THE UNIVERSITY OF MANITOBA

CINEFLUOROGRAPHIC STUDY OF MANDIBULAR MOVEMENTS IN CLASS II DIVISION 2 MALOCCLUSION

by

Arthur Campbell Stone

A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES

IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE

OF MASTER OF SCIENCE

DEPARTMENT OF DENTAL SCIENCE

WINNIPEG, MANITOBA

February, 1971

ABSTRACT

Many hypotheses have been presented on mandibular posture and movements in Class II Division 2 malocclusion, however research has been limited to two cephalometric studies which have both concluded that some subjects have an anterior-superior mandibular path of closure while others have a posterior-superior path of closure. No attempt was made by the investigators to explain why the path of closure varies in Class II Division 2 subjects.

The most accepted hypothesis on mandibular movements and posture in this type of malocclusion is that there is a posterior-superior path of closure which represents a posterior displacement of the mandible necessitated by the angulation of the upper incisors.

The present investigation was undertaken to confirm the above findings that the mandibular path of closure from rest to the occlusal position varies in Class II Division 2 subjects and to consider some of the associated variables.

Selection was based on Class II Division 2 characteristics, with a wide age range necessitated by the low incidence of this type of malocclusion. The subjects were divided into two groups on the basis of the mandibular closure patterns from rest to initial contact position. Group 1 consisted of eight male and five female Caucasian subjects with an average age of 16.6 years, while Group 2 consisted of six male and 10 female subjects with an average age of 13.0 years.

A cinefluorographic analysis was used to determine the direction of mandibular closure from rest to initial contact to the full closure

position at four different points on the mandible, with the movements measured in relation to the palatal plane. The cinefluorographic filming was done at a film speed of 30 frames per second without the use of a head holding device. Mandibular rotational centres were calculated from these measurements.

Cephalometric analyses consisting of both angular and linear measurements and various model analyses were used to evaluate and compare the skeletal, dental, and soft tissue patterns of the two groups.

A cephalometric analysis utilizing rest and full occlusion radiographs was used to determine the mandibular path of closure from rest to full occlusion. The cephalometric results were compared to the cinefluorographic results in order to evaluate the use of head posturing devices in cephalometric radiography.

On the basis of the results of this study the following conclusions were made:

1. Cinefluorography appears to be an effective method of studying mandibular movements in the sagittal plane.

2. The mandibular path of closure from rest to initial contact was in a posterior-superior or superior direction for the group with the younger mean age. The results suggest that this direction of movement was made necessary by the retroclination of the upper incisors and the proclination of the lower incisors.

3. The mandibular path of closure from rest to initial contact was in an anterior-superior direction for the group with the older mean age. It is suggested that this normal direction of mandibular closure was made possible by compensatory changes in the lower dento-alveolar component, with the lower incisors tipping lingually as the mandible came forward with growth.

4. Notwithstanding the cross-sectional nature of the study, it is felt that the large variation in mandibular rotational centres seen among individuals is a reflection of changes in mandibular closure patterns which occur as a result of growth and developmental changes.

5. There was a "distal shift" of the mandible during the movement from initial contact to full closure, however the small magnitude of this posterior displacement suggests that its elimination would have very little effect on skeletal or dental relationships.

6. Class II Division 2 malocclusion appears to have a Class I or a mild Class II skeletal pattern with the mandibular dento-alveolar components positioned posterior to normal in adults probably due to compensatory changes in these components which occur with mandibular growth.

7. The skeletal differences between the two groups were primarily the result of mandibular growth in the group with the older mean age.

8. The significantly smaller angulation of the lower incisors to the mandibular plane in the group with the older mean age was probably the result of compensatory lingual tipping of the lower incisors as the mandible moved forward with growth.

9. The smaller overbite evident in the older subjects was probably due to mandibular growth and eruption of the posterior teeth.

10. The use of mechanical head posturing devices with ear rods appears to cause an alteration in the physiological resting posture of the head and mandible.

ACKNOWLEDGEMENT

I wish to acknowledge the supervision and guidance provided by Dr. J. F. Cleall, Head of the Department of Orthodontics, University of Manitoba during the period of this study.

I wish to thank Dr. L. Melosky and Dr. E. Cohen for their assistance.

A special thanks to Dr. R. Ryll for his assistance and encouragement.

The author would also like to thank Dr. F. S. Chebib for making possible the statistical evaluation of the raw data and his secretary, Miss I. Mikola for typing this manuscript.

The collection and assimilation of the raw data for a thesis represents the work and cooperation of many people. In this respect I would like to thank the following: Miss C. Brown, Miss G. Downs, Miss A. Jaikaran and M. L. Hryciuk of the Orthodontic Department, Mr. A. Domokos and Mr. A. Scott of the Art Department and Mrs. T. Oliver of the Dental Library.

Acknowledgement is given to the Radiology Department of the Winnipeg Children's Hospital.

I also wish to thank my fellow classmate Dr. John Murray and the class of 1971 Dr. R. Banack, Dr. W. Colby and Dr. J. Jensen for their encouragement and friendship.

This research was supported by Medical Research Council Grant MA-3541.

Finally, I wish to thank my family, Carolyn, Arthur Jr. and Craig for their many sacrifices and understanding which made this phase of my education possible.

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CHAPTER I

INTRODUCTION

An important and necessary aim of orthodontic treatment is the establishment of esthetic and functional balance between the hard and soft tissues at the completion of therapy. Without this state of equilibrium, the patient is a candidate for relapse or "physiological recovery" as some orthodontists choose to call it. Why then does the orthodontist not achieve this desirable state of balance for all of his patients? One answer is that very little is understood about the details of etiology, growth, or anatomical and functional development of the different classes of malocclusion. This is particularly true of Class II Division 2 (Class II (2)) malocclusions with whom physiological recovery is rather common. Graber (1966) states that a disappointingly small percentage of the cases of Class II (2) malocclusion maintain the overbite correction that has been accomplished with orthodontic appliances, and that the reason for this is obscure.

There appear to be several different treatment formulas for Class II (2) malocclusion. One opinion is that the mandible is "locked distally" by the retroclined upper incisor and the excessive overbite, and will move forward during treatment as the incisors are tipped labially; therefore, non-extraction therapy is routinely indicated. Another non-extraction approach utilizes mandibular growth to correct the dental and skeletal interarch relationships. Others consider these cases more stable when treated by extraction of upper first bicuspids and the acceptance of a Class II molar relationship. The extraction principle is also extended to include the routine removal of four bicuspids.

These attitudes are based on the operators' clinical experience with other Class II (2) cases. Oftentimes the choice of treatment may be largely empirical. Each method is correct if applied to the right case; therefore the problem is one of selecting the correct method for each individual case. This is only possible with an understanding of the growth and functional development of Class II (2) malocclusion.

Research in this field has been so limited that very little information is available upon which to build a hypothesis concerning anatomical and functional development of this type of malocclusion. However, clinical observations have prompted some interesting speculations which will be discussed later.

Several radiographic cephalometric investigations have attempted to show that Class II (2) is a separate entity with regard to skeletal pattern, however only minor differences from Class I have been observed.

Investigations on mandibular movements have shown that some Class II (2) subjects have an anterior-superior path of mandibular closure, from rest to initial contact position, while other have a posterior-superior path of closure, however no explanation or speculations were made by the investigators. This difference in mandibular function and the differences in treatment response have led to the feeling that more than one type of malocclusion is included in the Class II (2) classification, or these patients are being treated at different, unrecognized stages of anatomical and functional development of the same malocclusion type.

It was therefore decided that a cinefluorographic-cephalometric study of Class II (2) malocclusions should be undertaken with the following objectives.

1. To evaluate a new method of studying mandibular movements in the sagittal plane.
2. To determine the direction of the path of closure of the mandible from rest to initial contact position and from initial contact position to full closure position in the sagittal plane, thus investigating previous findings that the path of closure varied in Class II (2) malocclusions.
3. To group the subjects on the basis of their direction of mandibular closure and determine if these groups differ in their skeletal, dental, and soft tissue patterns and mandibular rotational centres.
4. To determine if and how these differences can be related to function, growth, and development.
5. To determine if there is a posterior displacement of the mandible after initial contact.
6. To determine if these results have clinical implications.
7. To determine if the use of mechanical posturing devices in cephalometric radiography has any effect on the physiological resting posture of the head or mandible.

It was hoped that the accomplishment of these objectives would lead to a better understanding of the function and development of Class II (2) malocclusion, thereby making the approach to treatment planning more of a scientific rather than an empirical endeavour.

CHAPTER II

REVIEW OF LITERATURE

I. CLASSIFICATION

The Angle Classification of malocclusion is based on the occlusal relations of the teeth using the maxillary first molar as the "key" to occlusion and to the classification. Dr. Angle stated, "Division 2 (of Class II) is characterized specifically also by distal occlusion of the teeth in both lateral halves of the lower dental arch, indicated by the mesiodistal relations of the first permanent molars, but with retrusion instead of protrusion of the upper incisors."

Since Angle's time there has been a certain amount of controversy over what constitutes a true Class II (2) malocclusion. The typical Class II (2) incisor orientation is one in which the maxillary centrals are retroclined and the laterals are proclined or are in their normal alignment. However Angle did not single out the central incisors, but spoke of retrusion of the upper incisors; therefore cases in which all four incisors are retroclined should not be omitted from this classification.

Robertson and Hilton (1965) described the Class II (2) complex as having a Frankfort mandibular plane angle often smaller than average and an occlusion built on a Class I or mild Class II skeletal base relationship. The upper buccal segments are positioned slightly farther forward than the lower, while the upper incisors are in close proximity to the lowers. There is a deep incisor overbite. They describe two types of incisor configurations in Class II (2) cases. In the typical or classical case the upper central incisors are retroclined, and the laterals are proclined and overlap the centrals. In the atypical case the upper incisors are all retroclined, and there is a lack of space for the upper canines.

Logan (1962) expressed his belief that distocclusion was not an essential element of the Class II (2) complex. He believed that the Division 2 complex could be found in all its essentials associated with either neutro, disto, or mesiocclusion. He prefers to refer to this type of malocclusion as "Deckbiss", meaning "coverbite". Logan felt that this term had the merit of not requiring the presence of distocclusion as did Angle's description, since neutrocclusion was present in about 35 per cent of 200 cases he examined.

Ridley (1960) appeared to agree with Logan by regarding retroclined upper central incisors as the prime determining factor for classification.

Ingervall (1968) studied mandibular positions in Class II (2) malocclusion subjects and used the following criteria for classification; distocclusion unilaterally or bilaterally, retroclined maxillary central incisors, and an overbite deep enough so that the lower incisors had to bite gingivally to the cingulum of the upper centrals.

Nicol (1955) saw the high lip line as an essential feature of Class II (2) malocclusion.

Even though there is some disagreement concerning the requirements for the Class II (2) classification, the most commonly accepted criteria are retroclined maxillary central incisors with or without retroclined lateral incisors, and a Class II or Class II subdivision molar relationship.

II. ETIOLOGY

Although the etiology of Class II (2) malocclusion is unknown, there have been numerous hypotheses, based only on clinical observations, proposed to explain the cause of the molar relationships and the unique maxillary incisor configuration.

In Angle's (1907) text, he stated, "In this division (2) there are no complications from pathological conditions of the nasal passages, hence the mouth is kept closed the normal amount of time, and the lips perform their function normally, which causes the retrusion of the upper incisors during their eruption until they come in contact with the already retruded lower incisors, resulting in a crowding of the upper teeth, in the canine region." Angle called attention to the excessive overbite in one of his case reports and attributes it to the fact that the molars had failed to erupt to their normal height and had allowed the lower incisors to come in contact with the vault of the arch while the incisal edges of the upper incisors had passed beyond the gingival margins of the lower. He believed that the lingual tipping of the lower incisors was due to the downward and inward tipping of the upper incisors, and that all Class II (2) cases followed this pattern.

In Case's "Dental Orthopedia", he termed Class II (2) malocclusion as a "general bi-maxillary infra-occlusion".

Vosmik (1939), reported on a questionaire, submitted to a group of orthodontists, which requested that all etiological factors found associated with Class II (2) cases be enumerated. The report listed the following:

1. Perverted functional activity of the muscles of the lips effecting

a backward driving force.

2. Excessive action of the mentalis muscles, either in a habit spasm or sucking action.
3. Perversion of the swallowing function, especially the first stage, in the form of exaggerated sucking action.
4. Premature loss of deciduous molars.
5. Hypertoned, tense musculature of lips.
6. Hypertrophy and overdevelopment of the musculature of the cheeks.
7. Nervous, high strung, temperament.
8. Malnutrition in early infancy pointing to disturbance of calcium metabolism.
9. Hypertrophy of the mentalis muscles, an almost universal finding in these cases.
10. Distal pull by muscles attached to hyoid bone.
11. Posture habit.
12. The retarded forward growth of the mandible due to muscular pressure, a constitutional condition, or both.

In 1935, the Eastern Component Group of the Edward H. Angle Society of Orthodontia published a clinical study of Class II (2) cases in which they concluded: "The etiological factors that seem to be associated with these cases are, primarily, a failure in metabolic or developmental processes resulting in lack of vertical growth in the molar and premolar regions of the dentures and, secondarily, a perversion of the sucking function which leads to an abnormal degree of growth and development of the sucking muscles particularly manifested in a hypertrophy of the mentalis muscles. These hypertrophied and abnormally acting muscles produce distal pressure upon the anterior portion of the body of the mandible, and sufficient retardation of the forward growth to effect a distal locking of the mandibular molar teeth. From then on the forces of occlusion aid in checking the forward growth of the body of the mandible" (Perry 1960).

Strang (1958) stated that heredity was a major factor in the etiology of Class II (2) malocclusion. Faulty growth patterns of facial and cranial structures are evidenced by the lack of vertical growth below the nasal area, and by the distal positioning of the mandible.

Graber (1963) pointed out that there is evidence that in Class II (2) patients, the tongue tends to accentuate the excessive curve of Spee and interferes with the eruption of the posterior teeth by occupying the interocclusal space. He also postulated that, due to the lingual inclination of the maxillary incisors combined with excessive freeway space, and infraocclusion of the posterior teeth, there is functional guidance of the mandible. The mandible closes from rest position to initial contact, then the lingually inclined maxillary incisors guide the mandible into a retruded position during the balance of the closing movement to full occlusal contact.

Logan (1962) surveyed 200 Class II (2) cases and derived his own theory of the etiology of this type of malocclusion. He postulated that there was an innate retroclination of the upper centrals and canines, and a forward positioning of the unerupted permanent canines which allowed a mesial drift of the upper buccal segments, thus forcing the laterals forward. The distocclusion was thought to be the result of the mesial drift of the upper buccal segments being greater than the forward movement of the mandible with growth.

Deglutition

Rix (1946) found that 27 of 93 children studied in the mixed dentition stage had a tooth apart swallow and that 81 per cent of these 27 children had malocclusion. He concluded that the tooth apart swallow was atypical and caused dental malocclusion.

This direct cause-and-effect relationship between abnormal swallowing and malocclusion was supported by Straub's (1951) work on the deleterious effects of "perverted swallowing".

Rix (1953) discussed the possible role of abnormal swallowing as a causative factor in Class II (2) malocclusion. He stated that if the mode of swallowing of these children is watched it is seen to have lost its suckling character, but their mode of swallowing is abnormal in other respects. It appears that their teeth are separated in the act and there is obvious tension of the sealed lips. The tongue is withdrawn and both of the lips exert an abnormally large force from the front. The upper incisors erupt into this adverse muscular field and become retroclined, overerupted and come under the control of the tense lower lip.

Backlund (1963) investigated facial growth and the relation of oral habiits and soft tissues to the skeletal pattern and arch form. She found that the occurance of a tooth apart swallow was four times as great among patients with a large freeway space.

Cleall (1965) concluded that the criterion of "tooth apart" as an indication of abnormal swallowing was not justified. The results of his cinefluorographic study of deglutition revealed that 40 per cent of a normal sample made no tooth contact during swallowing, while 60 per cent of both the Class II and tongue thrust groups made no tooth contact.

To summarize, the literature reveals varying opinions regarding the possible cause and effect relationships between functional and morphological changes in the development of Class II (2) malocclusion. There seems to be an almost common opinion that the soft tissue "functional matrix" plays a key role in determining the upper incisor configuration.

III. INCISOR ANGULATION

Maxillary Incisors

It is evident from clinical observations that the upper central incisors are more lingually inclined in the Class II (2) configuration than in the normal or in any other type of malocclusion. This was confirmed by Renfroe (1948) in a cephalometric study comparing the facial patterns of Class I, Class II (1), and Class II (2) subjects.

Nicol (1955) produced evidence suggesting a difference in the crown-root ratio of the upper central incisors in Class II (2) subjects. Ridley (1960) substantiated this finding by showing an abnormal crown-root angulation in 55 of 105 cases of Division 2.

Backlund (1958) showed that the crowns of the upper centrals in Class II (2) were thinner labiolingually than those in other classifications. She showed that the angle between the long axis of the upper centrals and the slope of the cingulum was less in Class II (2), and the lower incisors contacted more lingually on the cingulum or the gingiva.

Robertson and Hilton (1965) did a study confirming Backlund's finding that the crowns were thinner labiolingually at the cingulum in Class II (2).

Mandibular Incisors

While stating his hypothesis on how the upper incisors erupted into their characteristic position in Class II (2), Angle (1907) expressed the opinion that the lower incisors were also lingually inclined.

Brodie (1941) obtained means of 90.9°, 89.3° and 86.6° for lower incisor inclinations of 94 malocclusions of Class I, Class II (1), and

Class II (2) respectively, with respective ranges of 28, 35 and 42 degrees. Brodie concluded that the axial inclination of the lower incisor, like any other anatomic feature, varies greatly among patients and is probably just as much a part of an individual's pattern as are other details of his physiognomy.

Schaeffer (1949) studied incisor angulations in a sample of 47 children ranging in age from 7 to 21 years, which included one Class II (2) malocclusion. He found that the mandibular incisor-mandibular plane angle could increase, decrease, or remain stable during growth.

Baum (1951) studied children in the age group from 11 to 13 years with normal occlusion and compared them to an older age group. He showed that the mandibular incisors were more upright in the older group when measured from both the mandibular and occlusal planes.

Bjork (1951) concluded from a cephalometric study on 603 Swedes and 400 Bantus, that the inclination of the incisor teeth was related to the facial type, age, and other factors; possibly even sex. Bjork and Palling (1954) showed the angle between the lower incisor and mandibular plane decreased by 1.7 degrees between the ages of 12 and 20 years.

Ridley (1960) analyzed 105 cases of Class II (2) malocclusion and found only 13 cases in which the lower incisor-mandibular plane angle was greater than 94 degrees. She considered the normal to be 90±4 degrees. Although this study comprised a very large sample (105), it was mostly a subjective analysis with no statistical conclusions; therefore, it is impossible to make any comparisons with the present investigation.

In a longitudinal study of 50 randomly selected children Adams and Richardson (1967) found that the lower incisors proclined 13 degrees between age 5 and 13 years.

From the review of literature one can conclude that over a period of time the inclination of the lower incisors can remain stable, increase, or decrease depending on age, occlusion, and other factors; however due to the lack of research no conclusion can be drawn concerning Class II (2) lower incisor angulation changes.

IV. SKELETAL MORPHOLOGY

Several cephalometric studies have compared the skeletal morphology of Class II (2) to other classes of malocclusion to determine if Class II (2) is a separate entity.

Renfroe (1948) compared the facial morphology of 16 Class II (2) cases with 43 Class I and 36 Division 1 cases. He found that:

1. Class II malocclusions of both divisions are not characterized by any lack of development of the mandible. Adams (1948) concurred with this finding.
2. The angle of the mandible is larger in Class I than in Class II of either division.
3. The mandibular dental arch is posteriorly positioned in Class II (2), however the chin point is almost as far forward as in Class I.
4. The lower border of the mandible was slightly longer in Class II (2) than in Division 1 or Class I.

The smaller size of the Class (2) sample in this study as compared to the other classes would certainly make the conclusions questionable.

Blair (1954) found the mean skeletal pattern of Class II (2), when compared with those of Class I and Class II Division 1 differed in having a more acute gonial angle, a decreased effective length of the mandible, and a more forward position of the anterior outlines of both mandible and maxilla. He concluded that a high degree of variability of facial skeletal patterns could be seen within each class of malocclusion.

Ballard (1956) reported on 50 untreated Class II (2) cases compared with 250 randomly selected cases. The cranial base angle was significantly smaller in the Class II (2) group.

Wallis (1963) found that the measurements of the cranial base (BaN, BaS, BaSN angle) with the exception of the anterior cranial base (SN) were consistently larger in Class II (2) than either of the control samples. The gonial angle was more acute than that found in the Class I and Class II Division 1 mandibles. From these results, he concluded that the Division 2 malocclusion group represented a significantly distinct population, although he pointed out that there was considerable variation within all classes of malocclusion.

Houston (1967) compared 100 Class II (2) cases with Class I and Class II (1) samples and found very few significant differences. The overall cranial base length and the anterior cranial base length were greater in Class II (2) than in Class I, but similar to Class II (1). The gonial angle was smaller in Class II (2) than in the other classes, but all other mandibular measurements were similar.

These studies point out the great amount of variability of skeletal morphology within the different classes of malocclusion. The only consistent differences found between Class II (2) and the other classes were a more acute gonial angle and a longer cranial base. It appears that the Class II (2) incisor configuration can be imposed on either a Class I or a Class II skeletal pattern. The small number of measurements used in each of these investigations indicates that there is still a need for more thorough study of the skeletal pattern in Class II (2). The common standards for describing skeletal patterns established by Downs (1948), Holdaway (1956), and Riedel (1948) were not used in any of the above mentioned studies.

V. CINEFLUOROGRAPHY

Cinefluorography was used in research before 1953 by Saunders et al (1951), Rushmer and Hendron (1951) and others, however with the introduction of practical X-ray image intensifiers by Phillips in 1953, cinefluorography became one of the most useful tools available for the study of oral functions.

Ardran and Kemp (1954, 55 and 58) studied deglutition under both pathological and normal conditions.

Ramsey et al (1955) studied the orientation of glossopharyngeal structures during swallowing. Ramsey et al (1960) published a text entitled "Cineradiography".

Timms (1962) analysed the positional relationships of the tongue and lower lip during swallowing, and the proximity of the upper and lower molars.

Moll (1960) did cineradiographic research in the field of speech, and worked towards standardizing the technique.

Sloan (1965, 1967) applied cephalometric radiography to cinefluorography, and analysed hyoid movement patterns during deglutition in orthodontic patients.

Cleall (1965), using a standardized technique, revealed that changes in the local oral environment were accompanied by rapid adaptation of the oropharyngeal structures. Cleall *et al* (1966) studied head posture utilizing cinefluorography, and found no significant differences between normal, Class II, and tongue thrust groups.

Recent cinefluorographic studies were completed by Milne (1969) on the adaptation of oropharyngeal structures during the period of exfoliation of the deciduous incisors and eruption of the permanent incisors, and Yip (1969) on velopharyngeal functions before and after surgical removal of tonsils and adenoids.

VI. PHYSIOLOGICAL REST POSITION

The physiological rest position has been the topic of a considerable amount of discussion, controversy, and research. Various types of equipment have been employed to study it and many different methods have been used to attain it.

In 1908, Bennett stated, "I think that it is fairly obvious that the opposing muscles put the mandible into a position in which their tonic contractions balance, modified slightly by its own weight."

Niswonger (1934) was probably the first to define the rest position as we think of it today. He defined it as "that position of the mandible in which it is involuntarily suspended by the reciprocal coordination of the muscles of mastication and the depressor muscles, with the upper and lower teeth separated, or the neutral position of the mandible."

Gillis (1941), another early proponent of the constancy of the rest position, defined it as "that position from which all mandibular movements begin and to which they return." He believed the normal freeway space to be between 3.0 and 3.5 mm.

With the advent of cephalometric radiography came the pioneer work of Thompson and Brodie.

Brodie (1941) was the first to utilize these techniques in studying the physiological rest position of the mandible. An assumption existed at this time that in the new born either the bony alveolar ridges or gum pads were in apposition. Brodie found that in a relaxed new born infant; neither of the above conditions were true. He found that the jaws were wide apart with the lips closed, and the tongue occupied the entire oral cavity projecting between the alveolar processes to rest behind the lips.

Brodie's results also showed that the angle formed by the anterior cranial base and the lower border of the mandible remained constant from birth, and that increases in the distance from nasion to the bony chin describe a typical growth curve. These two results led him to believe that the body of the mandible was suspended in a position of physiological rest between the hyoid and skull by an equilibrium of muscular tension above and below it, and that growth, particularly of the alveolar processes, together with the eruption of the teeth toward each other gradually enclosed the tongue.

Thompson (1941, 1946) added to Brodie's findings by studying older age groups, which included subjects undergoing orthodontic treatment, edentulous subjects, full and partial denture subjects, and a group of randomly selected children. His results led him to conclude that the resting position was determined by a balance of musculature which suspended the mandible, and was not affected by either the presence or absence of teeth. He found that the average freeway space in the normal dentition was 2 to 3 mm, which is the value we accept today.

Thompson (1946) altered his original hypothesis of stability of the rest position by acknowledging the effect of disease.

That the stability of the rest position was not related to the presence or absence of teeth, was also shown by Sarnat and Brodie (1942) in a cephalometric appraisal of a boy with complete anodontia. Despite the absence of deciduous and permanent teeth, the mandible did not alter its form and maintained a constant vertical and horizontal relationship with the maxilla and cranium.

Moyers (1941) utilized electromyography to demonstrate that changes in mandibular posture correlated with muscle activity.

Ricketts (1952, 1955) using cephalometric laminagraphy, showed pre and post treatment records of the temporomandibular joint in which the changes cast doubt upon the constancy of the rest position or the manner in which it was obtained. These findings led him to believe that there was a hyperactivity of the protrusive muscles in Class II cases due to functional requirements, which positioned the mandibular condyles downward and forward in the fossa.

McNutt (1955) observed considerable differences in the rest position of the mandible in 25 young adults using cephalometric radiography.

Javois (1956) and Mullin (1956) illustrated the constancy of the rest position through the use of electromyography, and observed that slight electrical activity occurs in the postural muscles of the mandible while it is in the rest position.

To summarize, it is widely accepted that the rest position of the mandible is a constant position determined by the equilibrium of muscular and gravitational forces, however controversy still exists concerning the adaptive postures of the mandible associated with morphological variations.

VII. MANDIBULAR MOVEMENTS

Abnormal mandibular movements and displacements are likely achieved through alteration of conditioned reflexes. A reflex is an involuntary activity mediated by the components of a reflex arc; the receptor, conductor and effector. The sensing components of the reflex arc in the stomatognathic system are the receptor organs, located in the temporomandibular joint, the periodontal and muscle ligaments, and among the fibres of the muscles concerned with head posture and mandibular movement. The conducting elements are neurons carried in the nerve supply to these various receptors, internuncial neurons providing connections in the central nervous system, and the nerve supply to the effector muscles. The masticatory muscles are supplied by branches of the fifth cranial nerve, however the suprahyoid, infrahyoid, and posterior neck muscles are also involved in the complex control of head posture and jaw motion. Ascending and descending fibre tracts in the brainstem provide connection with the cerebellum, lower cortical levels, and cerebral cortex to establish the higher centre control of reflex activity; completing the components of a servomechanism.

It is believed that the posture of the mandible is at least partly controlled by proprioceptors (in the temporomandibular joint and muscles) which are primarily important when the teeth are not in occlusion. In closing from non-occlusion to occlusion, if certain stimuli arise which signal incorrect posture of the mandible, the system will accomodate to achieve a position of occlusion that will bring the maximum harmony and protection to the teeth, their supporting structures, and the joints. This pattern of neuromuscular activity is thought to establish a habitual pathway within the neuromuscular circuit which will allow circumvention at the initial contact and thus provide a direct path to the occlusal position. In Class II (2) malocclusion, this could be occuring as the maxillary incisors erupt into an extreme lingually inclined position.

One of the early studies on mandibular movements, by Campion, was published in 1905. He found that there could be no one axis about which the mandible moves in opening and closing the mouth; and that the movement was a complex one consisting of rotation around an axis passing through the centre of the condyles, and secondarily of a forward and downward translation of the condyles.

Higley and Logan (1941) found that 70.6 per cent of young adults performed a sliding movement ("forward shift") of the condyles from intercuspal position to "approximately physiologic rest position" (2 mm opening). This study is of very little value in understanding mandibular movements since we know that there is great variation in the amount of freeway space and that the rest position certainly could not be set at a 2 mm opening. The sample was described as relatively normal which leaves undefined the types of occlusion which are being studied.

Thompson (1946), using composite cephalometric tracings of the rest and full occlusion position, showed an upward and backward path of closure of the mandible in Class II (2) cases and also in other types of malocclusion.

Thompson (1954) stated that on closure from an open mouth position the mandible closed directly into the position of displacement without being directed by the dental interference due to neuromuscular adaptation which serves to protect the supporting tissues of the teeth. He added that on closure from rest position, the mandible makes initial contact and continues to close on an abnormal path into an abnormal occlusal position.

Blume (1947) used Lindbloms (1957) temporomandibular roentgenographic technique to study the mandibular closure path in 21 Class II Division 1 malocclusions. He found that 16 of these subjects exhibited an upward and backward path of closure, and in these cases the relationship of the upper and lower posterior teeth, with the mandible at rest, was near normal, while the remaining five cases were "true Class II malocclusions". Blume also pointed out that the movement of the head of the condyle in the subjects with an upward and backward mandibular closure pattern was primarily of a translatory nature, while the condylar movement was rotary for the upward and forward patterns.

Using the same method as Blume, Boman (1948) did a study on the mandibular closure patterns in a normal sample. He showed that 88 per cent of the subjects had an upward and forward path of closure from rest to occlusion. His conclusions were the same as Blume's concerning the type of condylar movement involved. The path of closure was measured in relation to the sella-nasion plane by both Blume and Boman.

As mentioned earlier, the use of mechanical head posturing devices in cephalometric radiography probably have an effect on the physiological resting posture of the mandible (Cleall 1966). Therefore, the use of

Lindblom's technique, which employs a head holding device, by both Boman and Blume; could cast some doubt on the validity of the rest position in these studies. The method of determining the type of condylar movement (rotary or translatory) with two static cephalometric radiographs of the temporomandibular joint is also questionable.

Glowacz and Boman (1951) examined 18 of Blume's subjects who had undergone complete orthodontic treatment, and found that in 16 cases the translatory movement had changed to a rotatory type of movement.

Utilizing radiographic laminagraphy of the temporomandibular joint, Ricketts (1950, 1952) found that 66 per cent of his Class Division 1 sample exhibited an upward and backward path of closure of the mandible from rest to occlusion. He concluded that this was due to the downward and forward positioning of the mandible in rest position in accordance with functional requirements. His Class II (2) sample had an average path of closure in an anterior-superior direction.

Ricketts method of registering the rest position is questionable. He had the patient achieve the rest position while in an upright position using standard procedures. A plaster core was made of the rest position by injecting plaster between the teeth with a syringe. This core was held in the patients mouth during the laminagraphic filming in the prone position.

Posselt (1952) used cephalometric radiography to investigate the movements of the mandible in 65 dental students, ranging in age from 20 to 29, with no classification of the occlusion. Using the sella-nasion plane as reference, he found that 14 of the cases exhibited an upward and backward path of closure. The main criticism of this study is the type of sample used. It may have included all types of malocclusion with missing teeth and numerous other dental problems. This would introduce so many variables into the study that conclusions could not be applied to the population and would, therefore, be valueless.

Donovan (1953) found a "vertical drop" of the condyles in 20 of 25 children, however he still considered a "rotary movement" to be normal in adults.

In a cephalometric study on 50 children (86 per cent of them having malocclusion), Thorne (1953) found a general backward displacement of gnathion point in closing from rest to occlusion. Deviation varied from -0.3 mm to 6.3 mm with 14 cases having more than 2 mm of backward deviation.

From clinical observations, Grewcock and Ballard (1954) concluded that the downward and forward position of the mandible in Class II (2) malocclusion occurred in centric jaw relationship and that the movement from this position to occlusion was a bilateral distal displacement produced by abnormal cuspal contacts. Ballard (1956) showed that this conclusion was wrong since the mandible in Class II (2) cases was postured downward and forward to produce and maintain an anterior oral seal. The movement from this "habitual postural position" could not be a true distal displacement from centric relation. This forward posturing of the mandible was thought to occur in speech or any function necessitating lip contact. Although such reasoning is sound, it should be pointed out that it is substantiated only by clinical observations which are hardly adequate as a basis for theories.

Lead pellets were attached to the teeth as indicators in a cephalometric study of mandibular movements by Nevakari (1956). The movements of the pellets were measured in relation to the Frankfort horizontal plane of 137 dental students whose occlusion was not classified. The results indicated that 20 per cent of the subjects had a posterior-superior path of closure. The average centre of rotation was near the mastoid process. The same criticism can be made of this study that was made of Posselt's since there were no restrictions on selection of the subjects other than that of being a dental student. Another criticism of this study would be the use of lead pellets stuck to the teeth with wax, and sticks as indicators. These could prove to be unphysiological.

Superstine (1957) used rapid serial radiography in studying the centre of rotation of the mandible in children. He showed that the mandibular movements in children were different from those in adults.

Knowles (1958) pointed out the role of retained deciduous molars in the production of mandibular displacement in two cases.

In a paper presented before the Angle Society, Perry (1960) expressed his belief that if the maxillary incisors have an extreme lingual inclination as in Class II (2), and the incisor occlusal plane is at a different vertical level than that of the maxillary buccal segments, a distal displacement could result. He felt that in these instances the temporal muscles retract the mandible from the premature contacts, and a maximum occlusion is achieved in a distal position.

Steiner (1960), in a panel discussion on mandibular displacement and Perry's (1960) paper, expressed his belief that the rest position was not necessarily constant over a life time, and was not a logical base from which to judge mandibular displacement. He did not believe that an upward and backward path of closure necessarily implied a mandibular displacement. Using cephalometric radiographs, he found that 65 per cent or more of his Class II Diviision 1 patients closed upwards and backwards from rest to maximum occlusion.

The latest studies on mandibular movements were completed by Ingervall. In 1966, his study of a Class II Division 1 sample showed that the mandible moved in a posterior-superior direction from rest to the intercuspal position. In 1968 he completed a study on 22 Class II (2) malocclusions with a mean age of 11 years and 6 months. He measured the movement of two points in relation to the occlusal plane, and found that point infradentale moved 0.8 mm posterior and 3.8 mm superior from rest to the intercuspal position.

VIII. CENTRE OF ROTATION OF THE MANDIBLE

Tomes and Dolomore (1901) reported that there was no single fixed centre of rotation of the mandible and the centres lie 1.5 inches below the condyle and considerably behind it.

Campion (1905) also denied the existence of one axis about which the mandible rotates.

Bennett (1908) used lamps attached to a face bow fixed to the mandible, and projected the movements onto a wall. Using Reuleaux's method of location of instantaneous centres of rotation of the jaw, he found that movements of the mandible did not consist simply of rotations about the condyle, but that the centres of rotation were constantly shifting. He found that even with very small separations, there was some forward movement of the condyles.

Frank (1909) found that the first part of the opening movement of the mandible was a hinge like movement with the centre of rotation located at the intersection of the horizontal plane from the tip of the lower incisor to the cusp tips of the lower third molar with the perpendicular plane passing behind and touching the condyle.

Wadsworth (1925) reported that during the first depressive movement of the mandible, the jaw opened around a transverse axis passing through the condyles, with the condyles remaining seated in the fossa.

Kurth's (1943) employed graphic tracings and stroboscopic pictures to show that the centre of rotation of the mandible was near the mandibular foramen.

Thompson (1941), using cephalometric tracings, reported that the closing movement of the mandible from rest to occlusion was a hinge movement with the fulcrum located in the lower one half of the temporomandibular joint.

McCullum (1943) hypothesized that the condylar movements were constant throughout life unless joint disease intervened, and that the condyle had a definite opening and closing axis.

Through the use of cephalometric radiography, Boman (1948) showed that the centre of rotation of the mandible in his normal sample varied in location from the superior border of the condyle down through the condyle to a place below it.

Granger (1952) agreed with McCullum that the hinge axis was that line through the condyles, constant to the mandible, which determined the arc of closure upon which the teeth met in every contacting position of the mandible. He believed that all rotating movements of the condyle took place around the same centre.

From observations of graphic and roentgenographic recordings Posselt (1952) concluded that the mandible changed from intercuspal to rest position by a bodily movement. This confirmed the work of Gysi (1910) and Hildebrand (1936).

Nevakari (1956) used composite tracings of rest and occlusal radiographs to calculate the geometrical rotary axis of the mandibular movement from rest to full closure. He found that the movement was never of a pure hinge type with the axis through the condyles. Although the centre of rotation showed great variation, its location was mainly in the vicinity of the mastoid process.

Superstine (1957) used composite cephalometric tracings and Reuleaux's method to calculate the centres of rotation of the mandible in children. His results supported Bennett's original findings that the centre of rotation of the mandible may be constantly shifting. The average centres were clustered posterior to the angle of the mandible, with very few within the ramus or in front of the condylar area. He also showed extreme variation of the centres during each opening and closing sequence in the same child.

The variations in the results of these studies probably reflect the differences in the samples studied and the differences in the equipment and methods used.

IX. SUMMARY

A review of the literature reveals that much has been said about etiology, growth, and mandibular movements and/or displacements in Class

II (2) malocclusion, although very little research has been carried out in this field. The reason for this lack of research probably lies in the very low incidence (4 per cent) of this type of malocclusion. However, it is believed that research in this field could answer many of the unanswered questions concerning etiology, growth, and soft and hard tissue functions in all types of malocclusion.

The accepted direction of closure of the mandible in Class II (2) malocclusion appears to be in a posterior-superior direction, but a more thorough look at the literature reveals that this is only true in a part of the cases. Why are there differences in the direction of closure of the mandible from rest to occlusion within this malocclusion group? Are there differences in these subjects that could account for the differences in paths of closure of the mandible? The answers to these questions represent the main objectives of this study.

CHAPTER III

MATERIALS AND METHODS

I. SAMPLE

The sample consisted of 14 male and 15 female Caucasian subjects. Their ages ranged from 11 to 25.5 years; the average age was 14.5 years. Three of the subjects were students at the University of Manitoba Dental College, two were referred by practicing orthodontists and the remainder were seen in the Orthodontic Screening Program at the Dental College.

All of the subjects had Class II (2) malocclusions (Angle). The criteria for this classification, some of which are illustrated in Figures 1, and 2, are listed below.

1. Retroclined maxillary central incisors.
2. Proclined maxillary lateral incisors.
3. Bilateral or unilateral Class II molar relationship.
4. A complete, acceptably restored permanent dentition not necessarily fully erupted (third molars excluded).
5. No crown or onlay restorations.
6. No previous orthodontic treatment.
7. No history of muscular disorders or temporomandibular joint dysfunction.

II. CINEFLUOROGRAPHY

Equipment

The cinefluorographic equipment used in this study was provided by the Radiology Department of the Winnipeg Children's Hospital. The basic components of the cinefluorographic setup are diagrammatically represented in Figure 3. The equipment consisted of an X-ray source, a six inch automatic electronic image intensifier, a movie camera, and

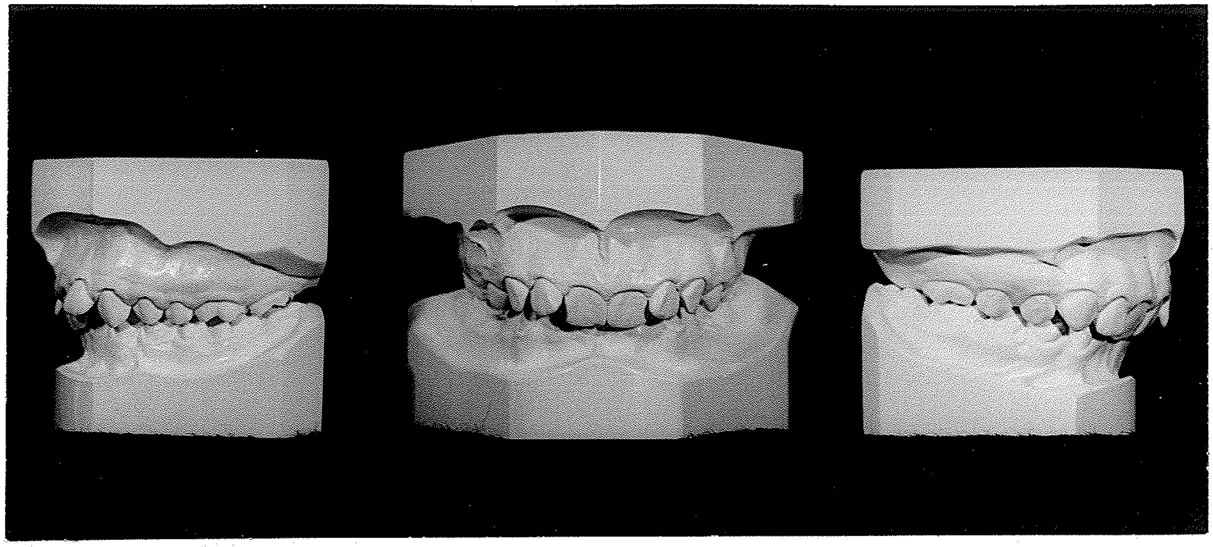

Figure 1. Photograph illustrating typical Class II Division 2 incisor configuration in centre, Class II molar relationship on left and Class I molar relationship on right.

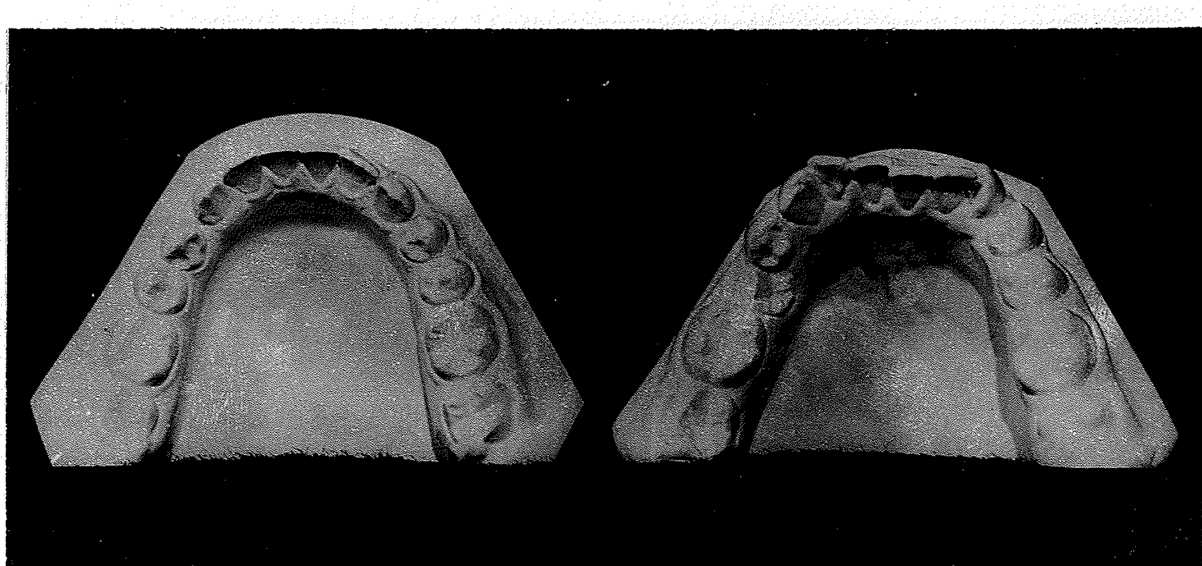

Figure 2. Photograph illustrating typical mandibular arches in Class II Division 2 malocclusion.

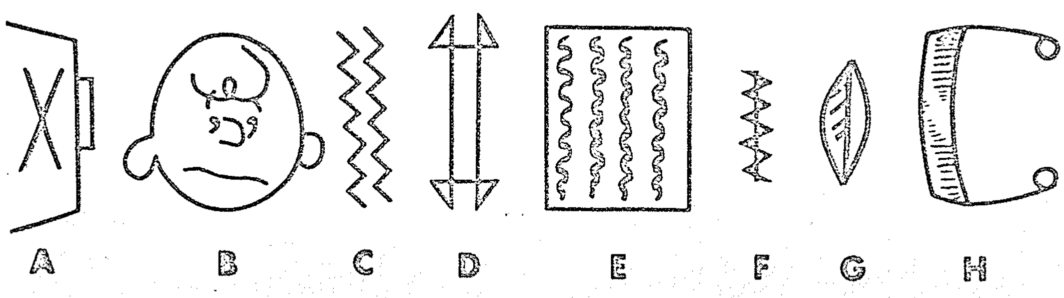

Figure 3. Basic components of the cinefluorographic equipment used in this study. (A) X-ray source; (B) patient; (C) X-ray image; (D) input phosphor; (E) image intensification device; (F) intensified image from output phosphor; (G,H) lens system and cine camera.

a television monitoring system, all manufactured by General Electric.

A plastic frame with a radiopaque true vertical marker was constructed and attached in the viewing field so that a true vertical line was recorded on each film frame. This allowed evaluation of head posture and sagittal movement.

A headholder was not used since it has been suggested (Cleall 1965) that anything that interferes with the movement of the head and associated structures may prove to be nonphysiological. This finding was substantiated by the present study and will be discussed in detail later.

The automatic electronic image intensifier was sychronized with the movie camera set to expose 30 frames per second. Various film speeds have been used in cinefluorographic studies. Ramsey (1955) and Cleall (1965) studied soft tissue movements using 60 frames per second, while Sloan (1967) used 24 frames per second to study hyoid bone excursions. The use of faster film speeds allows the recording of the very small and extremely rapid movements of oral structures, however, the exposure values must be increased causing the patient to receive a higher radiation dose.

The use of high speed emulsion "fast film" reduces the amount of radiation needed. Due to loss of resolution during image intensification a fine grained film is required. Therefore Ilford Pan F* film, a fast very fine grain film, was used to give the delineation of hard tissues required in this study.

A Tagarno 16 Movie Projector, shown in Figure 4, was used to edit

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* ILFORD, Essex, England

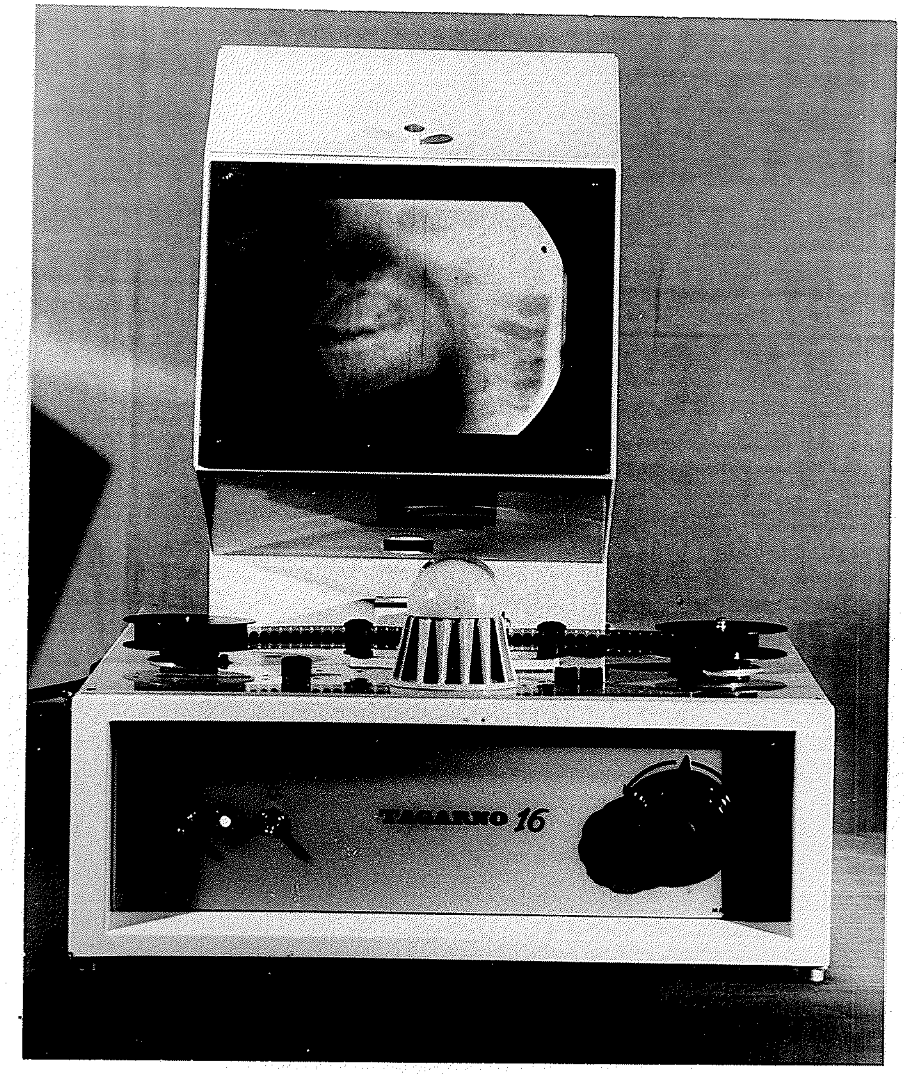

Figure 4. Photograph of Tagarno 16 Movie Projector used to select individual frames for cinefluorographic analysis.

the films for selection of the frames to be measured. This type of editor allows the operator to run the film at varying speeds and to stop at a desired frame. After the desired frames were selected, the film was transferred to a Vanguard Motion Analyser (Figure 5) for analysis. The analysis involved selection of the points to be measured and recording the coordinates of these points.

Radiation

The radiation dose in cinefluorography has been greatly decreased by the use of image intensification and unit synchronization. The following additional procedures have been employed in this study to reduce the radiation exposure to the subject.

1. The use of a lead apron covering all areas of the body except the head.
2. Framing the study area by using the television monitoring system.
3. The use of short exposure times (40 second).

The cinefluorographic equipment was tested using the method reported by Milne (1969). The average screening time was 40 seconds resulting in a total dose of 600 milliroentgens. This is equal to the radiation received during the exposure of three periapical dental radiographs. Since the roentgen unit measures the amount of ionizing radiation in the air, it does not indicate the amount of radiation absorbed by the tissue, which is measured in rads. Conversion to rads gives a tissue dosage which is well within the acceptable range for radiographic diagnostic procedures.

Technique

The cinefluorographic sequence was filmed with the patient seated

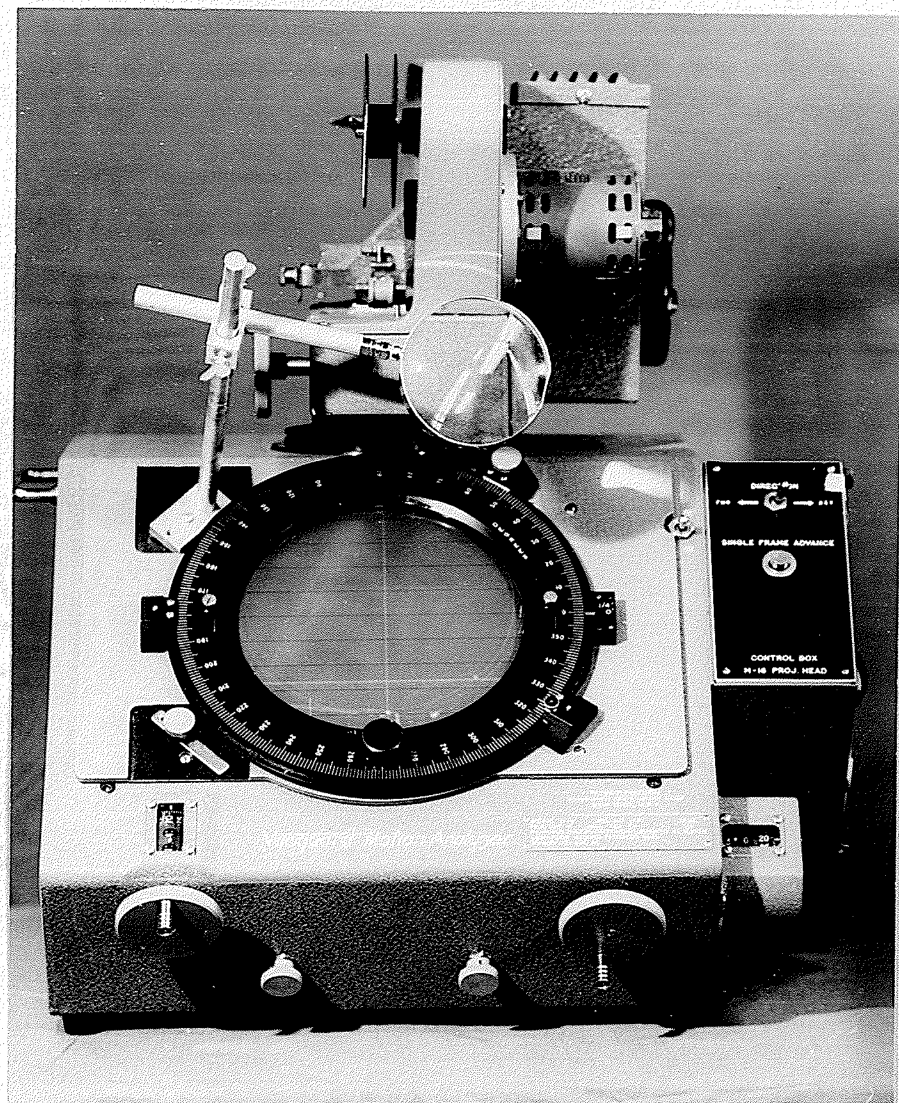

Figure 5. Photograph of Vanguard Motion Analyser on which individual cinefluorographic frames were analysed.

on a stool, looking at his reflection in a mirror placed at eye level and some distance away. Using fluoroscopy technique and the television monitor, the area to be filmed was framed and adjustments of the head in the coronal plane were made to eliminate blurring of the structures to be studied. Filming was limited to sagittal plane projections.

The monitor was used to determine when the mandible was in the physiological resting position. Then the following series of command sequences were given.

1. Say "Mississippi" (pause), close on your back teeth.
2. Wet your lips (pause), close on your back teeth.
3. Swallow (pause), close on your back teeth.
4. Say "Peter looks silly swimming" (pause), close on your back teeth.

The sequences which produced the rest position were repeated until several acceptable sequences were recorded. The most successful sequence for observing rest position in various subjects was number one, in which the term "Mississippi" was used.

III. ANALYSIS OF RECORDS

The following records were taken on each subject.

1. A clinical examination to determine if the subject was suitable for the study.
2. A brief medical and dental history.
3. Alginate impressions of both arches with wax registrations of the teeth in occlusion.
4. Lateral cephalometric radiographs with the mandible at the physiological resting position and at the full closure position.
5. A cinefluorographic sequence involving speech, swallowing and closure of the mandible.

Cinefluorographic Analysis

Selection of Points and Positions

Four points on the mandible were chosen for analysis so that not only a determination of the direction of closure, but also a study of other characteristics of the movement might be undertaken. The locations of these landmarks are illustrated in Figure 6 and are as follows:

1. The incisal tip of the most labially positioned mandibular incisor (LI).
2. The bifurcation of the roots of the mandibular right first molar (LM).
3. The most anterior point on the bony chin (Pogonion-Po).
4. The most inferior point on the bony symphysis (Menton-M).

The palatal plane was chosen as a reference line for this analysis because it could be accurately determined from frame to frame and has been shown to be almost perpendicular to a true vertical line. Cleall (1966), in a study of head posture, found this angular relationship to be 87.7 degrees in his normal sample and 88.3 degrees in his Class II sample. Ingervall (1968) used the occlusal plane as a reference plane in his cephalometric study of mandibular positions in Class II (2) malocclusion subjects. Two reference points on the palatal plane, illustrated in Figure 6, were used to provide an origin and direction for the coordinate analysis. Reference point A was at the intersection of a perpendicular from "A" point (subspinale point) to the palatal plane. Reference point B was at the intersection of a perpendicular from the most anterior point of the pterygomaxillary fissure to the palatal plane.

The frames to be analysed were selected on the Tagarno 16 film editor and marked. The film was then transferred to the Vanguard Motion Analyser and the coordinates of the six required points were determined. Three frames were selected for each subject on the basis of the following mandibular positions.

1. Physiological Resting Position (R) The subjects usually assumed this position more readily after speech sequences rather than when swallowing or wetting the lips.

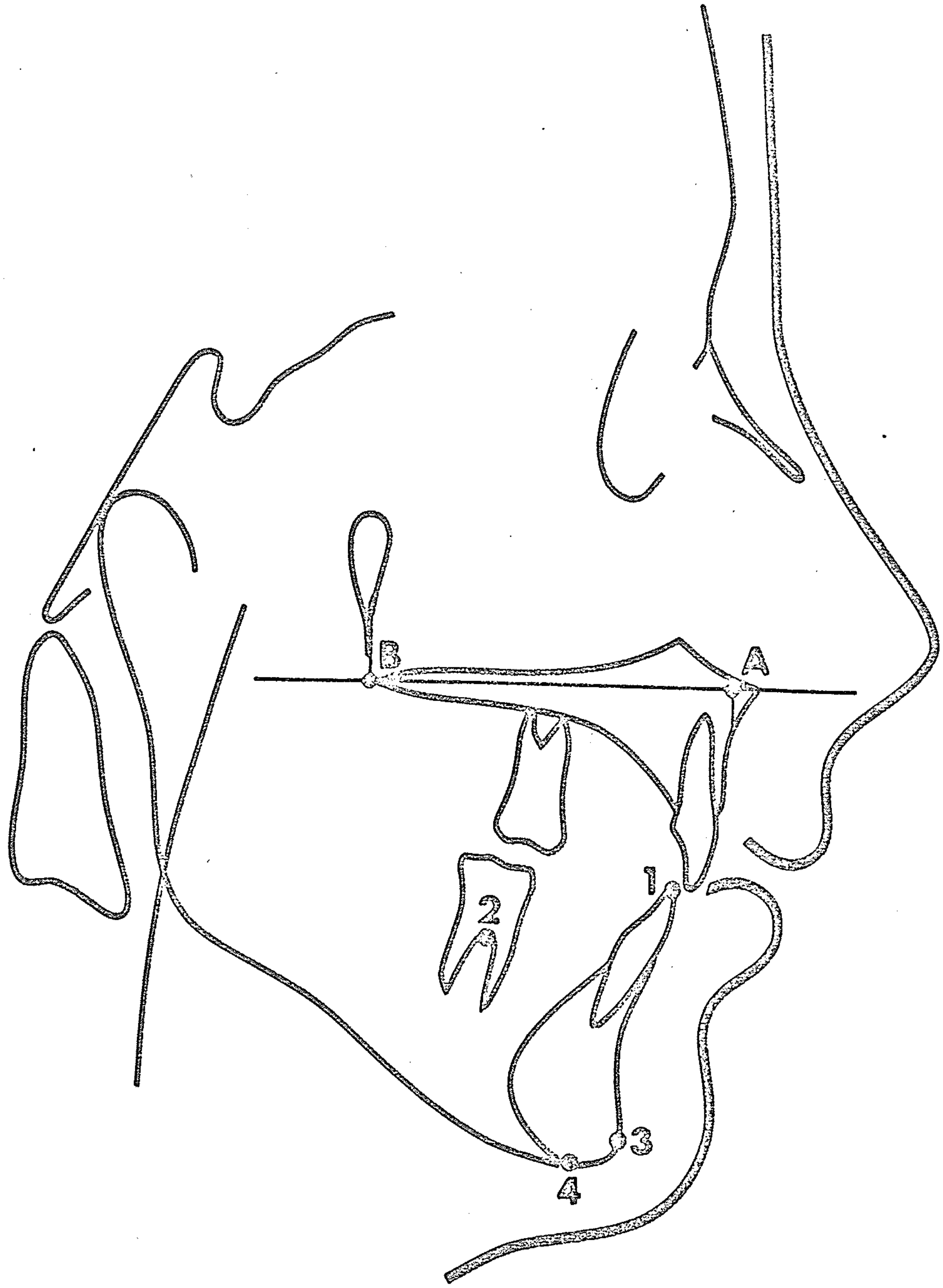

Figure 6. Illustration of four points selected for cinefluorographic analysis with reference plane and reference points A and B.

2. Initial Contact Position (IC) This position was reached when the tip of the lower incisor image first touched that of the upper incisor.
3. Full Closure Position (FC) This position required full occlusal contact of the teeth. The frame chosen for this position was selected as close after the initial contact frame as possible in order to minimize the effects of head movement. In many cases, the full closure and initial contact frames were the same.

Three representative frames selected from the 16 millimeter cinefluorographic films are illustrated in Figures 7 to 9. Due to the loss of detail and contrast during the enlarging and printing processes, graphic illustrations are included.

Coordinate Recording Technique

A template was made for each subject by projecting the rest position frame on the Vanguard Motion Analyser and tracing the facial structural outlines on a piece of acetate paper. The four landmarks and two reference points were also plotted and their coordinates recorded. This template was then superimposed on the initial contact frame projection using the technique of best fit of the maxillary structures. The coordinates for reference points A and B were recorded for the initial contact projection. The template was next moved so that the mandibular outlines were superimposed and the coordinates of the four mandibular landmarks were recorded. This procedure was repeated to obtain the coordinate values in the full closure frame. A pilot study to determine the accuracy of the template method of point location, as compared to identifying the points without the template; showed the template method to be more accurate. The coordinates were recorded in units of one hundredth of an inch, and corrected to absolute units in millimeters.

Figure 7. a) Reproduction from 16 mm cinefluorographic frame of rest position.

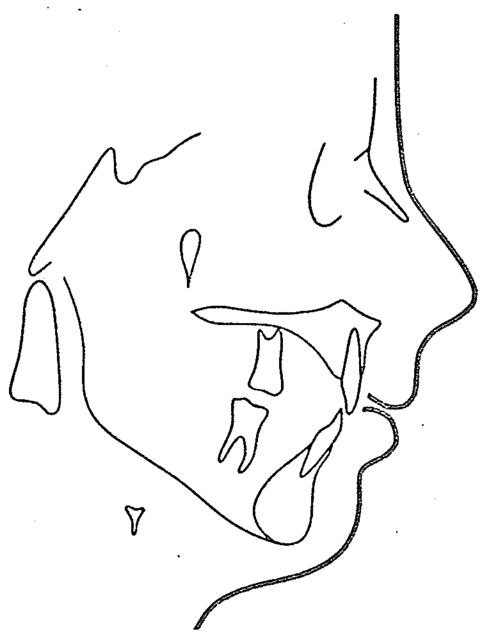

Figure 7. b) Diagrammatic illustration of the above reproduction.

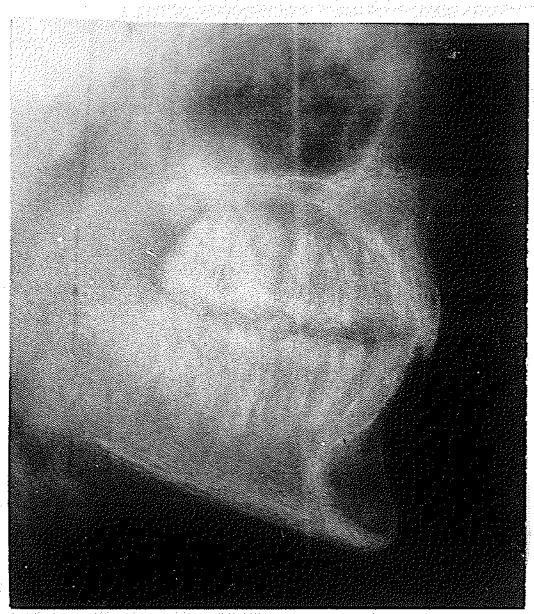

Figure 8. a) Reproduction from 16 mm cinefluorographic frame of initial contact position.

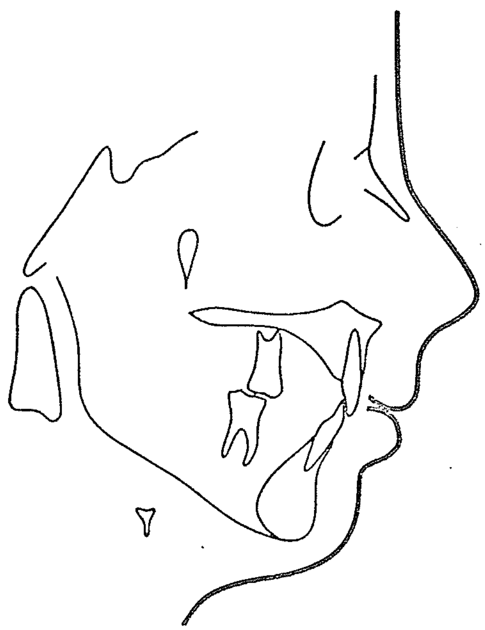

Figure 8. b) Diagrammatic illustration of the above reproduction.

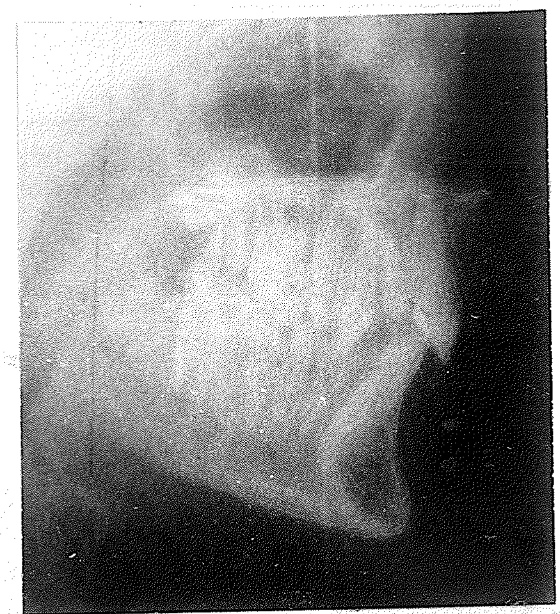

Figure 9. a) Reproduction from 16 mm cinefluorographic frame of full closure position.

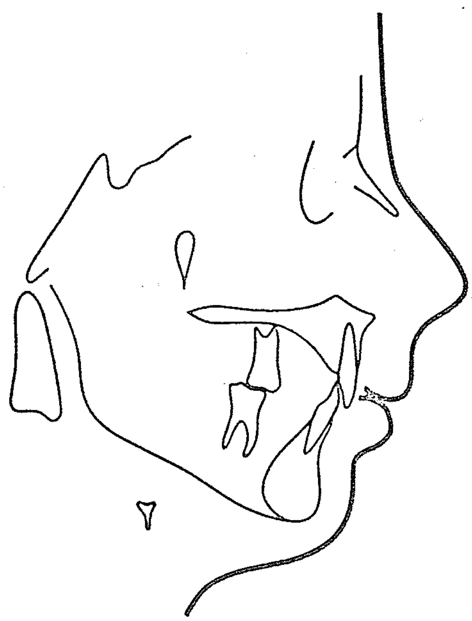

Figure 9. b) Diagrammatic illustration of the above reproduction.

Coordinate Analysis

A standardized set of eight linear and two angular measurements was obtained from the coordinate data. The analysis was designed to define the following, in the sagittal plane only:

1. The amount and direction of movement of the mandible from the physiological rest position to the full closure position.
2. The amount of freeway space.
3. The relationship of the palatal plane to a true vertical line as a measure of head posture.
4. The relationship of the teeth during swallowing.
5. The location of the centre of mandibular rotation during the movement from rest to initial contact position.

Linear Measurements

Length 1 The horizontal distance from the tip of the lower incisor to reference point A.

Length 2 The horizontal distance from the lower molar point to reference point A.

Length 3 The horizontal distance from pogonion to reference point A.

Length 4 The horizontal distance from menton to reference point A.

Length 5 The vertical distance from the lower incisor point to reference point A.

Length 6 The vertical distance from the lower molar point to reference point A.

Length 7 The vertical distance from pogonion to reference point A.

Length 8 The vertical distance from menton to reference point A.

These measurements are illustrated in Figure 10.

Angular Measurements

Angle a The angle formed by the intersection of the palatal plane with the true vertical (Figure 10).

Angle b The angle formed, at the full closure position by a line from the lower incisor point to reference point B to reference point A.

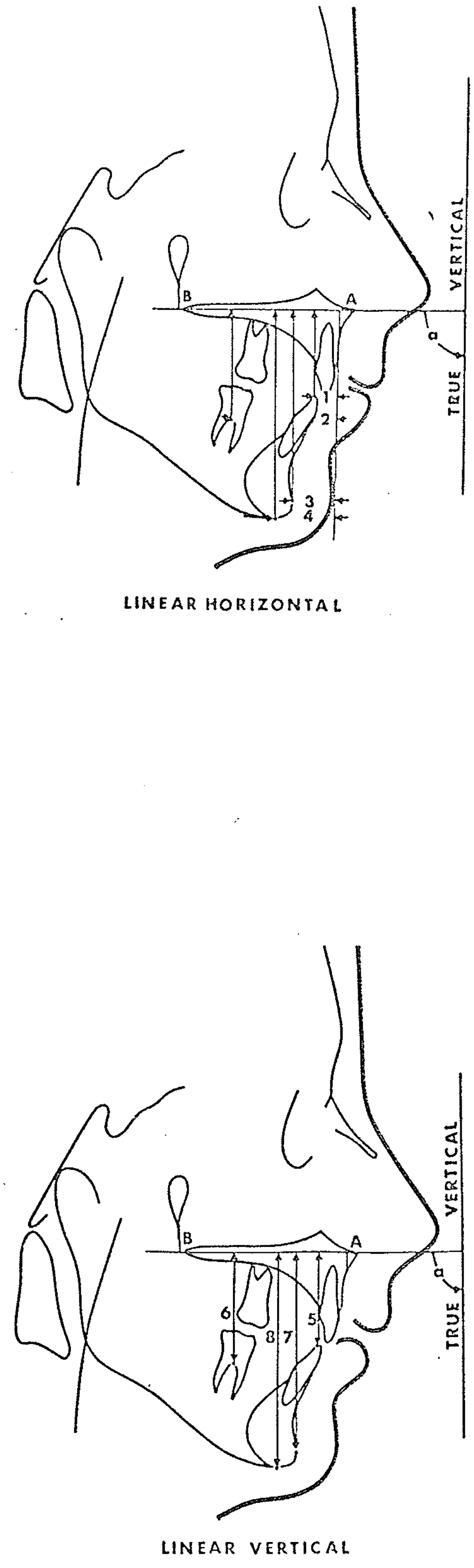

Figure 10. Illustration of cinefluorographic analysis.

The difference between these linear measurements from frame to frame delineate the amount and direction of mandibular movement from rest to initial contact to full closure position.

The freeway space was determined by the difference between Length 5 in rest and full closure positions.

Centre of Rotation

The centre of rotation of the mandible during its movement from rest to initial contact position can be determined using the method described by Rouleaux (1876), reviewed by Superstine (1957) and illustrated in Figure 11.

The two landmarks used are the tip of the lower incisor and pogonion. The cinefluorographic coordinates of these two points at the rest and initial contact positions are plotted on a graph with a straight line connecting like points. A perpendicular line is drawn from the centre of each of these two lines and the intersection of these two perpendicular lines represent the centre of rotation of the mandible when moving from rest to the full closure position. The centres of rotation of the mandible for the subjects in this study were calculated mathematically by a coordinate computer program (Cleall and Chebib 1970).

Cephalometric Analyses

Equipment and Technique

Lateral cephalometric radiographs were obtained using the conventional technique developed by Broadbent (1931). A Cephalometrix* cepha-

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* Moss Corporation, Chicago, Illinois.

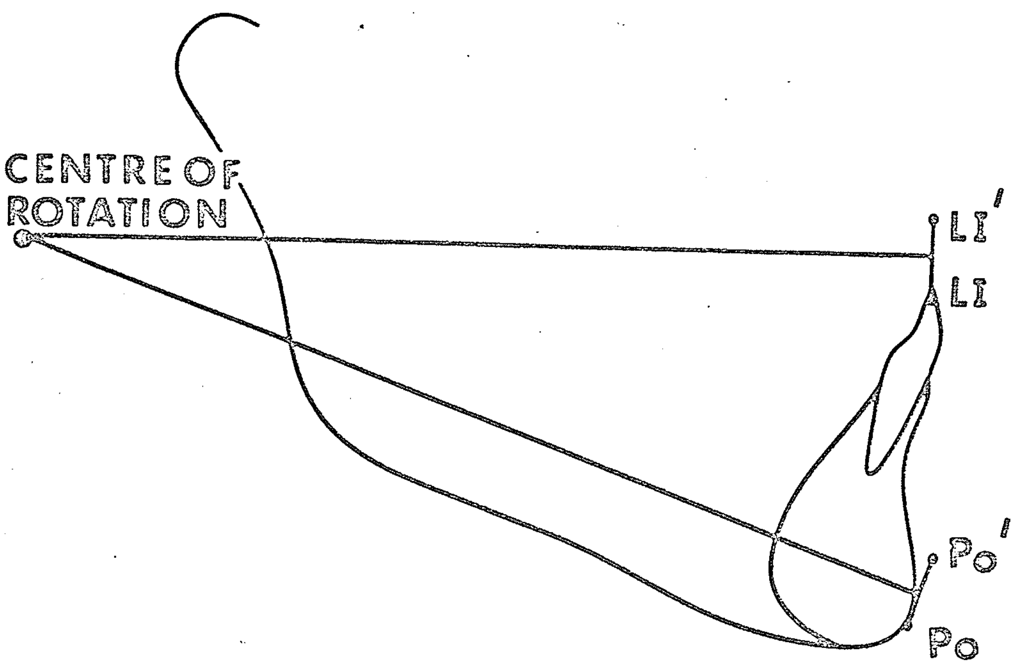


Figure 11. Illustration of Rouleaux's method for determining instantaneous centres of mandibular rotation. The lines from LI to LI[1] and Po to Po[1] represent the movement of these points as the mandible moves.

lometer was used which has an approximate focal point to film distance of five and one-half feet. Magnification was determined as described by Frostad (1969) and averaged nine per cent. This value was used to correct all linear measurements.

One cephalogram was taken with the mandible in full closure position and another in the rest position. The method used for obtaining the rest position was the command sequence "Mississippi". A head holder with ear rods was used.

A true vertical line was recorded on the film by suspending a plumb weight on a fine wire in front of the cassette.

Three types of cephalometric analyses were completed. They were designed to allow:

1. Comparison of cephalometric differences in the location of the mandible at the rest and full closure positions with those of the cinefluorographs.
2. Comparison of head posture in the cephalograms and cinefluorographs.
3. Comparison of the skeletal, dental, and soft tissue patterns of the two groups in the sample.
4. Analysis of correlations between different variables studied.

Analysis of Mandibular Positions

In order to determine if the use of a head holder and ear rods in taking cephalometric radiographs had any effect on head posture or mandible posture at the rest position, a cephalometric analysis of the change in position of the mandible from rest position to full closure was done and compared to the cinefluorographic results.

Two mandibular landmarks, the incisal tip of the most labial lower incisor and pogonion, were chosen to demonstrate the change in the position of the mandible from rest to full closure. These landmarks are illustrated in Figure 12 and the measurements were made in relation to the palatal plane.

The two landmarks were marked with a pin on the full occlusion radiograph. A tracing was made on acetate paper and the two points were transferred to the tracing. This tracing was superimposed on the radiograph of the rest position using the "best fit" method for the maxillary structures and cranial base. The mandible of the rest position radiograph was traced on this same paper resulting in a full tracing of the head with two mandibles; one in the occlusal position with the two points marked, and one in the rest position with no points marked. The tracing was returned to the full occlusion radiograph. The traced rest position mandible was superimposed on the radiographic full occlusion mandible, and the points were transferred to the tracing. The vertical and horizontal differences between the resulting two sets of points were measured to the nearest tenth of a millimeter. The method is illustrated in Figure 12.

The differences between the points on the two radiographs represent the change in position of the mandible from rest to full closure position.

Skeletal, Dental, and Soft Tissue Analyses

The full occlusion cephalometric radiographs were traced on the matte surface of acetate paper. Paired landmarks not superimposed were bisected, thereby reducing lateral landmarks to the same value as midsagittal structures where the error is less. The coordinates of each landmark were recorded on a Ruscom Logics Limited Strip Chart Digitizer. The computer program analysed these by the method described under Section

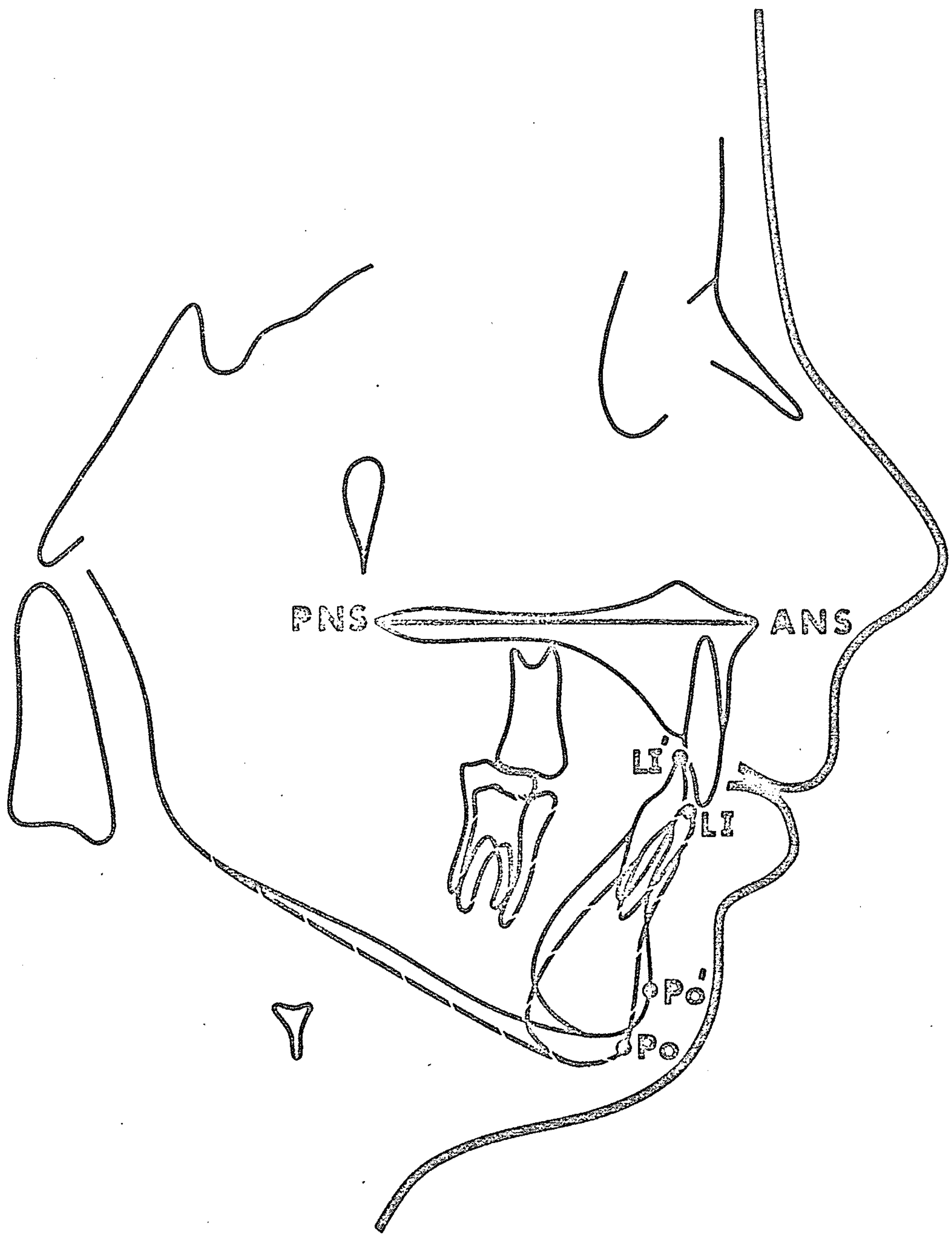


Figure 12. Illustration of the cephalometric method of determining the mandibular path of closure. The broken line represents the mandible at the rest position; the solid line at the full closure position. The difference between LI and LI[1] and Po and Po[1] represents the resultant direction and magnitude of the mandible's movement from rest to full closure.

V, (Statistical Analysis) and calculated the angles to 0.001 degrees and the linear measurements to 0.01 millimeters.

Thirty-three cephalometric landmarks were used in the analyses and are illustrated in Figure 13. A description of these landmarks will be found in the glossary.

Skeletal Analysis

The 13 skeletal angular measurements are illustrated in Figure 14.

Angle a   Cranial base angle (N-S-Ba).

Angle b   Cranial base angle (N-S-Ar).

Angle c   Angle of the mandible (Con-Go-M).

Angle d   Facial angle (N-Po-FH).

Angle e   Relationship of pogonion to cranial base (S-N-Po).

Angle f   Relationship of maxillary apical base to cranial base (SNA).

Angle g   Relationship of mandibular apical base to cranial base (SNB).

Angle h   Apical base relationship (ANB).

Angle i   Relationship of mandibular plane to palatal plane (M-LBM—ANS-PNS).

Angle j   Relationship of mandibular plane to cranial base (M-LBM—S-N).

Angle k   Relationship of FH to cranial base (FH—S-N).

Angle l   Angle of convexity (N-A-Po).

Angle m   Relationship of hyoid bone to cranial base (HY—S-N).

The 16 skeletal linear measurements are illustrated in Figure 15.

Distance 1 Length of posterior cranial base (Ba-S).

Distance 2 Length of anterior cranial base (S-N).

Distance 3 Length of cranial base (N-Ba).

Distance 4 Length of mandible (M-W).

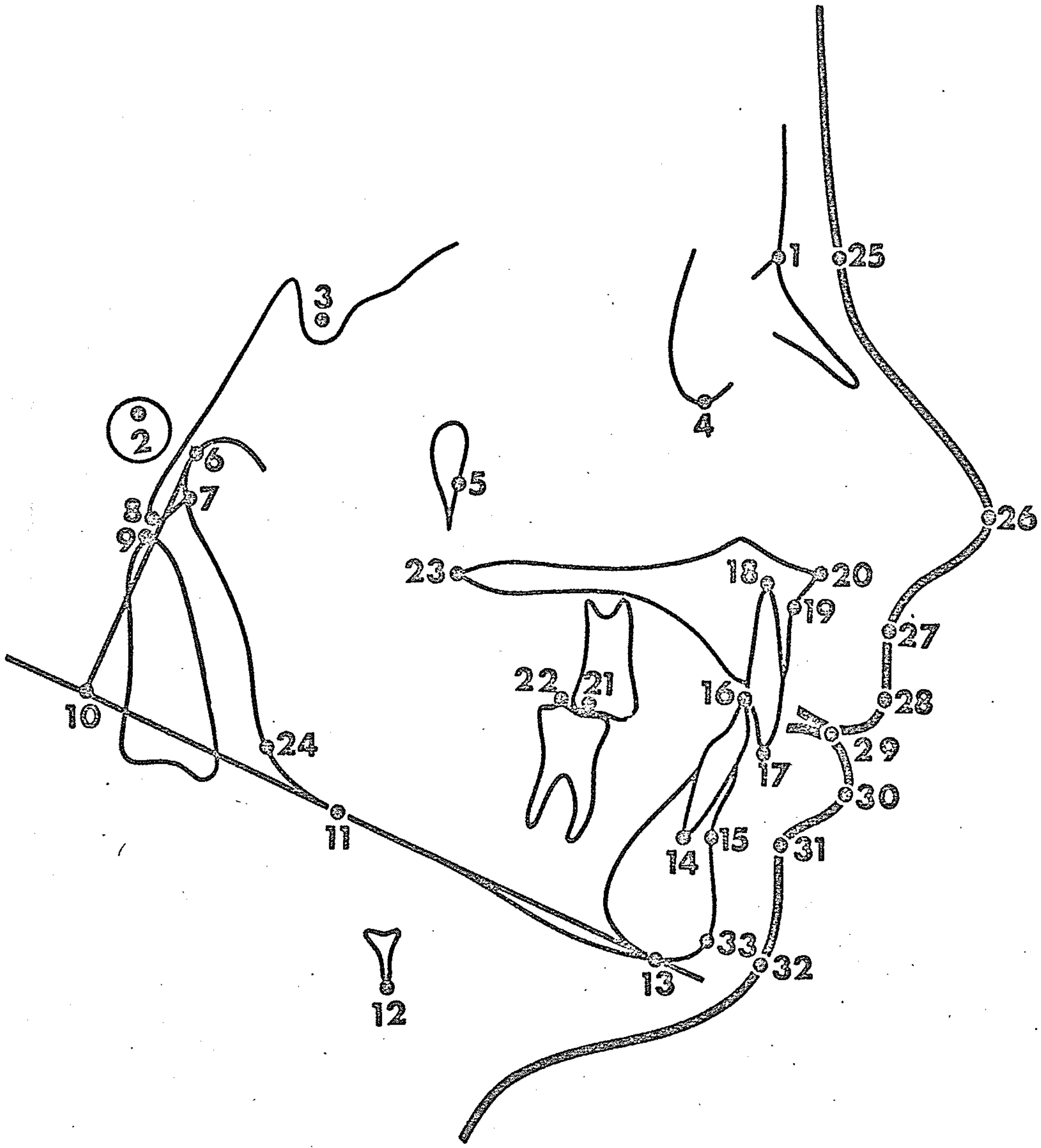
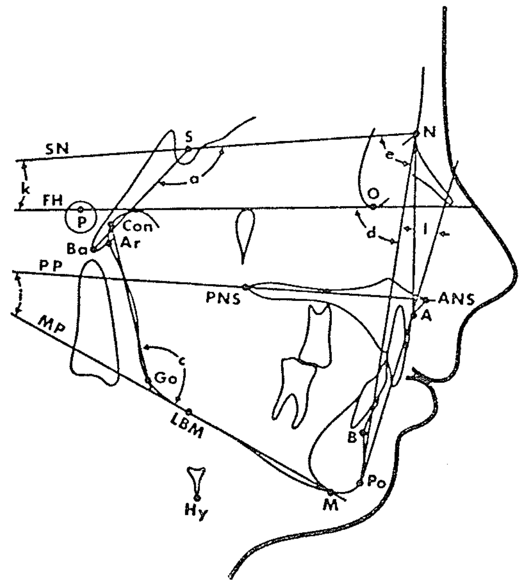


Figure 13. Illustration of cephalometric landmarks used in skeletal, dental, and soft tissue analyses.



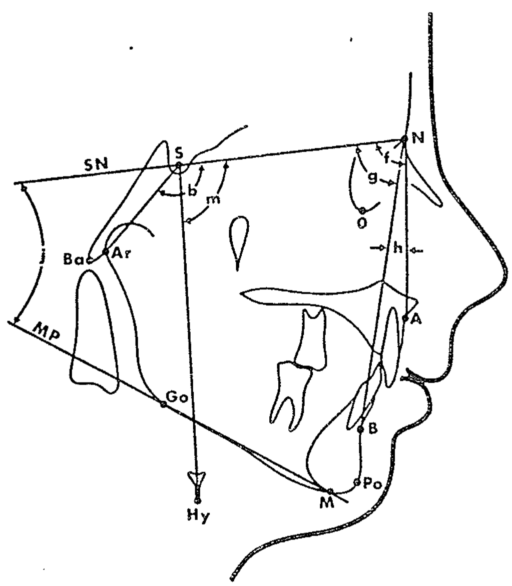
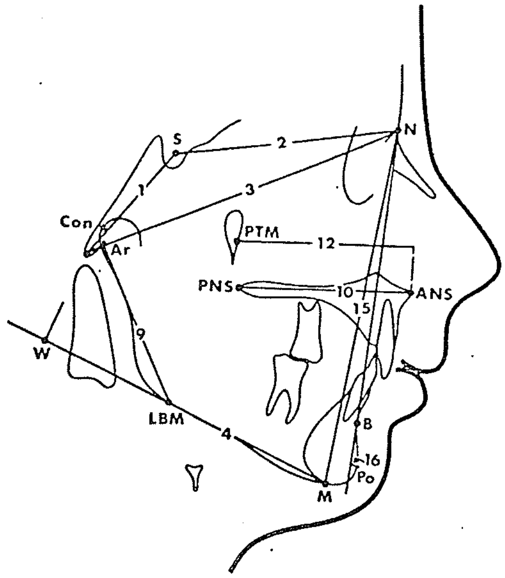


Figure 14. Illustration of the cephalometric skeletal angular analysis used in this study.



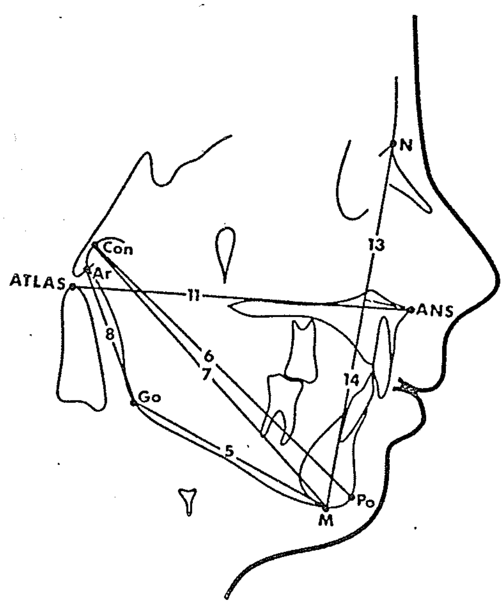


Figure 15. Illustration of the cephalometric skeletal linear analysis used in this study.

Distance 5 Length of mandible (M-Go).

Distance 6 Length of mandible (Po-Con).

Distance 7 Length of mandible (M-Con).

Distance 8 Length of ramus (Ar-Go).

Distance 9 Length of ramus (Ar-LBM).

Distance 10 Length of palatal plane (ANS-PNS).

Distance 11 Distance from atlas to ANS (AT-ANS).

Distance 12 Maxillary length (Ptm-ANS).

Distance 13 Upper face height (N-ANS).

Distance 14 Lower face height (ANS-M).

Distance 15 Total face height (N-M).

Distance 16 Length of chin (Po-NB).

Dental Analysis

Figure 16 is an illustration of the nine dental angular measurements.

Angle a Relation of $\overline{1}$ to mandibular plane.

Angle b Relationship of $\overline{1}$ to FH.

Angle c Relationship of $\overline{1}$ to cranial base.

Angle d Relationship of $\underline{1}$ to FH.

Angle e Relationship of $\underline{1}$ to cranial base.

Angle f Relationship of $\underline{1}$ to palatal plane.

Angle g Relationship of $\underline{1}$ to $\overline{1}$.

Angle h Relationship of $\overline{6}$ to cranial base.

Angle i Relationship of $\underline{6}$ to cranial base.

Figure 17 is an illustration of the six dental linear measurements.

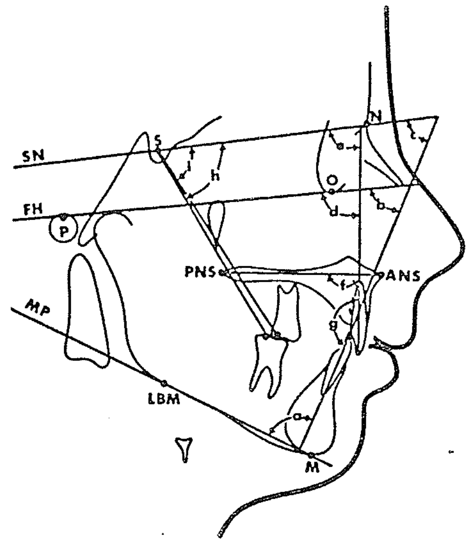


Figure 16. Illustration of the cephalometric dental angular analysis used in this study.

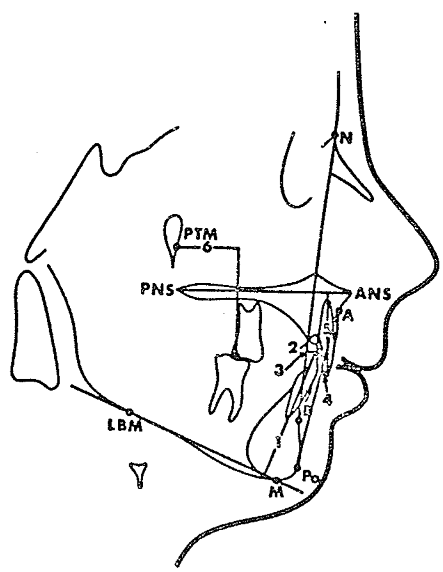


Figure 17. Illustration of the cephalometric dental linear analysis used in this study.

Distance 1 $\overline{1}$ to mandibular plane (vert.).

Distance 2 $\overline{1}$ to APo (horiz.).

Distance 3 $\overline{1}$ to NB (horiz.).

Distance 4 $\underline{1}$ to APo (horiz.).

Distance 5 $\underline{1}$ to palatal plane (vert.).

Distance 6 Ptm to $\underline{6}$ (horiz.).

Soft Tissue Analysis

The three soft tissue angular measurements are illustrated in Figure 18.

Angle a S. T. Facial angle (N-TN-TP).

Angle b S. T. Nose angle (TN-TT-TP).

Angle c S. T. Lip angle (TT-TU-TL).

The nine soft-tissue linear measurements are illustrated in Figure 19.

Distance 1 Length of upper lip ($\underline{1}$-TU) (horiz.).

Distance 2 Length of lower lip ($\overline{1}$-TL) (horiz.).

Distance 3 Chin thickness (Po-TP) (horiz.).

Distance 4 Thickness of soft tissue at nasion (N-TN) (horiz.).

Distance 5 Length of nose (TA-TT) (horiz.).

Distance 6 Length of lips (TA-TB) (vert.).

Distance 7 Nose to chin (TT-TP) (vert.).

Distance 8 Tip of $\underline{1}$ to upper lip line ($\underline{1}$-UL) (vert.).

Distance 9 Tip of $\overline{1}$ to upper lip line ($\overline{1}$-UL) (vert.).

Diagnostic Model Analyses

The following items were observed on the diagnostic models.

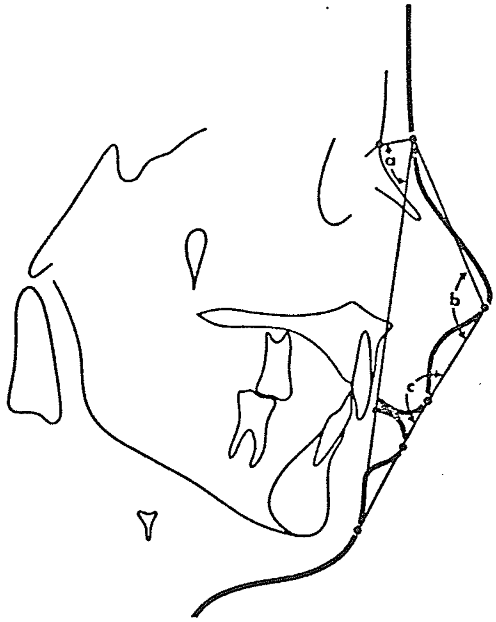


Figure 18. Illustration of the cephalometric soft tissue angular analysis used in this study.

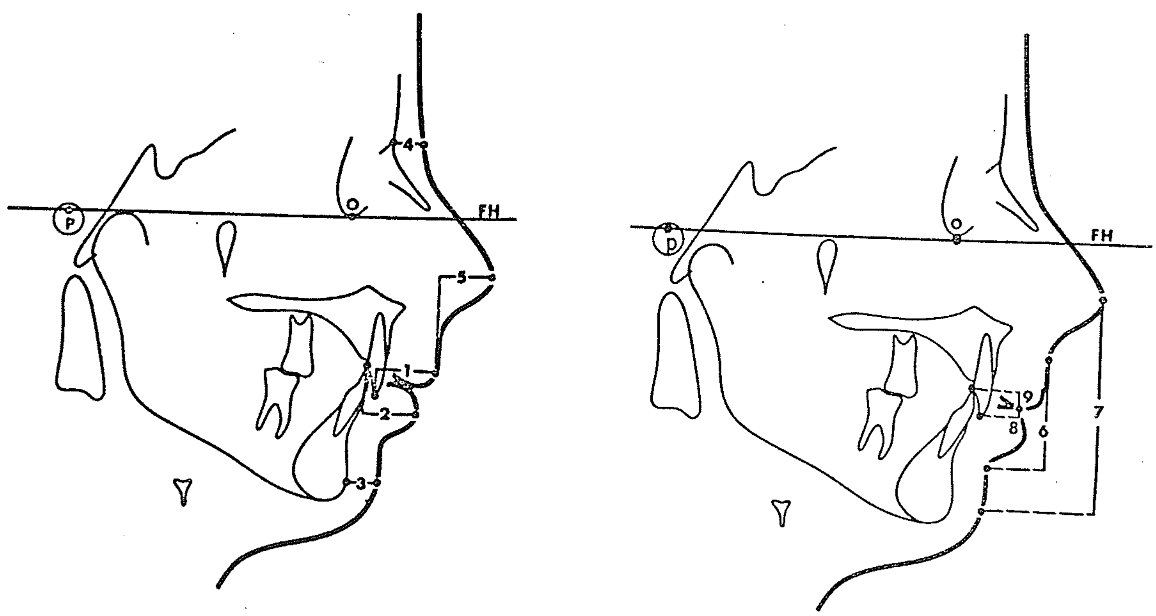


Figure 19. Illustration of the cephalometric soft tissue linear analysis used in this study.

1. Overbite was determined by measuring the percentage of vertical overlap of the upper central incisors over the lower central incisors.
2. Overjet was determined by measuring the horizontal distance from the labial surface of the most anterior lower incisor to the lingual surface of the most posterior upper incisor.
3. The lower incisors were subjectively examined for wear on their labial surfaces. A positive finding denoted wear on any one or more of the four incisors.
4. An arch size-tooth size analysis was done to determine the degree of crowding present. An arch length deficiency of five millimeters or more indicated a crowded arch. The method used was that described by Carey (1949).
5. A tooth size analysis was done as described by Bolton (1958) and illustrated in Figure 20.
6. Arch length and intercanine width were determined by the method reported by Moorrees et al (1969), and illustrated in Figure 21. Intermolar width was determined by measuring the distance between the mesiolingual cusp tips of the maxillary first molars as illustrated in Figure 21.

IV. SOURCES OF ERROR

Distortion and Magnification

Cleall (1966), in his cinefluorographic study of head posture, used a uniform wire grid to assess the degree of magnification and distortion and found a progressive linear magnification of 14 per cent. This is greater than the usual percentage of magnification found with conventional cephalometric equipment because of a shorter anode to subject distance and a larger subject to image distance. Since these distances were not standardized in the cinefluorographic technique it was necessary to determine the magnification factor for each subject in order to correct the linear measurements to absolute units. The correction method used by Milne (1969) was used.

The cephalometric radiographs were calculated to have a nine per cent magnification factor (Frostad 1969). The distance from the incisal

OVERALL RATIO

$$\frac{\text{Sum mandibular "12" ______ mm.}}{\text{Sum maxillary "12" ______ mm.}} = \text{______} \times 100 = \text{______}\%$$

Overall Ratio

Mean 91.3±0.26
S. D. (o) 1.91
Range 87.5 - 94.8

Max. "12"	Mand. "12"	Max. "12"	Mand. "12"	Max. "12"	Mand. "12"
86	77.6	94	85.8	103	94.0
86	78.5	95	86.7	104	95.0
87	79.4	96	87.6	105	95.9
88	80.3	97	88.6	106	96.8
89	81.3	98	89.5	107	97.8
90	82.1	99	90.4	108	98.6
91	83.1	100	91.3	109	99.5
92	84.0	101	92.2	110	100.4
93	84.9	102	93.1		

PATIENT ANALYSIS

If the overall ratio exceeds 91.3 the discrepancy is in excessive mandibular arch length. In above chart locate the patient's maxillary "12" measurement and opposite it is the correct mandibular measurement. The difference between the actual and correct mandibular measurement is the amount of excessive mandibular arch length.

______ = ______ = ______
Actual Mand. "12" Correct Mand. "12" Excess Mand. "12"

If overall ratio is less than 91.3:

______ = ______ = ______
Actual Max. "12" Correct Max. "12" Excess Max. "12"

ANTERIOR RATIO

$$\frac{\text{Sum Mandibular "6" ______ mm.}}{\text{Sum Maxillary "6" ______ mm.}} = \text{______} \times 100 = \text{______}\%$$

Anterior Ratio

Mean 77.2±0.22
S. D. (o) 1.65
Range 74.5 - 80.4

Max. "6"	Mand. "6"	Max. "6"	Mand. "6"	Max. "6"	Mand. "6"
40.0	30.9	45.5	35.1	50.5	39.0
40.5	31.3	46.0	35.5	51.0	39.4
41.0	31.7	46.5	35.9	51.5	39.8
41.5	32.0	47.0	36.3	52.0	40.1
42.0	32.4	47.5	36.7	52.5	40.5
42.5	32.8	48.0	37.1	53.0	40.9
43.0	33.2	48.5	37.4	53.5	41.3
43.5	33.6	49.0	37.8	54.0	41.7
44.0	34.0	49.5	38.2	54.5	42.1
44.5	34.4	50.0	38.6	55.0	42.5
45.0	34.7				

PATIENT ANALYSIS

If anterior ratio exceeds 77.2:

______ = ______ = ______
Actual Mand. "6" Correct Mand. "6" Excess Mand. "6"

If anterior ratio is less than 77.2:

______ = ______ = ______
Actual Max. "6" Correct Max. "6" Excess Max. "6"

Figure 20. Illustration of Bolton's (1958) tooth size analysis used in this study.

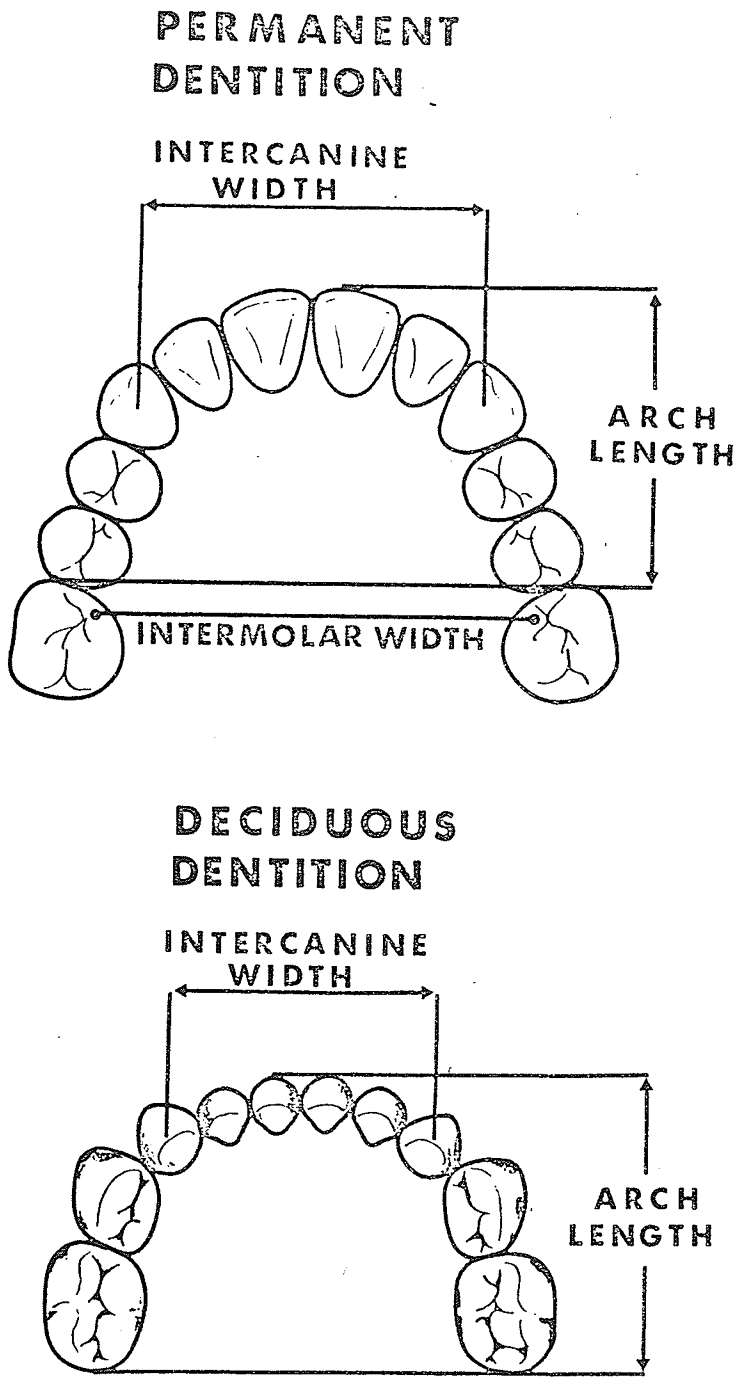


Figure 21. Illustration of Moorrees (1969) method of arch length, intercanine width, and intermolar width determination used in this study.

edge of the lower incisor to menton (LI-M) was measured on these radiographs and was corrected to absolute units using the nine per cent magnification factor. The same linear measurement was obtained from the cinefluorographic film and the correction factor for the cinefluorographic measurements was calculated from the formula:

$$\frac{\text{LI-M (Ceph. corrected)}}{\text{LI-M (Cine)}} = \text{Correction Factor}$$

The average magnification for the sample was 15.3 per cent.

Measurement Error

A pilot study on five subjects was completed to determine the error of measurement for the template method of point location, thus enabling the operator to determine if the method was accurate enough to use in this type of investigation.

The coordinates of the six points on each of the three frames were recorded for each of the five subjects. This was repeated two weeks and four weeks later resulting in a total of three sets of coordinates for each of the five subjects. The mean differences between sets one and two, one and three, and two and three were calculated and three different standard deviations were determined for both the X and Y coordinates, using the following formula:

$$SD = \sqrt{\frac{\Sigma d^2}{n-1}}$$

where d is the difference between two measurements of the same point.

The three error determinations were averaged as

$$\sqrt{\frac{\Sigma d_1^2 + \Sigma d_2^2 + \Sigma d_3^2}{3n-3}}$$

which represents the measurement error, as a standard deviation, associated with a single measurement for an X or Y coordinate (Table I). It represents an average standard deviation of an individual X and Y coordinate. The measurement error has no statistical application since it is inherent in the sampling errors reported in the results, however it allows the reader to evaluate the accuracy of the individual measurements.

Table I.

Cinefluorographic measurement errors calculated from triple determinations of mandibular positions for five subjects. (mm)

	Measurement Error	
Determinations Compared	Horizontal(X)	Vertical(Y)
First and Second	0.424	0.554
First and Third	0.499	0.638
Second and Third	0.438	0.562
Mean	0.455	0.585

V. STATISTICAL ANALYSIS

The cinefluorographic sequence included several closing movements for each individual. These closure patterns were seen to be identical by subjective assessment; thus the selection of frames for quantitative analysis was made from a number of reproducible closure patterns.

The coordinates of the landmarks in the selected cinefluorographic frames were recorded and constituted the basic data for further statistical analysis. The computer program (Cleall and Chebib 1970) superimposed each template mathematically with regard to a preselected point of origin and point of direction and calculated standardized coordinates for each of the original coordinates. The linear distances and angles were calculated using these standardized coordinates for each subject. The mean values for the movements from rest to initial contact to full closure position were calculated for each group and tested for significance against their standard errors to determine whether there had been a significant movement. Similar tests were also performed for both groups combined.

The values of the location of centres of rotation were calculated for each individual and the mean values were calculated for each group and for the two groups combined.

The coordinates of specified landmarks on the cephalometric radiographs were recorded on a Ruscom Logics Limited Strip Chart Digitizer. The computer program superimposed these by the same method as used for the cinefluorographic coordinates and determined the values of 25 angular and 31 linear measurements for each subject. Means and standard deviations of these linear and angular measurements were computed for each group and for the two groups combined.

To determine whether the two groups differed in skeletal, dental, and soft tissue patterns and other independent measurements, tests of significance between the two groups were performed for each of the following variables.

1	Overbite
2	Overjet
3	Head posture
4	Tooth size (Mx6)
5	Tooth size (Md6)
6	Tooth size (Mx12)
7	Tooth size (Md12)
8	Sex
9	Age
10	Subdivision classification
11	Tooth apart swallow
12	Crowding-upper arch
13	Crowding-lower arch
14	Crowding-either arch
15	Wear on the labial surface of lower incisors
16 - 49	Angular measurements (ceph.)
50 - 81	Linear measurements (ceph.)
82	Arch length
83	Intercuspid width
84	Intermolar width
85	Freeway space (cine.)

The tests of significance used were the T-test for continuous variables and a contingency chi square test of independence for non-continuous variables.

In order to determine the degree of correlation between pairs of variables, correlation coefficients for all possible pairs of 86 variables were calculated. These were inspected and tested for significance and certain combinations are discussed in the results. This was performed for each group and both groups combined.

CHAPTER IV

RESULTS

The results are presented in three sections. Section I gives the results of the cinefluorographic analysis of the mandibular movements, and shows the division of the sample into two groups on the basis of the closure path direction. The results of the cephalometric determination of the changes in the mandible's orientation during movement from the rest to the full closure position are also presented. Section II compares the mean values of selected measurements in the two groups to determine if these groups are separate entities on the basis of criteria other than the path of closure. Section III deals with simple correlations between the mean values of selected variables in each group and the two groups combined.

I. CINEFLUOROGRAPHIC MANDIBULAR MOVEMENTS

The analysis of mandibular movements in the sagittal plane, from rest to initial contact to full closure position, revealed that there were several different patterns of closure.

The subjects were classified into two groups according to the direction of the mandible's movement from rest to initial contact position, using lower incisor point measurements.

Group 1 consisted of 13 individuals whose mandibles, at the initial contact position, were located anterior-superiorly to the position at rest. Group 2 contained 16 individuals whose mandibles, at the initial contact position, were located posterior-superiorly or superiorly to the position at rest.

Rest to Initial Contact

In Group 1 the mean components of the movements from rest to initial contact, using the lower incisor measurements, were 1.3 mm anteriorly and 4.2 mm superiorly. The anterior component had a range of 0.3 to 2.0 mm, and the superior component had a range of 0.5 to 8.6 mm (Table II). On the other hand, Group 2 showed average components of 0.5 mm posteriorly and 4.5 mm superiorly. The ranges were -1.3 to 0 mm and 1.8 to 8.1 mm for the horizontal and vertical components respectively (Table III). For the two groups combined the location of lower incisor point, at the initial contact position, was 0.3 mm anterior and 4.4 mm superior to its position at rest (Table IV). A diagrammatic illustration of the mean movements from rest to initial contact position, measured at the lower incisor, are presented in Figures 22, 23 and 24 for Group 1, 2, and 1 + 2, respectively.

The direction of the horizontal and vertical components of the mandibular movements from rest to initial contact, measured at the lower molar point, were the same as those measured at lower incisor point for each of the two groups and the two groups combined; however, the horizontal component was ten per cent less in Group 1, thirty per cent less in Group 2, and twenty per cent less in the two groups combined, while the vertical component was approximately twenty-five per cent less in each group. These results are to be expected since the lower molar is closer to the centre of rotation of the mandible than the lower incisor

Table II.

Cinefluorographic means, standard errors, and ranges of the horizontal and vertical components of the mandibular movements from rest to initial contact position measured at four different points for Group 1. (mm)

Point	Component	Mean	Standard Error	Range
Lower Incisor	Horizontal	(+)1.30	0.10	(+)0.30 — (+)2.00
	Vertical	4.20	0.60	0.50 — 8.60
Lower Molar	Horizontal	(+)1.20	0.20	(+)0.10 — (+)2.00
	Vertical	2.90	0.40	0.30 — 5.10
Pogonion	Horizontal	(+)2.60	0.30	(+)0.20 — (+)4.80
	Vertical	4.20	0.60	0.70 — 8.30
Menton	Horizontal	(+)2.80	0.40	(+)0.30 — (+)5.30
	Vertical	3.80	0.50	0.60 — 7.60

(+) Anterior
(-) Posterior

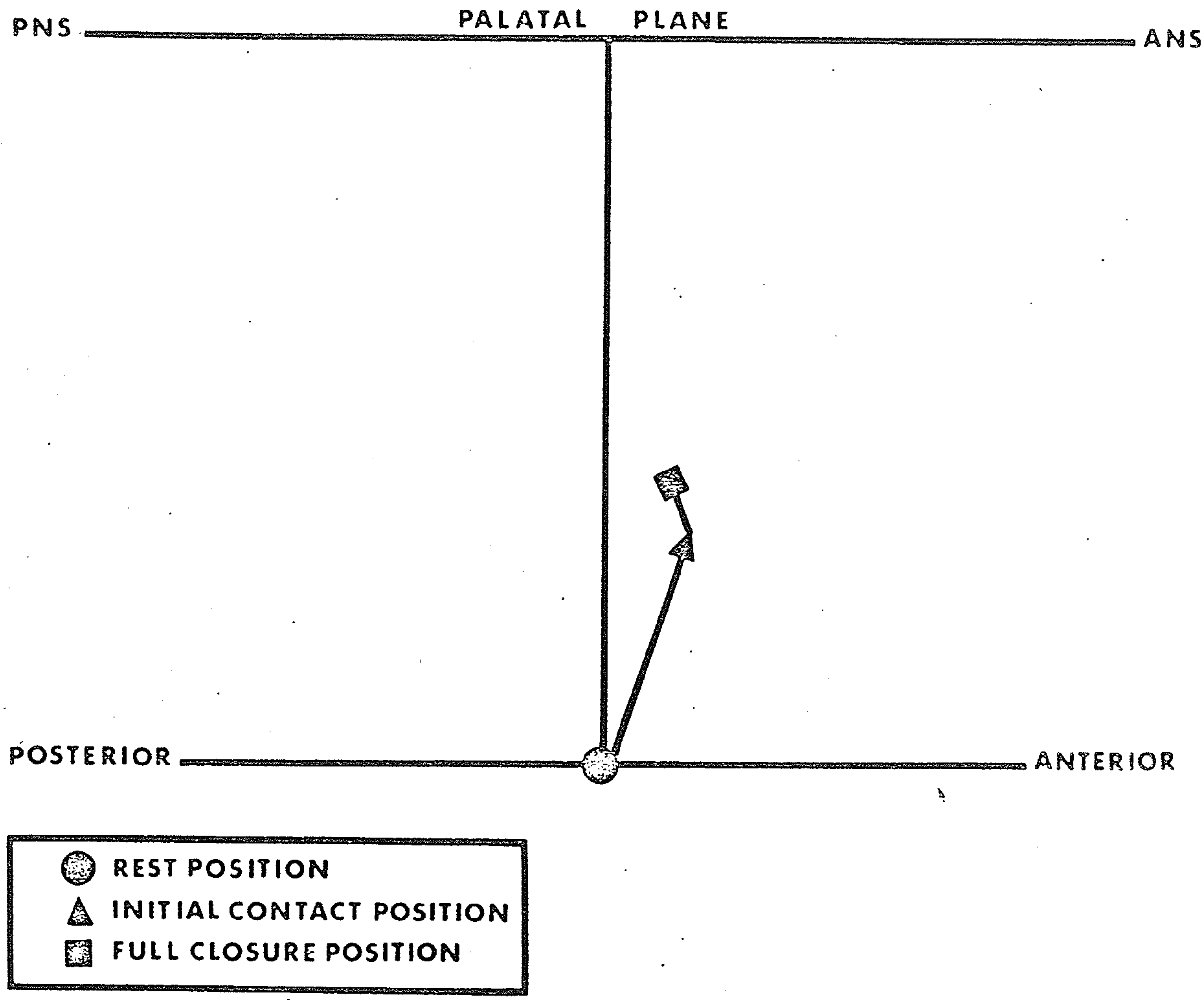


Figure 22. Diagrammatic illustration of the mandibular movements from rest to initial contact to full closure position, at the lower incisor point, for Group 1.

Table III.

Cinefluorographic means, standard errors, and ranges of the horizontal and vertical components of the mandibular movements from rest to initial contact position measured at four different points for Group 2. (mm)

Point	Component	Mean	Standard Error	Range
Lower Incisor	Horizontal	(-)0.50	0.09	(-)1.30 — 0.00
	Vertical	4.50	0.50	1.80 — 8.10
Lower Molar	Horizontal	(-)0.30	0.07	(-)0.80 — 0.00
	Vertical	3.30	0.30	1.30 — 5.00
Pogonion	Horizontal	(+)0.80	0.30	(-)1.00 — (+)2.80
	Vertical	4.30	0.50	1.60 — 7.70
Menton	Horizontal	(+)1.10	0.30	(-)1.00 — (+)3.60
	Vertical	4.10	0.40	1.70 — 7.30

(+) Anterior
(-) Posterior

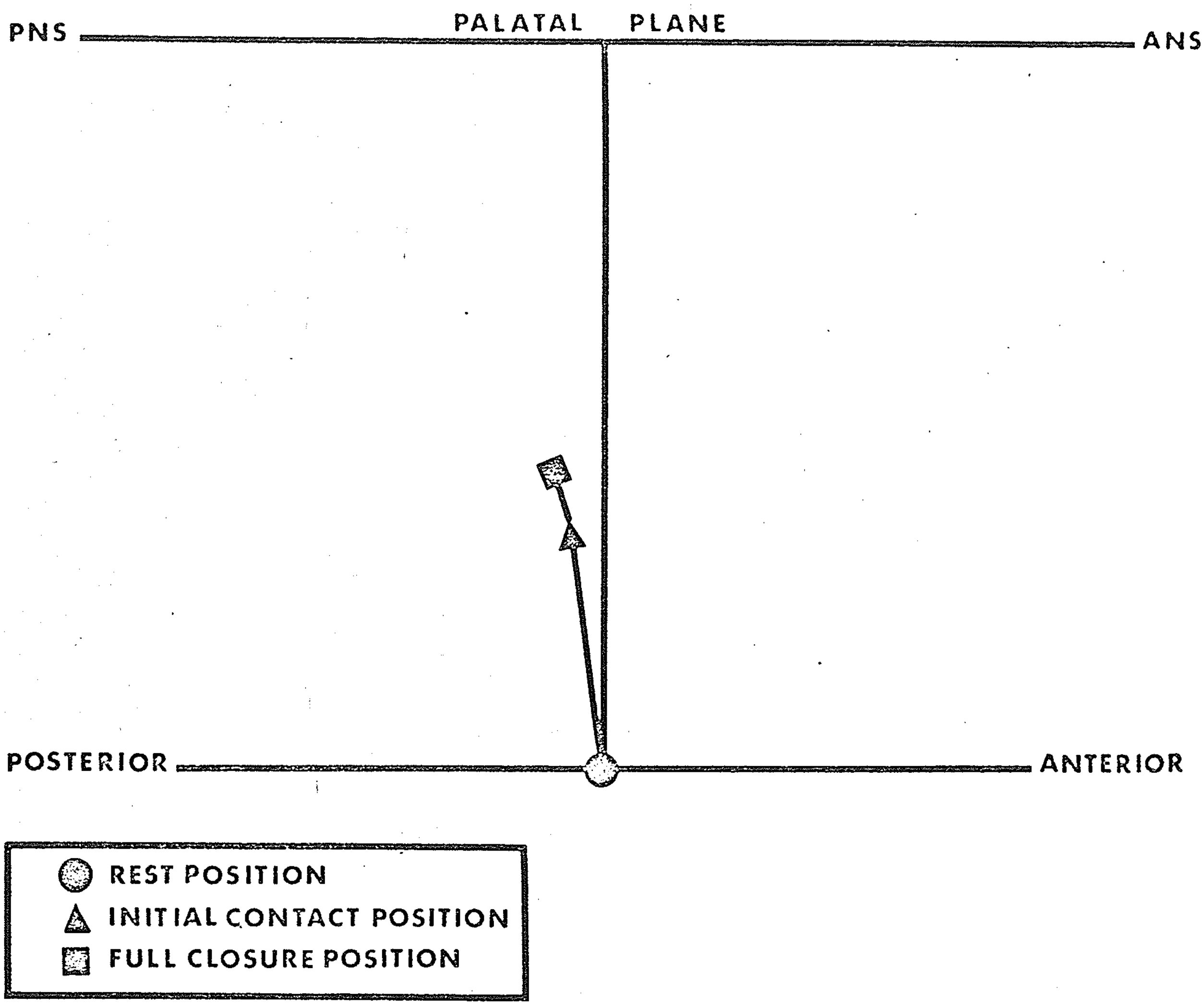


Figure 23. Diagrammatic illustration of the mandibular movements from rest to initial contact to full closure position, at the lower incisor point, for Group 2.

Table IV.

Cinefluorographic means, standard errors, and ranges of the horizontal and vertical components of the mandibular movements from rest to initial contact position measured at four different points for Groups 1 and 2 combined. (mm)

Point	Component	Mean	Standard Error	Range
Lower Incisor	Horizontal	(+)0.30	0.20	(-)1.30 — (+)2.00
	Vertical	4.40	0.40	0.50 — 8.60
Lower Molar	Horizontal	(+)0.40	0.20	(-)0.80 — (+)2.00
	Vertical	3.15	0.30	0.30 — 5.10
Pogonion	Horizontal	(+)1.70	0.30	(-)1.00 — (+)4.80
	Vertical	4.30	0.40	0.70 — 8.30
Menton	Horizontal	(+)1.90	0.30	(-)1.00 — (+)5.30
	Vertical	4.00	0.30	0.60 — 7.60

(+) Anterior
(-) Posterior

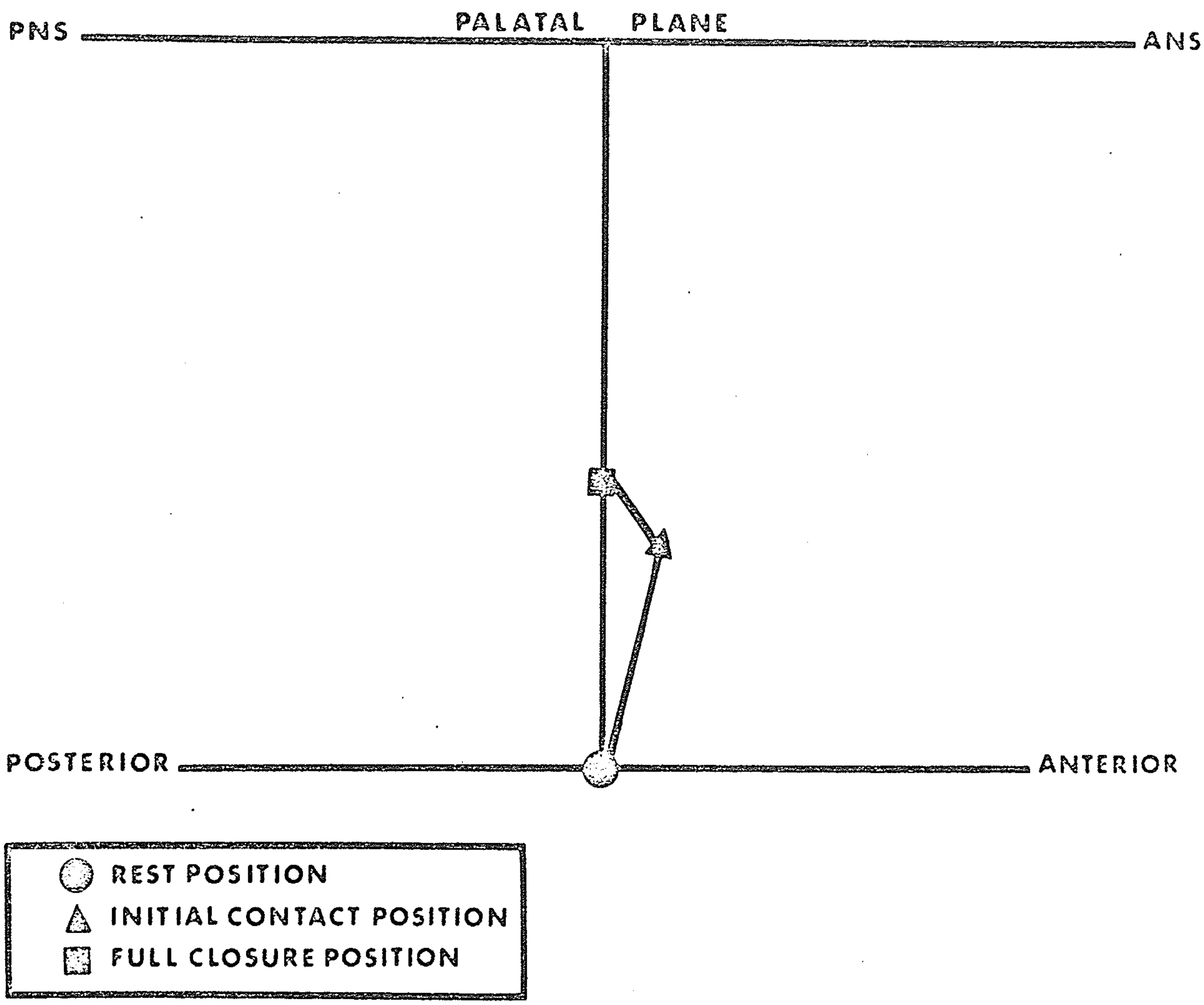


Figure 24. Diagrammatic illustration of the mandibular movements from rest to initial contact to full closure, at the lower incisor point, for the two groups combined.

(Figures 25, 26). The results of these measurements for the lower molar point are included in Tables II, III and IV.

The mean components of the movements from rest position to initial contact for Group 1, measured at pogonion, were 2.6 mm anteriorly and 4.2 mm superiorly, while the means for Group 2 were 0.8 anteriorly and 4.3 superiorly. For the two groups combined, pogonion was situated 1.7 mm more anteriorly and 4.3 mm more superiorly in the initial contact position than in the rest position.

The direction of the horizontal and vertical vectors of the mandibular movements, from rest to initial contact, were the same at pogonion and menton for each of the two groups and the two groups combined. The horizontal vector at menton was seven per cent greater than that of pogonion in Group 1, twenty three per cent larger in Group 2, and thirteen per cent greater for the two groups combined; while the vertical component was five to ten per cent less in each instance. These differences in the amounts of movement between pogonion and menton can be explained by their relationship to the centres of rotation of the mandibles (Figures 25, 26). The mean movements from rest to initial contact position, measured at pogonion and menton, are given in Tables II, III and IV.

<u>Initial Contact to Full Closure</u>

In Group 1 the mean movement from initial contact to full closure, measured at lower incisor, was 0.5 mm posteriorly with a range of -2.00 to 0.40 mm and a vertical component of 0.8 mm. Group 2 had a mean movement of 0.3 mm posteriorly with a range of -1.4 to 0 mm and a vertical component of 0.3 mm. The combined results for the two groups show a mean "posterior shift" of 0.4 mm with a vertical component of 0.6 mm. Figures 22, 23 and 24 are diagrammatic illustrations of these results combined with the results of the differences between the rest and initial contact positions.

It should be pointed out, that even though the results of the "posterior shift" from initial contact to full closure are small, the movement could be observed subjectively in most of the cases.

The mean "posterior shift" for Group 1, measured at the lower molar point, was 0.3 mm; while Group 2 had a 0.2 mm shift, and the two groups combined had a shift of 0.3 mm.

The results of the movements from initial contact to full closure, measured at each of the four points, are given in Tables V, VI and VII.

There was no difference in the position of pogonion at initial contact and full closure in the anterior-posterior direction, however pogonion was located more superiorly at full closure. This was also true of menton.

Rest to Full Closure

As a result of Group 1's mandibular movements from rest to initial contact and initial contact to full closure, the location of the mandible at the full closure position was 0.8 mm anterior and 4.9 mm superior to its position at rest, when measured at the lower incisor point. On the other hand, Group 2 was 0.8 mm posterior and 4.8 mm superior to its position at rest. The mean results of the two groups combined showed that there was no difference in the horizontal location of lower incisor at the rest and full closure positions, although lower incisor was more

Table V.

Cinefluorographic means, standard errors, and ranges of the horizontal and vertical components of the mandibular movements from initial contact to full closure position, measured at four different points, for Group 1. (mm)

Point	Component	Mean	Standard Error	Range
Lower Incisor	Horizontal	(−)0.50	0.20	(−)2.00 — (+)0.40
	Vertical	0.80	0.20	0.00 — 3.20
Lower Molar	Horizontal	(−)0.30	0.10	(−)1.10 — (+)0.70
	Vertical	0.40	0.20	0.00 — 2.10
Pogonion	Horizontal	(+)0.10	0.20	(−)1.30 — (+)1.20
	Vertical	0.80	0.30	0.00 — 3.40
Menton	Horizontal	(+)0.10	0.20	(−)0.80 — (+)1.40
	Vertical	0.70	0.20	0.00 — 3.00

(+) Anterior
(−) Posterior

Table VI.

Cinefluorographic means, standard errors, and ranges of the horizontal and vertical components of the mandibular movements from initial contact to full closure position measured at four different points for Group 2. (mm)

Point	Component	Mean	Standard Error	Range
Lower Incisor	Horizontal	(-)0.30	0.10	(-)1.40 — 0.00
	Vertical	0.30	0.10	0.00 — 1.20
Lower Molar	Horizontal	(-)0.20	0.10	(-)1.30 — 0.00
	Vertical	0.20	0.10	0.00 — 1.70
Pogonion	Horizontal	(-)0.10	0.10	(-)1.20 — 0.00
	Vertical	0.40	0.20	0.00 — 2.20
Menton	Horizontal	(-)0.10	0.10	(-)1.40 — 0.00
	Vertical	0.30	0.20	0.00 — 2.10

(+) Anterior
(-) Posterior

Table VII.

Cinefluorographic means, standard errors, and ranges of the horizontal and vertical components of the mandibular movements from initial contact to full closure position measured at four different points for Groups 1 and 2 combined. (mm)

Point	Component	Mean	Standard Error	Range
Lower Incisor	Horizontal	(-)0.40	0.10	(-)2.00 — (+)0.40
	Vertical	0.60	0.10	0.00 — 3.20
Lower Molar	Horizontal	(-)0.30	0.10	(-)1.30 — (+)0.70
	Vertical	0.30	0.10	0.00 — 2.10
Pogonion	Horizontal	(-)0.10	0.10	(-)1.30 — (+)1.20
	Vertical	0.50	0.10	0.00 — 3.40
Menton	Horizontal	(-)0.05	0.10	(-)1.40 — (+)1.40
	Vertical	0.50	0.10	0.00 — 3.00

(+) Anterior
(-) Posterior

superior at the full closure position.

Lower molar was positioned 0.9 mm more anteriorly and 3.5 mm more superiorly at the full closure position than at rest in Group 1, while in Group 2 lower molar was 0.5 mm more posterior and 3.5 mm more superior. For the two groups combined there was no difference in the anterior-posterior position at lower molar, however it was 3.4 mm superior.

The mean differences in the orientation of the mandible betwen the rest and full closure position measured at lower incisor and lower molar are given in Table VIII.

The location of pogonion at the full closure position for Group 1 was 2.6 mm anterior and 5.0 mm superior to its position at rest, while in Group 2 it was 0.7 mm anterior and 4.7 mm superior. For the two groups combined, pogonion was 1.6 mm anterior and 4.8 mm superior (Table VIII).

The location of menton for Group 1, at the full closure position, was 2.9 mm anterior and 4.6 mm superior to its position at rest, while in Group 2 it was 0.8 mm anterior and 4.4 mm superior, and for the entire sample it was 1.8 mm anterior and 4.5 mm superior (Table VIII).

The resting posture of the mandible for Group 1, measured by the angle Reference point B to Reference point A to lower incisor, was 77.4 degrees compared to 80.2 degrees for Group 2. This illustrates that the lower incisor for Group 1 was positioned posteriorly to the lower incisor for Group 2 at the rest position. This is shown in Table XVII as Cine angle b.

Table VIII.

Mean differences in the cinefluorographic rest and full closure positions for the horizontal and and vertical components measured at four different points for Group 1, 2, and 1 and 2 combined. (mm)

Point	Component	Group 1	Group 2	Group 1+2
Lower Incisor	Horizontal	(+)0.80	(-)0.80	(-)0.15
	Vertical	4.90	4.80	4.90
Lower Molar	Horizontal	(+)0.90	(-)0.50	(+)0.10
	Vertical	3.50	3.50	3.40
Pogonion	Horizontal	(+)2.60	(+)0.70	(+)1.60
	Vertical	5.00	4.70	4.80
Menton	Horizontal	(+)2.90	(+)0.80	(+)1.80
	Vertical	4.60	4.40	4.50

(+) Anterior
(-) Posterior

II. CEPHALOMETRIC MANDIBULAR MOVEMENTS

The difference in the position of the mandible at the rest and full closure positions was measured on the composite tracings, as described in Chapter III, at both the pogonion and lower incisor points. The cephalometric results were compared to the cinefluorographic results to determine if the use of the head holder and ear rods, for taking the cephalometric radiographs, had any effect on the posture of the mandible or the head.

For Group 1, the position of lower incisor at full closure was 0.7 mm anterior and 5.6 mm superior to its position at rest, while pogonion was 2.5 mm anterior and 5.4 superior (Table IX). These cephalometric means were not significantly different from the cinefluorographic means for Group 1 (Table X).

Table IX.

Means, standard errors, and ranges of the differences in the cephalometric rest and full closure positions measured at lower incisor and pogonion for Group 1. (mm)

Point	Component	Mean	Standard Error	Range
Lower Incisor	Horizontal	(+)0.70	0.20	(-)1.30 — (+)2.90
	Vertical	5.60	0.80	1.00 — 10.40
Pogonion	Horizontal	(+)2.50	0.50	(-)0.40 — (+)5.20
	Vertical	5.40	0.80	0.90 — 10.90

(+) Anterior
(-) Posterior

Table X.

Means, means of differences, and significance of differences, for the horizontal and vertical components of the cinefluorographic and cephalometric mandibular movements from rest to full closure position, measured at lower incisor and pogonion, for Group 1. (mm)

Point	Component	Cinefluorographic Mean	Cephalometric Mean	Mean of Differences
Lower Incisor	Horizontal	(+)0.80	(+)0.70	0.10
	Vertical	4.90	5.60	0.50
Pogonion	Horizontal	(+)2.60	(+)2.50	0.09
	Vertical	5.00	5.40	0.40

(+) Anterior
(-) Posterior
** Significant at the .01 level
* Significant at the .05 level

For Group 2 the position of lower incisor was the same at the rest and full closure positions, but was 5.8 mm superior at full closure to its position at rest. Pogonion was 1.7 mm anterior and 5.5 mm superior (Table XI). These means were statistically different from the cinefluorographic means for Group 2 (Table XII).

The mean results for the two groups combined show that the lower incisor point was 0.4 mm more anterior and 5.7 mm more superior at the full closure position than at the rest position, while pogonion was 2.1 mm anterior and 5.5 mm superior (Table XIII). The lower incisor differences were statistically different from the cinefluorographic differences at the .05 level of significance, however, the differences at pogonion were not statistically different (Table XIV).

Table XI.

Means, standard errors, and ranges of the differences in the cephalometric rest and full closure positions measured at lower incisor and pogonion for Group 2. (mm)

Point	Component	Mean	Standard Error	Range
Lower Incisor	Horizontal	(+)0.10	0.20	(-)1.10 — (+)1.60
	Vertical	5.80	0.60	
Pogonion	Horizontal	(+)1.70	0.30	(-)0.50 — (+)3.90
	Vertical	5.50	0.60	1.30 — 8.70

(+) Anterior
(-) Posterior

Table XII.

Means, means of differences, and significance of differences, for the horizontal and vertical components of the cinefluorographic and cephalometric mandibular movements from rest to full closure position, measured at lower incisor and pogonion, for Group 2. (mm)

Point	Component	Cinefluorographic Mean	Cephalometric Mean	Mean of Differences
Lower Incisor	Horizontal	(-)0.80	(+)0.10	(-)0.90**
	Vertical	4.80	5.60	0.80*
Pogonion	Horizontal	(+)0.70	(+)1.70	1.00*
	Vertical	4.70	5.30	0.50

(+) Anterior
(-) Posterior
** Significant at the .01 level
* Significant at the .05 level

Table XIII.

Means, standard errors, and ranges of the differences in the cephalometric rest and full closure positions measured at lower incisor and pogonion for Groups 1 and 2 combined. (mm)

Point	Component	Mean	Standard Error	Range
Lower Incisor	Horizontal	(+)0.40	0.20	(-)1.30 — (+)2.90
	Vertical	5.70	0.50	1.00 — 10.40
Pogonion	Horizontal	(+)2.10	0.30	(-)0.50 — (+)5.20
	Vertical	5.50	0.50	0.90 — 10.90

(+) Anterior
(-) Posterior

Table XIV.

Means, means of differences, and significance of differences, for the horizontal and vertical components of the cinefluorographic and cephalometric mandibular movements from rest to full closure position, measured at lower incisor and pogonion, for Groups 1 and 2 combined. (mm)

Point	Component	Cinefluorographic Mean	Cephalometric Mean	Mean of Differences
Lower Incisor	Horizontal	(-)0.05	(+)0.40	0.40*
	Vertical	4.90	5.70	0.80*
Pogonion	Horizontal	(+)1.60	(+)2.10	0.50
	Vertical	4.80	5.50	0.70

(+) Anterior
(-) Posterior
** Significant at the .01 level
* Significant at the .05 level

The average cephalometric freeway space for the sample, measured at the lower incisor point, was 5.7 mm, which was significantly greater (.05) than the cinefluorographic freeway space of 4.9 mm. These results suggest that the subjects tend to posture their mandibles in a more open position when the head holder and ear rods are used for cephalometric exposures.

The mean cephalometric head posture for the sample was compared to the cinefluorographic head posture by an analysis of variance. The mean cephalometric head posture of 86.4 degrees was statistically less, at the .01 level, than the cinefluorographic head posture of 89.2 degrees. This suggests that the subjects tipped their heads forward and downward in relation to the true vertical when the head holder and ear rods were used.

Table XV gives the results of the comparison between cephalometric and cinefluorographic freeway space and head posture.

Table XV.

Means, standard errors, means of differences, and significance of differences of cinefluorographic and cephalometric results for freeway space (mm) and head posture (degrees).

	Cinefluorographic		Cephalometric		
Measurement	Mean	Standard Error	Mean	Standard Error	Mean of Differences
Freeway Space	4.90	0.40	5.70	0.50	0.80*
Head Posture	89.20	0.80	86.40	0.60	2.80**

** Significant at the .01 level
* Significant at the .05 level

III. GROUP COMPARISONS

Eighty-six measurements in each group were selected for comparison by an analysis of variance. A complete table of these results is found in the appendix (Table XXVI).

Non-continuous Measurements

The tooth apart swallow was evident in 15 per cent of the subjects in Group 1 compared to 38 per cent in Group 2. The remaining subjects swallowed with their teeth together. The difference between the two groups was not statistically significant, however it could indicate a trend. Cleall (1965) found that 40 per cent of his normal sample had a tooth apart swallow, while 60 per cent of his Class II Division 1 sample had a tooth apart swallow. The mean for this sample was 30 per cent (Table XVI).

Crowding in one or both of the arches was greater in Group 1 than Group 2, with the difference statistically significant at the .05 level. There were twelve subjects in the sample with no crowding in either arch. Ten of these subjects had a posterior-superior path of closure, from rest to initial contact, indicating that crowding could possibly have some effect on the path of closure of the mandible (Table XVI).

Wear on the labial surface of the mandibular incisors was evident in 38 per cent of the subjects. The difference in the number of subjects with wear present was not significant between the two groups (Table XVI).

The sample was well balanced, with reference to sex, with 15

Table XVI.

Percentages for each of seven "non-continuous" measurements for the two groups and the values of the contingency chi squares.

Measurement	Group 1 (%)	Group 2 (%)	X^2
Subdivision	38	25	0.607
Tooth apart swallow	15	38	1.756
Crowding (mx.)	39	13	2.639
Crowding (md.)	54	38	0.774
Crowding (either)	85	38	6.563**
Wear (md. incisors)	77	88	0.562
Sex (males)	62	38	1.659

** Significant at the .01 level
* Significant at the .05 level

females and 14 males. There was no significant sex difference between the two groups (Table XVI).

<u>Continuous Measurements</u>

Table XVII gives the results of a comparison between groups for 13 continuous measurements.

Due to the low incidence of approximately four per cent (Logan 1962) of Class II (2) malocclusion it was difficult to assemble a suitable sample for a study of this nature, therefore a wide age range had to be accepted. The average age of the subjects in Group 1 was 16.6 years, with a range of 11 to 25.5, compared to Group 2's mean of

Table XVII.

Means, standard errors, differences of the means, and significance of differences between Groups 1 and 2 for 13 "continuous" measurements.

	Group 1		Group 2		
Measurement	Mean	Standard Error	Mean	Standard Error	Difference
Overbite (%)	83.08	3.82	88.44	3.44	5.36
Overjet (mm)	1.62	0.40	3.19	0.36	1.57**
Head Posture (degrees)	88.54	1.28	89.77	1.15	1.23
Tooth Size-Mx. 12 (mm)	96.77	1.34	93.86	1.29	2.91
Tooth Size-Md. 12 (mm)	88.50	1.46	86.29	1.40	2.21
Tooth Size-Mx. 6 (mm)	48.65	0.71	45.32	0.69	3.33**
Tooth Size-Md. 6 (mm)	38.23	0.60	36.54	0.58	1.69*
Age (years)	16.58	0.87	12.96	0.78	3.82**
Arch length (mm)	25.05	0.66	25.22	0.59	0.17
Intercuspid Width (mm)	33.80	0.83	32.34	0.72	1.46
Intermolar Width (mm)	40.21	0.93	37.77	0.84	2.44
Freeway Space (mm)	4.98	0.61	4.71	0.55	0.27
Cine. Angle b (degrees)	76.19	1.28	75.14	1.26	1.05

** Significant at the .01 level
* Significant at the .05 level

13.0 years, with a range of 11 to 15.9. The mean difference of 3.6 years was statistically significant at the .01 level. This difference in age probably accounts for the large differences in the linear cephalometric measurements.

Wallis (1963), Ridley (1961), Ricketts (1952) and Ingervall (1968) have shown that excessive overbite is a characteristic of Class II Division 2 malocclusion. The average overbite for this sample of 86 per cent substantiates these findings.

It was hypothesized that the degree of overbite was related in some manner to the differences in mandibular closure paths. The overbite for Group 2 was six per cent greater than that for Group 1, however this was not statistically significant.

The overjet for Group 1 was 1.6 mm compared to 3.2 mm for Group 2, with the difference being significant at the .01 level. This difference, along with the difference in overbite, will be discussed in detail.

There was only one degree of difference between the cinefluorographic head postures of the two groups. The mean head posture for the entire sample was 89 degrees.

Four measurements involving tooth size were studied. There was no significant difference between the two groups in the size of the maxillary 12 teeth, nor the mandibular 12 teeth. The maxillary six anterior teeth in Group 1 were significantly larger, at the .01 level, than those in Group 2, however this was offset by the significantly larger mandibular six anteriors in Group 1.

There were no significant differences between the two groups in either intercanine width or arch length.

The mean intermolar width was 2.5 mm greater in Group 1 than in Group 2, and even though this was not statistically significant the F value was close to the .05 level, which could indicate a possible trend.

Excessive freeway space has been shown to be a characteristic of Class II Division 2 malocclusion by Wallis (1963), Ridley (1960), Ricketts (1950) and Ingervall (1968). The mean freeway space of 4.9 mm for this sample substantiates these findings. It was postulated that a big difference in freeway space between the two groups would help explain the difference in closure paths, however there was no significant difference between them; the mean difference being only 0.3 mm.

Cephalometric Measurements

Skeletal Angular

The skeletal angular results revealed several significant differences between the skeletal patterns of the two groups. Table XVIII gives the results of these selected measurements.

The cranial base angles measured were from nasion to sella to basion, and from nasion to sella to articulare. The means for the two groups were within one degree of each other for both measurements, which was to be expected since growth of the cranial base ceases at a much earlier age (Brodie 1941) (Scott 1958) than the youngest age in the sample.

There was no difference in the position of the hyoid bone between the two groups.

There was no significant differences between the two groups in

Table XVIII.

Means, standard errors, differences of the means, and significance of difference between Groups 1 and 2 for 13 cephalometric skeletal angular measurements.

Measurement	Group 1 Mean	Group 1 Standard Error	Group 2 Mean	Group 2 Standard Error	Difference
N-S-Ba	133.65	1.13	133.82	1.01	0.17
N-S-Ar	125.20	1.29	126.30	1.16	1.10
SNA	82.58	0.85	81.94	0.80	0.64
SNB	77.30	0.64	75.77	0.58	1.53
ANB	5.31	0.47	6.16	0.42	0.85
Md. Pl.-Pal. Pl.	21.70	1.17	22.67	1.06	0.93
Md. Pl.-U. Occl. Pl.	8.88	1.17	9.08	1.06	0.20
Md. Pl.-SN	30.18	1.36	31.27	1.23	1.09
S-N-Po	79.33	0.69	77.28	0.62	2.05*
Facial Angle	85.69	0.96	82.56	0.86	3.13*
Con-Go-M	129.81	1.48	128.81	1.34	1.00
Angle of Convexity	6.83	1.20	9.80	1.09	2.97
Md. Pl. Angle	23.83	1.43	25.99	1.29	2.16

** Significant at the .01 level
* Significant at the .05 level

the angular relationships between the mandibular plane, occlusal plane, palatal plane, Frankfort horizontal plane and SN plane. The mean standard deviation of these angular relationships was 4.0 degrees in Group 1, with a mean in Group 2 of 5.0 degrees. This difference in standard deviations was evident for almost every skeletal measurement, suggesting a possible greater homogeneity of the skeletal structure within Group 1.

The angle of convexity was 3.0 degrees greater in Group 2 than in Group 1, and both the SNPo and facial plane angles were larger in Group 1; the difference being significant at the .05 level. These differences probably reflect mandibular growth changes which are a function of the age differences between the two groups.

There were no significant differences in the relationships of the apical bases to the cranial base or to each other, however SNB was slightly larger in Group 1 suggesting that a forward movement of A point with growth is only slightly exceeded by that of B point. The mean ANB angle for the sample was 5.8 degrees.

There was no significant difference between the groups in the size of the gonial angle.

Table XIX is a comparison of three angular measurements from Down's (1948) normal sample with Group 1, 2 and the two groups combined.

Skeletal Linear

Table XX shows the results of the comparison between groups for selected skeletal linear measurements.

There was less than 0.2 mm difference in the mean length of both the anterior and posterior cranial bases for the two groups.

Table XIX.

A comparison of certain skeletal measurements from Down's (1948) normal sample with Group 1, 2 and the two groups combined (degrees).

Sample	Facial Plane (Angle) Mean	Facial Plane (Angle) Range	Angle of Convexity Mean	Angle of Convexity Range	Mandibular Plane (Angle) Mean	Mandibular Plane (Angle) Range
Down's	87.8	82.0 — 95.0	0.0	-8.5 — 10.0	21.9	17.0 — 28.0
Group 1	85.7	75.5 — 94.0	6.8	0.0 — 14.0	23.8	16.4 — 30.3
Group 2	82.6	75.3 — 86.5	9.8	0.0 — 18.5	26.0	17.8 — 37.6
Group 1+2	83.7	75.3 — 94.0	8.7	0.0 — 18.5	25.0	16.4 — 37.6

The lengths of the maxilla, the mandible, the mandibular ramus, the chin, and anterior face height; were significantly greater in Group 1 than in Group 2, however these differences were probably due to the differences in age between the two groups. This is substantiated by the high positive correlations between these variables and age in Group 1 (Table XXIV).

The average skeletal measurements for both groups fell within Down's (1948) normal range, suggesting that Class II (2) malocclusions have a Class I skeletal pattern (Table XIX). The large ANB angle (5.8 degrees) for the sample tends to contradict this, however this will be discussed later.

Dental Angular

The results of the dental angular measurements revealed some significant differences between the groups that could have some relation

Table XX.

Means, standard errors, differences of the means, and significance of difference between Groups 1 and 2 for 15 cephalometric skeletal linear measurements. (mm)

Measurement	Group 1 Mean	Group 1 Standard Error	Group 2 Mean	Group 2 Standard Error	Difference
S-Ba	40.79	1.10	39.74	1.00	1.05
S-N	67.84	0.80	66.28	0.70	1.56
Ba-N	100.10	1.50	98.10	1.40	2.00
M-W	96.60	1.80	89.70	1.60	6.90**
M-Go	64.76	1.30	61.53	1.20	3.23
M-Con	106.27	1.80	98.36	1.70	6.91**
Po-Con	107.53	1.80	100.17	1.60	7.36**
Ar-LBM	51.85	1.40	47.36	1.30	4.49**
Ar-Go	44.12	1.30	40.58	1.20	3.54**
Po-NB	3.40	0.60	2.30	0.40	1.10*
ANS-PNS	52.92	1.30	50.77	1.10	2.15
Ptm-ANS	52.53	1.10	49.37	1.00	3.16*
N-ANS	49.39	1.10	47.39	1.00	2.00
ANS-M	56.77	1.20	53.89	1.10	2.88
N-M	106.12	1.90	101.43	1.70	4.69*

** Significant at the .01 level
* Significant at the .05 level

to the differences in the mandibular paths of closure. These results are shown in Table XXI.

Table XXI.

Means, standard errors, differences of the means, and significance of difference between Groups 1 and 2 for 9 cephalometric dental angular measurements.

Measurement	Group 1 Mean	Group 1 Standard Error	Group 2 Mean	Group 2 Standard Error	Difference
$\overline{1}$ to Md. Pl.	89.90	2.11	95.81	1.90	5.91*
$\overline{1}$ to F. H.	66.07	2.06	59.07	1.86	7.00*
$\overline{1}$ to SN	59.72	1.86	53.79	1.68	5.93*
$\underline{1}$ to FH	94.26	2.01	93.49	1.81	0.77
$\underline{1}$ to SN	92.09	1.62	91.79	1.46	0.30
$\underline{1}$ to PP	83.61	1.82	83.19	1.64	0.42
$\underline{1}$ to $\overline{1}$	151.80	2.77	145.58	2.50	6.22
$\overline{6}$ to SN	67.65	0.78	68.44	0.70	0.79
$\underline{6}$ to SN	67.05	0.63	67.29	0.57	0.24

** Significant at the .01 level
* Significant at the .05 level

The position of the first molars in relation to both the Frankfort horizontal plane and the SN plane were not significantly different.

The average angulation of the lower incisors to the mandibular plane was 89.9 degrees in Group 1 compared to 95.8 degrees for Group 2, with the difference of 5.9 degrees significant at the .05 level. The angulation of the lower incisors to both the Frankfort Horizontal and SN planes was significantly larger at the .05 level in Group 1. The possible relationship between the angulation of the lower incisors and the path of closure will be discussed in detail later.

The angulation of the upper incisor to Frankfort horizontal, palatal, upper occlusal, and the SN planes was calculated. The mean difference between the two groups for each of these four measurements was less than one degree.

Dental Linear

The degree of eruption of the incisors was calculated in the two groups by measuring from the tip of the upper incisor to the palatal plane and from the tip of the lower incisor to the mandibular plane, however no significant difference was found between the two groups (Table XXII).

The lower incisor in Group 1 was positioned 1.1 mm more posterior to the APo plane than in Group 2, and 1.1 mm less anterior to the NB plane (Table XXII). These differences reflect the differences in angulation of the lower incisors.

The tip of the upper incisor in Group 2 was positioned 1.5 mm more anterior to the APo plane than in Group 1, with the difference sig-

Table XXII.

Means, standard errors, differences of the means, and significance of difference between Groups 1 and 2 for 7 cephalometric dental linear measurements. (mm)

	Group 1		Group 2		
Measurement	Mean	Standard Error	Mean	Standard Error	Difference
$\overline{1}$ to Md. Pl.	37.27	0.90	36.40	0.80	0.87
$\overline{1}$ to APo	3.02	0.60	1.86	0.50	1.16
$\overline{1}$ to NB	1.56	0.60	2.69	0.50	1.13
$\underline{1}$ to APo	-0.96	0.60	-2.50	0.60	1.54*
$\underline{1}$ to Pal. Pl.	26.68	0.70	26.31	0.60	0.37
Ptm to $\underline{6}$	15.42	0.90	12.96	0.80	2.46*
$\underline{1}$ - Md. Pl.	3.33	0.11	3.22	0.10	0.11

** Significant at the .01 level
* Significant at the .05 level

nificant at the .05 level (Table XXII). The difference is probably due to the significantly larger chin (Po-NB) in Group 1.

For Group 1, the distance from the maxillary first molar to PTM was significantly larger than for Group 2, with the difference significant at the .05 level (Table XXII). High positive correlations between this measurement and the length of the maxilla indicate that the above difference is evidently due to the greater length of the maxilla in Group 1.

Soft Tissue Angular

The soft tissue facial angle was five degrees greater in Group 1 than in Group 2 as was expected due to the larger skeletal facial angle in Group 1, however none of the three soft tissue angular variables were significantly different (Table XXIII).

Soft Tissue Linear

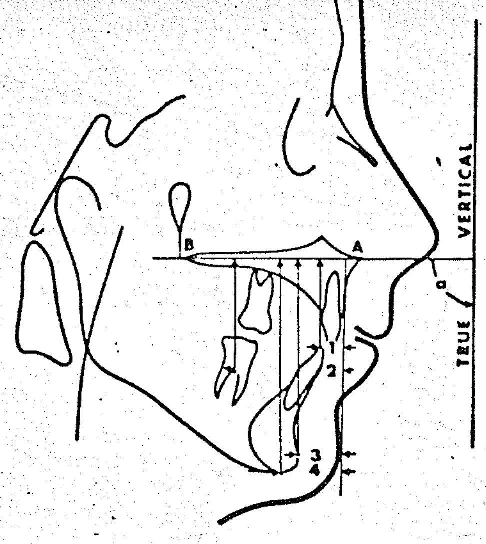
There was no significant difference between the two groups in the thickness of the upper lip, measured from tip of the incisor to the most anterior point on the lip, but the lower lip was significantly thicker in Group 1 at the .05 level. This difference also reflects the difference in angulation of the lower incisors between the groups.

Table XXIII.

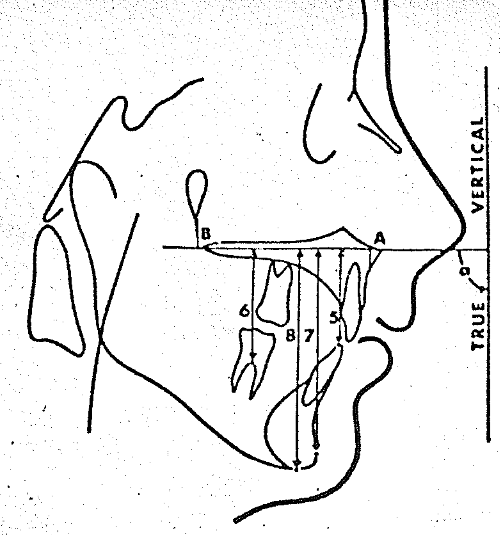
Means, standard errors, differences of the means, and significance of difference between Groups 1 and 2 for 1 angular and 4 linear (mm) cephalometric soft tissue measurements.

	Group 1		Group 2		
Measurement	Mean	Standard Error	Mean	Standard Error	Difference
S. T. Facial Angle	90.90	3.17	86.30	2.86	4.60
Length of Upper Lip (hor.)	17.37	0.80	16.92	0.70	0.45
Length of Lower Lip (hor.)	15.41	0.60	13.73	0.50	1.68*
Length of Chin (hor.)	11.02	0.40	11.02	0.40	
Nose to Chin (vert.)	60.35	1.20	57.46	1.10	2.89*

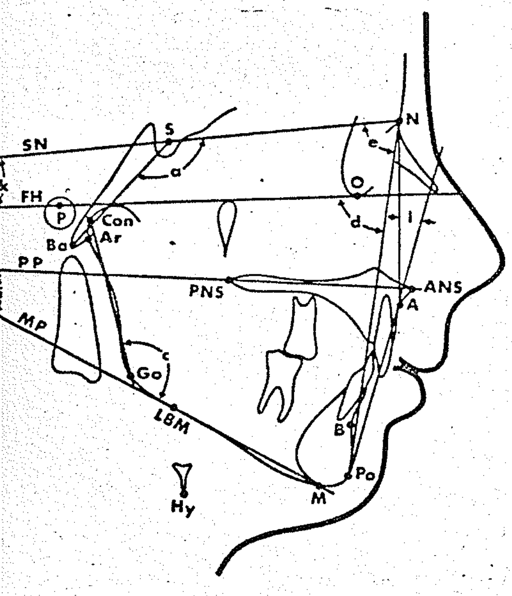
** Significant at the .01 level
* Significant at the .05 level



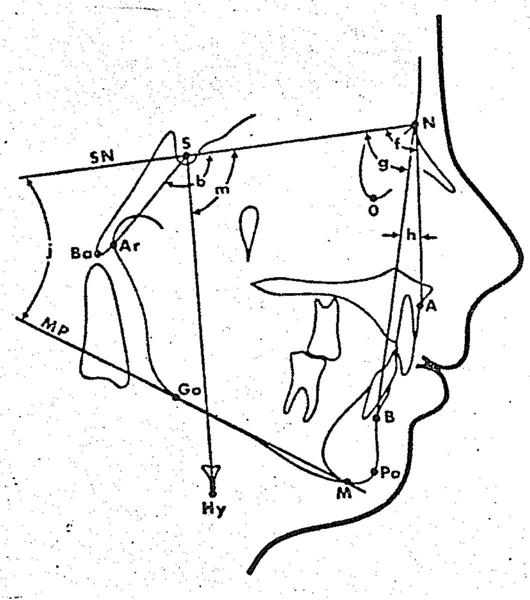
Cinefluorographic
Linear Horizontal



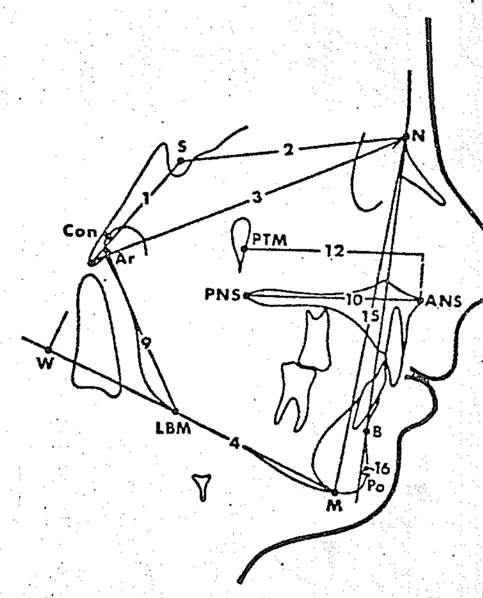
Cinefluorographic
Linear Vertical



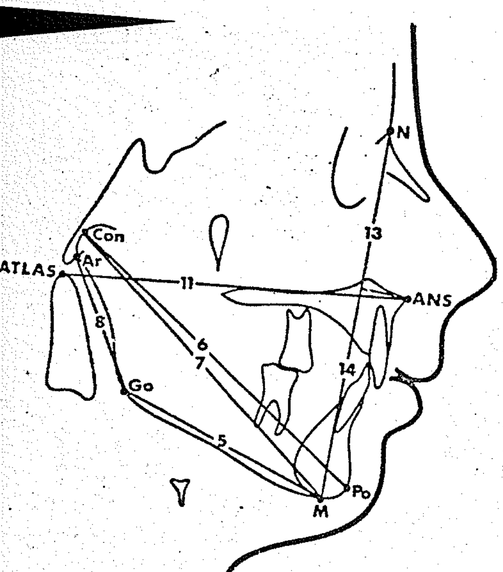
Cephalometric
Skeletal Angular



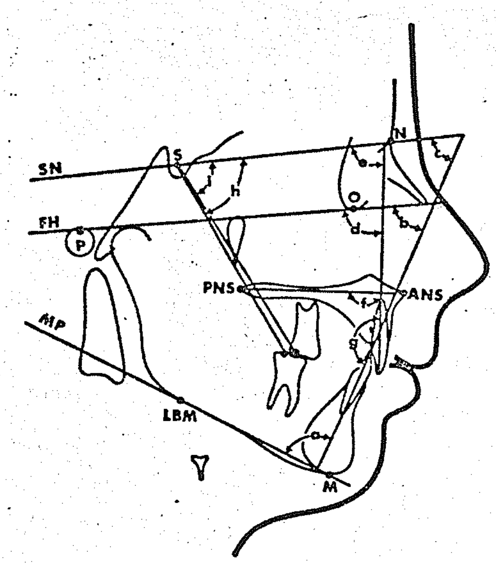
Cephalometric
Skeletal Angular



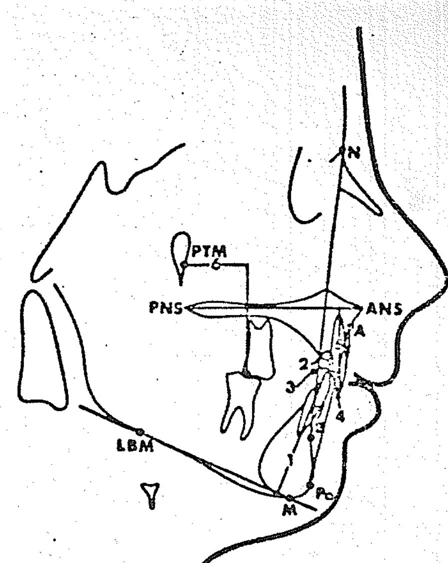
Cephalometric
Skeletal Linear



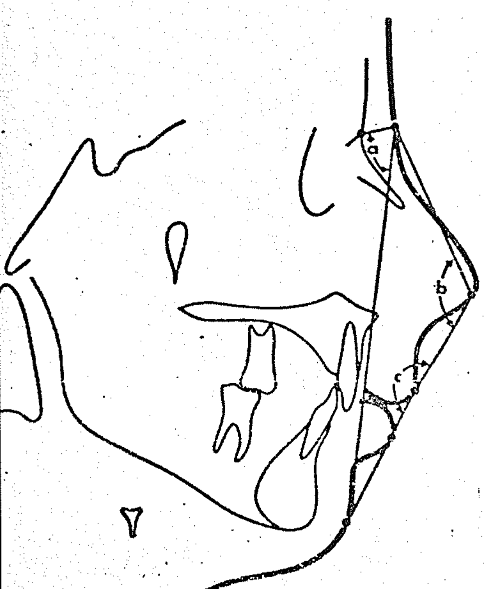
Cephalometric
Skeletal Linear



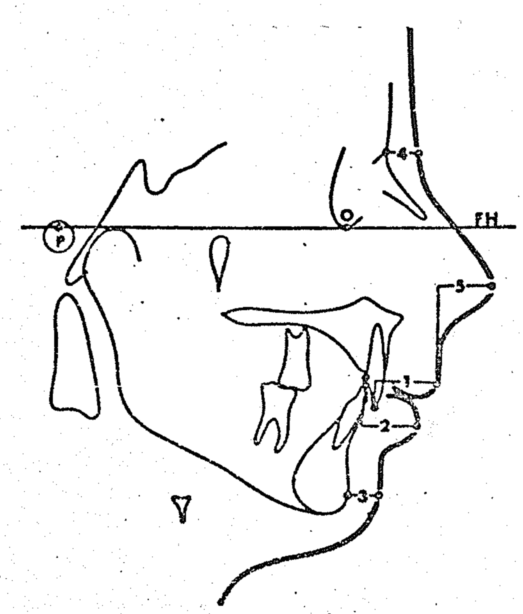
Cephalometric
Dental Angular



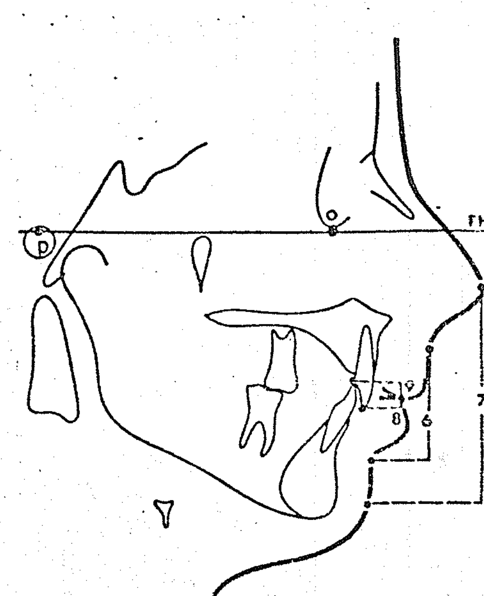
Cephalometric
Dental Linear



Ceph. Soft Tissue Angular



Ceph. Soft Tissue Linear



Ceph. Soft Tissue Linear

There was no difference between the two groups in the thickness of the soft tissue chin, which does not reflect the large difference between the groups in the size of the bony chin.

The distance from the soft tissue chin to nose was significantly greater in Group 1 as expected due to the greater anterior face height in Group 1.

There was no significant differences between groups for the other soft tissue measurements.

Table XXIII gives the results of the comparison of selected soft tissue measurements.

IV. SIMPLE CORRELATIONS

Correlation coefficients were calculated for all possible pairs of 86 variables selected from the cinefluorographic, cephalometric and model analyses. Since it is impractical to present even a small percentage of these results, only a selected number will be presented. Some of these have been referred to earlier in the results. All results are for the two groups combined unless otherwise indicated.

Statistically significant negative correlations were found between age; and overbite, overjet, head posture, angle $\overline{1}$ to mandibular plane and occurance of the tooth apart swallow. These were all significant at the .01 or .05 level as shown in Table XXIV. There was also a negative correlation between the interincisal angle and the tooth apart swallow, significant at the .05 level. These correlations suggest that with an increase in age; the overbite, overjet, and head posture decreased, the lower incisors became more lingually inclined, and the

Table XXIV.

Simple correlation coefficients for selected pairs of cinefluorographic, cephalometric, and diagnostic model variables

Variable	Correlation Coefficients
Age: Md. Path of Closure	0.377*
Age: Overjet	-0.568**
Age: Head Posture	-0.391*
Age: $\overline{1}$-Md. Pl. (angle)	-0.389*
Age: Tooth Apart Swallow	-0.381*
Age: Po-NB	0.273
Age: Intermolar Width	0.463**
Age: Overbite	-0.584**
Age: $\overline{1}$-Md. Pl. (linear)	0.578**
Age: $\underline{1}$-Pal. Pl. (linear)	0.665**
Age: $\underline{1}$-Md. Pl. (linear)	0.561**
Age: Ar-Go	0.627**
Age: M-Go	0.533**
Age: N-M	0.731**
Age: TT-TP	0.705**
Sex: Con-Go-M	0.409*
Sex: Intermolar Width	0.408*
Sex: Ba-S	0.381*
Sex: N-Ba	0.378*
Overjet: $\overline{1}$-Md. Pl. (angle)	0.658**
Overjet: ANB	0.186
Overjet: $\underline{1}$-$\overline{1}$	-0.592**
Overbite: Ar-Go	-0.334
Overbite: Ar-LBM	-0.371*
Overbite: N-M	-0.391*
ANB: $\underline{1}$-SN	-0.513**
ANB: $\underline{1}$-FH	-0.514**
ANB: $\underline{1}$-Pal. Pl. (angle)	-0.480**

(Cont'd)

Variable	Correlation Coefficients
ANS-PNS: $\underline{1}$-SN	-0.430*
ANS-PNS: $\underline{1}$-FH	-0.363*
ANS-PNS: $\underline{1}$-Pal. Pl. (angle)	-0.371*
$\overline{1}$-Md. Pl. (angle): Po-NB	-0.437*
$\overline{1}$-Md. Pl. (angle): M-W	-0.492**
$\overline{1}$-Md. Pl. (angle): SNPo	-0.462*
$\overline{1}$-Md. Pl. (angle): SNB	-0.398*
$\overline{1}$-Md. Pl. (angle): Con-Go-M (Group 1)	-0.613*
$\overline{1}$-Md. Pl. (angle): Angle of Convexity	0.399*
$\overline{1}$-Md. Pl. (angle): Md. Path of Closure	-0.499**
$\overline{1}$-Md. Pl. (linear): N-M	0.719**
$\overline{1}$-Md. Pl. (linear): Ar-Go	0.364*
$\overline{1}$-Md. Pl. (linear): Ar-LBM	0.440*
$\overline{1}$-Pal. Pl. (linear): N-M	0.646**
$\underline{1}$-Pal. Pl. (linear): Ar-LBM	0.623**
$\underline{1}$-Pal. Pl. (linear): Ar-Go	0.666**
$\overline{1}$-TL: $\overline{1}$-Md. Pl. (angle	-0.275
$\overline{1}$-TL: $\overline{1}$-FH	0.544**
$\overline{1}$-TL: $\overline{1}$-SN	0.539**
$\underline{1}$-TU: $\underline{1}$-SN	-0.630**
$\underline{1}$-TU: $\underline{1}$-Pal. Pl. (angle)	-0.409*
$\underline{1}$-TU: $\underline{1}$-FH	-0.560**
Head Posture: Hy-FH	-0.531**
Head Posture: Hy-SN	-0.627**
$\underline{1}$-$\overline{1}$: Tooth Apart Swallow	-0.366*
Freeway Space: TT-TP	0.475**

** Significant at the .01 level
* Significant at the .05 level

occurence of the tooth apart swallow decreased. This could be interpreted as adaptation of the swallowing mechanism to changing morphology, or maturation of the swallowing mechanism.

An interesting finding was the negative correlation, significant at the .05 level, between the angle $\overline{1}$ to mandibular plane and the gonial angle in Group 1 (Table XXIV). This suggests that the lower incisors are more lingually inclined in the subjects with more obtuse gonial angles, perhaps suggesting a compensatory angulation of the lower incisors for a large gonial angle, which is sometimes suspected in Class III cases. Even though no conclusion can be drawn from this, it certainly suggests that research on this topic should be undertaken since it could have clinical implications.

Another interesting group of correlations were those involving the degree of overbite. There was a positive correlation between age and the distance $\overline{1}$ to mandibular plane and between age and the distance $\underline{1}$ to palatal plane, both significant at the .01 level. This could imply that the upper and lower incisors continue to erupt with age and are both probably overerupted, as is often suspected from clinical observations of Class II Division 2 cases. Even though the upper incisors are overerupted, a positive correlation, significant at the .01 level, between age and the distance $\underline{1}$ to mandibular plane suggests that this distance becomes greater with age due to a decrease in overbite. The decrease in overbite is probably due to the vertical growth of the mandible and the eruption of the posterior teeth. The decrease in overbite was suggested by the negative correlations between overbite; and age (.01), ramus height (.05) and anterior face height (.05). The large amount of vertical growth is shown by the high positive correlations between age; and anterior face height, ramus height and soft tissue nose to chin distance, all significant at the .01 level. Significant positive correlations that illustrated the continued eruption of upper and lower incisors were between distance $\underline{1}$ to palatal plane; and anterior face height, and ramus height and between distance $\overline{1}$ to mandibular plane; and anterior face height and ramus height, all significant at the .01 level (Table XXIV).

There were negative correlations, significant at the .01 level, between the ANB angle and the angles $\underline{1}$ to SN, $\underline{1}$ to FH and $\underline{1}$ to palatal plane. These possibly indicate that the greater the discrepancy between the apical bases; the more the upper incisor is inclined lingually, perhaps due to the pressure of the lower lip.

All of the linear skeletal and soft tissue measurements were positively correlated with age which was expected due to growth.

The positive correlations between overjet and angle $\overline{1}$ to mandibular plane which was significant at the .01 level, and the lack of a significant correlation between overjet and the ANB angle suggests that in Class II Division 2 malocclusion the overjet is usually a function of the incisor angulation rather than of a skeletal discrepancy as seen in Class II Division 1. There was also a negative correlation between overjet and the interincisal angle, significant at the .01 level. Table XXIV shows the results of these correlations.

There was a positive correlation, significant at the .05 level, between age and molar width suggesting a possible increase in molar width with age (Table XXIV).

There were negative correlations between head posture and the position of the hyoid bone in relation to both FH and SN planes, significant at the .01 level (Table XXIV). This shows that the position of the hyoid bone may be directly related to head posture and perhaps illustrates the functional balance of the muscular components involved in the maintenance of head posture.

The angle of convexity showed a positive correlation with the angle $\overline{1}$ to mandibular plane, significant at the .05 level, which infers that the angle of convexity decreases as the lower incisor becomes more lingually inclined. This decrease in convexity reflects forward growth of the mandible which occurs with age (Table XXIV).

There were significant positive correlations which suggested that the gonial angle, intermolar width, posterior cranial base and cranial base were larger in males than in females in this sample (Table XXIV).

The negative correlations between the horizontal length of the upper lip; and angles $\underline{1}$ to FH, $\underline{1}$ to SN, $\underline{1}$ to palatal plane and between the horizontal length of the lower lip; and angles $\overline{1}$ to mandibular plane, $\overline{1}$ to FH and $\overline{1}$ to SN suggest that as the incisors become more lingually inclined the soft tissue does not follow the incisors lingually, but maintains its position or grows in thickness. Burstone (1959) found that during treatment the alteration of the soft tissue mass is in part postural, reflecting a change in the manner of lip closure and in part, the result of growth (Table XXIV).

Freeway space was positively correlated (.01) with the distance from the tip of the soft tissue nose to the tip of the soft tissue chin. This implies that the subjects with a larger freeway space have the greatest lower face height.

IV. CENTRES OF ROTATION

The centre of rotation of the mandible for each subject was calculated by the computer, as described earlier, for the movements from rest to initial contact and rest to full closure. The means of the coordinates of the cephalometric landmarks of the mandible were utilized to draw the average mandibles for Groups 1, 2, and 1+2 as illustrated in Figures 25, 26 and 27. The centres of rotation for each individual were plotted on the respective drawings.

Most of the centres for Group 1 are clustered posterior to the centre of the ramus. One of the centres was so far anterior and inferior to the mandible that it was not included in the illustration of Group 1 results. One centre was posterior and superior to the condyle. The average centre of rotation for Group 1 was approximately 40 to 50 mm posterior to the centre of the ramus as illustrated in Figure 25. The average mandibular rotational centre for the movement from rest to full closure was located approximately 10 mm anterior and 5 mm inferior to the average centre calculated from the rest to initial contact movement.

The individual centres of rotation for Group 2 were more scattered than in Group 1. A number of the centres were clustered posterior to the gonial angle with two centres inside the mandible at the angle and two immediately inferior to the angle. Two centres were so far from the mandible that they were not included in the illustration for Group 2 results in Figure 26. The computer was unable to calculate two centres suggesting that the condylar movement was purely translatory. The average centre of rotation for Group 2 was approximately 50 mm posterior

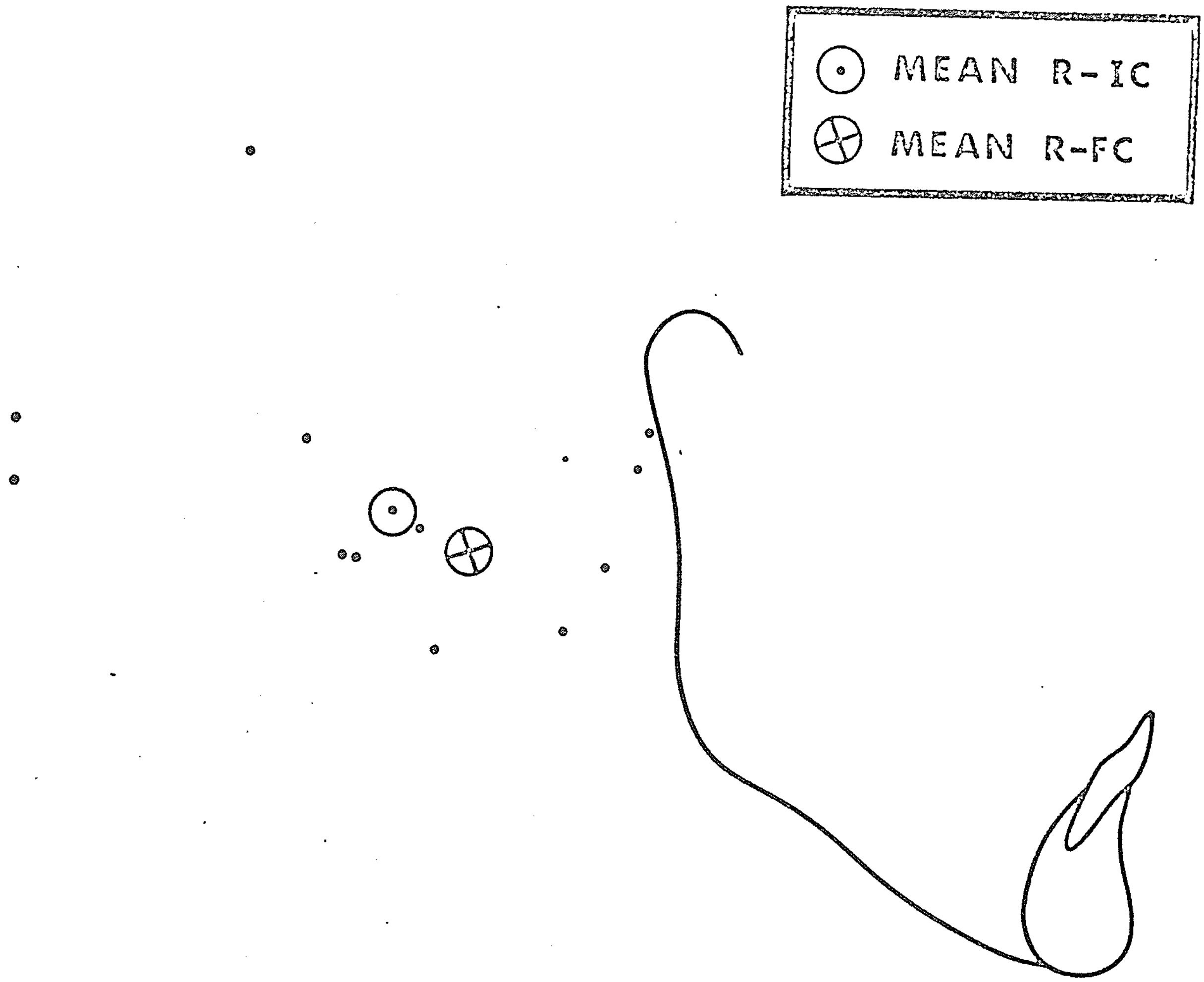


Figure 25. Illustration of the individual and mean mandibular centres of rotation for the movement from rest to initial contact and the mean for the movement from rest to full closure for Group 1.

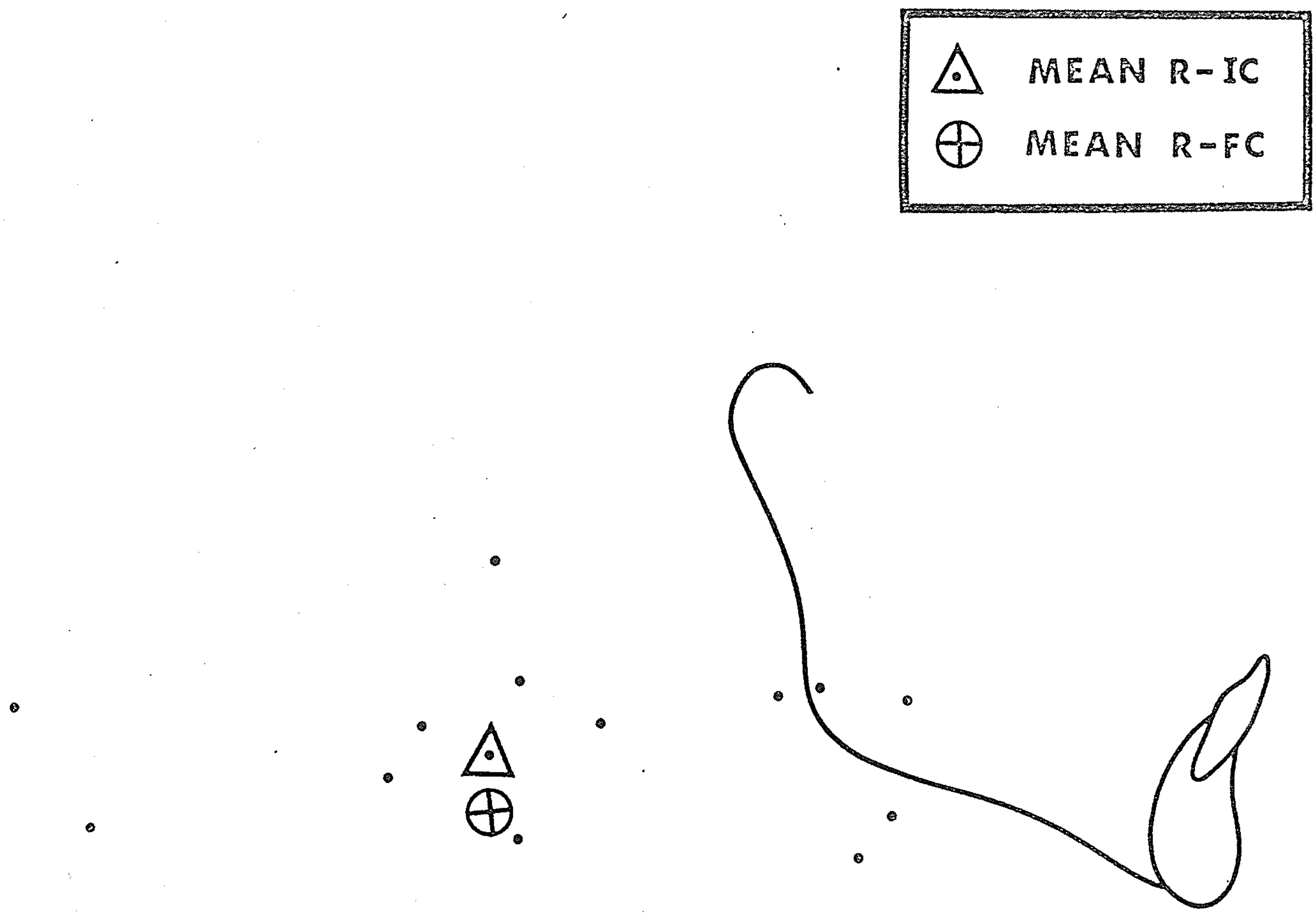


Figure 26. Illustration of the individual and mean mandibular centres of rotation for the movement from rest to initial contact and the mean for the movement from rest to full closure for Group 2.

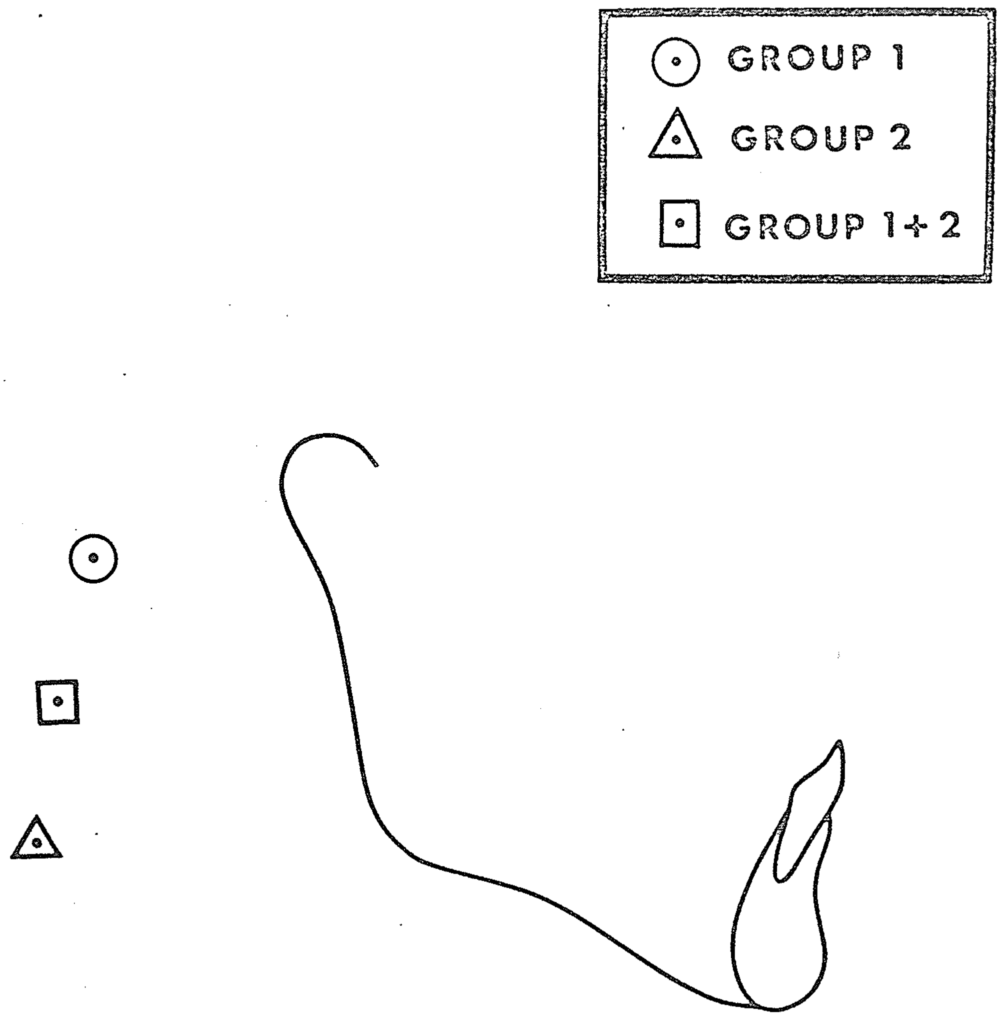


Figure 27. Illustration of the mean mandibular centres of rotation for the movements from rest to initial contact for Group 1, 2, and 1+2 combined.

to the apex of the gonial angle. For the movement from rest to full closure position, the average mandibular rotational centre was 10 mm directly inferior to the average centre for the movement from rest to initial contact.

The mean centres for the two groups were tested (unpaired t-test) to determine if they were statistically different. Although there was no significant difference between the two, this could be due to the large variation between individuals within the groups.

The average centre of rotation of the mandible for the two groups combined was 50-60 mm posterior to the ramus and half way between the apex of the gonial angle and the centre of the ramus as illustrated in Figure 27.

CHAPTER V

DISCUSSION

Mandibular Movements

Rest to Initial Contact

As was postulated, more than one pattern of mandibular closure, from rest to initial contact position, was found in the present study. The direction of closure at the lower incisor for 13 of the 29 subjects was anterior-superiorly while the remaining 16 subjects moved in a posterior-superior or in a straight superior direction. The average anterior movement was approximately three times greater than the average posterior movement. The anterior movements were very easy to assess subjectively while some of the posterior movements were so small that they could have been called straight vertical movements.

The average movement from rest to initial contact was in an anterior-superior direction for the overall sample, which is the real path of closure since the movement from initial contact to full closure represents a forced retrusion (distal shift) at the lower incisor.

The path of closure at the lower molar point was in the same direction as that at lower incisor in both groups; however the vertical component was 30 per cent less, due to the closer proximity of the lower molar to the centre of rotation of the mandible. Exceptions were five subjects in Group 2 who showed almost pure translatory movement of the condyle. In these five cases the vertical movement of the lower molar was only five per cent less than that of the lower incisor. This means that the vertical space between the teeth at rest (freeway space) was almost the same in the molar region as in the incisor region. Pogonion and menton moved in an anterior-superior direction in every subject except the five cases mentioned above in which they moved posterior-superiorly.

Centre of Rotation

The mandibular centre of rotation for the movement from rest to initial contact for two of the five cases mentioned above could not be calculated by the computer since they were pure translatory movements. Two other cases had rotational centres that were at such a distance from the condyle that they could not be plotted, while in the fifth instance the rotational centre was inferior to the lower border of the mandible. These three cases had predominantly translatory condylar movements.

The remaining 24 cases were characterized by variability, with the average centre in Group 2 located posterior to gonion, while Group 1 was posterior to a point just above the centre of the ramus. This indicates that the cases with an anterior-superior path of closure have more of a rotary type of condylar movement due to the proximity of their rotational centres to the condyle. These results support Bennett's (1908) original findings that the centre of rotation about which the mandible may be regarded as moving at any instant has a position outside the condyle.

Initial Contact to Full Closure

The movement of the mandible from initial contact to full closure has been referred to as the "distal shift" of the mandible in Class II (2) patients. The lower incisor contacts the lingual surface of the upper incisor and slides upward and backward, sometimes coming to rest on the soft tissue. The posterior displacement at the lower incisor occurred in seven subjects in Group 2 and nine in Group 1, while only nine of these subjects showed a posterior displacement of pogonion and menton. The movement in most cases was very small and difficult to measure, however it could be observed subjectively in most cases. Evidence that this distal shift does occur may be found in the presence of wear on the labial surface of the lower incisors in all but five subjects. Three of these five were the three youngest subjects in the sample. The reason for the "distal shift" is probably the angulation of the upper incisors and the shape and size of their cingula. Robertson and Hilton (1965) demonstrated that in Class (2) malocclusion the upper incisors were thinner (labiolingually) at the cingulum than in normal occlusion.

It appears from the results of this study that the elimination of the "distal shift" would have very little effect on the apical base or dental relationships and therefore cannot be considered as a clinically significant consideration in planning treatment for Class II (2) malocclusions.

Rest to Full Closure

For Group 1, the mandible at lower incisor was positioned one millimeter more anteriorly in the full closure position than in the rest position compared to one millimeter posteriorly in Group 2. The average difference for the two groups combined was zero, indicating that the average mandibular movement from rest to full closure for the entire sample was in a straight superior direction. If the "distal shift" from initial contact to full closure were eliminated, the average path of closure would be in an anterior-superior direction. The path of closure, from rest to full closure differed from Rickett's (1950) Class II (2) results which showed an anterior-superior direction and Ingervall's (1968) Class II (2) results which had a posterior-superior direction (Table XXV). It is interesting to note that their Class II Division 1 samples had more of a posterior path of closure than their Class II (2) samples, which is contrary to what would be expected in looking at the skeletal and dental morphology of the two divisions.

Comparison of Studies

Many differences in methods and samples must be taken into consideration when comparing the present study with others. These differences were of such magnitude that a statistical comparison was impractical. Table XXV illustrates the characteristics of selected studies concerned with mandibular movements.

Rest Position Registrations

The differences in the radiographic methods of determining the mandibular path of closure are not as important as the differences in methods of registering the rest position. In the present study the "free head position" was used during filming since it was believed that the use of mechanical head posturing devices, as used in other studies, dis-

Table XXV.

Name	Method	Sample Classification	Age (Years) Range	Average	Reference Plane	Measuring Point	Path of Closure
Thompson(46)	ceph.	Cl. II (2)	---	----	---	Md. Incisor	Post.-sup.
Blume(47)	ceph.	Cl. II (1)	8-15	11.1	SN	Md. Incisor	Post.-sup. (75%)
Boman(48)	ceph.	Normal	---	----	SN	Md. Incisor	Ant.-sup. (88%)
Ricketts(50)	lamina.	Cl. II (2)	5-22	14	LOP	Lower Molar	Ant.-sup. (mean)
Ricketts(50)	lamina.	Cl. II (1)	5-22	14	LOP	Lower Molar	Post.-sup. (mean)
Posselt(52)	ceph.	----------	20-29	----	S-N	Steel Ball	Ant.-sup. (72%)
Nevakari(56)	ceph.	----------	21-29	----	FH	Lead Pellet	Ant.-sup. (80%)
Steiner(60)	ceph.	Cl. II (1)	---	----	---	-----------	Post.-sup. (65%)
Ingervall(66)	ceph.	Cl. II (1)	7.5-13	9.8	UOP	Infradentale	Post.-sup. (mean)
Ingervall(68)	ceph.	Cl. II (2)	8.2-14.8	11.5	UOP	Infradentale	Post.-sup. (mean)
PRESENT STUDY(70)	cine.	Cl. II (2)	11.0-25.5	14.6	PP	Md. Incisor	Superior (mean)

turbs the delicate muscular equilibrium; and that a posturing of the mandible in other than the physiologic rest position could result. The use of metal pellets stuck to, or between, the teeth to be used as reference points on the radiographs could also prove to be unphysiologic. This view was suggested by Cleall (1965) and has been supported in the present study by the results of a comparison of the path of closure, freeway space, and head posture recorded cinefluorographically and using the cephalometric technique. A cephalostat with ear rods was used to stabilize the head during cephalometric exposures.

The mean "cinefluorographic" freeway space of 4.9 mm was significantly less than the "cephalometric" freeway space of 5.7 mm, while an assessment of the head posture showed that the head was more extended on the cinefluorographs than on the cephalograms. The mean movement from rest to full closure, measured on the cinefluorographs was in a straight superior direction compared to the "cephalometric" path of closure which was anterior-superiorly. These findings indicate that when the cephalostat with ear rods was used, the subject had a tendency to flex his head, posturing the mandible downward and backward. This is not meant to imply that the mandible is postured downward and backward each time mechanical head holding devices are used since the results indicated that some of the mandibles were postured upward and backward, upward and forward, and downward and forward. The posturing of the mandible probably depends on the position of the head in the head holding device and the placement of the ear rods. These findings support the findings of Preiskel (1965) and Dombrady (1966) that the physiological rest position varies with the position of the head.

Reference Planes

Another important factor to consider in comparing the different studies is the reference plane used for measuring changes in mandibular positions. The various anatomical reference planes used by the different investigators are illustrated in Table XXV. Measurements of horizontal movements in the sagittal plane should be measured in relation to the plane which is closest to the true horizontal to facilitate comparisons between studies. In the present study the palatal plane was used since its relationship to the true vertical was 89.2 degrees compared to the other anatomical planes which were: SN 97.8^{o}, Frankfort horizontal 91.9^{o}, lower occlusal 86.3^{o} and upper occlusal 76.7^{o}. On the basis of these results, it is recommended that either the palatal plane or the Frankfort horizontal plane be used as reference planes for investigations of mandibular movements.

Age

Another important factor limiting any statistical comparisons was the age differences in various studies. Some authors did not state age while others gave only age ranges. Rickett's age range and mean were closest to those of the present study, however they represented Division 1 and 2 combined. In the present study we were forced to accept a large age range due to the low incidence of this type of malocclusion, however this large age range inadvertently resulted in the demonstration of a most important finding relating to the angulation of the lower incisors.

Group Differences

Skeletal

The mean age for the subjects with the anterior-superior path of closure (Group 1) was significantly greater than for the subjects with the posterior-superior path of closure (Group 2), which probably accounts for the differences in skeletal linear measurements. Group 1 had a longer maxilla, mandible, ramus, face height, and bony chin, all of which reflect growth changes.

The greater face height in Group 1 was probably the result of both vertical growth and eruption of the posterior teeth. It was very evident from observing the study models that the buccal segments were more erupted in the older patients. The mean overbite in Group 1 was 83 per cent compared to 88 per cent for the Group 2. A negative correlation between age and overbite, and age and the distance from the upper incisor tip to the mandibular plane, support the finding that overbite decreases with age.

The measurement Po-NB is considered a measure of the bony chin. Group 1 had a significantly larger bony chin than Group 2 suggesting that the chin size increased with growth, however the correlation between age and Po-NB was not significant. There was a significant correlation between Po-NB and $\overline{1}$ to mandibular plane angle. It is evident that the chin point came forward with growth since SNPo is significantly greater in Group 1, however there was no significant difference in SNB between the groups. The forward movement of the mandible due to growth at the condyle is shown by a significantly longer mandible (M-W) in Group 1 and the lack of a significant difference between the groups in the length of the mandible measured from menton to gonion. Thus we conclude that as growth occurs; pogonion moves forward a significant amount while B points moves forward by a much lesser amount. Even though there are no clinical studies to show that the bony chin of Class II (2) patients is larger than normal, this impression is sometimes obtained from clinical observations. The lack of forward movement of B point due to compensatory changes in the dento-alveolar components as the mandible moves forward with growth accounts for the increase in Po-NB and the impression that the bony chin is getting larger. This does not discount the possibility of appositional bone growth at the chin.

The forward movement of the mandible, with growth, accounts for the significantly greater facial angle and SNPo angle in Group 1. These were the only angular measurements that were significantly different in the two groups. The lack of any significant forward movement of B point, as described above, accounts for the fact that there was no significant difference in the ANB angle between the two groups.

Soft Tissue

The only differences in the soft tissue measurements of the two groups were a thicker lower lip (horizontal) and a greater distance from nose to chin in Group 1. The lower lip was measured from the tip of the lower incisor to the most anterior point on the lower lip, therefore the thicker lower lip in Group 1 probably reflects the more retroclined lower incisors in Group 1. Significant negative correlations between the ANB angle and $\underline{1}$ to SN and $\underline{1}$ to FH show that the greater the apical base discrepancy, the more the upper incisors are lingually inclined. These correlations suggest that the lower lip controls the angulation of the upper incisors, which is often suspected from clinical observations. Nicol (1955) showed that the most superior point on the lower lip was at a greater distance above the tip of the upper incisor in a Class II (2) sample than the normal and Class I samples and therefore concluded that the upper central incisors in Class II (2) were tilted lingually by the control exerted by too great a vertical length of the lower lip.

The horizontal thickness of the soft tissue chin was exactly the same in both groups indicating that the growth of the soft tissue chin was not influenced by the growth of the bony chin.

Dental

There was no significant difference between the two groups in the angulation of the upper incisors, nor was there any significant correlation between age and angulation of the upper incisors, suggesting that there is no change in angulation during the pubertal growth period. The lower incisor to mandibular plane angle was 96 degrees in Group 1 which was significantly larger than the 90 degree angle for Group 2. There was a significant negative correlation between age and $\overline{1}$ to mandibular plane angle. These results clearly indicate that in Class II (2) malocclusion the lower incisors become more lingually inclined with age. This agrees with Bjork's (1951) finding that the angulation of the lower incisors is related to facial type, age, and other factors. This is further supported by the negative correlation between age and overjet, and the positive correlation between overjet and $\overline{1}$ to mandibular plane angle which suggest that as the lower incisors tip lingually with age, the overjet decreases. This decrease in overjet is probably the result of the horizontal growth of the mandible.

It should be pointed out here that there were four subjects in Group 2 who appeared to be in their growth periods, and were possibly undergoing the lower incisor changes discussed above. Their average lower incisor angular was 92 degrees with an average age of 13.5 years.

<u>Growth and Compensatory Changes</u>

It has been shown that for Group 1 (older mean age and retroclined lower incisors) mandibular closure occurred in an anterior-superior direction; while in Group 2 (younger mean age and proclined lower incisors) the mandible moved in a posterior-superior or superior direction. On the basis of an anticipated decrease in anterior-posterior arch discrepancy with age, it was thought at the onset that older subjects would close posteriorly due to incisal guidance and younger subjects would close in an anterior direction. Such was not the case.

Another possibility was that the mandible was "locked" distally due to the upper incisor angulation and overeruption, thus functioning on the mandible in the same manner as cervical traction on the maxilla and redirecting the horizontal growth in a vertical direction. This was postulated by the Eastern Component Group of the Edward H. Angle Society of Orthodontists (1935) in a statement that read, "the forces of occlusion aid in checking the forward growth of the body of the mandible" in Class II (2) malocclusion. This was evident in only one case in the present sample. Case #20, who had a posterior-superior path of closure with a pure translatory condylar movement and a $\overline{1}$ to mandibular plane angle of 106 degrees, was 16 years old and from all indications fully grown. She had the second longest ramus and the third shortest mandible, indicating that growth had moved the mandible in a predominately vertical direction. Another indication of the large amount of vertical growth was a 70 per cent overbite. There were indications that her mandible did come forward slightly with growth. The ANB angle was below the group average and there were only two subjects in the group with larger SNPo angles. This subject will be referred to again later. It should be pointed out that there is no evidence that the mandible would not have grown in the same manner if the upper incisors were not retroclined.

Group 1

It is evident in the cases where mandibular growth is advanced that due to compensatory changes of the dento-alveolar components, the mandible is allowed to come forward with growth. Evidence that the mandible did come forward as the incisors become more lingually inclined is the greater SNB and SNPo angles in Group 1 and by significant negative correlations between the $\overline{1}$ to mandibular plane angle and SNB, SNPo, and MW. These results support Bjork's (1955) findings that the dental and alveolar arches are of a compensatory shape at the adult stage and that increased protrusion of the mandible relative to the upper jaw results in compensatory changes in the dento-alveolar components. Bjork also found that the development of the facial component was independent of the development of the dento-alveolar components, but that the dento-alveolar components were intimately dependent on the development of the facial components. The results of the present study suggest that the development of certain facial components (mandible) are influenced by the dento-alveolar components in some Class II (2) malocclusions as illustrated by case #20. Figure 28 is a diagrammatic illustrating of the change in lower incisor angulation which occurs as the mandible grows.

As the lower incisors become more retroclined and the bite is opened by growth and eruption, the mandible gradually assumes its normal path of closure and the lower incisors contact the upper incisors in a more anterior position. This is due to compensatory changes in the temporomandibular joint and the neuromuscular mechanism as they gradually change the rotation and/or translation of the mandible so that the teeth come into occlusion with a minimum of trauma. The change in the mandibular path of closure as the incisors become more lingually inclined with growth is shown by a negative correlation between $\overline{1}$ to mandibular plane and mandibular path of closure and a positive correlation between age and mandibular path of closure; both are statistically significant (Table XXIV).

It is evident that if these compensatory changes in the various components did not occur during the period of mandibular growth, the mandible would have to grow in a predominately vertical direction as shown in the present study by case #20, or the horizontal mandibular growth would cause an anterior crossbite as illustrated by Ridley (1960). These

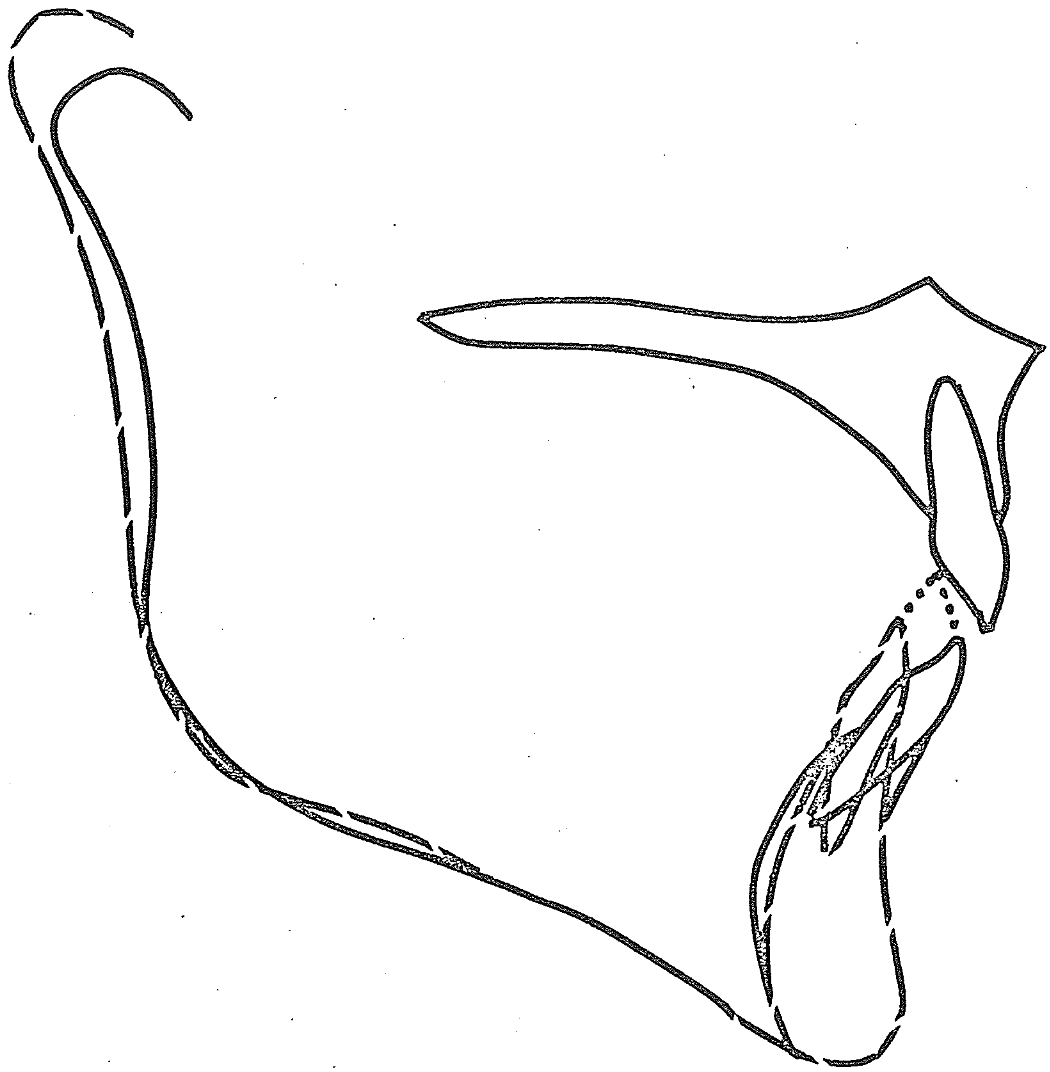


Figure 28. Diagrammatic illustration of mandibular growth with the accompanying decrease in incisor angulation. The full grown mandible (broken line) is superimposed on the younger mandible (solid line) at the symphysis.

cases are probably rare, but they illustrate what occurs if these coordinated compensatory adjustments do not occur within the temporomandibular joint, the neuromuscular complex and the dento-alveolar components during the growth period.

Group 2

The group with the lower mean age (Group 2) represents subjects with various amounts of mandibular growth potential and therefore the compensatory changes mentioned above have not occurred or they are in the process of occurring. The posterior-superior path of closure for this group is the result of the same type of compensatory changes in the temporomandibular joint and neuromuscular mechanism as occurred in the group with the greater mean age during the mandibular growth period. These changes occurred as the incisors erupted and the occlusion developed in order to move the mandible to its occlusal position without the lower incisors striking prematurely on the retroclined upper incisors. The protective reflex mechanism causes the temporomandibular joint and mandibular musculature to make adjustments so that the mandible rotates and/or translates in such a manner that the teeth come into occlusion with a minimum of trauma. As mentioned earlier, there is a distal shift after initial contact in some cases, however it is minimal.

The compensatory movements of the mandible in the young developing Class II (2) malocclusion are somewhat like any other situation where a premature contact is avoided by changes in the mandible's movement pattern. The difference is that these adjustments occur early in development as the incisors erupt, thus forcing the remainder of the dentition to erupt into a pattern which is also compensatory in nature. It is therefore easy to understand that in order for the mandible to assume its normal upward and forward movement, changes have to be made in the entire dento-alveolar complex, both in the sagittal, vertical, and coronal planes, the neuromuscular complex, and the temporomandibular joint. Complete alteration of the anatomical and functional development of the dento-alveolar mechanism can be accomplished only with the aid of mandibular growth.

The five subjects in Group 2 with the pure or predominately translatory condylar movements were probably examples of more severe functional adaptations by the involved tissues. The proclination of the lower incisors (99 degrees) along with the small freeway space (2.5 mm), which was only five per cent less in the molar region than in the incisor region, show that a predominantly translatory condylar movement is necessary in order for the teeth to close into their occlusal positions with a minimum of trauma. Any type of rotary movement at the condyle would leave the buccal segments out of occlusion when the incisors contact.

The present study had apparent shortcomings necessitated by a shortage of time and the low incidence of Class II (2) malocclusion. The important findings of the dento-alveolar compensatory changes which accompanied mandibular growth and a change in the mandibular path of closure were due to the wide age range. It is apparent that the next step in the study of Class II (2) malocclusion should be a longitudinal growth study which would validate the present findings and produce a much needed picture of the growth and development of Class II (2) malocclusions.

Centre of Rotation

The variation in the centres of rotation found in the present study and in studies by Bennett (1908) and Superstine (1957) illustrates that each individual mandible performs a different type of movement from rest to initial contact due to the differences in dental and skeletal anatomy and neuromuscular functions among individuals. This ability of the mandibular musculature to move the mandible in such a manner so as to compensate for malposed teeth and other oral dysplasias is probably the reason why most malocclusions appear to function adequately with a minimum of damage to the tissue over a life time. This is not to say that we can inadvertently move teeth and expect the mandibular complex to compensate by changing its type of movement, for it is also shown that anatomical changes play an important role in establishing a functionally balanced system as demonstrated by case #20 which is described on page 120.

Class II Division 1 Implications

It is interesting to note that by applying the concepts of compensatory changes discussed previously, to Class II Division 1 malocclusion, an explanation for the variation in paths of closure can be made. Blume (1947), Ricketts (1950), and Ingervall (1966) have shown the mandibular path of closure to vary in Class II Division 1 malocclusions.

The most accepted explanation for the abnormal posterior closure pattern found in some Class II Division 1 malocclusions has been that the mandible is positioned downward and forward in an "atypical" rest position due to functional requirements and thus moves to the occlusal position in a posterior-superior direction, (Ricketts 1952, Ballard 1956, Posselt 1962).

Bjork (1955) found that in cases with large overjets, there were dento-alveolar compensatory changes with the lower incisors suffering a forward inclination and the upper incisors becoming more lingually inclined. It is logical to assume that as the lower incisors become more labially inclined, the remaining dento-alveolar units compensate by moving or tipping anteriorly, otherwise there would be spacing between the incisors and cuspids. In order for the more anteriorly positioned lower teeth to come into occlusion as the mandible moves from the rest to the occlusal position, the mandibular path of closure has to change. This gradual change in mandibular rotation is accomplished by compensatory changes in the temporomandibular joint and neuromuscular complex in the same manner as in Class II (2). The subjects with the anterior-superior path of closure probably have not gone through these mandibular compensatory changes. It is likely that this natural phenomenon occurs in every occlusion throughout life as the balance between anatomical and functional components is maintained in the same manner as in any other system in the body.

Clinical Implications

It is apparent from the results of this study that anatomical growth and functional factors have to be taken into consideration in the diagnosis and treatment planning for Class II (2) malocclusions.

In the cases where mandibular growth is completed and the incisors have tipped lingually, it would be a fallacy to expect the mandible to come forward as the maxillary incisors are tipped labially, even after levelling and Class II elastics, since in this study it has been shown that there is a normal path of closure with no posterior displacement in the movement from rest to initial contact. Any change in arch relationship would consist of a temporary postural change. This leaves no alternative but to extract in the upper arch when the lower arch is acceptable, thus accepting a Class II molar relationship, or to extract four bicuspids when the lower arch is crowded.

In the younger subjects with the lower incisors proclined, the treatment would be different. Every effort should be made to treat these cases non-extraction, realizing of course that this is not always possible. Treatment timing is the most important factor in treatment since successful treatment is dependent on utilization of the pubertal growth period.

Treatment may consist of aligning, levelling, and coordinating the arches while cervical traction is being utilized to redirect the horizontal maxillary growth. With the aid of Class II mechanics and horizontal mandibular growth the skeletal and dental units will move into a Class I relationship. In these cases, even though there is a posterior displacement of the mandible, which is probably corrected as the arches are coordinated, it is doubtful that full attainment of a Class I relationship can be accomplished without the aid of mandibular growth.

On the basis of the results of this study, it is felt that the most successful approach to treatment could be undertaken in the early mixed dentition phase of development. If the patient can be seen immediately after the upper central incisors have erupted into occlusion, the centrals can be tipped labially into alignment and retained there until the buccal segments have erupted into full occlusion. This would allow the mandible to assume its normal occlusal position and would allow the posterior teeth to fully erupt thus eliminating the posterior displacement of the mandible and the deep overbite.

The key clinical implication in this study is the necessity for a clear understanding of the different phases of growth and development of the oral tissues in Class II (2) malocclusion in order that the correct treatment time and method may be selected. It is felt that the angulation of the lower incisor to the mandibular plane may be an important aid in determining what phase of development the patient is in, thus helping to avoid unnecessary extractions and prolonged treatment.

CHAPTER VI

SUMMARY AND CONCLUSIONS

The present investigation was undertaken to confirm previous cephalometric findings that in Class II (2) malocclusion the mandibular path of closure from rest to full closure position was anterior-superior in some subjects and posterior-superior in others and to consider some of the associated variables. The subjects were divided into two groups on the basis of their direction of mandibular closure. Group 1 consisted of eight male and five female Caucasian subjects with an average age of 16.6 years, while Group 2 consisted of six male and ten female Caucasian subjects with an average age of 13.0 years. Selection was based on Class II (2) malocclusion characteristics.

A cinefluorographic analysis was used to determine the direction of mandibular closure from rest to initial contact to full closure position at four different points on the mandible. The mandibular rotational centres were calculated for these movements.

A cephalometric analysis consisting of both angular and linear measurements and various model analyses were used to evaluate and compare the skeletal, dental, and soft tissue patterns of the two groups and an analysis of variance was performed to determine the significance of the differences between the groups.

Certain cinefluorographic and cephalometric results were compared in order to evaluate the use of mechanical head posturing devices in cephalometric radiography.

On the basis of the results of this study the following conclusions were made:

1. Cinefluorography appears to be an effective method of studying mandibular movements in the sagittal plane.

2. The mandibular path of closure from rest to initial contact was in a posterior-superior or superior direction for the group with the younger mean age. The results suggest that this direction of movement was made necessary by the retroclination of the upper incisors and the proclination of the lower incisors.

3. The mandibular path of closure from rest to initial contact was in an anterior-superior direction for the group with the older mean age. It is suggested that this direction of mandibular closure was made possible by compensatory changes in the lower dento-alveolar component, with the lower incisors tipping lingually as the mandible came forward with growth.

4. Notwithstanding the cross-sectional nature of the study, it is felt that the large variation in mandibular rotational centres seen among individuals is a reflection of changes in mandibular closure patterns which occur as a result of growth and developmental changes.

5. There was a "distal shift" of the mandible during the movement from initial contact to full closure, however the small magnitude of this posterior displacement suggests that its elimination would have very little effect on skeletal or dental relationships.

6. Class II (2) malocclusion appears to have a Class I or a mild Class II skeletal pattern with the mandibular dento-alveolar components positioned posterior to normal in adults probably due to compensatory changes in these components which occur with mandibular growth.

7. The skeletal differences between the two groups were primarily the result of mandibular growth in the group with the older mean age.

8. The significantly smaller angulation of the lower incisors to the mandibular plane in the group with the older mean age was probably the result of compensatory lingual tipping of the lower incisors as the mandible moved forward with growth.

9. The smaller overbite evident in the older subjects was probably due to mandibular growth and eruption of the posterior teeth.

10. The use of mechanical head posturing devices with ear rods appears to cause an alteration in the physiological resting posture of the head and mandible.

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APPENDIX

Table XXVI.

Means, differences of the means, and significance of difference between Groups 1 and 2 for 87 measurements. Means for Groups 1 and 2 combined.

Measurement	Group 1 Mean	Group 2 Mean	Difference	Groups 1+2 Mean
Overbite (%)	83.08	88.44	5.36	86.03
Overjet (mm)	1.62	3.19	1.57**	2.48
Head Posture (degrees)	88.54	89.77	1.23	89.22
Tooth Size-Mx. 12 (mm)	96.77	93.86	2.91	95.26
Tooth Size-Md. 12 (mm)	88.50	86.29	2.21	87.36
Tooth Size-Mx. 6 (mm)	48.65	45.32	3.33**	46.92
Tooth Size-Md. 6 (mm)	38.23	36.54	1.69*	37.36
Sex-males (%)	62.00	38.00	24.00	48.00
Age (years)	16.58	12.96	3.82**	14.59
Subdivision (%)	38.00	25.00	13.00	31.00
Tooth Apart Swallow (%)	15.00	38.00	23.00	27.00
Crowding-Mx. (%)	39.00	13.00	26.00	31.00
Crowding-Md. (%)	54.00	38.00	16.00	48.00
Crowding-either (%)	85.00	38.00	47.00*	58.00
Wear-Md. incisors (%)	77.00	88.00	11.00	82.00
Angles (degrees)				
N-A-Po	6.83	9.80	2.97	8.47
N-S-Ba	133.65	133.82	0.17	133.74
N-S-Ar	125.20	126.30	1.10	125.81
N-S-$\overline{6}$	67.65	68.44	0.79	68.08
N-S-$\underline{6}$	67.05	67.29	0.24	67.18
N-S-Hy	91.16	90.93	0.23	91.03
FH-PNS	28.99	27.11	1.88	27.95
FH-$\underline{6}$	37.83	37.13	0.70	37.45
FH-Hy	71.21	70.42	0.79	70.78
S-N-ANS	87.66	86.43	1.23	86.50

(Cont'd)

Measurement	Group 1 Mean	Group 2 Mean	Difference	Groups 1+2 Mean
S-N-A	82.58	81.94	0.64	82.23
S-N-B	77.30	75.77	1.53	76.44
S-N-Po	79.33	77.28	2.05*	78.20
A-N-B	5.31	6.16	0.85	5.78
Con-Go-M	129.81	128.81	1.00	129.26
TN-TT-TP	129.97	129.87	0.10	129.92
FH-$\overline{6}$	38.23	37.75	0.48	37.97
TT-TU-TL	174.31	176.08	1.77	175.29
N-TN-TP	90.90	86.30	4.60	89.00
N-S-FH	6.35	5.28	1.07	5.76
$\underline{1}$-SN	92.09	91.79	0.30	91.93
$\underline{1}$-FH	94.26	93.49	0.77	93.84
$\underline{1}$-PP	83.61	83.19	0.42	83.38
$\overline{1}$-MP	89.90	95.81	5.91*	92.80
$\overline{1}$-FH	66.07	59.07	7.00*	62.21
$\overline{1}$-SN	59.72	53.79	5.93*	56.44
$\underline{1}$-$\overline{1}$	151.80	145.58	6.22	148.37
MP-FH	23.83	25.99	2.16	25.03
MP-PP	21.70	22.67	0.97	22.24
MP-UOP	8.88	9.08	0.20	9.00
MP-LOP	19.56	19.34	0.22	19.45
MP-SN	30.18	31.27	1.09	30.79
$\underline{1}$-UOP	70.79	69.60	1.19	70.14
FH-N-Po	85.69	82.56	3.13*	84.00
Linear (mm)				
$\overline{1}$-MP	34.10	33.10	1.00	33.50
$\overline{1}$-APo	-2.70	-1.60	-1.10	-2.30
$\overline{1}$-NB	1.40	2.50	1.10	2.20
$\underline{1}$-PP	24.30	23.90	0.40	24.10

(Cont'd)

Measurement	Group 1 Mean	Group 2 Mean	Difference	Groups 1+2 Mean
$\underline{1}$-APo	0.80	2.30	1.50*	1.78
$\underline{1}$-MP	3.33	3.22	0.11	3.25
S-Ba	40.79	39.74	0.90	40.20
S-N	67.84	66.28	1.40	66.90
Ba-N	100.10	98.10	2.00	99.11
M-W	96.60	89.70	6.90**	92.65
Po-Con	107.53	100.17	7.36**	103.47
M-Con	106.27	98.36	7.90**	101.91
M-Go	64.76	61.53	2.90	62.98
Ar-LBM	51.85	47.36	4.49**	49.37
Ar-Go	44.12	40.58	3.10**	42.17
ANS-PNS	52.92	50.77	1.90	51.72
$\underline{1}$-$\underline{6}$	31.70	31.60	0.10	31.63
ANS-AT	96.10	93.30	2.80	94.53
Ptm-ANS	52.53	49.40	3.10	50.79
Ptm-$\underline{6}$	15.40	13.96	2.50*	14.05
N-ANS	49.40	47.40	2.00	48.28
ANS-M	56.77	53.89	2.60	55.18
N-M	106.12	101.43	4.20*	103.53
$\underline{1}$-TU	17.37	16.92	0.30	17.13
$\overline{1}$-TL	15.41	13.73	1.60*	14.48
Po-TP	11.02	10.90	0.00	10.97
N-TN	7.93	7.00	0.90	7.41
TA-TT	16.10	14.40	1.70	15.31
TA-TB	29.80	29.10	0.70	29.37
TT-TP	60.35	57.46	2.70*	58.75
$\underline{1}$-UL	3.00	3.50	0.50	3.30
$\overline{1}$-UL	3.36	3.00	0.36	3.12
Arch length (mm)	25.05	25.22	0.17	25.14
Intercuspid Width (mm)	33.80	32.34	1.46	32.96

(Cont'd)

Measurement	Group 1 Mean	Group 2 Mean	Difference	Groups 1+2 Mean
Intermolar Width (mm)	40.21	37.77	2.44	38.86
Freeway Space (mm)	4.98	4.71	0.27	4.83
Cine Angle b (degrees)	76.19	75.14	1.05	76.00
Po-NB (mm)	3.40	2.30	1.10*	3.34

** Significant at the .01 level
* Significant at the .05 level

GLOSSARY

GLOSSARY

Cepahlometric Points

Skeletal

A Point (A) (#19)

The deepest point on the midline contour at the alveolar process between the anterior nasal spine and the alveolar crest of the maxillary central incisor.

Anterior Nasal Spine (ANS) (#20)

The median, sharp bony process of the maxilla at the lower margin of the anterior nasal opening.

Articulare (Ar) (#7)

The point of intersection of the external dorsal contour of the mandibular condyle and the temporal bone. The midpoint is used when the profile radiogram shows double projections of the rami.

Atlas (At) (#9)

The most superior point of the bony atlas.

B point (B) (#15)

The deepest midline point on the mandible between infradentale and pogonion.

Basion (Ba) (#8)

The most forward and lowest point on the anterior margin of the foramen magnum.

Condylion (Con) (#6)

The intersection of a perpendicular from the mandibular plane and the posterior border of the condyle.

Gonion (Go) (#24)

The lowest most posterior and most outward point on the angle of the mandibular base line and the line tangent to the posterior border of the ramus.

Hyoid (Hy) (#12)

The most inferior point on the hyoid bone.

Lower Border of the Mandible (LBM) (#11)

The most inferior point on the posterior one third of the mandible's lower border.

Menton (M) (#13)

The lowest point of the symphysis menti of the mandible.

Nasion (N) (#1)

The most anterior point of the frontonasal suture.

Orbitale (O) (#4)

The deepest point of the infraorbital margin.

Porion (P) (#2)

The midpoint on the upper edge of the external auditory meatus. As a cephalometric landmark it is located at the midpoint on the upper edge of the metal rods of the cephalometric.

Posterior Nasal Spine (PNS) (#23)

The process formed by the united projecting ends of the posterior borders of the palatal processes of the palatal bone.

Pogonion (Po) (#33)

The most prominent anterior point on the bony chin.

Pterygomaxillary fissue (Ptm) (#5)

The projected contour of the fissure formed by the anterior curvature of the pterygoid process and the posterior wall of the tuberosity of the maxilla. The cephalometric point is the most posterior point on the posterior wall of the maxillary tuberosity.

Sella (S) (#3)

The centre of the sella turcica (that is, the pituitary fossa).

Wylie Point (W) (#10)

The intersection of the mandibular plane with a perpendicular line which is tangent to the posterior border of the condyle.

Dental

Point #14

Apex of the most anterior mandibular incisor.

Point #16

Incisal tip of the most anterior mandibular incisor.

Point #17

Incisal tip of the most posterior maxillary central incisor.

Point #18

Apex of the most posterior maxillary central incisor.

Point #21

Distobuccal cusp tip of the maxillary right first molar.

Point #22

Distobuccal cusp tip of the mandibular right first molar.

Soft Tissue

Point #25 (TN)

The most anterior point on the soft tissue nose parallel to nasion.

Point #26 (TT)

The most anterior point on the soft tissue nose.

Point #27 (TA)

The most posterior point on the soft tissue between TT and TU.

Point #28 (TU)

The most anterior point on the upper lip.

Point #29 (UL)

The most inferior point on the upper lip.

Point #30 (TL)

The most anterior point on the lower lip.

Point #31 (TB)

The most posterior point on the soft tissue between TL and TP.

Point #32 (TP)

The most anterior point on the soft tissue chin.

Cephalometric Reference Lines

Frankfort Horizontal (FH)

A line through porion and orbitale.

Lower Occlusal Plane (LOP)

A line through the incisal tip of the most anterior mandibular incisor and the distobuccal cusp tip of the mandibular right first molar.

Mandibular Plane (MP)

A line through menton and LBM.

Palatal Plane (PP)

A line joining the anterior nasal spine and the posterior nasal spine.

Sella-Nasion Plane (SN)

A line joining sella and nasion.

Upper Occlusal Plane (UOP)

A line through the incisal tip of the most posterior maxillary incisor and the distobuccal cusp tip of the maxillary right first molar.