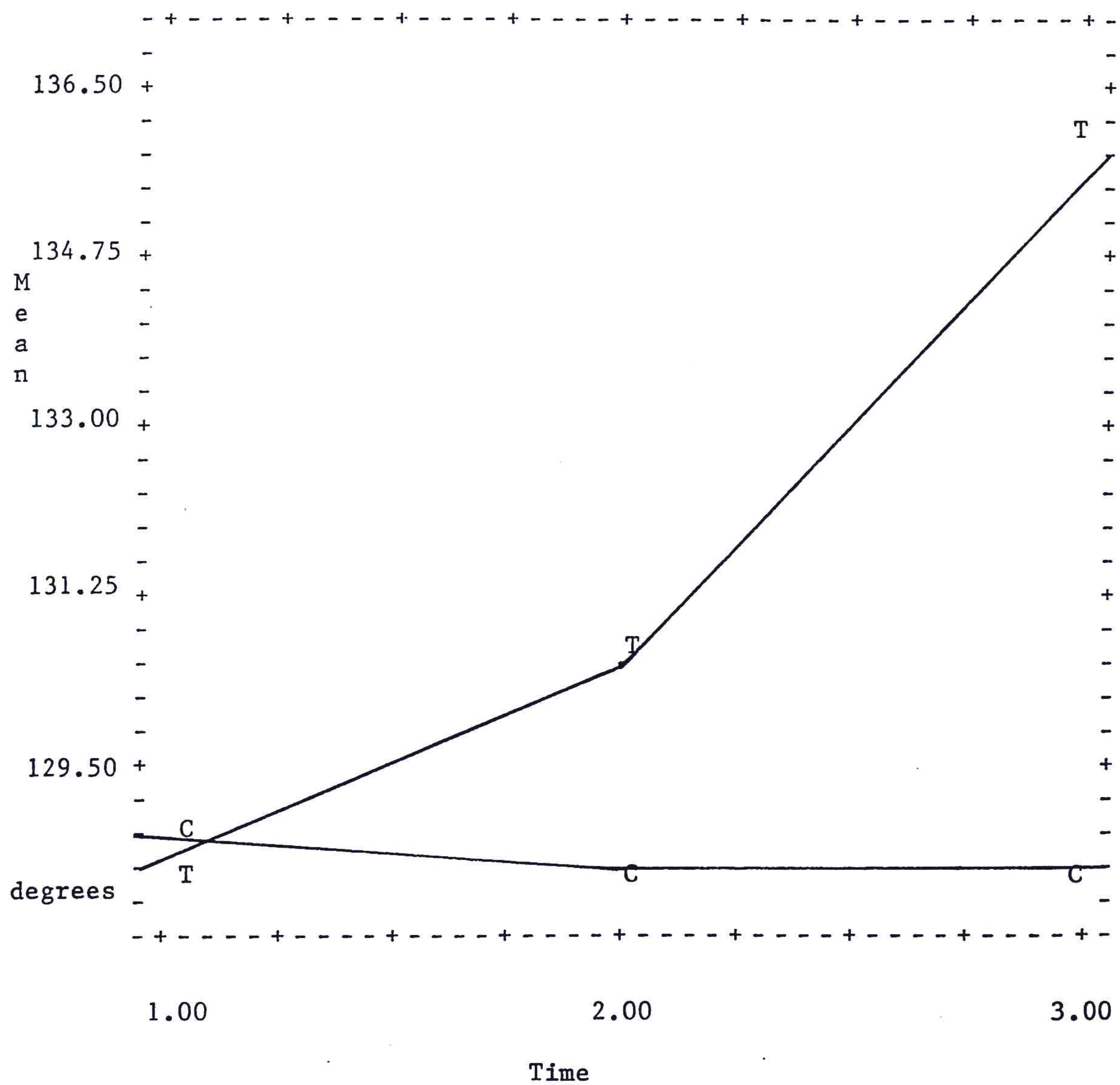
The analysis of variance and covariance with repeated measures indicated a significant interaction of time with group with a p value <.01 (Table XXII).

The t-test was done at $time_1$, $time_2$ and $time_3$ respectively and indicated a statistically significant result at $time_3$ with a p value < .01 (Table XXIII).

A plot of mean values against time for the interincisal angle illustrates an increase of 1.37 degrees for the treated group during T_2-T_1 and a decrease of 0.11 degrees for the control group. During the second time interval T_3-T_2, the interincisal angle kept increasing considerably about 5.49 degrees in the treated group while the control group decreased only slightly about 0.23 degrees (Tables XIV and XXI).

TABLE XIV

Variable #23: U1-L1



GROUP = Treated, SYMBOL = T
GROUP = Treated, SYMBOL = C

Variable #24

The Overbite.

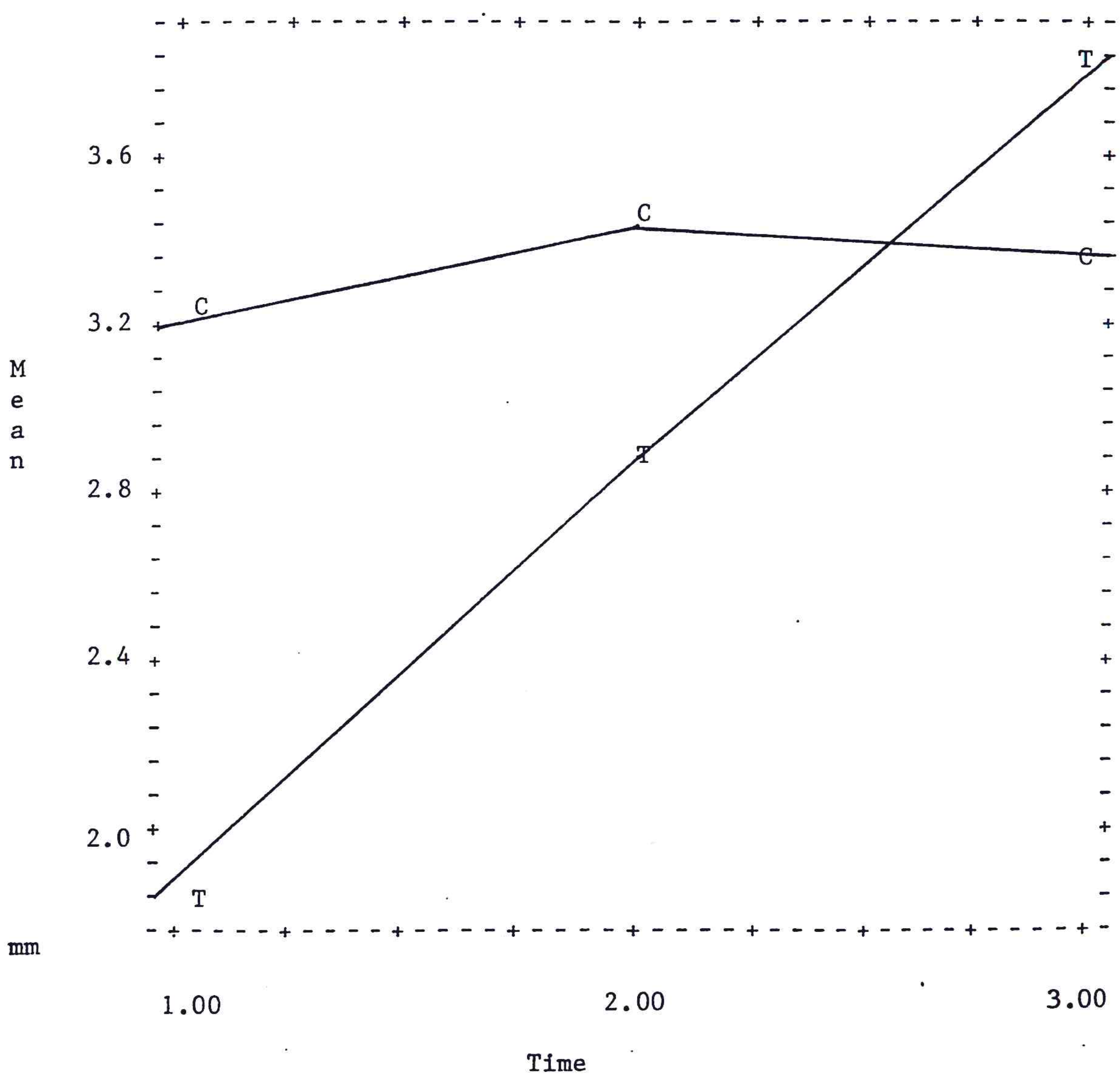
The analysis of variance and covariance with repeated measures demonstrated a significant interaction of time with group for the overbite at .01 level (Table XXII).

The t-test was significant at $time_1$, indicating that there was a difference between the groups during that time (Table XXIII).

But the plot of mean values against time illustrates how the overbite increases constantly during the two time periods (1.14 mm and 2.96 mm). Meanwhile the overbite for the control group increases 0.12 mm during T_2-T_1 and then decreases back 0.10 mm during T_3-T_2 (Tables XV and XXI).

TABLE XV

Variable #24: OB



GROUP = Treated, SYMBOL = T
GROUP = Treated, SYMBOL = C

Variable #25

The ANB Angle.

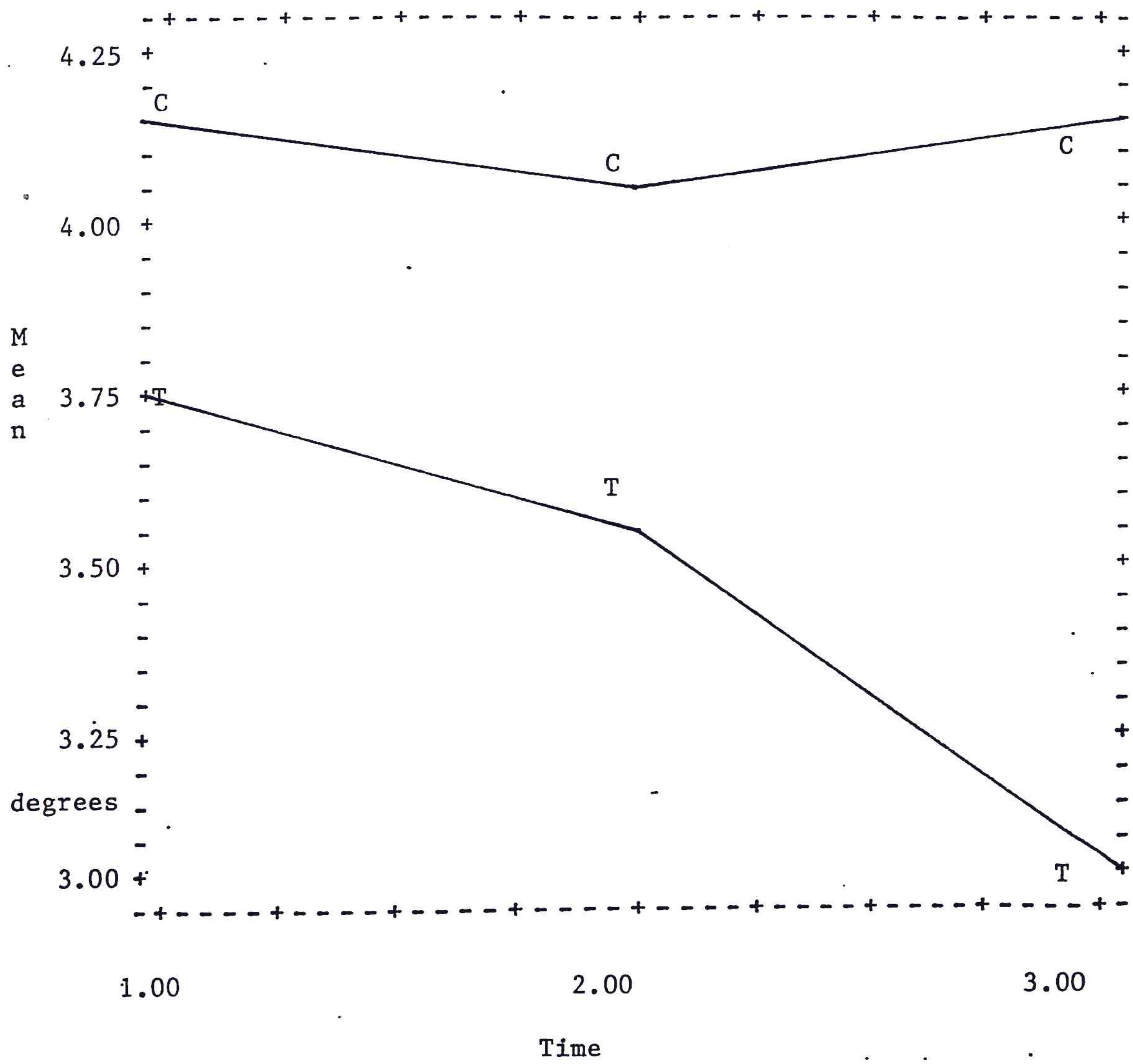
There was a significant interaction of time with group at .01 level demonstrated by the analysis of variance and covariance with repeated measurements (Table XXII).

Because of this interaction, the t-test was performed at $time_1$, $time_2$ and $time_3$ respectively. The t-test was found to be significant at $time_3$ with a $p < .05$ (Table XXIII).

A plot of mean values against time illustrates how the ANB angle for the control group remained almost constant during the two time intervals. Meanwhile, the ANB angle for the treated group decreased 0.17 degrees during T_2-T_1, and decreased another 0.53 degrees during T_3-T_2 (Tables XVI and XXI).

TABLE XVI

Variable #25: ANB



GROUP = Treated, SYMBOL = T
GROUP = Control, SYMBOL = C

Variable #26

Upper Incisor to Sella-Nasion Line.

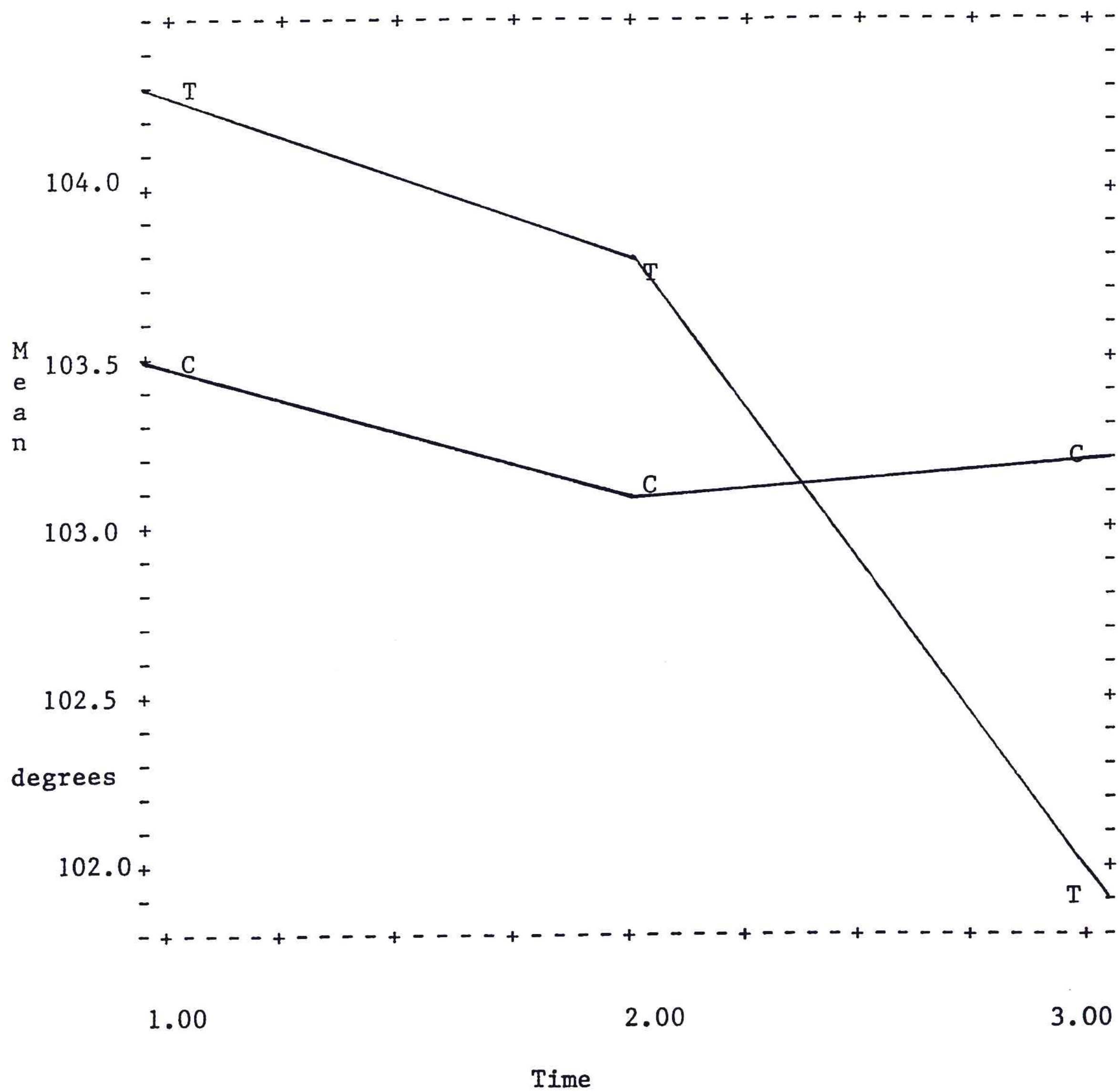
The analysis of variance and covariance demonstrated a significant interaction of time with group at .01 level (Table XXII).

The t-test did not indicate any significant results for $time_1$, $time_2$ and $time_3$ (Table XXIII).

A plot of mean values against time illustrates similar decrease for both groups during T_2-T_1. However during the second time interval, there is a decrease of 1.94 degrees for treated and 0.09 degrees increase for control group (Tables XVII and XXI).

TABLE XVII

Variable #26: U1.SN



GROUP = Treated, SYMBOL = T
GROUP = Control, SYMBOL = C

Variable #27

Lower Incisor to Mandibular Plane Angle.

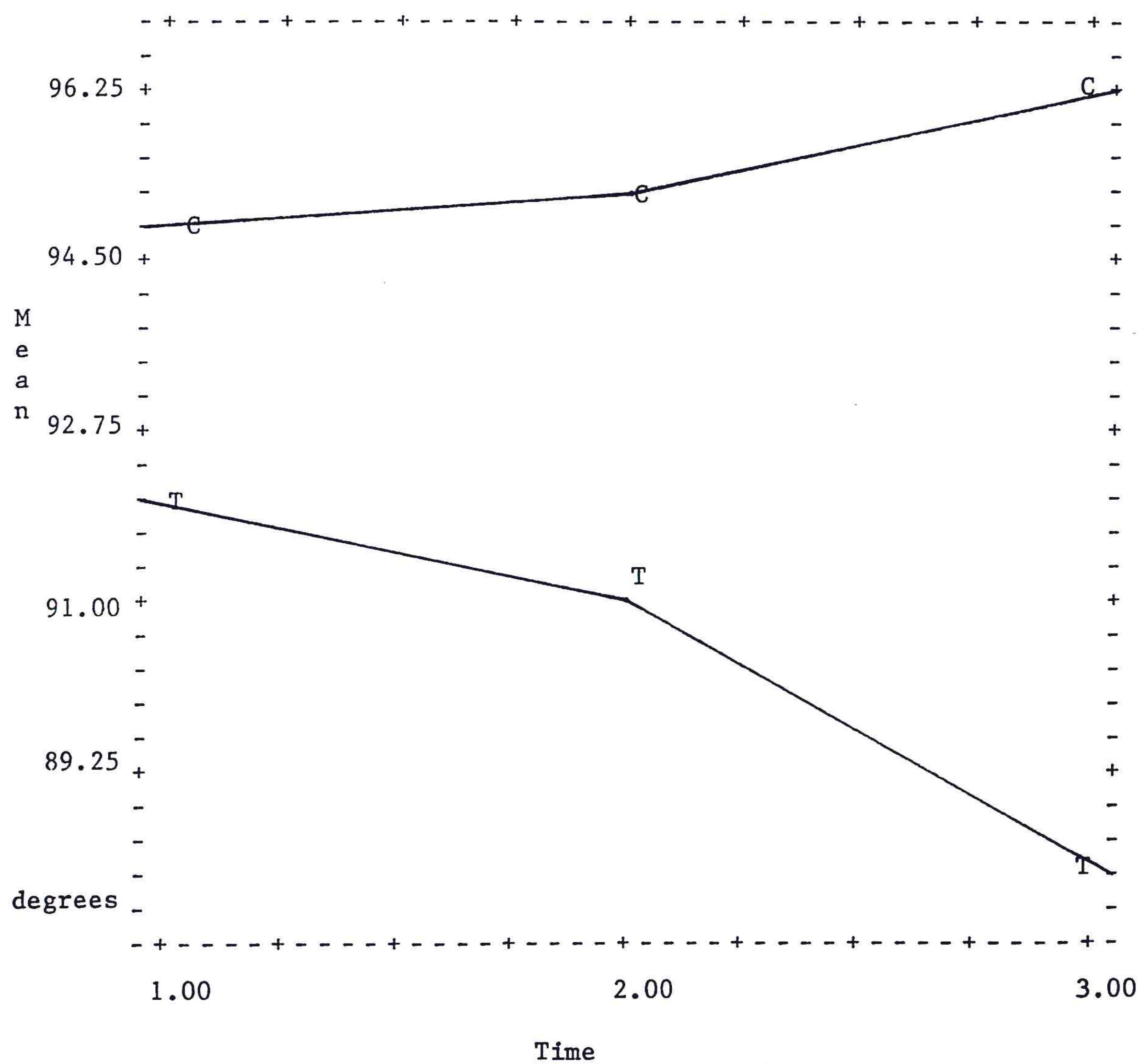
There was a significant magnitude of change for the lower incisor inclination demonstrated by the analysis of variance and covariance at .01 level (Table XXII).

The t-test was also signficant at $time_1$, $time_2$ and $time_3$ respectively (Table XXII).

The plot of mean values against time illustrates how the inclination of lower incisor is increasing in the control group while it's decreasing in the treated group. The increase in the control group is 1.34 degrees for T_2-T_1 and 1.03 degrees for T_3-T_2. The decrease in the treated group is 1.35 degrees for T_2-T_1 and 2.45 degrees for T_3-T_2 period (Tables XVIII and XXI).

TABLE XVIII

Variable #27: L1.MP



GROUP = Treated, SYMBOL = T
GROUP = Treated, SYMBOL = C

TABLE XIX

FREQUENCY DISTRIBUTION FOR DIRECTION OF CHANGE
TREATED T_2-T_1 COMPARED WITH CONTROL C_2-C_1

Variable	Group	Mandibular Protrusion N	Mandibular Protrusion %	No Change N	No Change %	Maxillary Protrusion N	Maxillary Protrusion %	Pearson Chisquare Test Prob. P Value
1. AR.A,Ar.B	T	5	14	28	80	2	6	0.6 (NS)
	C	4	11	27	77	4	12	
2. AR.SPr,SR.IPr	T	5	14	28	80	2	6	0.3 (NS)
	C	4	11	31	89	0	0	
3. MCF/PM AL	T	5	14	27	77	3	9	0.5 (NS)
	C	5	14	29	83	1	3	
4. RAM AL	T	1	3	33	94	1	3	0.3 (NS)
	C	4	11	29	83	2	6	
5. RMCF/SK	T	2	6	30	86	3	8	0.6 (NS)
	C	3	9	27	77	5	14	
6. RMCF/D	T	4	11	30	86	1	3	0.1 (NS)
	C	1	3	30	86	4	11	
7. Molar Posit.	T	2	6	32	91	1	3	0.8 (NS)
	C	1	3	33	94	1	3	
8. MX/MD AB/SK	T	6	17	27	77	2	6	0.4 (NS)
	C	6	17	24	69	5	14	

TABLE XIX (Continued)

Variable	Group	Mandibular Protrusion N	Mandibular Protrusion %	No Change N	No Change %	Maxillary Protrusion N	Maxillary Protrusion %	Pearson Chisquare Test Prob. P Value
9. MX/MD AB/D	T	5	14	28	80	2	6	0.6 (NS)
	C	4	12	27	77	4	11	
10. MX/MD SPr/IPr SK	T	6	17	26	74	3	9	0.7 (NS)
	C	4	12	27	77	4	11	
11. MX/MD Spr/IPr DENT	T	1	3	31	89	3	8	0.2 (NS)
	C	4	11	30	86	1	3	
12. PM VERT	T	3	8	31	89	1	3	0.5 (NS)
	C	2	6	30	86	3	8	
13. C.O ALIGN	T	3	9	27	77	5	14	0.4 (NS)
	C	4	11	29	83	2	6	
14. GONIAL ANG	T	2	6	31	88	2	6	0.6 (NS)
	C	3	9	28	80	4	11	
15. CSPEE-INC	T	0	0	33	94	2	6	0.2 (NS)
	C	1	3	34	97	0	0	
16. PAL PL AL	T	3	9	27	77	5	14	0.5 (NS)
	C	1	3	28	80	6	17	
17. INF MX PL	T	1	3	34	97	0	0	1.0 (NS)
	C	1	3	34	97	0	0	

TABLE XIX (Continued)

Variable	Group	Mandibular Protrusion N	Mandibular Protrusion %	No Change N	No Change %	Maxillary Protrusion N	Maxillary Protrusion %	Pearson Chisquare Test Prob. P Value
18. MX N/PPL	T	0	0	35	100	0	0	(NS)
	C	0	0	35	100	0	0	

TABLE XX

FREQUENCY DISTRIBUTION FOR DIRECTION OF CHANGE
TREATED T_3-T_2 COMPARED WITH CONTROL C_3-C_2

Variable	Group	Mandibular Protrusion N	Mandibular Protrusion %	No Change N	No Change %	Maxillary Protrusion N	Maxillary Protrusion %	Pearson Chisquare Test Prob. P Value
1. Ar.A,AR.B	T	7	20	25	71	3	9	0.5 (NS)
	C	4	11	27	78	4	11	
2. Ar.SPr,Ar.IPr	T	4	11	27	78	4	11	0.3 (NS)
	C	1	3	30	86	4	11	
3. MCP/PM AL	T	4	11	29	83	2	6	0.3 (NS)
	C	2	6	28	80	5	14	
4. RAM AL	T	0	0	33	94	2	6	0.3 (NS)
	C	2	6	31	88	2	6	
5. RMCF/SK	T	0	0	26	74	9	26	0.2 (NS)
	C	2	6	28	80	5	14	
6. RMCF/D	T	1	3	32	91	2	6	0.3 (NS)
	C	4	11	29	83	2	6	
7. Molar Posit.	T	1	3	33	94	1	3	0.8 (NS)
	C	2	6	32	91	1	3	
8. MX/MD AB/SK	T	6	17	27	77	2	6	0.7 (NS)
	C	8	23	24	69	3	8	

TABLE XX (Continued)

Variable	Group	Mandibular Protrusion N	Mandibular Protrusion %	No Change N	No Change %	Maxillary Protrusion N	Maxillary Protrusion %	Pearson Chisquare Test Prob. P Value
9. MX/MD AB/D	T	6	17	27	77	2	6	0.2 (NS)
	C	3	9	26	74	6	17	
10. MX/MD SPr/IPr	T	11	31	23	66	1	3	0.7 (NS)
	C	9	26	24	68	2	6	
11. MX/MD SPr/IPr	T	4	11	30	86	1	3	0.1 (NS)
	C	1	3	29	83	5	14	
12. PM VERT	T	1	3	30	86	4	11	0.8 (NS)
	C	2	6	29	83	4	11	
13. C.O ALIGN	T	9	26	26	74	0	0	0.03 * (p<.05)
	C	4	12	26	74	5	14	
14. GONIAL ANG	T	5	14	29	83	1	3	0.7 (NS)
	C	3	8	31	89	1	3	
15. CSPEE-INC	T	1	3	34	97	0	0	0.6 (NS)
	C	1	3	33	94	1	3	
16. PAL PL AL	T	1	3	28	80	6	17	0.4 (NS)
	C	2	6	30	86	3	8	
17. INF MX PL	T	1	3	27	77	7	20	0.5 (NS)
	C	2	6	29	83	4	11	

TABLE XX (Continued)

Variable	Group	Mandibular Protrusion N	Mandibular Protrusion %	No Change N	No Change %	Maxillary Protrusion N	Maxillary Protrusion %	Pearson Chisquare Test Prob. P Value
18. MX N/PPL	T	0	0	35	100	0	0	(NS)
	C	0	0	35	100	0	0	

* Statistically significant at .05 level.

TABLE XXI

MEANS AND STANDARD DEVIATIONS OF MEASURED VARIABLES IN THE TREATMENT AND CONTROL SAMPLES

Variable		T_1	C_1	T_2	C_2	T_3	C_3
1	$\bar{x}$	-1.4522	-1.2460	-1.5383	-1.3047	-2.9546	-1.1233
	SD	2.0522	2.1763	2.3573	2.4856	2.8338	2.5428
2	$\bar{x}$	0.5394	0.7924	0.6168	0.8345	0.1898	1.1035
	SD	1.7694	1.8120	2.0207	1.8695	1.9822	1.7880
3	$\bar{x}$	0.2121	-0.3785	0.1230	-0.6771	-0.0991	-0.3880
	SD	2.1168	2.5678	2.0888	2.4294	2.1146	2.5607
4	$\bar{x}$	2.0018	1.9253	2.2665	1.7973	2.6426	1.8767
	SD	1.8564	1.4527	2.2421	1.5237	3.3979	1.7455
5	$\bar{x}$	-2.6289	-1.9846	-2.5437	-1.3375	-0.9712	-0.5732
	SD	2.9406	2.6713	2.8549	2.3872	3.5107	2.8801
6	$\bar{x}$	-3.2336	-2.0015	-3.7097	-1.7702	-3.9250	-2.4765
	SD	3.1800	3.0926	2.8004	2.8630	3.1243	2.9374
7	$\bar{x}$	-1.2860	-0.8149	-1.4599	-0.8314	-1.6979	-1.0596
	SD	0.7834	0.5611	0.7786	0.6471	0.8487	0.5774
8	$\bar{x}$	-0.3053	0.0938	-0.2776	-0.1371	-3.3649	-1.0186
	SD	3.1102	3.0614	4.2487	4.1596	4.7046	5.2533
9	$\bar{x}$	-0.1650	-0.4299	-0.0772	-0.4720	-1.2556	-0.0624
	SD	2.1604	2.0257	2.2977	2.2645	3.0238	2.3827

TABLE XXI (Continued)

Variable		T_1	C_1	T_2	C_2	T_3	C_3
10	$\bar{x}$	1.7993	2.1325	1.8775	2.0022	-0.2202	1.2085
	SD	2.7659	2.8533	4.0009	3.3736	4.1571	4.3442
11	$\bar{x}$	1.8267	1.6086	2.0779	1.6671	1.8887	2.1645
	SD	1.9746	1.7023	2.0668	1.7281	2.2653	1.6611
12	$\bar{x}$	1.5260	1.9463	2.0067	2.2959	2.4281	2.1954
	SD	2.4129	2.7757	3.1041	2.6021	2.7677	2.7986
13	$\bar{x}$	1.1495	1.3338	1.2579	1.1992	0.1902	1.2244
	SD	2.4104	2.6283	2.7426	2.7556	3.1959	3.2552
14	$\bar{x}$	0.8798	-1.6664	0.1967	-1.8572	-0.5249	-2.3291
	SD	4.2504	5.0333	4.1889	5.3697	4.4631	5.5382
15	$\bar{x}$	2.2863	2.5858	2.6428	2.7075	3.4361	2.1652
	SD	1.6159	1.2760	1.3891	1.4557	1.8598	1.2084
16	$\bar{x}$	1.2753	-0.5520	1.7309	0.1872	3.1151	0.8809
	SD	4.4773	5.0188	4.5505	4.6132	4.9724	4.8885
17	$\bar{x}$	-7.4443	-3.8871	-8.6993	-4.7346	-7.5254	-4.9426
	SD	7.1312	5.8850	5.8644	5.8100	12.4459	6.2531
18	$\bar{x}$	4.0465	3.6254	3.6813	3.4437	4.6399	3.5122
	SD	2.7204	3.1147	2.5693	2.3662	3.7179	3.1497
19	$\bar{x}$	6.6286	5.7143	6.4143	5.9571	5.5571	6.1714
	SD	2.4173	1.6373	2.3024	1.6688	2.1171	1.7654

TABLE XXI (Continued)

Variable		T_1	C_1	T_2	C_2	T_3	C_3
20	$\bar{x}$	2.1143	1.8286	2.0571	2.1429	0.9714	2.3000
	SD	1.7826	1.6177	2.0065	1.4327	1.8548	1.5349
21	$\bar{x}$	66.3857	65.8857	66.2286	65.8143	65.6429	65.8286
	SD	2.7388	2.8156	2.9589	2.6460	3.1868	2.8951
22	$\bar{x}$	20.9143	20.2286	20.1714	20.1143	21.0571	19.7143
	SD	3.0134	3.2275	2.8644	3.8484	3.7569	3.8315
23	$\bar{x}$	128.3428	128.6571	130.7143	128.5428	136.2000	128.3143
	SD	9.3994	8.9507	9.1766	8.9553	8.2882	7.8357
24	$\bar{x}$	1.8000	3.2000	2.8429	3.4286	3.8000	3.3286
	SD	1.8198	1.4410	1.6305	1.2135	1.4562	1.2541
25	$\bar{x}$	3.7286	4.1429	3.5571	4.0286	3.0286	4.0857
	SD	1.8524	1.9462	1.8581	1.8863	2.1826	1.8290
26	$\bar{x}$	104.3143	103.5429	103.8286	103.0857	101.8857	103.1714
	SD	6.4842	5.9722	6.1140	6.3726	5.5135	6.1524
27	$\bar{x}$	92.1714	94.9714	90.8286	95.3143	88.3714	96.3429
	SD	5.1018	6.0366	5.9185	5.6348	5.4669	4.9464

TABLE XXII

ANALYSIS OF VARIANCE AND COVARIANCE
WITH REPEATED MEASURES: P VALUES

Variable	Group: Treated Versus Control	Time	TG: Interaction of Time with Group
1. Ar.A,Ar.B	0.1428 (NS)	0.0069	0.0006* $(p < .01)$
2. Ar.SPr, Ar.IPr	0.2552 (NS)	0.8976	0.0779 (NS)
3. MCF/PM AL	0.2882 (NS)	0.4414	0.2853 (NS)
4. RAM AL	0.3149 (NS)	0.4299	0.3504 (NS)
5. RMCF SK	0.2539 (NS)	0.0000	0.1257 (NS)
6. RMCF D	0.0232* $(p < .05)$	0.0385	0.3170 (NS)
7. Molar Posit.	0.0001* $(p < .01)$	0.0008	0.5599 (NS)
8. MX/MD AB/SK	0.2476 (NS)	0.0000	0.0477* $(p < .05)$
9. MX/MD AB/D	0.7241 (NS)	0.1827	0.0011* $(p < .01)$
10. MX/MD SPr/IPr SK	0.3935 (NS)	0.0003	0.2285 (NS)
11. MX/MD SPr/IPr D	0.7780 (NS)	0.1760	0.1029 (NS)
12. PM VERT	0.7939 (NS)	0.0298	0.2987 (NS)
13. C.O ALIGN	0.5191 (NS)	0.1035	0.1336 (NS)
14. GONIAL ANG	0.0612 (NS)	0.0002	0.3042 (NS)
15. CSPEE INC	0.2952 (NS)	0.1273	0.0000* $(p < .01)$
16. PAL PL AL	0.0890 (NS)	0.0000	0.5177 (NS)
17. INF MX PL	0.0259* $(p < .05)$	0.5204	0.7422 (NS)

TABLE XXII (Continued)

Variable	Group: Treated Versus Control	Time	TG: Interaction of Time with Group
18. MX N/PPL	0.3262 (NS)	0.2944	0.3591 (NS)
19. U1-APog	0.5862 (NS)	0.0083	0.0000* (p < .01)
20. L1-APog	0.3374 (NS)	0.0002	0.0000* (p < .01)
21. Y axis to SN	0.7182 (NS)	0.0109	0.0238* (p < .05)
22. OP to SN	0.3407 (NS)	0.4519	0.1713 (NS)
23. U1-L1	0.1104 (NS)	0.0000	0.0000* (p < .01)
24. OB	0.1271 (NS)	0.0000	0.0000* (p <.01)
25. ANB	0.1502 (NS)	0.0018	0.0040* (p <.01)
26. U1-SN	0.9567 (NS)	0.0007	0.0064* (p < .01)
27. L1-MP	0.0001* (p < .01)	0.0030	0.0000* (p < .01)

* : statistically significant

TABLE XXIII

COMPARISON OF TWO GROUPS WITH t-TEST
FOR THE VARIABLES WITH TG INTERACTION

Variable	P Values		
	$Time_1$	$Time_2$	$Time_3$
1. Ar.A,Ar.B	0.6847 (NS)	0.6879 (NS)	0.0059* ($p < .01$)
8. MX/MD AB/Sk	0.5902 (NS)	0.8892 (NS)	0.0531* ($p < .05$)
9. MX/MD AB/D	0.5984 (NS)	0.4716 (NS)	0.0711 (NS)
15. CSPEE INC	0.3924 (NS)	0.8495 (NS)	0.0012* ($p < .01$)
19. U1.APog	0.0689 (NS)	0.3449 (NS)	0.1918 (NS)
20. L1.APog	0.4850 (NS)	0.8377 (NS)	0.0017* ($p < .01$)
21. Y axis to SN	0.4540 (NS)	0.5390 (NS)	0.7993 (NS)
23. U1-L1	0.8865 (NS)	0.3199 (NS)	0.0001* ($p < .01$)
24. OB	0.0007* ($p < .01$)	0.0928 (NS)	0.1513 (NS)
25. ANB	0.3649 (NS)	0.2959 (NS)	0.0315* ($p < .05$)
26. U1.SN	0.6063 (NS)	0.6203 (NS)	0.3605 (NS)
27. L1.MP	0.0398* ($p < .05$)	0.0018* ($p < .01$)	0.0000* ($p < .01$)

*: statistically significant

DISCUSSION

The purpose of this study is to evaluate the skeletal and dental changes involved in Angle Class I cases treated with serial extraction procedures. In evaluating what will be described as treatment changes, one should keep in mind all of the other factors involved, such as the functional matrices, genetics and neurophysiologic events which are ongoing in the craniofacial complex of a growing individual.

The treated and control groups were matched as much as possible during $time_1$, before the treatment had begun. Among the measured 27 variables, the mean values of 4 variables were found to be quite different during $time_1$, for treated as compared to control groups. Those 4 variables are; ramus/middle cranial fossa dental horizontal dimension, inferior maxillary plane, the inclination of the upper incisor to A.Pog line and the amount of overbite. The differences in those variables could be assumed as being some of the underlying anatomic features that seem to identify with the treated cases at $time_1$ before any treatment had begun.

The ramus/middle cranial fossa dental horizontal dimension variable was found to have a higher negative value in the treated group at $time_1$ than in the control group. This would indicate an increased relative horizontal dental arch dimensions measured from Ar along REF. The changes that occur during the two time intervals will be discussed later.

The inferior maxillary plane at $time_1$ was found to be oriented in a clockwise direction in both groups contributing to mandibular protrusive effect. But the treated group appeared to present this tendency to a greater degree. The changes of this variable at $time_2$ and $time_3$ will also be discussed later.

The upper incisors were found to be more procumbent at $time_1$ in the treated group than in the control group. This could be due to the existing tooth size/arch length discrepancy in the treated group, with the presence of crowding as one of the reasons why serial extraction procedures are performed.

The last variable that seemed to be different at $time_1$ for the two groups was the amount of overbite. The treated group presented less overbite than the control group before the treatment had begun. As mentioned by Dewel (1967), Penman (1969) and many others, one of the undesirable effects of serial extraction was the deepening of the bite. This could explain the reason why only patients with minimal of overbite were selected to be treated by serial extraction procedures.

Skeletal Changes

Serial extraction procedures did not seem to have any effect on the regional directions of growth. All the variables in the counterpart analysis except one, indicated no directional change demonstrated by the frequency distributions. The corpus-occlusal alignment was the only significant variable for a directional change with a mandibular protrusive effect occurring after the extraction of four first premolars. However, this finding was not supported by the analysis of variance which indicated no significant magnitude of change. The occlusal plane to Sella-Nasion also indicated no significant changes of this angle for the two time periods. Therefore, it could be assumed that, this finding most probably had occurred by chance alone.

The inferior boundary of the nasomaxillary complex overall did not change in the treated group while the control group indicated a trend towards a clockwise rotation contributing to a mandibular protrusive effect. The decrease in the amount of clockwise rotation of the inferior maxillary plane would indicate less mandibular protrusive effect. This lack of clockwise rotation in the treated group could cause the lower anterior teeth to erupt as a compensation and this would explain the increase in curve of Spee. However, the palatal plane alignment and maxillary nerve/palatal plane remained constant.

The relative skeletal horizontal dimensions of the middle cranial fossa and ramus remained constant for both groups throughout the period evaluated. 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 relative to the middle cranial fossa.

The aggregate cranial floor/maxilla relative to ramus/corpus horizontal dimension at A point and B point, maxillary/mandibular arches skeletal dimensions A point compared with B point and ANB angle demonstrated a significant relative decrease for treated group contributing to mandibular a protrusion effect. The ramus width relative to the middle cranial fossa being constant during treatment time, the relative increase in mandibular bony arch length in the treated group could only be explained by an actual lengthening of the corpus through accelerated remodeling accompanied, perhaps, by some restriction of maxillary skeletal growth. The ramus alignment indicated no anterior positioning which would have lengthened the horizontal expression of the ramus.

Also, no changes were noted for middle cranial fossa/posterior maxillary relative alignment, PM compared with ramus/MCF vertical dimensions and the gonial angle alignment.

Dental Changes

The ramus/middle cranial fossa horizontal dental dimensions measured from Ar along REF and molar positions composite have decreased for the treated group during the two time periods contributing to relative mandibular protrusion. This finding would indicate a relatively more mesial drift of the mandibular first molars than the upper first molars. This drift actually occurred towards the extraction sites of the four first premolars. The control group also demonstrated some mesial drift but to a lesser extent than in the treated group (leeway space).

The maxillary/mandibular arches, dental dimensions, A point compared with B point indicated a relative increase in mandibular dental arch length in the treated group contributing to mandibular protrusion. This finding is supported by an actual horizontal mandibular skeletal arch lengthening. Even though there was a mesial migration of lower molars, no incisal flaring was noted. This finding is justified by having no significant increase in the same variable measured at IPr instead of B point. In fact, other variables such as L1-MP and L1-A.Pog were found to have decreased very significantly in the treated group, which would actually lead to an increase in the curve of Spee. The availability of space distal to the canines permits the lingual and distal tipping of the anterior teeth, which is why the interincisal angle had increased considerably in the treated group.

The recumbent lower incisors, increased interincisal angle and increased curve of Spee are the dental changes which explain the significant increase of overbite in patients treated with serial extraction procedures.

SUMMARY AND CONCLUSIONS

The focus of this study was to evaluate the treatment effects of serial extraction procedure on a sample of 35 growing Angle Class I individuals.

The objectives were to determine what were the anatomic features that seemed to identify with the treated cases before treatment, which particular anatomic parts were responsive to this treatment and finally whether the changes were skeletal, dental or both.

The treatment sample and matched control group each consisted of 17 males and 18 females spanning an average range of 7.9 to 12.0 years of age. Three radiographs for each individual were analyzed using the counterpart analysis of Enlow and some additional cephalometric measurements. This anatomic method is useful in determining morphologic and morphogenic relationships among regions within a given person. Frequency distributions were determined for 18 variables of the counterpart analysis in order to assess any directional change. In addition, analysis of variance and covariance was calculated for all of the 27 variables in order to determine any magnitude of change over two time intervals. The t-test at $Time_1$, $Time_2$ and $Time_3$ was done for the variables which indicated an interaction of time with group. Finally means and standard deviations were determined for 27 variables.

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

1. The treated group was representative of four underlying anatomic features at $Time_1$ before any treatment had begun. The ramus/middle cranial fossa dental horizontal dimension variable was found to have a higher negative value than in the control group, which would contribute to mandibular protrusive effect. The inferior maxillary plane at $Time_1$ was found to be oriented in a clockwise direction contributing also to mandibular protrusion. The upper incisors were found to be more procumbent at $Time_1$ in the treated group than in the control group. And finally the amount of overbite seemed to be less in the treated group before the treatment had begun.
2. The cumulative effects of the aggregate of changes in the composite of anatomic relationships evaluated in this study indicated that no directional changes have occurred when the two groups were compared to each other. Only the corpus/occlusal alignment indicated a mandibular protrusive effect and was significant at 0.05 level. However, there was no significant magnitude of change for the same variable which suggests that it might have occurred by chance alone.
3. Skeletal changes contributing to a mandibular protrusive effect included the aggregate cranial floor/maxilla relative to ramus/corpus horizontal dimension at A and B point and the maxillary/mandibular arches skeletal dimensions at

A point compared with B point. The relative skeletal horizontal dimensions of the middle cranial fossa and ramus remained constant over the two time periods. Then, the ramus width relative to the middle cranial fossa being constant, the relative increase in mandibular bony arch length could only be explained by an actual lengthening of the corpus through remodeling processes and/or some restriction of maxillary skeletal growth. This corpus lengthening would require an extensive remodeling and relocation of the ramus. The ANB angle also demonstrated a decrease in the treatment group. Finally, the inferior boundary of the nasomaxillary complex overall did not change in the treatment group while it underwent a clockwise rotation in the control group.

4. Dental changes contributing to a mandibular protrusive effect included the ramus/middle cranial fossa horizontal dental dimensions and molar positions composite which indicated a mesial drift of the first molars.

The maxillary/mandibular arches, dental dimensions, A point compared with B point demonstrated a relative increase in the mandibular dental arch length. The curve of Spee increased following a lack of clockwise rotation of the inferior maxillary plane and a decrease of L1-APog and L1-MP. Finally, overbite increased in the treated group following an increase of the interincisal angle and the curve of Spee.

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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 sphenoid 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).
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.