A CINEFLUOROGRAPHIC AND CEPHALOMETRIC RADIOGRAPHIC STUDY OF CLASS I ANGLE ACCEPTABLE OCCLUSION

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by

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ABSTRACT

The norms utilized in the cephalometric radiographic analyses developed over the past twenty-five years have been based generally on small samples which possessed mesognathic and straight facial and profile patterns. No consideration was given to possible differences between the two sexes, yet it is now a well established fact that females mature earlier than males. In addition to the maturation factor, the question has arisen as to whether or not the variance in skeletal patterns manifested by heterogeneous ethnic backgrounds might also be a parameter to be considered when establishing standards for orthodontic diagnosis.

The present study was designed to investigate the preceding parameters using cephalometric radiography. A combined cinefluorographic and cephalometric technique also was utilized to objectively interrelate the dynamics of the physiological mandibular border movements in the sagittal plane to the craniofacial skeletal and dental pattern. The change in head posture during deglutition and during the border movements described by the mandible was studied to determine the possible existence of functional differences between head posture and some of the interrelationships of the oropharyngeal structures.

The sample consisted of a group of 21 males and 27 females who had an Angle Class I acceptable occlusion. The

ages ranged from 11 years, 11 months to 14 years, 2 months, with a mean age of 13 years, 5 months.

A lateral projection cinefluorographic technique was used. By measuring the changing relationships of six points on the mandible to the palatal plane during movement between 10 selected positions, the physiological border movements and the centres of rotation of the mandible were described. The comparison of angular changes between a true vertical line and the palatal reference plane allowed assessment of head posture. Cinefluorographic frames representative of 5 stages of swallowing were used in the analysis of the degree of head flexion during this function.

Comparisons were made between different individuals and also among individuals. The statistical and subjective assessment of the results suggested the following conclusions:

1. The facial and profile pattern for a Class I Angle acceptable occlusion sample in Winnipeg, Manitoba appears to be retrognathic and convex.
2. Separate sex norms for routine orthodontic cephalometric radiographic diagnosis probably are not indicated.
3. The significant differences between the two sexes observed for all of the variables involving the hyoid bone suggest the sexes should be separated for future studies in which that parameter is studied.
4. The use of mechanical restraining ear rods in rest position appears to alter the head posture, resulting in an extension of the head in relation to a horizontal plane.

In addition, the mandible was displaced in a rotatory manner downward and backward in the female and translated forward and superiorly in the male.

5. The fact that differences in head posture were observed during the 10 stage mandibular movement sequence, yet were not observed in the 5 stage deglutition sequence suggested that a greater degree of neuromuscular integration probably was present between the postural muscles of the head and the oropharyngeal mechanism than between the postural muscles of the head and the muscles of mastication.

6. Cinefluorography rather than cephalometric radiography appears to be a more accurate method for determining the centres of rotation of the mandible from rest position to habitual occlusion.

7. The condylar and incisal guidance paths appeared to be parallel from habitual occlusion to end to end position in Class I acceptable occlusion in which there was minimum overbite and overjet.

8. The presence of a slide from habitual occlusion to retruded contact position suggested that for Class I "normal" occlusion in 13 year old children, the absence of condylar centricity should not be considered pathologic.

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CHAPTER I

INTRODUCTION

Man's method of mastication has been the result of ages of evolutionary progress with change in form most often following change in function. Thus, the mandible, the temporomandibular joint and the teeth of the carnivora, herbivora and omnivora were different from one another because they were utilized for different purposes (McMillan, 1934).

Man has a stomatognathic system that combines all the characteristics of his evolutionary predecessors. Early investigators fractionated the cycle of mandibular movement into its various components exemplified by the animal groups. Individual studies were made of each movement rather than depicting the end result of the various muscular efforts.

Since research workers became cognizant of the desirability of maintenance of the normal physiology of the stomatognathic system, the interactions between mandibular movements and functioning of the teeth have been under constant investigation. Many studies were incomplete and ambiquous with regard to technique and nomenclature; consequently, the conclusions are now open to question.

Timms (1964) has said that form will function optimally only when its morphological relationships are in perfect balance. Society has decided that Class II protrusions, Class III prognathisms, and misaligned teeth in general are undesirable aberrations; however, the difference in observed behaviour among the so-called aberrant groups is more likely accounted for by differing morphology rather than by markedly differing physiology. Thus, for the purpose of this thesis, Class I "normal" occlusion infers a healthy neuromuscular background and an acceptable occlusal relationship.

De Kock et al. (1968) queried whether separate age and sex norms should be used for cephalometric analysis in the diagnosis and treatment planning of malocclusions. It was suggested that the mandibular plane angle decreased with age and that certain variables associated with the mandibular plane were different in males and females. In addition to differences between age and sex, the question arose as to whether or not the variance in skeletal patterns manifested by a variety of ethnic backgrounds might also be a factor to be considered.

Function implies movement and therefore does not lend itself readily to investigative studies which are essentially static. Winnipeg, Manitoba, Canada is composed of a heterogeneous population of middle Europeans and Anglo-saxons. This population manifests more retrognathic facial types and convex profiles than the samples used for the analyses of Downs' or Steiner. Considering the foregoing, it was therefore decided that a combined cinefluorographic-cephalometric radiographic investigation of male and female thirteen year old school children with Angle's Class I acceptable occlusion should be undertaken to determine:

1. The morphological skeletal and dental pattern in order to provide standards from which to assess children possessing malocclusions.

2. The effect of restraining ear rods on the rest position of the mandible.

3. The centre of rotation of the mandible from rest position to habitual occlusion and during selected mandibular movements.

4. The change in head posture during the deglutition cycle and the mandibular movement sequence.

5. The physiological border movements of the mandible as assessed from cinefluorographic records.

6. The change in position and shape of the tongue during the deglutition sequence.

CHAPTER II

REVIEW OF LITERATURE

I. CINEFLUOROGRAPHY

Initially the utilization of cinefluorography was directed to studies concerning the anatomy and physiology of the heart, urinary tract, oesophagus, stomach and cerebral circulation. Klatsky (1940) was one of the first pioneers to utilize cinefluorography for dental investigation including descriptions of mastication and deglutition.

Deglutition

The concepts of "normal" and "abnormal" swallowing were conceived from the alleged interrelationship between the movements of the tongue, lips, and mandible during swallowing and the form of the surrounding hard skeletal and dental structures. "Normal" swallowing has been defined as that swallow which occurs when the lips remain in repose, the posterior teeth contact, and the tongue contained within the confines of the oral cavity. "Abnormal" swallowing has been said to occur when the movement of the lips and/or tongue produces an adverse effect on the dentition. Rix (1946) accepted this direct cause-and-effect relationship with his use of "teeth-open" and "teeth-shut" behavioural patterns as diagnostic criteria in the assessment of swallowing normality or abnormality as it related to malocclusion.

The first investigators to question this particular cause-and-effect relationship with cinefluorography were Ardran and Kemp (1951). They observed both teeth-apart and teeth-together swallows in a sample of 250 adults who possessed no gross abnormalities of the dentition or facial skeletal pattern.

Further subjective studies to evaluate functional tongue patterns and occlusal relations during swallowing were carried out by McLean (1962), who observed 22 children with excellent occlusion, and Tompkins (1963), who studied a group of twelve year old children with Class II, Division 1 malocclusion. These studies were compared directly and in all phases analysed it was concluded that the basic tongue pattern of the Class II group was comparable to the teeth-together tongue pattern present in the excellent occlusion group. In thirty-four per cent of the sample each subject exhibited both teeth-together and teeth-apart swallows.

It could now be concluded that from a subjective appraisal it was unwarranted to insist upon teeth being together with no perioral muscular movement during normal swallowing.

One of the first major studies to quantify the results and convey meaningful information regarding the functional anatomical relationships was carried out by Cleall (1965). Cinefluorography and cephalometric radiography were combined to statistically compare adolescents with good skeletal and dental patterns with those having Class II Angle malocclusions and with those having tongue thrusts. It was concluded that movements during swallowing were highly dependent upon the skeletal and dental morphology of the individual. Sixty percent of the subjects exhibited teeth together swallows. The study concluded that to define "normal" swallowing as teeth-together swallowing should no longer be considered tenable.

Cleall et al (1966) reported movement patterns of the oropharyngeal structures during swallowing were relatively constant and reproducible within the individual, although great variation in these patterns could exist between different individuals.

A cinefluorographic study of the differences between saliva and bolus swallows in young adults (21 to 30 years of age) was conducted by Levy (1966). A higher incidence of teeth-together swallows than that observed by Cleall was noted. Cortical maturation was suggested as a factor in the alteration of the swallowing pattern.

Form and Function

Form and function have usually been studied as separate entities in spite of the fact that they are closely interrelated. Notwithstanding the contribution made by cephalometric radiography to the study of form, the introduction of cinefluorography has allowed the dynamics of function within the static form to be studied and analysed.

A combined cephalometric-cinefluorographic deglutition study of 15 male edentulous subjects was conducted by Hicks (1967). With and without the dentures in place no deviations were observed in the movements of the oropharyngeal structures from the previously described "normal" or accepted patterns of movement during deglutition.

Wolk (1969), in addition to using cinefluorography, utilized electromyographic and myometric methods. Cinefluorographic sequences of six patients were taken before mandibular resection and a few months post-surgery to evaluate the changes in hyoid bone and tongue movement. The original tongue thrust pattern was still observed at the time the post-surgical records were taken. He concluded that the tongue and its associated musculature had a limited role, if any, in the anterior relapse which had been noted in mandibular resection patients. The tongue was related to the anterior aspect of the mandible in the same relative way post-surgery as pre-surgery.

Cinefluorography was utilized by Yip (1969) who reported that although enlarged tonsils and adenoids altered velopharyngeal function both in deglutition and speech, the effect was not as marked as had been suggested. Oral and pharyngeal structures in the pre-surgical subjects showed an adaptation to the altered environment so that respiration and deglutition could be maintained.

Milne (1970), in a cinefluorographic study of six to eight year old children, reported that an increase in tongue thrust and speech distortion during the period of time when the maxillary deciduous central incisors were exfoliated was a physiological phenomenon. The habits were not retained after the permanent incisors had erupted and it was suggested that any retention of these habits after this developmental phase were probably present in the deciduous dentition.

Mandibular Movement

Movements of the mandible have been studied for the past century. Techniques ranging from a photographic study of the movements of the condyle by Luce (1889) to the sophisticated temporomandibular joint laminograms of Ricketts' (1952) have been used. These studies utilized basically static techniques in an attempt to study the functioning stomatognathic mechanism.

Early investigations of the movements of the mandible were made by Berry and Hofman (1956) who, utilizing cine-fluorography with imagine intensification, described condylar movements in the sagittal plane.

Scully (1959), using cinefluorography, studied the masticatory movements of the human mandible in five adults who possessed complete natural dentitions with normal function and who exhibited no significant malocclusions. The right temporomandibular joint was filmed in "empty" and bolus movements. In empty movements it was observed that the condyle moved downward and upward in the same path. During chewing movements the bolus became the fulcrum instead of the condyle, which suggested the muscles rather than the joint were responsible for varied mandibular movements.

A cinefluorographic analysis of mandibular movements was reported by Koivumaa (1961) in which the condylar movements followed no definite path during mastication. There was, in contrast to Scully's paper, considerable irregularity in the opening and closing path of the condyle as seen in the sagittal plane. The course of this movement could not be determined from the protrusion movement and it was also observed that the molars were the centre of rotation of the mandible during chewing. The sample for this study consisted of three adults who possessed deep, medium, and low overbites and good dentitions. There was no normal sample and comparisons among the three subjects were probably not valid.

A cinefluorographic-mandibulographic study of opening and closing movements of the mandible was conducted by Araiche (1966). The sample was comprised of twenty-six subjects of which there was an even distribution of normal, Class I and Class II occlusions. The head of the subject was immobilized in a head holder and natural head posture could not thus be ascertained. It was observed, upon opening, the interincisor point moved downward and backward while the condyle moved downward and forward. Different opening and closing paths were found between subjects and in the same subject. No relation was found between the occlusal classification and the recorded patterns of mandibular movement.

A cephalometric-cinefluorographic study conducted by Stone (1971) reported two groups of Class II, Division 2 malocclusions with different closure patterns. The mandibular path of closure from rest position to initial contact position was in a posterior-superior direction for the younger age group and in an anterior-superior direction for the older age group. A small "distal shift" of the mandible was observed during the movement from initial contact to full closure.

In summary, cinefluorography was initially used in dentistry as a subjective tool to observe form and function. The development of sophisticated radiographic equipment, computer data centres and advanced statistical analyses over the last two decades has provided a quantitative tool by which valid dynamic longitudinal and cross-sectional studies can be conducted.

II. PHYSIOLOGY OF MANDIBULAR MOVEMENTS

Sherrington (1917), in demonstrating jaw reflexes, revealed the neurological basis of mastication. It was shown in the decerebrate preparation of a cat that the jaw was closed. Opening was induced when stimuli were applied to the gingiva bordering the upper and lower teeth, the teeth themselves and the front of the hard palate.

When the stimuli were stopped, the mandible rapidly returned to a closed position.

According to Kawamura and Tsukamoto (1960), the cortical jaw area predominantly innervated the mandibular depressor muscles (digastric) rather than the elevators (massetter). The mandible thus moved about the temporomandibular joints by means of muscular contraction which was elicited, graded and restricted by neural impulses which arose centrally or peripherally (Perry, 1960). The impulses which arose centrally were conducted from the large cells of Betz. These cells were the primary site for initiation of all voluntary activity. The particular cells responsible for mandibular movement varied from those responsible for other volitional activity in their location in the cerebral cortex and their associational and reflex connections. These cells were primarily associated with willed activity.

Reflex level activity has been found to be the main factor in mandibular displacement. The reflex arc has been found to consist of the receptor organs of the periodontal membrane, the temporomandibular joints and the muscles themselves.

Anderson (1968) investigated dental pressure receptors and described two main types which originated in the trigeminal mesencephalic nucleus. Type I innervated one tooth and the actual receptors in the periodontal ligament showed directionality. Type II were similar, but differed in that they innervated a large peripheral field which involved groups of teeth and sometimes adjacent soft tissue. In addition, Jerge (1964) described a neuron related to muscle spindles.

In mandibular movements, reflexes were involved in at least two phases of mandibular position -- mastication and posture (Giannelly and Goldman, 1971). Although masticatory movements were initiated voluntarily, they were regulated reflexively. The synergistic and reciprocal antagonistic actions of the muscles were coordinated by the myotatic reflex. It was shown by Jerge (1964) that the main depressor muscles do not contain muscle spindles; consequently, it is assumed, the myotatic reflex functioned to reverse the opening movements. Jerge postulated that sensory stimuli involved with the proprioceptors of the periodontal ligament and gingiva through complex polysynaptic connections have the ability to activate the alpha motor neuron of the digastrics with particular reference to stimulating reflex jaw opening. Cyclical jaw movements appeared to be related to jaw-closing myotatic, monosynaptic reflex and a complicated polysynaptic jaw-opening reflex which arose from extramuscular proprioceptive receptors.

During vertical mandibular opening, the stretch receptors of the massetter and temporalis muscles are activated in unison bilaterally. In a similar fashion the afferent neurons are silenced by the reduced tension on the spindles during closure.

The spindles within the massetter and/or temporalis muscles are activated during horizontal movements with little vertical opening. It was suggested by Giannelly and Goldman (1971) that this may indicate a synergistic action of the massetter and temporalis during vertical movement and antagonistic action in movements with little vertical opening.

III. REST POSITION OF THE MANDIBLE

The rest position of the mandible has been defined as:

> the postural position of the mandible when the patient is relaxing comfortably in the upright position and the condyles are in a neutral or unstrained position in the glenoid fossa.*

The postural or rest position of the mandible was unrelated to the teeth since the teeth were not in contact and were separated by the "freeway" space. It has been verified electromyographically as the position of muscle quiesence (Garnick and Ramfjord, 1962).

Rest position was first mentioned by Bennett (1908), however, he made no actual observations regarding this position and received little recognition for its discovery.

Niswonger (1934) proposed the first physiological explanation of rest position as follows:

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* The Academy of Denture Prosthesis: Glossary of Prosthodontic Terms, Ed. 2, J. Prosthet. Dent. 10: Nov.-Dec. Suppl. 1960.

> The rest position may be called the neutral position of the mandible since the flexor and extensor, or opening and closing, muscles are in a state of equilibrium. Also, the mandible is suspended here, so to speak, being aided by the masticatory and depressor muscles. The rest position may be assumed voluntarily and is constantly assumed subconciously. It makes no difference whether the patient is edentulous or the person is an infant or an adult or is aged.

According to Brodie (1941), muscle tensions exerted above and below the mandible determined its relation to the upper half of the face. This was the first mention that musculature may have established a mandibular rest or postural position that was relatively constant.

A distinction between rest vertical dimension and occlusal vertical dimension was made by Thompson and Brodie (1942) in a cephalometric study. The results strongly supported the hypothesis that the physiological rest position of the mandible was stable. However, Thompson (1954) observed variables which contradicted the earlier study. Hypertonicity and hypotonicity coupled with fatigue of the musculature affected "tone".

Sicher (1952) stated the tonus of each muscle was constant but the tonus decreased during sleep, deep anaesthesia and unconciousness. He also believed the rest position of the mandible changed when the head posture was altered.

In a study of Class I malocclusions, Ricketts (1952) utilized cephalometric laminography and showed pre and post treatment records of the temporomandibular joint in which he concluded there was much doubt as to the constancy of the rest position. These observations were based on the functional requirements of Class II malocclusion which required the positioning of the mandibular condyles downward and forward in the fossa in the interest of respiration and/or speech.

By utilizing electromyography, Mullen (1956) observed any change in head or body position would ultimately change the equilibrium of the muscles and inevitably affect the postural position of the mandible. It was also noted that if the subject showed anxiety or fear of the equipment, or was irritated by the ear posts of the head positioner, the postural position was altered.

Sutcher (1967) also stated that the ear rods of the conventional cephalostat may cause a forward or ventral positioning of the mandible from the postural position.

In summary, the postural position is probably represented by the balance between the tone of the anti-gravity elevator muscles and the force of gravity. Since no spindles were contained in the main depressor muscles, the theory of reflex activity for neuromuscular balance between antagonistic muscles probably does not exist for the mandible. The rest position has been shown to be relatively constant from infancy to senility but can be altered by such variables as body and head posture, psychic factors, large horizontal overjet and compensatory tongue and lip positions. It can not be termed a border position (Posselt, 1962).

IV. MANDIBULAR MOVEMENTS IN THE SAGITTAL PLANE

Basic movements of the mandible differ in several respects from the functional movement patterns according to Posselt (1968). Movements, including shifts of the condyle, were symmetrical movements and could be described by projecting them onto the sagittal or median planes. Only those movements pertinent to the author's thesis will be described.

Rest Position to Habitual Occlusion

One of the first physiological studies of mandibular movement was that of Luce (1889). In a photographic study the condyles were observed moving forward simultaneously with opening. By combining Luce's recordings into a single drawing, Sönstabö (1961) showed the shape of the composite conformed to the average movement area which was registered by Posselt (1952). The presence of a terminal hinge opening movement was suggested by this pattern.

In contrast to Luce's study, Tomes and Dolomore (1901) found no single fixed centre of rotation and the centres of rotation could lie 1.5 inches inferior and posterior to the condyle.

Campion (1905) used a rudimentary face bow and placed the stylus over the condyles. From initial opening movements he noted that the condyles first rotated around an axis passing through their centre. During further opening, the condyles translated downward and forward and followed an ogee slope.

Bennett (1908) attached lamps to a face bow fixed to the mandible and projected the mandibular movements to a wall. Using Rouleaux's method of calculating centres of rotation, he concluded there was translation even with small opening movements.

The suggestion that a range of movement was available was made by Gysi (1910) who placed the rotation centre about 1.8 centimeters below and behind the condyles.

Hildebrand (1931) used the kinematographic method whereby an extra-oral indicator was attached to the lower teeth. Movement of the indicator was recorded by three dimensional cinematography with the aid of a mirror positioned forty-five degrees to the median plane. A sagittal displacement of the condyle usually occured during the first third of an empty opening movement.

In a graphic and stroboscopic study of five patients, Kurth (1942) demonstrated the centre of origin of masticatory movements could not possibly be near the heads of the condyles because the direction of movement is upward in the transverse vertical plane from centric relation. Kurth felt the area of origin must be below the head of the condyles and probably had its location in the region of the mandibular foramen.

The mandibular foramen location was first suggested by the anatomist Prentiss (1923) who concluded that the mandibular foramen was the least point of motion in the movements of the mandible and that no trauma could be incurred by the inferior dental division of the fifth cranial nerve during jaw movements. Sicher (1937) agreed with this concept and reported this fact as characteristic in distinguishing man from the chimpanzee.

By utilizing tomography, Beyron (1942) studied ten subjects. The hinge axis was located by using a kinematic face bow and then films were taken in the retruded contact position, not maximum intercuspation. Upon opening ten millimeters, the axial point of each condyle was located in a region around the indicator. The point was within the outline of the condyle but not in any regular relationship to any definite part of the latter.

Ricketts (1950), in a cephalometric-laminographic study, observed the condyle was very stable in the Class I (Angle) normal occlusion group.

The mandible translated from intercuspal to rest position according to Posselt (1952) who used graphic and roentgenographic recordings in his study.

Hjortsjo et al. (1954) performed a tomographic study of the temporomandibular joints of twenty-one males aged twenty to twenty-five years. It was concluded that, in approximately one-half of the subjects, rotation and lateral movement and translation of the mandible occured from centric occlusion to rest position.

In a cephalometric graphic study, Nevakari (1956) concluded that the movement of the mandible from rest position to occlusal position had never been a pure hinge movement with the axis through the condyles, but had in all cases been situated outside the condyle and its location had exhibited considerable individual variation. On the average, the axis of the movement had been located near the mastoid process.

Koski (1962) discussed various theories of the axis of the opening movement of the mandible. It was concluded from anatomic consideration that no stationary hinge-axis existed for the vertically moving mandible. The axis during small opening movements may frequently be located at the mastoid process region (Nevakari, 1956), but it probably shifted depending upon the magnitude of movement and the position of the patient.

Araiche (1966) utilized a cinefluorographic-mandibulographic method and observed both rotation and translation occured in the movement from rest position to occlusion irrespective of occlusal classification. It was concluded that there was no correlation between occlusal classification and recorded patterns of mandibular movement.

A cinefluorographic study of Class II, Division 2 malocclusions by Stone (1971) illustrated scattered centres of rotation posterior to the ramus. For the movement from rest to full closure position, the average rotational centre was ten millimeters directly inferior to the average centre for the movement from rest to initial contact.

In summary, two differing opinions can be stated regarding the rotation centre of the mandible as it moved from rest to occlusion or intercuspal position. One opinion suggested the closing movement was purely rotation provided the patient had a normal, well functioning dentition, while the other suggested in normal subjects the path of closure from rest position to intercuspal position included translation of the mandible.

Protrusion

The protrusive path described by Posselt (1968) started from the retruded contact position, passed through the intercuspal position and edge to edge position, and ended in the most protruded contact position in front of the edge to edge position. The path described was irregular from tooth guidances and involved a shift of the incisal point of approximately ten millimeters.

Whether the condyles or the cusps of the articulating teeth were the influencing factor for mandibular movement in natural dentition, has been a continuing controversial topic. Gillis (1926) commented,

> if the cusp inclines of the articulating teeth were the guiding factor, no such thing as the traumatizing of a single tooth or several teeth could possibly occur because the movement of the mandible would first be altered to accomodate the new guiding factor...that it is free to shift about under the guidance of the tooth cusps is not tenable.

McCollum (1939) further emphasized the constancy of the condylar movement. He concluded the condyles will adjust themselves to inconvenience from the teeth, but will not change to make the adjustment permanently an adaptation. McCollum believed there should be contact between the guiding surfaces of all the teeth during excursive movements of the mandible.

A radiographic study by Donovan (1953) compared one hundred adults with normal temporomandibular function and found no significant correlation between the condylar and incisal paths.

In contrast to Donovan, Dierkes (1957) studied the condylar, molar and incisive paths in fifteen adults with excellent anatomical occlusion and symptomless temporomandibular joints. A positive correlation was found between the condylar and incisal paths. Using wax check bites, it was noted in those individuals who possessed an incisal path steeper than the condylar path, the perforations became more pronounced in the incisor region as the differences in the paths increased. In those subjects in which the condylar path was steeper than the incisal path there was no significant degree of perforation of the wax records and degree of incisal attrition.

Lockwood (1964) compared the movements of the mandible from the occlusal position to the incisive position to the protrusive position in five subjects who possessed excellent anatomical occlusion of the teeth. A positive correlation between the condyle, molar and incisal paths was not shown. However, the gnathological segment of the study exhibited a harmonious relationship between these paths as shown by the number of teeth in contact at the incisive and in both left and right lateral excursions.

The movements of the mandibular condyles in the sagittal plane and the inclination of the condyle path were studied by Ingervall (1972) in children aged seven and ten years and in adults. There was a positive correlation of the inferior movement of the condyle with the inclination of the condyle path recorded between the intercuspal and five millimeter protruded position. The anterior movement of the condyles to maximal protrusion was the same in all age groups. The inferior movements of the condyles from intercuspal position to maximum protrusion increased as did the inclination of the condyle path with age. Ingervall found no correlation between the inclination of the condyle path and the inclination of the incisal path and, in contrast to Lockwood (1964), no correlation between the inclination of the condyle path and the number of tooth contacts on the working and non-working sides.

In summary, the less the overbite, the smaller the incisal path inclination, the more pronounced the attrition, and the less irregular would be the whole protrusive path. If the condyle path and incisal inclination were equal, the protrusion path of the mandible would be parallel. It has been found that either the incisal path inclination was steeper than the condylar path inclination or the opposite (Posselt, 1968).

Anterior Border Opening Movement

The anterior border opening movement was performed while the mandible was in maximum protrusion during the entire course of the movement. Posselt (1962) described the maximal opening capacity of the mandible measured between the edges of the maxillary incisors as fifty-sixty millimeters.

Nevakari (1960) described a mean opening of fifty-six millimeters for twenty to twenty-five year old adults. The males opened further than the females but no difference was noted between the boys and girls in the six to twelve year old range.

A maximal opening capacity of approximately fifty millimeters for twenty to thirty year old adults was reported by Sheppard and Sheppard (1965). A larger opening capacity between the ages of eleven to fifteen years than in the adults was observed. In contrast, Nevakari found the maximal opening capacity increased steadily from seven years of age to twenty years of age.

Ingervall (1970), in a study of the range of movement of males and females of varying ages, found no difference in the opening capacity, or protrusion, between boys and girls. Ingervall noted a high correlation in his comparison between ten year old girls and women. It was suggested that in ten year old girls the mobility of the mandible had, on the average, reached adult levels. A strong correlation was observed between the opening capacity of the mouth and the maximal protrusion movement between boys and girls.

The range of movement of the mandible in relation to facial morphology in ten year old children was studied by Ingervall (1970). The analysis suggested the range of movement varied both with certain dimensions of the face and the shape of the face. The opening capacity varied with the length of the mandible and the length of the anterior cranial base. As these dimensions were positively correlated with body height and weight, variables with which the opening capacity was also positively correlated, it was suggested the opening capacity varied with body size and also possibly with physical development. Maximal opening varied with the shape of the face as noted by the positive correlation with the inclination of the mandibular ramus.

In summary, the determination of the range of movement of the mandible has been used as a simple objective method to assess the masticatory system, be it a functional disorder or an evaluation of the effect of various therapeutic measures.

Habitual Opening and Closing Movement

Posselt (1968) showed that although repeated habitual opening and closing movements do not coincide exactly, they have a fairly characteristic main course with the starting and end-point being the intercuspal position.

Studies by Nevakari (1956) and Tallgren (1957) reported a largely rotatory movement from rest to intercuspal position. Upon opening from intercuspal position, the condyles started translating immediately. As the mandible opened further from the postural position, relatively more translation took place, and in the last phase of opening the movement was mainly rotation.

Nevakari (1960) noted that, in the position of maximal opening, about seventy per cent of the condyles in a normal population were anterior to the crests of the articular eminence, so that neither luxation nor subluxation took place.

In a cinefluorographic and mandibulographic study of mandibular movements, Araiche (1966) confirmed Nevakari's observation that in many individuals the condyles move anterior to the articular eminence. In contrast to Osborne (1957), Lindblom (1960) and Scully (1962), Araiche noted that the closing path of the mandible was different than the opening path.

<u>Movement from Maximum Intercuspation to Retruded Contact Position</u>

Oriented temporomandibular joint radiographs by Hildebrand (1931) showed that seven in nine normal individuals were able to retrude the mandible 0.5-1.0 mm. posterior to maximum intercuspation.

In observing twenty individuals, Bjork (1947) found that the mandible could be retruded an average distance of 1.0 mm. from maximum intercuspation; however, his method of examination was not stated. Similarly, Sicher (1960) stated at least ninety per cent of healthy young adults with a full complement of teeth and normal occlusion could retrude the mandible 0.5 mm. to 1.0 mm. from maximum intercuspation.

By comparing the overjet directly on the subject with the mandible in intercuspal position, and relating the overjet to wear facets on the subject's plaster models, Heath (1949) concluded that retruded contact position was one to two millimeters posterior to the intercuspal position.

Movement from retruded contact position to intercuspal position was observed by Posselt (1952) in a cephalometric and graphic study of fifty normal dental students. The subjects' heads were secured in a cephalostat and exposures of retruded contact and intercuspal position were made. The distance measured between the steel balls fixed to the labial surface of the interdental papilla between the mandibular central incisors was taken as the movement of the mandible from retruded contact position to maximum intercuspation. Posselt showed that the mandible at the lower incisors moved posteriorly 1.25 mm. ± 1.0 mm. and inferiorly 0.9 mm. ± 0.75 mm. from the intercuspal position when measured parallel to the sella-nasion line. In eighty-eight per cent of the sample the mandible could be moved posterior to the position of maximum intercuspation or intercuspal position.

Donovan (1953), in a cephalometric and temporomandibular joint radiograph study, observed one hundred normal and one hundred abnormal functioning temporomandibular joints and recorded the various mandibular positions and functional paths. The mandible was not touched or forced as the subject moved through the various mandibular excursions. In the normal group the condylar position from intercuspal position to the muscular retruded contact position moved 1.03 mm. ± 0.43 mm. In general, the normal group could retrude the mandible more than the malfunction groups; thus, it was concluded that the retruded position of the mandible was not the position at which to commence diagnosis of malfunction of the dentition.

A research report by Stuart (1955) states:

> Those patients who have good, well-formed teeth, arranged in well-aligned, nicely formed arches always, as far as we have been able to observe, present a condition in which the cuspal interdigitation of the teeth agrees with condylar centricity.

Stuart's opinion of condylar centricity suggested a slide from retruded contact to maximum intercuspation or intercuspal position was pathologic.

A study of twenty-seven subjects who possessed excellent occlusion of the teeth was made by Schwartz (1955). Oriented temporomandibular joint radiographs were taken while the mandible was in rest position, maximum intercuspation and voluntary most retruded position. Ninety-three per cent of the subjects were able to retrude the mandible from maximum intercuspation.

An examination of retruded contact position was made by Ingervall (1964). Thirty-one girls aged nine to ten years and twenty-nine women aged sixteen to twenty-two were examined. Wax records were used to stabilize the mandible in retruded contact position. Frontal and lateral cephalometric radiographs with the mandible in retruded contact position and maximum intercuspation were utilized to show the amount of mandibular movement from retruded contact position to maximum intercuspation. In the children's group the mean difference between the two positions in the sagittal plane was 0.85 mm. ± 0.35 mm. and in the vertical plane 1.05 mm. ± 0.58 mm. This compared to the adult group's measurements of 0.89 mm. ± 0.40 mm. in the sagittal plane, and 1.34 mm. ± 0.69 mm. in the vertical plane. No subject presented with maximum intercuspation and retruded contact position coincident.

A review of the literature indicated a concensus of opinion which suggested that in normal occlusion, intercuspal position and retruded contact position were not coincident. It was concluded by Ingervall (1966) that children who possessed Class II, Division 1 malocclusions could retrude the mandible, on the average, further than those children who possessed Class I "normal" occlusion. Assuming the conclusion to be valid, it would be desirable to know the length of the slide from intercuspal position to retruded contact position for the Manitoba Class I acceptable occlusion sample in order to provide a standard by which a functional analysis of the Class II, Division 1 malocclusion patients could be evaluated.

V. HEAD POSTURE

Natural head posture has been a topic of interest for the past century. Broca (1862), using a horizontal or vertical reference line outside the cranium, observed that when man was standing, his visual axis was horizontal and his head was in the natural position.

Realizing the horizontal positioning of the head was a physiological concept, Schmidt (1876) concluded craniologists would have to define which anatomic plane within the skull corresponded to the physiological horizontal. This was accomplished at the cranio-metrical conference in Frankfurt am Main (1884).* The Frankfurt horizontal line, with reference points well defined both clinically and cranio-metrically, was adopted.

Subsequent to Broadbent's (1931) and Hofrath's (1931) technique of cephalometric radiography, orthodontists not only used the Frankfurt horizontal for orienting the

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*Craniometrische Konferenz zu Frankfurt: Verstandigung uber ein gemeinsames craniometrisches. Verfahren (Frankfurter Verstandigung). Arch. Anthrop., 15: 1-8, 1884.

living head in a cephalostat but attempted to use the Frankfurt horizontal to assess facial esthetics and treatment planning.

Bjork (1947) found no significant correlation between the free horizontal balance and the sella-nasion line. He felt the postural correlation was a compensation that kept the profile vertical.

Lundstrom (1955) discussed the variation in inclinations of the Frankfurt horizontal and the true vertical. The difference in natural head posture and the true horizontal was important in the aesthetic appreciation and actual metric analysis of the profile and facial type.

The mean position of the Frankfurt plane was shown by Downs (1956) to be an upward tip of 1.3 degrees with a standard deviation of 5.0 degrees. In no instance did the patient assume the same successive posture, thus subjective assessment was required to determine when the subject was in a natural free balance of head posture. Downs noted the occasional discrepancies between facial typing and photographic facial typing disappeared when a correction was made for those subjects who did not possess a level Frankfurt plane.

A cephalometric study by Moorrees and Kean (1959) of two groups of female students taken one week apart showed the standard deviation of head position was 2.05 degrees in the first group and 1.54 degrees in the second group. The true vertical, and/or a horizontal perpendicular to it was preferable as a reference line within the cranium as the biologic variation of the intracranial lines was greater than the variation found in the registration of natural head posture.

In a cinefluorographic study of head posture and its relationship to deglutition on three adolescent groups and an adult group, Cleall (1966) found a 90.1 degree measurement for the Frankfurt horizontal to the true vertical with a standard deviation of 3.0 degrees in a normal group. A comparison of the three adolescent groups gave no evidence to suggest the resting posture of the head had any connection with the facial profile or the dento-skeletal configuration.

Mills (1968) suggested the concept of natural head position in conjunction with a grid method of cephalometric analysis. A closer correlation of the lateral head radiographs with the clinical appearance of the patient was thus allowed. The clinician was no longer influenced by reference landmarks based on variable intracranial structures which are often far removed from the anatomic location of the discrepancy.

A cephalometric study was conducted by Solow and Tallgren (1971) to determine head posture in standing subjects in both head positions, the natural self balance position and the mirror position. In both head positions, the maxillary and mandibular reference lines were more variable to the true vertical than to the cranial base. Examination of the craniofacial variability to the true vertical and to the cervical column revealed the mandibular line showed the largest variability both to the true vertical and to the cervical reference lines. It was suggested that there may be interrelationships between the facial morphology and the head balancing position.

A cinefluorographic study of Class II, Division 2 (Angle) malocclusions by Stone (1971) found that the use of mechanical head posturing devices with ear rods appeared to cause an alteration in the physiologic resting posture of the head and mandible.

Helkimo et al. (1971) graphically recorded the retruded contact position with the subject in different postures and with the head in different positions. The precision of recording retruded position was not affected by the posture of the subject (sitting or lying).

In summary, the varying degrees of inconstancy in the before mentioned studies probably was related to the varying nature of the experimental methods. It would appear that as soon as the subject's posture was disturbed by restraining ear rods in a cephalostat or by anxiety as to the researcher's commands, the endogenous postural pattern of activity may not be produced (Ballard, 1955).

CHAPTER III

MATERIALS AND METHODS

I. SAMPLE

The sample consisted of a group of forty-eight Manitoba school children who possessed Angle's Class I acceptable occlusion. There were 27 females and 21 males ranging in age from 11 years, 11 months to 14 years, 2 months. The average age was 13 years, 5 months. The 48 children, considered to have ideal occlusion, were a subgroup of a sample of 444 children examined to ascertain the epidemiology of malocclusion in 12 year old Winnipeg School children (Banack, 1972).

The criteria for normal children were:

1. All permanent teeth present with first molars and cuspids in a Class I relation but with second molars not necessarily fully erupted (third molars excluded).
2. Minimum overbite and overjet.
3. No previous permanent tooth extractions.
4. No previous orthodontic treatment.

The facial and profile photographs and plaster study model photographs are shown for Subject 06-012 in Figures 1 and 2, respectively.

II. RECORDS

The following records were taken on each subject.

1. A clinical examination to determine patient acceptability.

Figure 1. Facial and profile photographs of Subject 06-012.

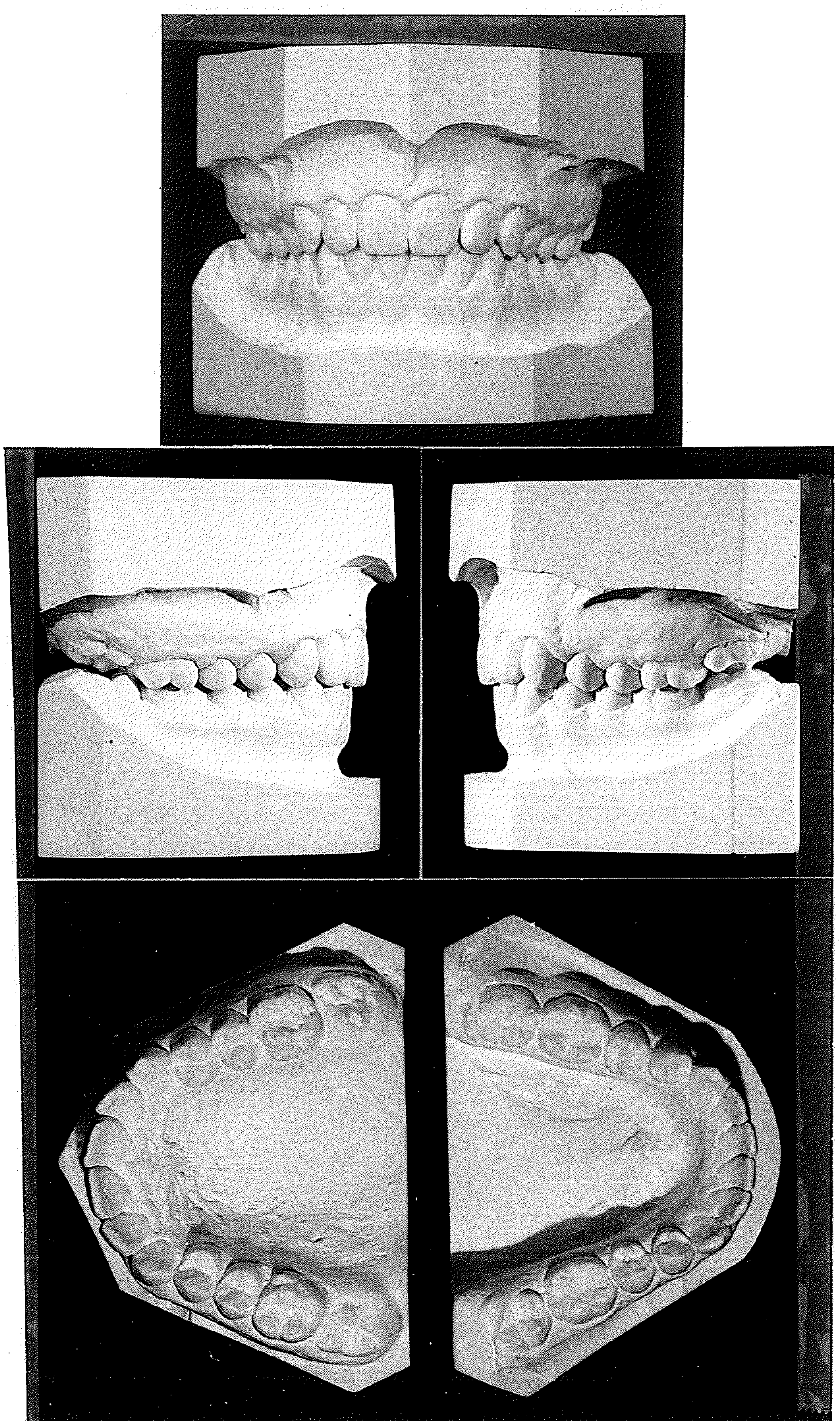

Figure 2. Photographs of plaster study models illustrating the Class I acceptable occlusion of Subject 06-012.

2. Alginate impressions of both arches.

3. A lateral cephalometric radiograph at rest, in occlusion, wide open and a postero-anterior radiograph utilizing a Cephalometrix* cephalometer.

4. Radiographs were taken of the left hand and wrist following the technique described by Tanner and Whitehouse (1959).

5. Panorex radiograph**.

6. A lateral cephalometric x-ray at rest and in occlusion, and a cinefluorographic sequence which included speech, swallowing cycles, and mandibular movements, were obtained with a Picker*** radiographic fluoroscopic unit.

Cinefluorographic Records

The cinefluorographic records of the patients were obtained in the Orthodontic Department, Faculty of Dentistry, University of Manitoba****. A Picker radiographic fluoroscopic unit containing an 8 3/4" image intensifier with a 16 mm. movie camera attached was used. Above the patient there was a twelve inch television monitor which permitted

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* Moss Corporation, Chicago, Illinois.

** S.S. White, Dental Products Division, Philadelphia, Pennsylvania.

*** Picker X-ray Engineering Ltd., 1174 Sanford Road, Winnipeg, Manitoba.

**** Faculty of Dentistry, 780 Bannatyne Avenue, Winnipeg 3, Manitoba.

fluoroscopic viewing of the patient during the filming sequence shown in Figure 3. The film speed was set at 30 frames per second using Kodak* Ektachrome daylight film EF449 for maximum contrast of hard and soft tissues.

A vertical and horizontal cross-wire was impregnated in the plastic viewing field in front of the x-ray image to provide evaluation of head posture during swallowing and mandibular movements.

Cephalometric Records

The cephalometric records were obtained in the same Picker radiographic fluoroscopic unit used for the cine-fluorographic records. Prior to the filming sequence, two lateral cephalometric radiographs were taken at a focal spot-target distance of 121.92 cm. (48 inches) in the manner described by Broadbent (1931). A true vertical plumb bob was hung laterally to the film (Kodak Blue Brand BB-14), so that head posture could be evaluated at rest and in habitual occlusion. In the cassette between the film and the patient a grid was placed for better definition. An 0.02 second exposure at 85KV and 50 mA was used for all subjects.

Technique

The patient was seated in a dental lounge chair and coached through the mandibular movement sequence which was to be requested of him at the time of filming. This was

*Kodak Canada Ltd., 918 St. James Street, Winnipeg, Manitoba.

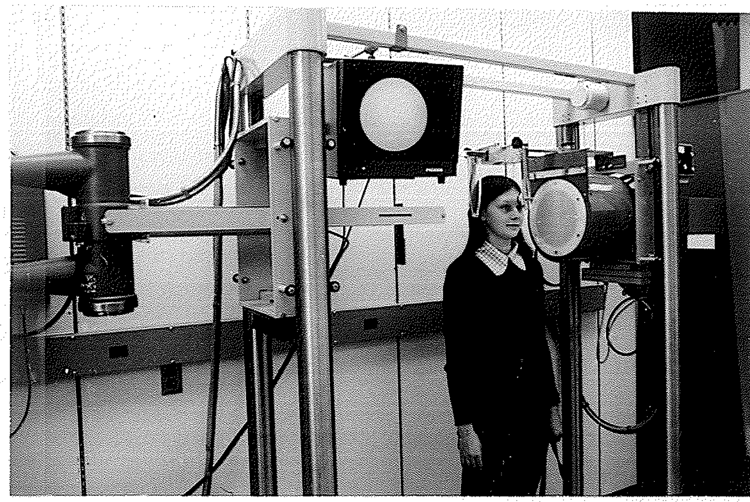

Figure 3. A photograph showing the positioning of a subject in the Picker radiographic fluoroscopic unit.

necessary to ensure a relaxed patient and thus reduce apprehension during the filming in order to eliminate the necessity of a second radiation exposure.

When the patient was confident that he could carry out the instructions he was placed standing in the cine-fluorographic machine and restraining ear rods were inserted. The patient, with the teeth in habitual occlusion, was requested to look straight ahead as if looking at himself in a mirror, and then a lateral cephalometric x-ray was taken. In order to establish rest position he was directed to lick his lips, relax and say Mississippi, and then, another lateral cephalometric x-ray was taken.

The restraining ear rods were swung away, the plumb bob was removed and the patient was fluoroscoped to ensure that he was orientated properly in a relaxed position of natural head posture for filming. The mid-line of the tongue and lips was marked with Picker Microtrast barium paste to allow better differentiation of the soft tissues on the film. The patient was then given a cup containing 5 ml. of water and instructed to:

1. Swallow the water.
2. Say "Peter looks silly swimming".
3. Swallow.
4. Relax.
5. Close teeth together.
6. Keep the posterior teeth in contact and slide the jaw as far forward as possible.
7. Open as wide as possible.
8. Close the teeth together.
9. Keep the posterior teeth in contact and slide the jaw as far back as possible and swallow.
10. Relax.

As the movements were carried out by the patient himself they represented his physiologic range. The instructions provided a five stage deglutition sequence and a 10 stage mandibular movement sequence which will be described under Coordinate Recording Technique.

Radiation

In image intensifier radiography the radiation dosage to the patient was reduced by a factor of over one thousand times (Boucher, 1962). By concomitantly accelerating the image and electrostatically reducing its size, there was a resultant increased brightness of the image on the output phosphor which was photographed by the 16 mm. camera. Radiation to the patient was further reduced by pulsing the x-ray beam and synchronizing this with the exposure of each frame of the film.

The radiographic fluoroscopic unit was surveyed by the Radiation Protection Section* of the Manitoba Cancer Foundation to detect potential radiation hazards to the operator and patient. They reported:

> When used for cineradiography the exposure rate at the beam entrance surface of an adult skull phantom is 148 mR per foot of film exposed with the following settings:
>
> KVp selector setting-------------------automatic
> camera speed setting---------------30 frames per second
> density correction setting-------------0
> focal spot-phantom surface distance----48 inches
> ----- Fluoroscopic procedures used on this unit are for field localization purposes only and as a result the time of fluoroscopic operation per patient is very low.

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* Protection Section, 700 Bannatyne Avenue, Winnipeg 3, Man.

With regard to the cephalometric exposure they reported:

> The x-ray tube when operated for radiography at indicator settings of 85KVp-50mA-1/5 second (10mAs) gives rise to an exposure of 20 mR at a 48 inch distance from the focal spot (2mR per mAs).

A normal filming sequence lasting forty-five seconds and using approximately fifty feet of film would result in a lesser degree of radiation to the patient than that received during a full mouth dental survey using ultra-speed film.

III. ANALYSIS OF RECORDS

Selection of Landmarks and Stages

Cinefluorographic records - mandibular movement. Seven landmarks on the mandible and one landmark on the hyoid bone were selected as moving points from which mandibular rest position, path of closure, centres of rotation and translation of the mandible could be assessed. To assess the envelope of motion of the mandibular movement sequence, the movement of the incisal edge of the lower incisor was selected.

To measure the change in head posture during the various stages of mandibular movement, the change in angulation of the palatal plane to the true vertical was assessed.

Five stationary points, 3 on the maxilla and 2 representing the true vertical, were utilized to assess the motion of the moving points. Two landmarks, namely the mesiobuccal cusp tip of the maxillary first molar and a point on the buccal groove of the mandibular first molar, were superimposed as one landmark in habitual occlusion position.

The locations of these landmarks are illustrated in Figure 4 and the definitions appear in the Glossary.

Cinefluorographic records - deglutition. Three points on the tongue plus one point on the hyoid bone were selected as moving points from which to assess the changing morphology of the tongue and the position of the hyoid bone during the five stages of swallowing to be described. To assess head posture during the five stage swallowing sequence, five stationary points, 3 on the maxilla and 2 representing the true vertical were selected to provide the reference points to orient the frames for computer analysis.

The locations of these landmarks are illustrated in Figure 5 and the definitions appear in the Glossary.

Cephalometric analysis. Thirty-nine landmarks shown in Figure 6 and defined in the Glossary were noted on the two lateral cephalometric radiographs. One was taken at rest and the other one was exposed in habitual occlusion position. These landmarks were used:

1. To provide standards for a skeletal and dental analysis of thirteen year old Manitoba school children with Class I acceptable occlusion.
2. To evaluate the change in head posture from rest to habitual occlusion when the restraining ear rods were inserted; and to compare the results to the alteration in head posture from rest to habitual occlusion in the cine when no ear rods

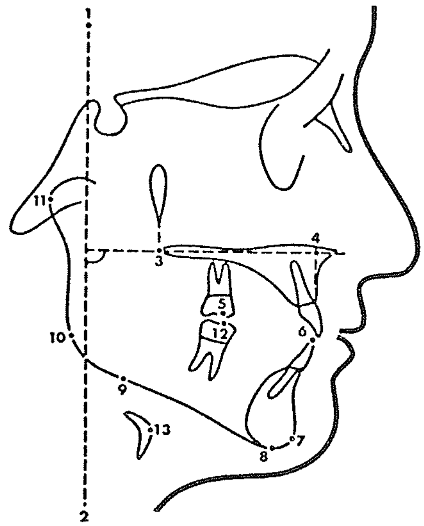

Figure 4. Illustration of 13 landmarks used in the analysis for the cinefluorographic mandibular movement sequence.

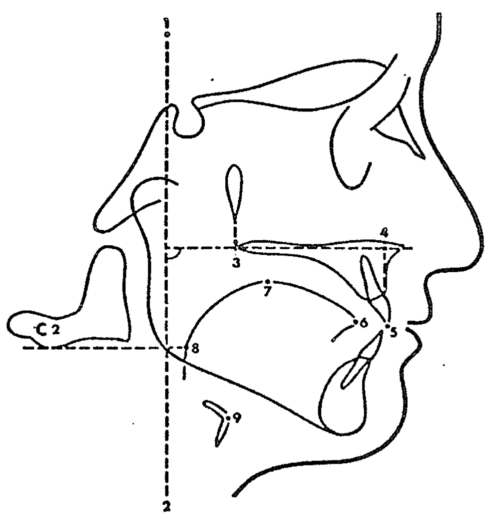

Figure 5. Illustration of 9 landmarks used in the analysis for the cinefluorographic deglutition sequence.

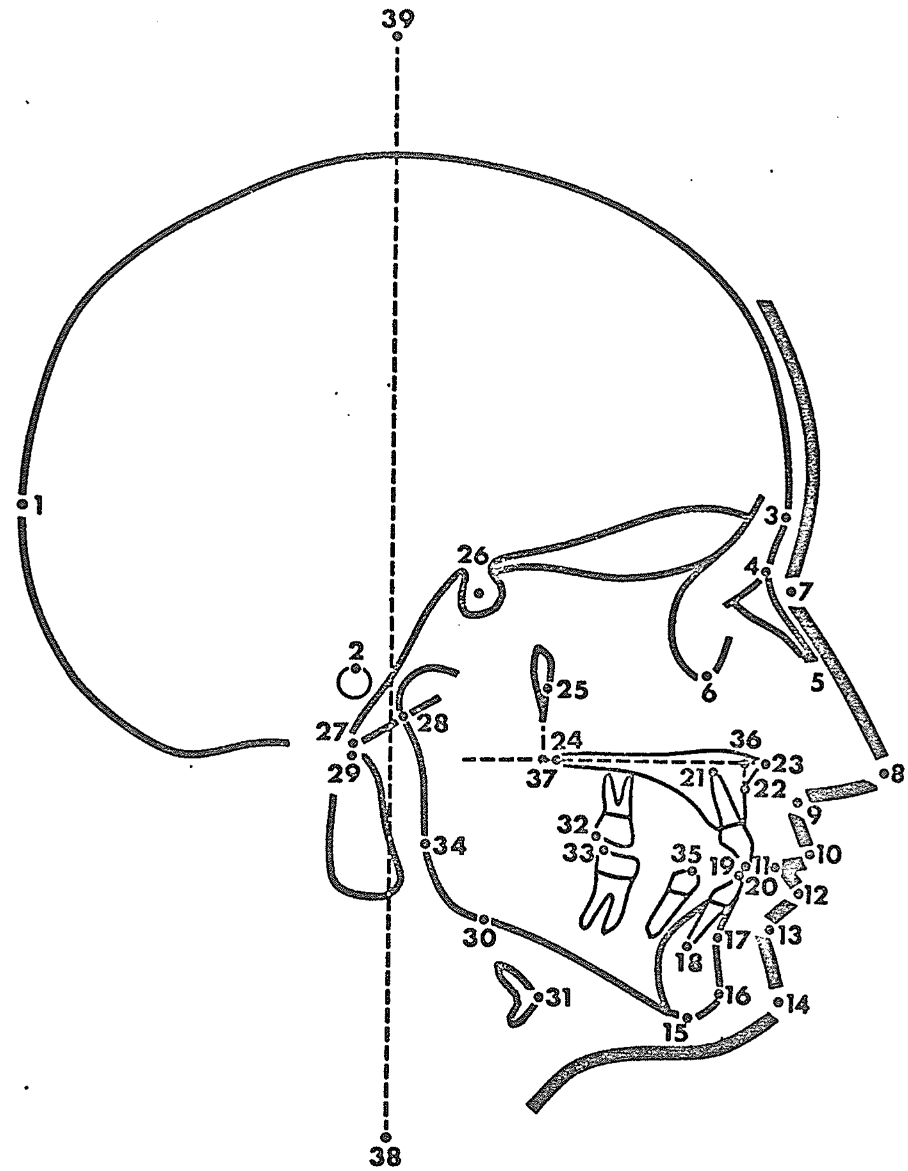

Figure 6. Illustration of 39 landmarks used in the cephalometric analysis.

were utilized.

3. To assess in rest position the mandibular displacement of the mandible with the restraining ear rods in place, and to compare the resultant displacement to the rest position of the mandible in the cine when the ear rods were swung away. The change in position of a line drawn from the incisal tip of the lower incisor to pogonion was used to demonstrate the displacement of the mandible in rest position.

The depth of the curve of spee was measured by computing the perpendicular distance from the tip of the lower first bicuspid to a line joining the incisal edge of the lower incisor and the disto-buccal cusp of the mandibular first molar. These landmarks are illustrated in Figure 7.

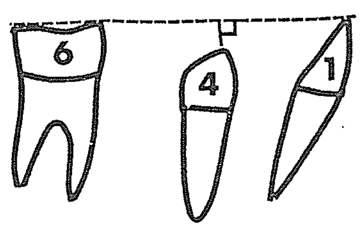

Figure 7. Illustration of the methodology used to calculate the depth of the curve of Spee.

The horizontal overjet was measured by computing the horizontal distance between the incisal edge of the mandibular incisor, and the incisal edge of the maxillary incisor. This is illustrated in Figure 8.

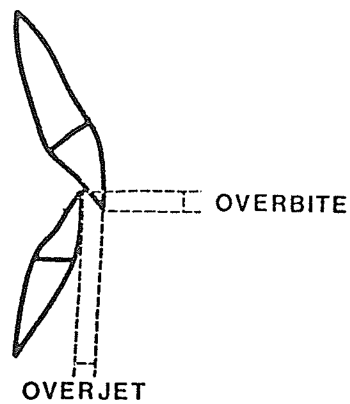

Figure 8. An illustration of the methodology used to calculate the vertical overbite and the horizontal overjet.

The vertical overbite was measured by computing the vertical distance between the incisal edge of the maxillary incisor and the incisal edge of the mandibular incisor. This is illustrated in Figure 8.

Coordinate Recording Technique

Mandibular movements and deglutition sequences. The frames to be analyzed for both the mandibular movement sequence and the swallowing sequence were selected by repeated viewings on a Tagarno 16 film editor*, Figure 9, at regular speed, slow motion and frame by frame. To facilitate future

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* Phillips Electronic Equipment Ltd., Winnipeg, Man.

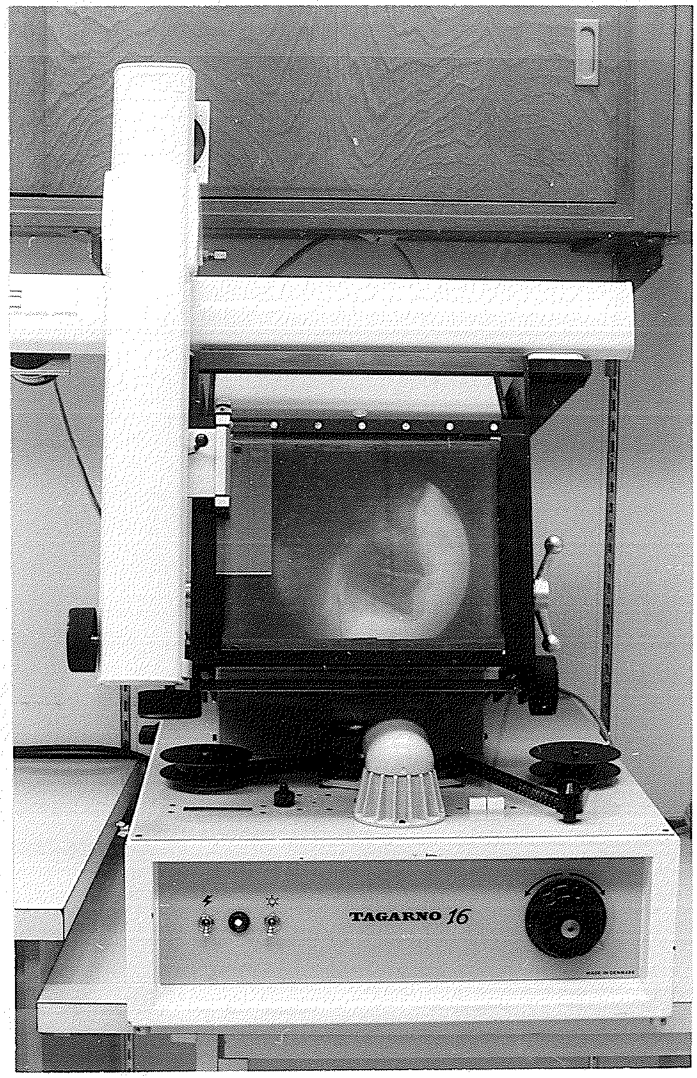

Figure 9. Photograph of Tagarno 16 Movie Projector and attached Ruscom Strip Chart Digitizer used to select and analyse the individual cinefluorographic frames and cephalometric radiographs.

readings of the frames, the first frame of the film was numbered zero. The frame numbers of the frames selected for analysis were noted on the built-in frame counter in the editor and documented for future reference.

The frames were subjectively selected for each subject on the basis of the following mandibular positions:

1. Physiological Resting Position (r).
2. Initial Contact Position (ic). This position was attained when the lower incisor first contacted the upper incisor.
3. Full Closure Position (fc). This position required maximum intercuspation of the teeth and usually was attained within 3-5 frames after initial contact.
4. End to End (e-e). This position was represented by the incisal edge of the mandibular incisor contacting the incisal edge of the maxillary incisor.
5. Minimum Protrusion (mnp). This position occurred immediately after end to end position as the lower incisor passed into anterior crossbite with the maxillary incisor.
6. Maximum Protrusion (mxp). This position was the fullest extent to which the patient could protrude his mandible.
7. Wide Open (wo). This was the widest position the patient was able to open his mandible.

8. Initial Contact (ic). The same position as 2.

9. Full Closure (fc). The same position as 3.

10. Retruded Contact Position (Ret). This was the most posterior position that the patient could move his mandible from full closure position.

The envelope of motion traced by the lower incisor passing through these stages is illustrated in Figure 10. Reproductions of the 16 mm. cinefluorographic frames showing the 10 mandibular movements and their diagrammatic illustrations are illustrated in Figures 11, 12, 13, 14, 15, 16, 17, 18, 19 and 20, respectively.

The frames were subjectively selected for each subject on the basis of the following swallowing sequence (Cleall, 1966).

Stage 1. The initial rest position before any movement took place.
Stage 2. When the tongue tip had moved forward and upward and contacted the upper incisors or palatal mucosa.
Stage 3. After the tongue had rolled back and this movement reached the junction of the hard and soft palates.
Stage 4. When the hyoid bone was at its most anterior and highest position (normally when saliva was being swallowed at the level of the epiglottis approximately).
Stage 5. The resting position at the end of the swallowing sequence.

Reproductions of the 16 mm. cinefluorographic frames and their diagrammatic illustrations for the above 5 stages of deglutition are shown in Figures 21, 22, 23, 24 and 25.

A separate maxillary and mandibular template of matte acetate tracing paper was made for each subject using frames

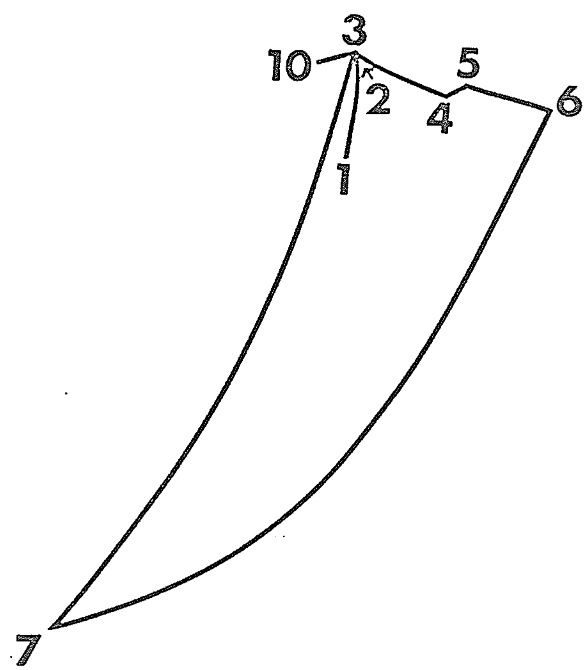

Figure 10. Diagrammatic illustration of the envelope of motion traced by the lower incisor through the 10 stage mandibular movement sequence. Stages 8 and 9 have been omitted for illustrative purposes as they are synonymous with stages 2 and 3.

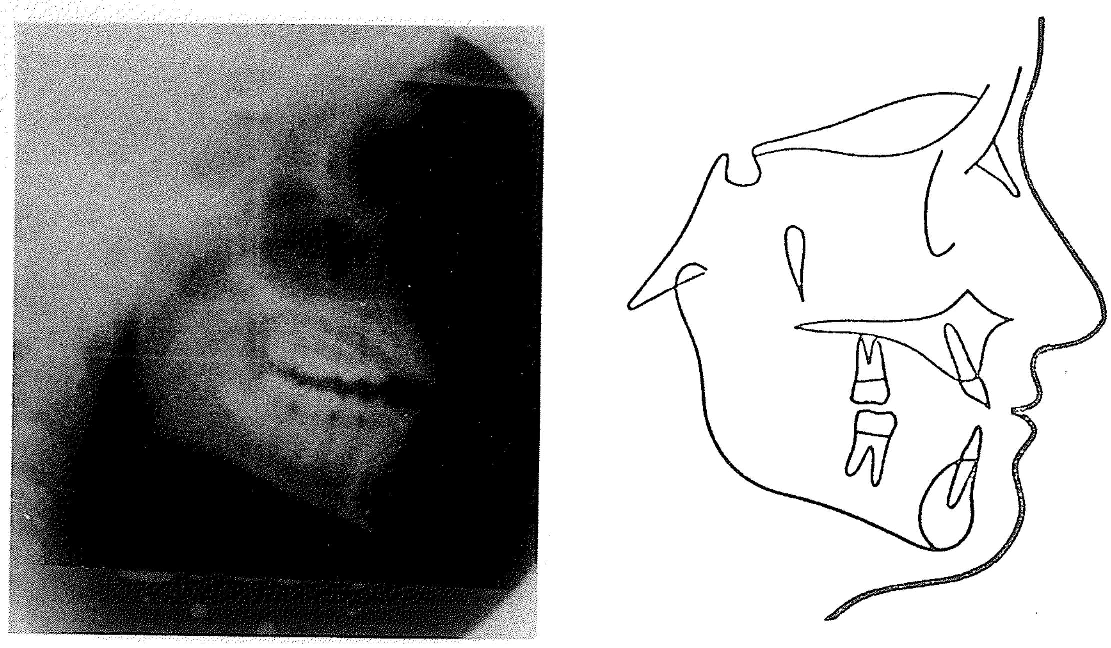

Figure 11. A reproduction and diagrammatic illustration of 16 mm. cinefluorographic frame of rest position (Stage 1).

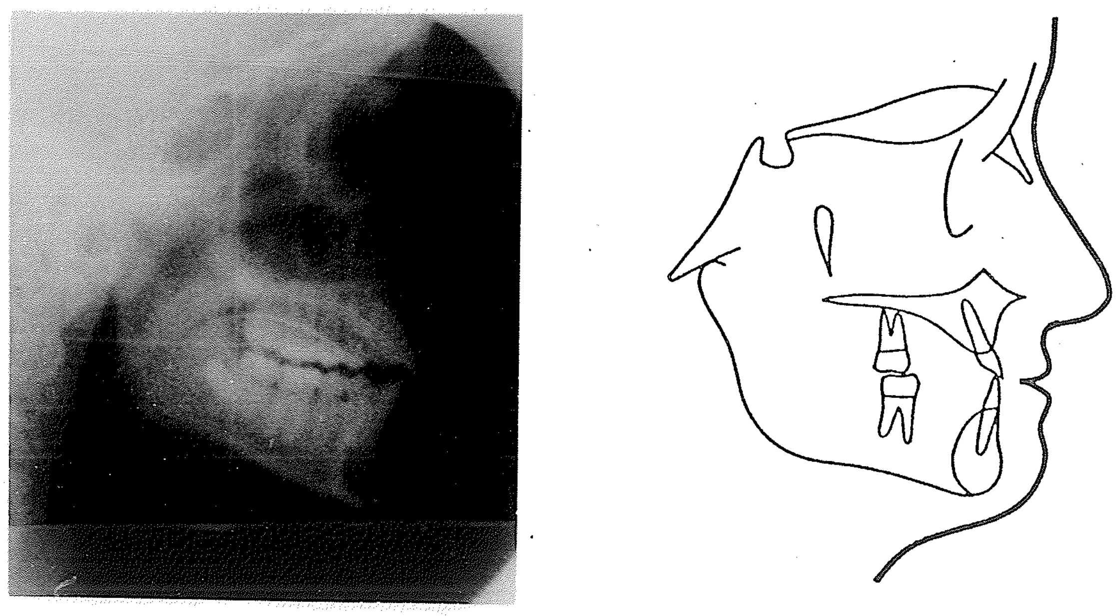

Figure 12. A reproduction and diagrammatic illustration of 16 mm. cinefluorographic frame of initial contact position (Stage 2).

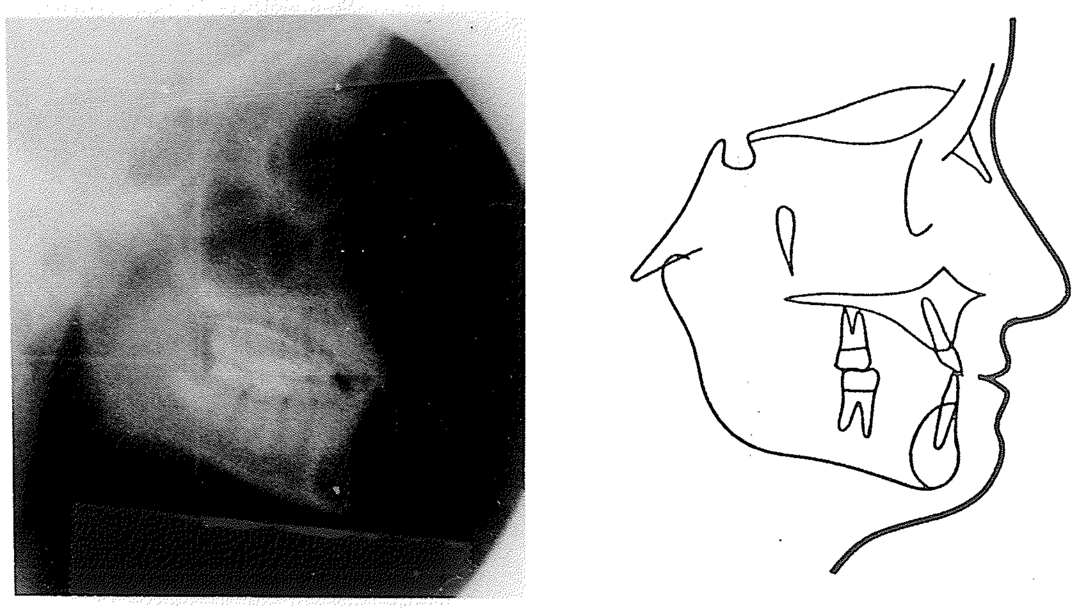

Figure 13. A reproduction and diagrammatic illustration of 16 mm. cinefluorographic frame of full closure position (Stage 3).

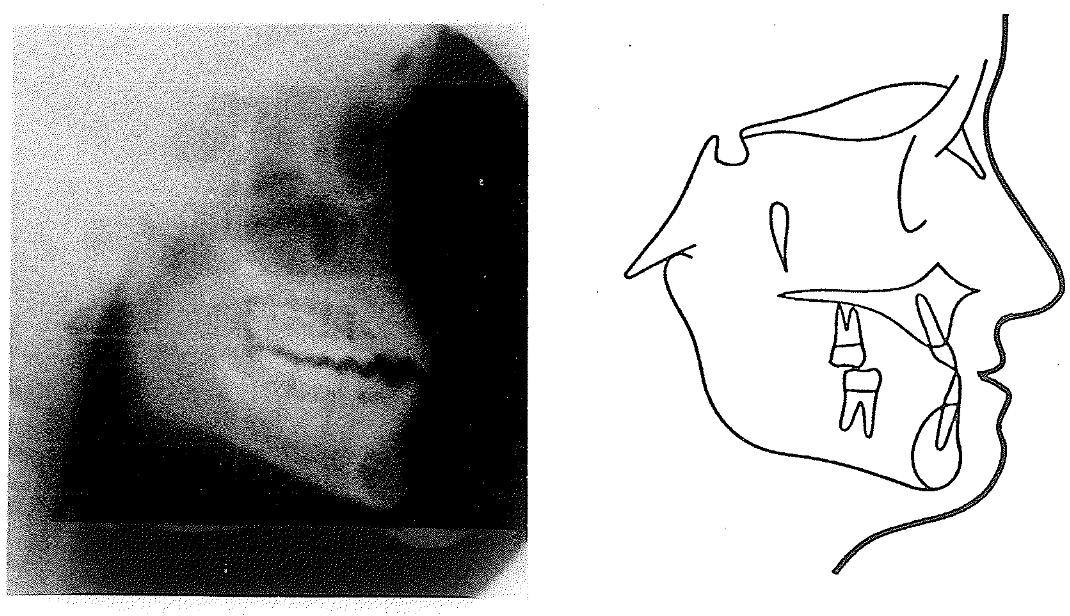

Figure 14. A reproduction and diagrammatic illustration of 16 mm. cinefluorographic frame of end to end position (Stage 4).

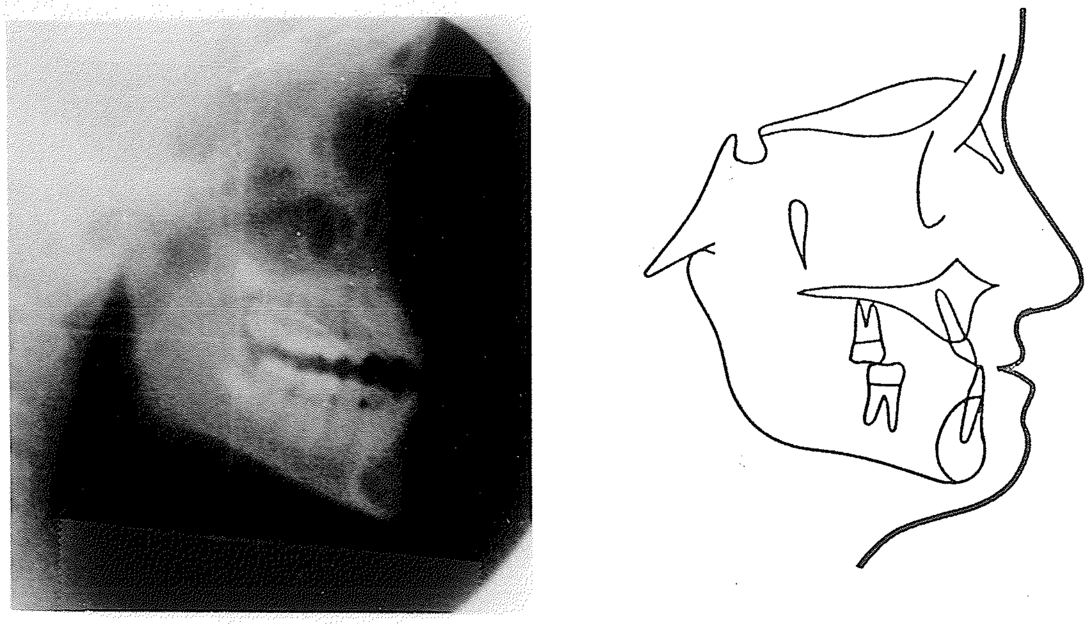

Figure 15. A reproduction and diagrammatic illustration of a 16 mm. cinefluorographic frame of minimum protrusion position (Stage 5).

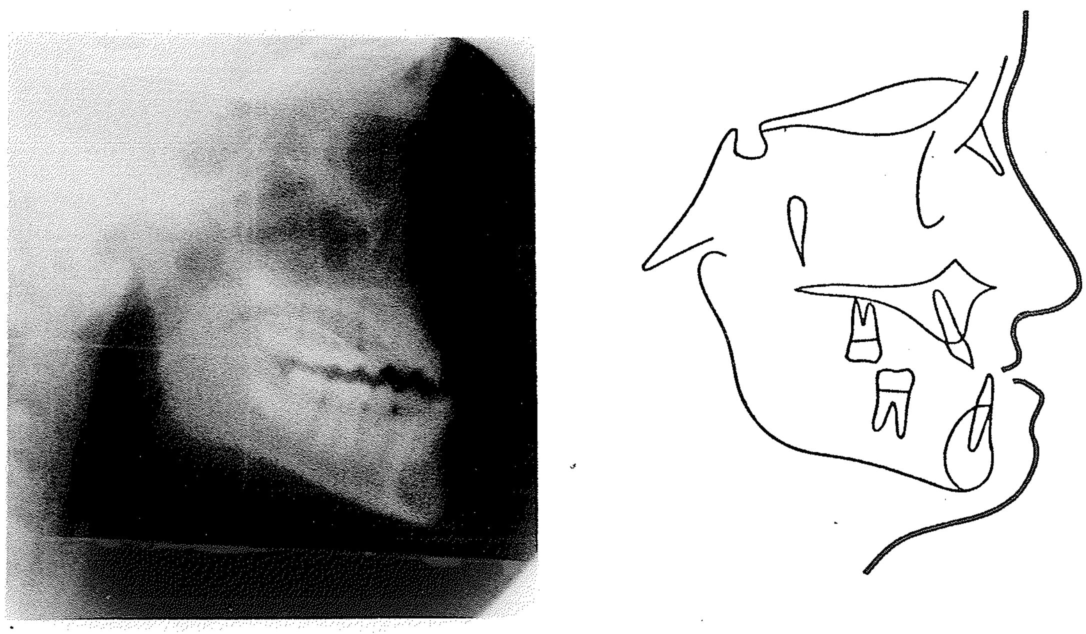

Figure 16. A reproduction and diagrammatic illustration of a 16 mm. cinefluorographic frame of maximum protrusion position (Stage 6).

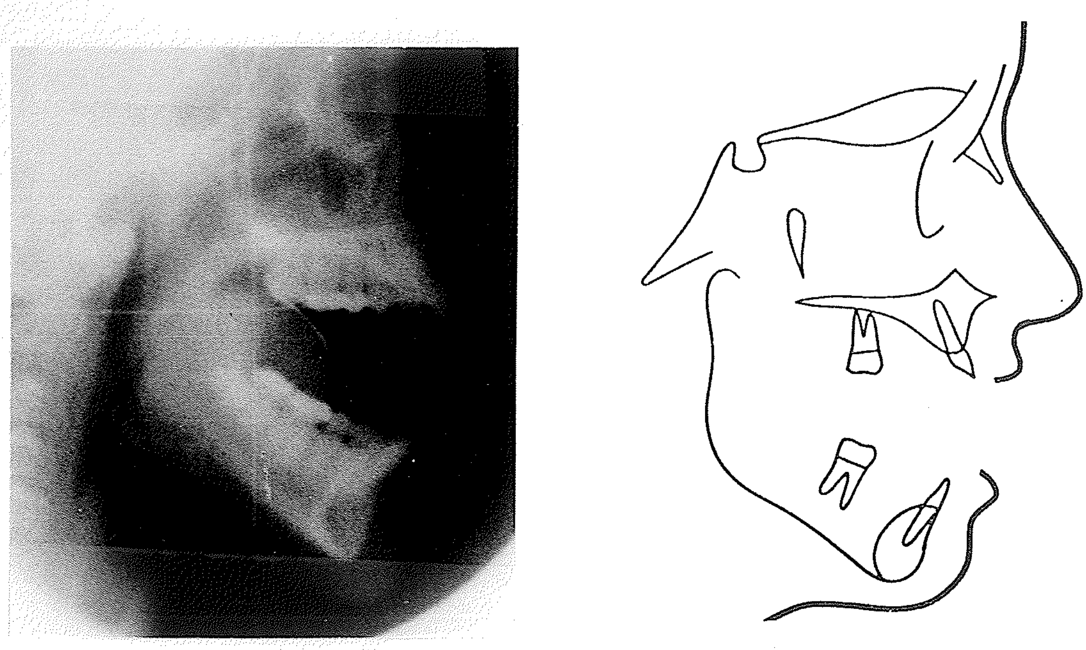

Figure 17. A reproduction and diagrammatic illustration of a 16 mm. cinefluorographic frame of wide open position (Stage 7).

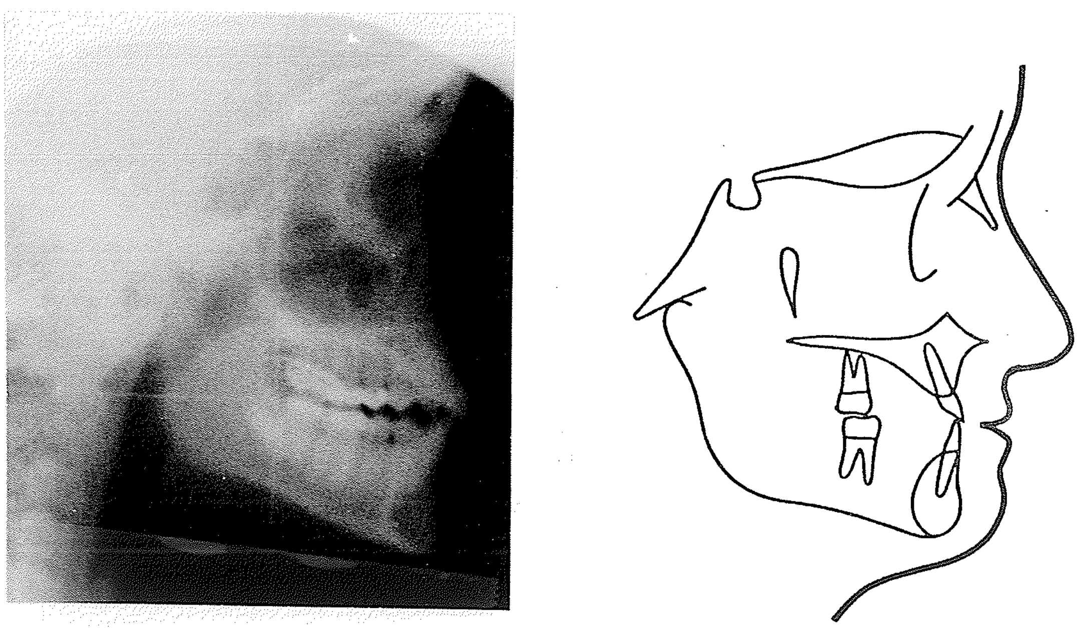

Figure 18. A reproduction and diagrammatic illustration of a 16 mm. cinefluorographic frame of initial contact position (Stage 8).

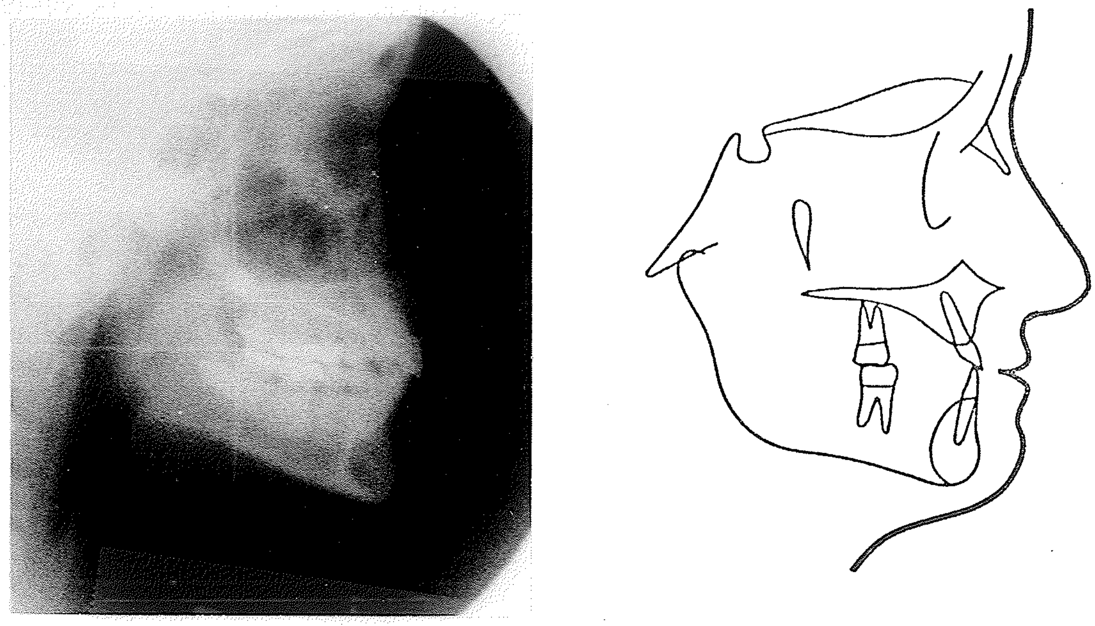

Figure 19. A reproduction and diagrammatic illustration of 16 mm. cinefluorographic frame of full closure position (Stage 9).

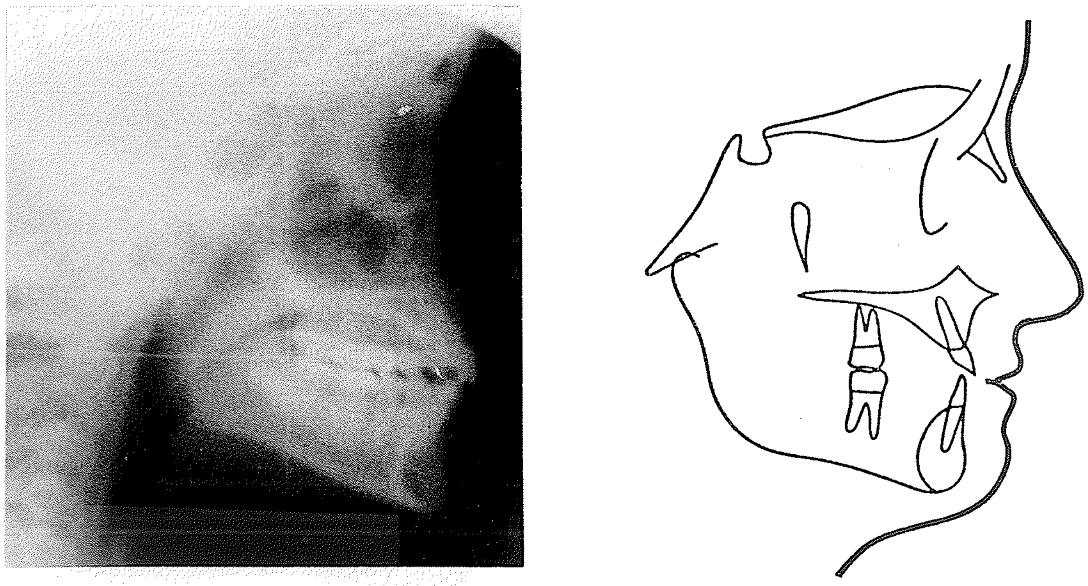

Figure 20. A reproduction and diagrammatic illustration of 16 mm. cinefluorographic frame of retruded contact position (Stage 10).

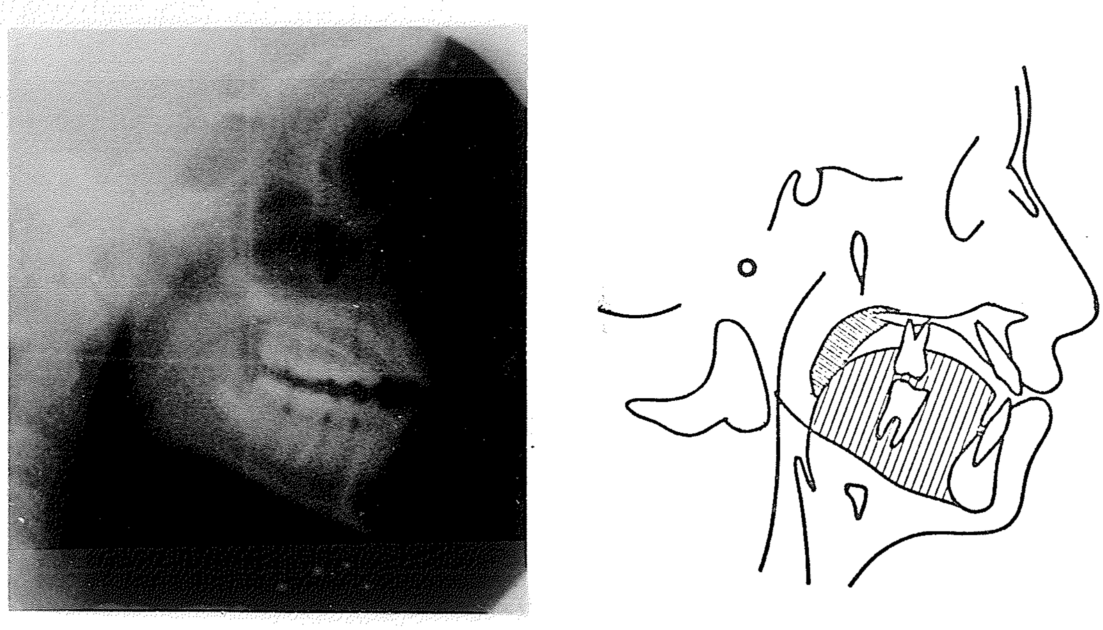

Figure 21. A reproduction and diagrammatic illustration of 16 mm. cinefluorographic frame of rest position (Stage 1).

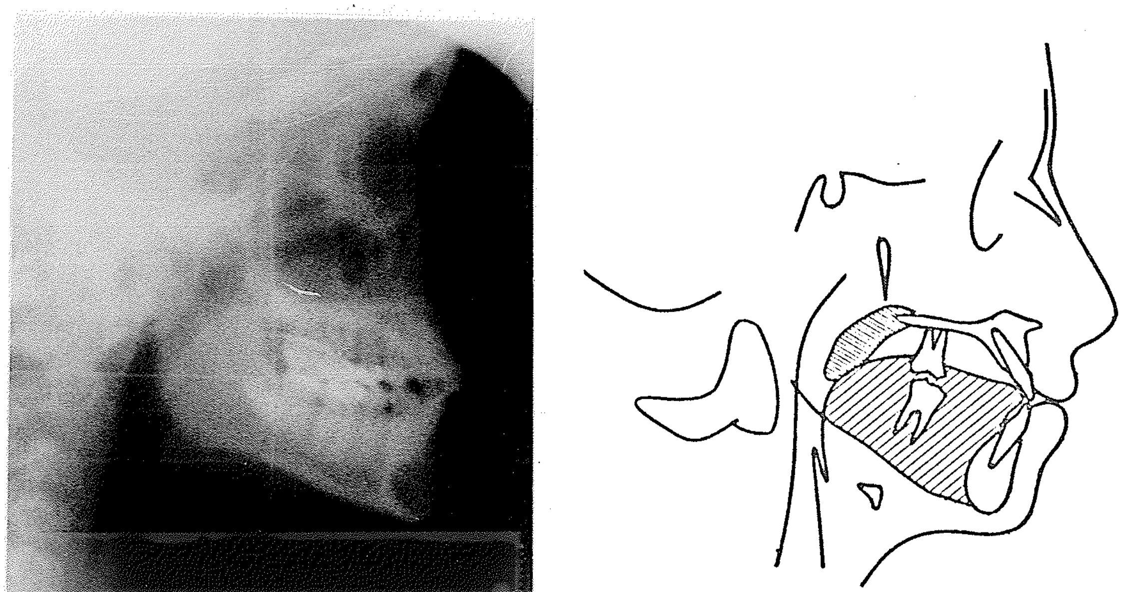

Figure 22. A reproduction and diagrammatic illustration of 16 mm. cinefluorographic frame of when the tongue tip contacted the maxillary incisors (Stage 2).

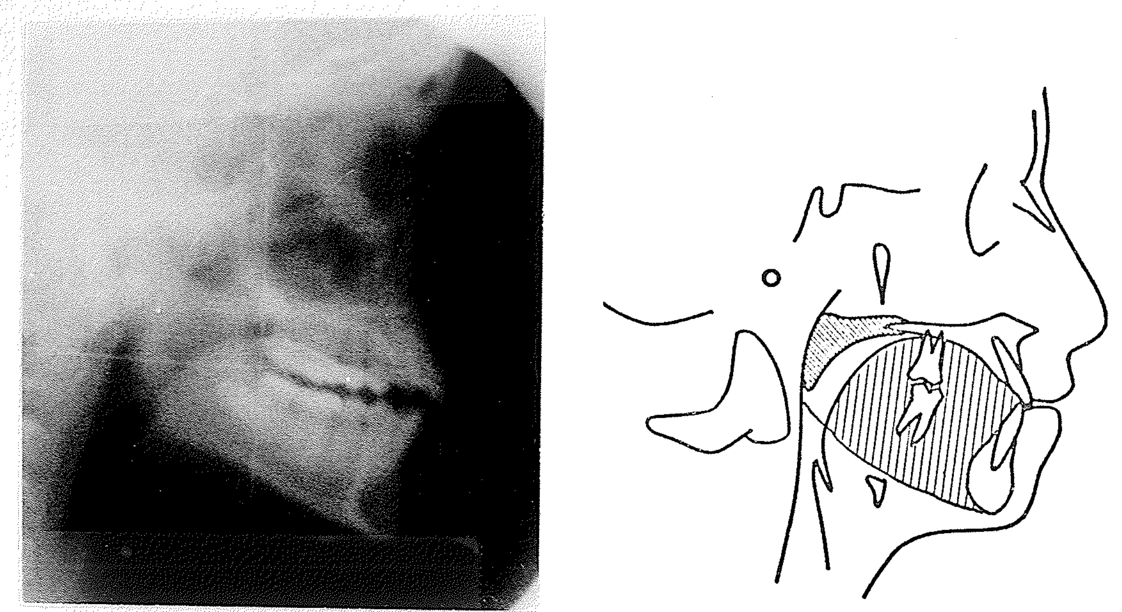

Figure 23. A reproduction and diagrammatic illustration of 16 mm. cinefluorographic frame of when the dorsum of the tongue reached the junction of the hard and soft palate (Stage 3).

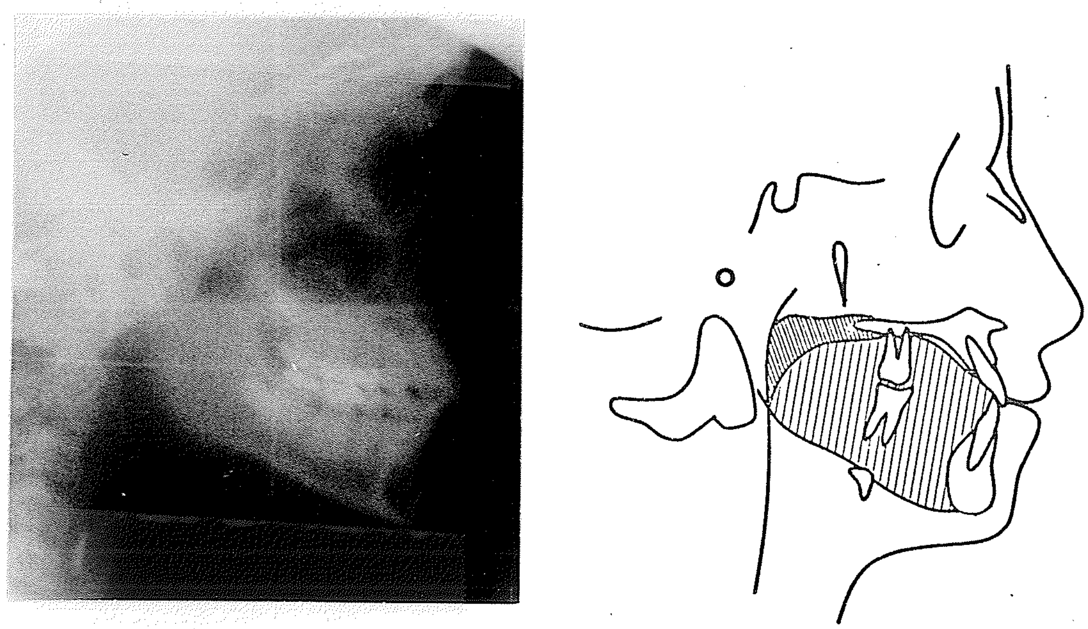

Figure 24. A reproduction and diagrammatic illustration of 16 mm. cinefluorographic frame of when the hyoid bone reached its most anterior, superior position (Stage 4).

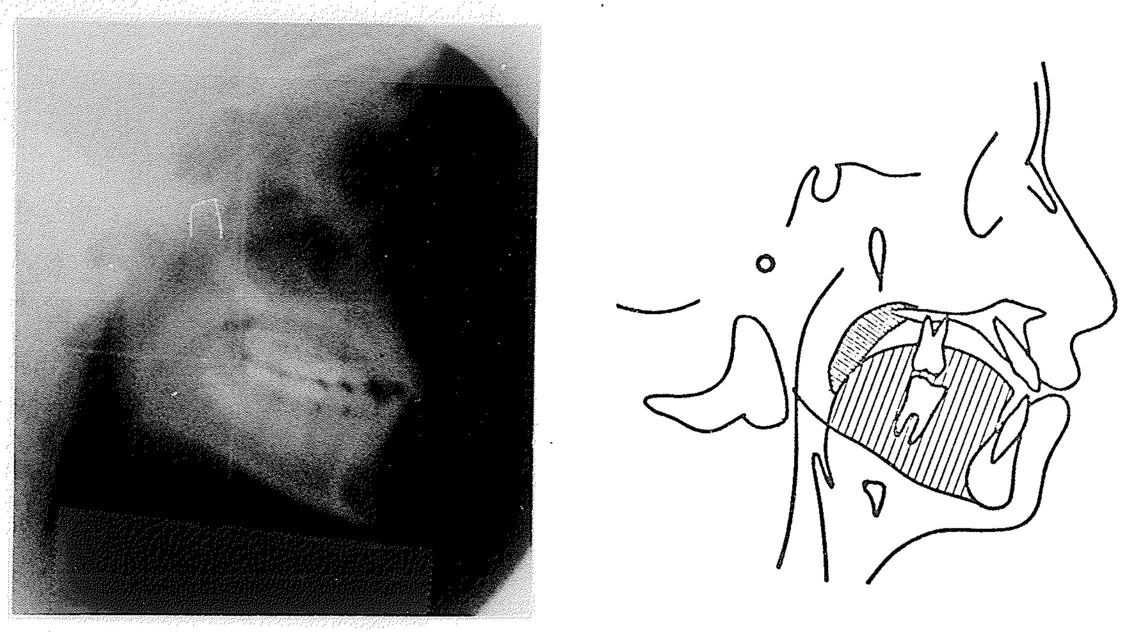

Figure 25. A reproduction and diagrammatic illustration of 16 mm. cinefluorographic frame of the resting posture at the end of the swallowing sequence (Stage 5).

best depicting the required landmarks. For each frame analyzed the templates were fitted by a best fit method. It has been shown that the accuracy of the template method of point location, as compared to identifying the points without the templates, showed the template method to be more accurate (Stone, 1971). A template was not required to locate the points on the tongue due to the changing positions of these landmarks; therefore, they were subjectively assessed.

Attached to the Tagarno motion analyzer was a Ruscom* strip chart digitizer which recorded the landmarks on IBM cards utilizing an IBM** 26 Printing Card Punch. Figure 26 illustrates the operation of the digitizing equipment in the orthodontic radiographic research room. The data was then statistically analyzed by the Computer Department for Health Sciences, University of Manitoba***.

Lateral cephalometric radiographs. The two lateral cephalometric radiographs were digitized for each patient on the Ruscom strip chart digitizer attached to the Tagarno motion analyzer. The coordinates were punched on IBM cards and statistically analyzed by the Computer Department for Health Sciences at the University of Manitoba. In order to provide a more accurate landmark selection, a matte acetate

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*Ruscom Logics Limited, Rexdale, Ontario, Canada.

**IBM, Don Mills, Canada.

***University of Manitoba Health Sciences Computer Department, 753 McDermot, Winnipeg, Manitoba.

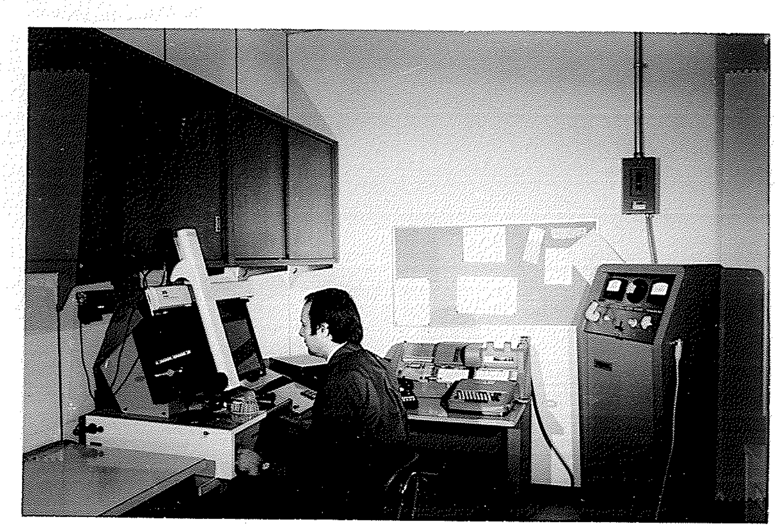


Figure 26. Illustration showing the operation of the digitizing equipment in the radiographic research room of the Orthodontic Department.

tracing template was made of the reference plane on the maxilla and the lower incisor and body of the mandible in the manner previously described for the cinefluorographic analysis.

The lateral cephalometric radiograph in occlusion was digitized first. The template was removed, placed on the rest position radiograph which then was digitized.

The differences between the points selected for the lower incisor and the two radiographs represented the change in position of the mandible from rest to full closure or habitual occlusion.

A total of 78 points, 39 for each radiograph were digitized for each patient.

Coordinate Analysis

A standardized set of 105 linear measurements and 75 angular measurements were obtained from the coordinate data to define in the sagittal plane:

1. The location of the centre of mandibular rotation during the ten stages of mandibular movement.
2. The relationship of the palatal plane represented by the reference plane to the true vertical as a measure of head posture during the five stages of swallowing.
3. The relationship of the palatal plane represented by the reference plane to the true vertical as a measure of head posture during the ten stages of

mandibular movement.

4. The amount and direction of movement of the mandible from physiological rest position through the ten stages of mandibular movement previously described.

Cinefluorographic linear measurements. The following 7 measurements are illustrated in Figure 27.

1. Mandibular movement.

Length 1. The intersite distance between the buccal cusp of the maxillary first molar and the buccal groove of the mandibular first molar.

Length 2. The intersite distance between the anterior border of the hyoid bone and reference point 3 on the palatal plane.

Length 3. The vertical distance between the tip of the lower incisor and the palatal plane.

Length 4. The vertical distance between pogonion and the palatal plane.

Length 5. The vertical distance between the buccal groove of the mandibular first molar and the palatal plane.

Length 6. The vertical distance between the anterior edge of the hyoid bone and the palatal plane.

Length 7. The vertical distance between condylion and the palatal plane.

The 9 linear measurements (8-16) used for the cine-fluorographic deglutition sequence are shown in Figure 28.

2. Deglutition.

Length 8. The intersite distance between the tip of the tongue and the dorsal surface of the tongue.

Length 9. The intersite distance between the dorsal surface of the tongue and the posterior edge of the tongue.

Length 10. The intersite distance between the posterior edge of the tongue and the anterior edge of the hyoid bone.

Length 11. The intersite distance between the anterior edge of the hyoid bone and the tip of the tongue.

Length 12. The intersite distance between the incisal edge of the maxillary incisor and the tip of the tongue.

Length 13. The intersite distance between the incisal edge of the maxillary incisor and the anterior edge of the hyoid bone.

Length 14. The intersite distance between the anterior edge of the hyoid bone and the posterior reference point 3 on the palatal plane (PTM).

Length 15. The vertical distance between the anterior edge of the hyoid bone and the palatal plane.

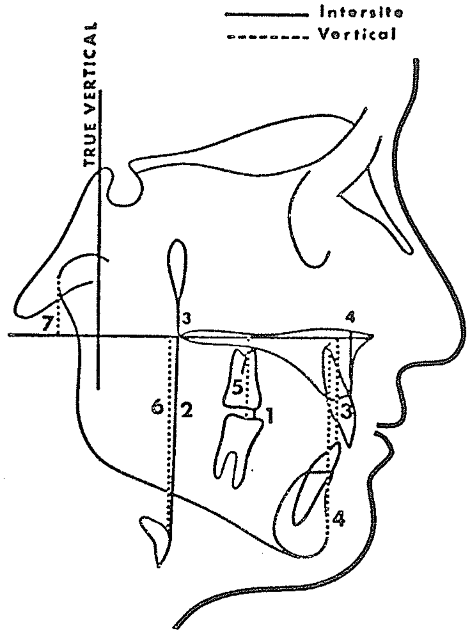


Figure 27. Illustration of the 7 (1-7) cinefluorographic linear measurements used in the mandibular movement analysis.

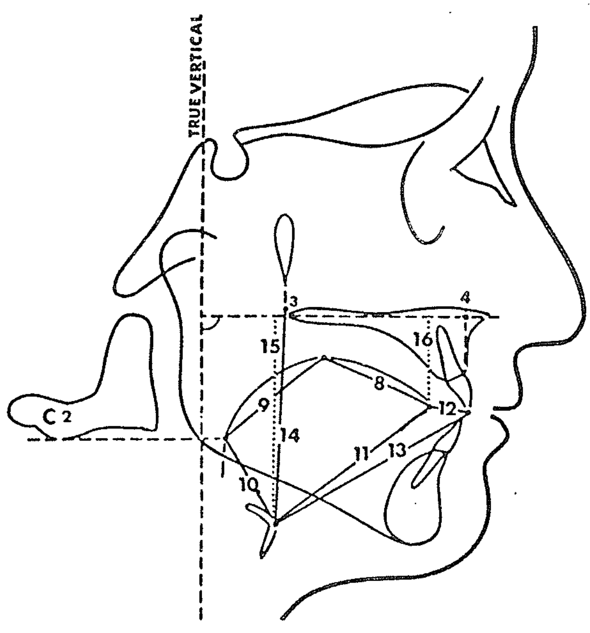


Figure 28. Illustration of the 9 (8-16) cinefluorographic linear measurements used in the deglutition analysis.

Length 16. The vertical distance between the tip of the tongue and the palatal plane.

Cinefluorographic angular measurements. The following mandibular movement measurements are illustrated in Figure 29.

1. Mandibular movement.

Angle a. The angle formed between the incisal edge of the lower incisor and the palatal plane represented by reference point 4 to reference point 3.

Angle b. The angle formed between the palatal plane and the mandibular plane.

Angle c. The angle formed between the mandibular plane and the true vertical.

Angle d. The angle formed by the intersection of the palatal plane and the true vertical.

2. Deglutition.

Angle e. The angle formed between the posterior of the tongue, the dorsum of the tongue and the tip of the tongue.

Angle f. The angle formed between the dorsum, the posterior of the tongue and the hyoid bone.

Angle g. The angle formed between the posterior of the tongue, the hyoid bone, and the anterior tip of the tongue.

Angle h. The angle formed between the hyoid bone, the tip of the tongue and the dorsum of the tongue.

Angle i. The angle formed between the hyoid bone and the palatal plane represented by reference point 3 to reference point 4.

Angle j. The angle formed between the tip of the tongue and the palatal plane represented by reference point 4 to reference point 3.

Angle k. The angle formed between the reference plane and the true vertical.

The foregoing deglutition measurements are illustrated in Figure 30.

Centre of rotation. The centre of rotation for the movement of the mandible was established from stage to stage for seven mandibular movements. These movements were from:

Stage 1 (rest) - Stage 3 (full closure).

Stage 6 (maximum protrusion) - Stage 7 (wide open).

Stage 7 (wide open) - Stage 2 (initial contact) - Stage 3 (full closure).

Stage 7 (wide open) - Stage 10 (retruded contact position).

Stage 1 (rest) - Stage 10 (retruded contact position).

Stage 9 (full closure) - Stage 10 (retruded contact position).

The rotation centres were located by erecting two perpendiculars from the point of bisection of the distances moved by the lower incisor and pogonion for mandibular movement stages. The ensuing intersection of the two perpendiculars

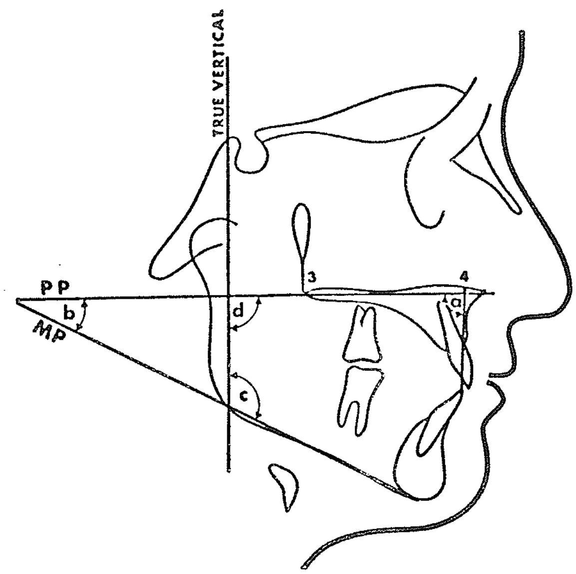


Figure 29. Illustration of the 4 cinefluorographic angular measurements (a-d) used in the 10 stage mandibular movement sequence.

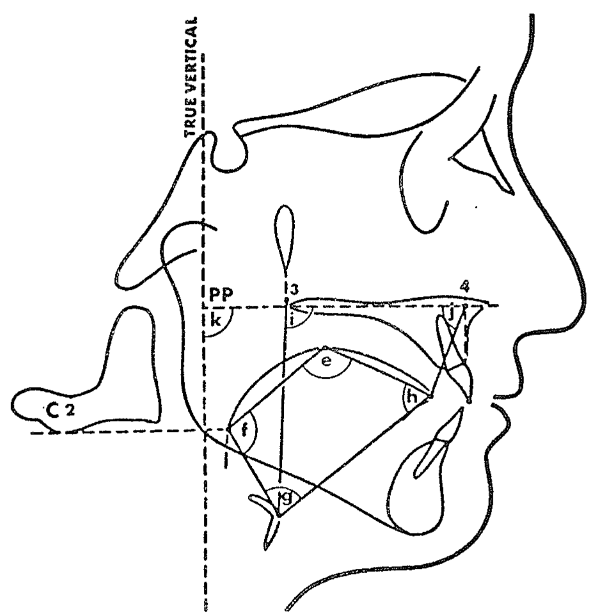


Figure 30. Illustration of the 7 cinefluorographic angular measurements (e-k) used in the 5 stage deglutition sequence.

at any given stage represented the centre of rotation. This is schematically represented in Figure 31. The centres were mathematically calculated by the coordinate computer program (Cleall and Chebib, 1971).

Cephalometric skeletal linear measurements. The 19 skeletal linear measurements are illustrated in Figure 32.

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

Distance 2. Length of posterior cranial base (Ingervall) (S-Ar).

Distance 3. Length of anterior cranial base (S-N).

Distance 4. Length of cranial base (N-Ba).

Distance 5. Vertical position of maxilla (PTM-SN).

Distance 6. Length of mandible (Me-Go).

Distance 7. Length of mandible (Po-Ar).

Distance 8. Length of ramus (Ar-Go).

Distance 9. Length of palatal plane (ANS-PNS).

Distance 10. Anterior position of maxilla (PTM-palatal plane).

Distance 11. Length of chin (Po-NB).

Distance 12. Length of cranial base (N-Ar).

Distance 13. Distance between Atlas and ANS (Atlas-ANS).

Distance 14. Length of body of mandible (Me-tgo).

Distance 15. Length of ramus (Ar-tgo).

Distance 16. Length of maxilla (Ptm-ANS).

Distance 17. Length of maxilla (Ptm-"A"pt).

Distance 18. Upper face height (N-ANS).

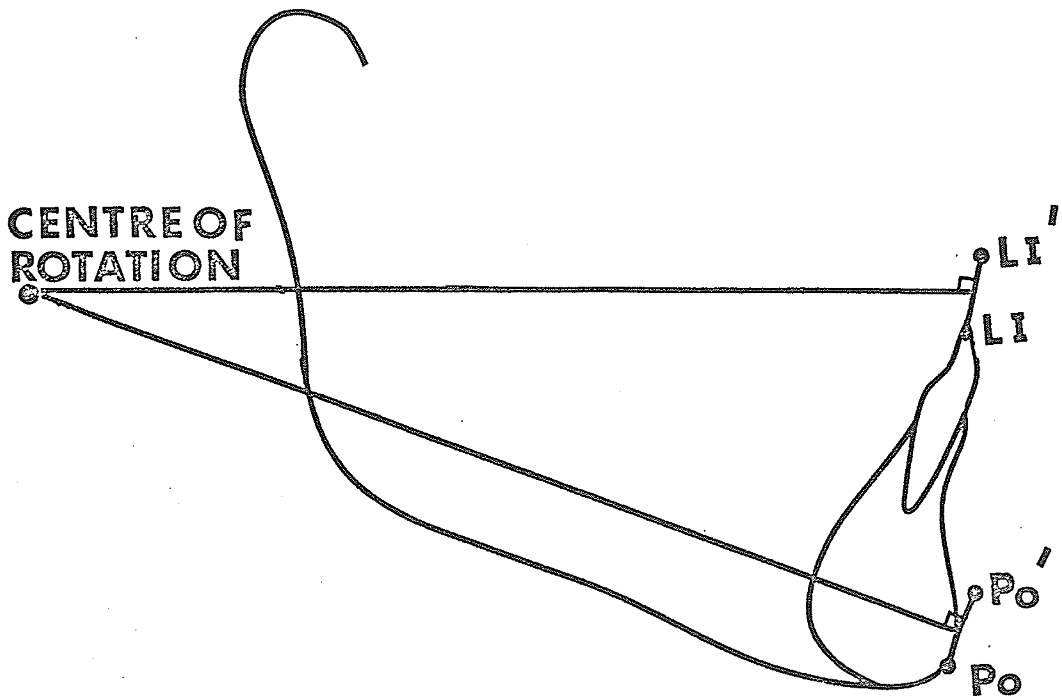


Figure 31. Illustration of the methodology used to calculate the centre of rotation of the mandible between stages.

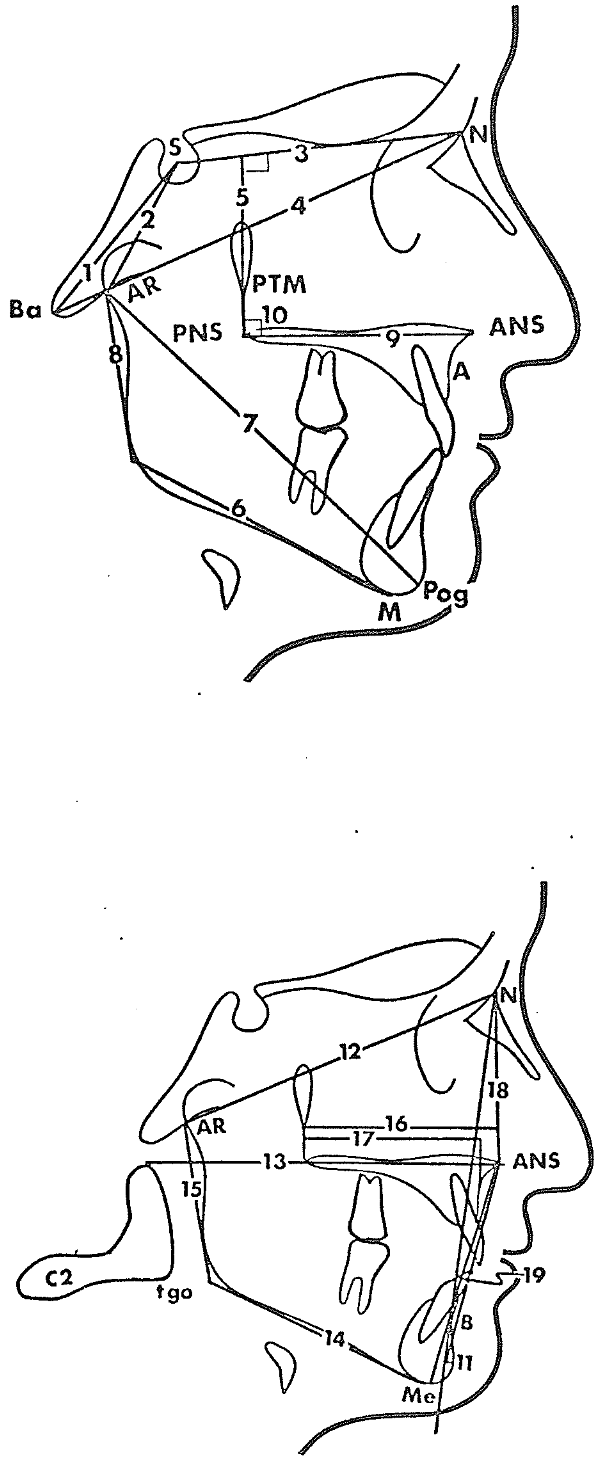


Figure 32. Illustration of the 19 cephalometric skeletal linear measurements used in the analysis.

Distance 19. Lower face height (ANS-Me).

Cephalometric angular measurements. The 15 skeletal measurements are illustrated in Figure 33.

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

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

Angle c. Gonial angle (Ar-GO-Me).

Angle d. Relationship of the palatal plane to the mandibular plane (ANS-PNS-Me-LBM).

Angle e. Relationship of Frankfurt Horizontal to SN plane (Por-Orb-S-N).

Angle f. Relationship of the mandibular plane to FH (Me-LBM-FH).

Angle g. Downs' facial angle (FH-N-Po).

Angle h. Facial plane angle (S-N-Po).

Angle i. Relationship of mandibular plane to SN plane (SN-Me-LBM).

Angle j. Y axis angle (FH-S-Po).

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

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

Angle m. Relationship of the apical bases to each other (ANB).

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

Angle o. Relationship of hyoid bone to cranial base (Hyoid-S-N).

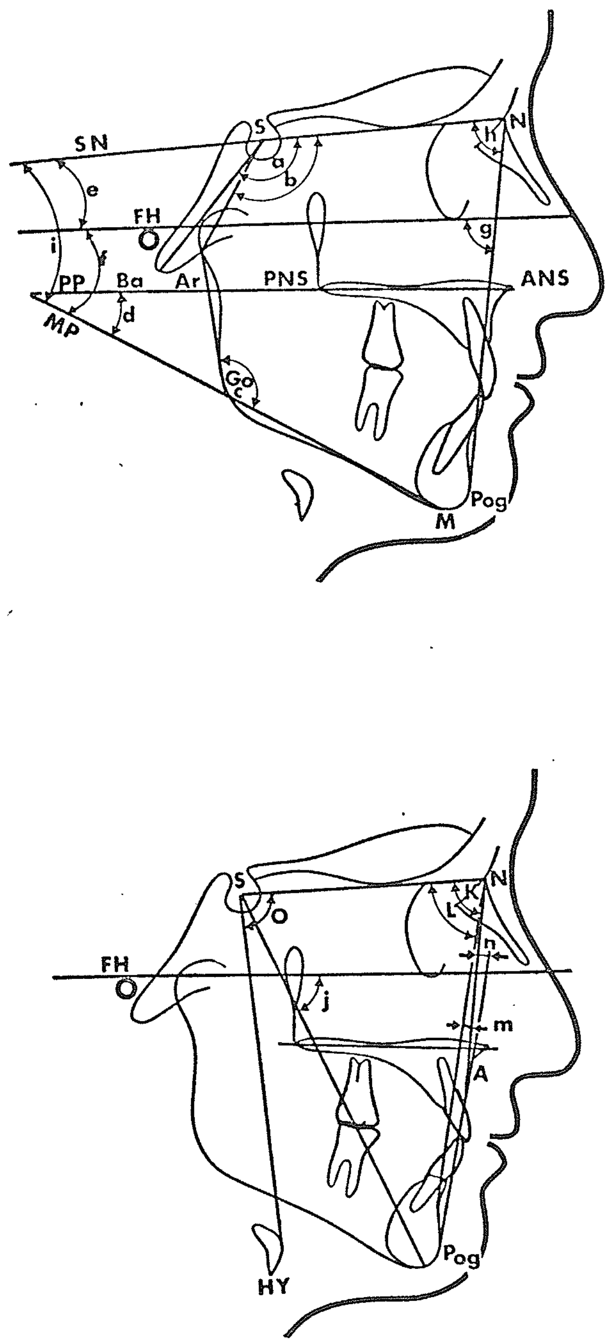


Figure 33. Illustration of the 15 (a-o) cephalometric skeletal angular measurements used in the analysis.

Cephalometric dental analysis. The 5 dental linear measurements are illustrated in Figure 34.

Distance 1. The distance from the incisal edge of $\overline{1}$ to mandibular plane (vert.).

Distance 2. The distance from the incisal edge of $\underline{1}$ to the palatal plane (vert.).

Distance 3. The distance from the incisal edge of $\overline{1}$ to the NB plane (horiz.).

Distance 4. The distance from the incisal edge of $\overline{1}$ to the APog plane (horiz.).

Distance 5. The distance from the incisal edge of $\underline{1}$ to the APog plane (horiz.).

The 10 dental angular measurements are illustrated in Figure 35.

Angle a. The relation of $\overline{1}$ to the Frankfurt horizontal ($\overline{1}$-Por-Or).

Angle b. The relation of $\overline{1}$ to the cranial base ($\overline{1}$-S-N).

Angle c. The relation of $\overline{1}$ to the NB plane ($\overline{1}$-N-B).

Angle d. The relation of $\underline{1}$ to NA plane ($\underline{1}$-N-A).

Angle e. The relation of $\underline{1}$ to palatal plane ($\underline{1}$-ANS-PNS).

Angle f. The relation of $\underline{6}$ to cranial base ($\underline{6}$-S-N).

Angle g. The relation of $\overline{6}$ to the cranial base ($\overline{6}$-S-N).

Angle h. The relation of the upper incisor to the lower incisor ($\underline{1}$-$\overline{1}$).

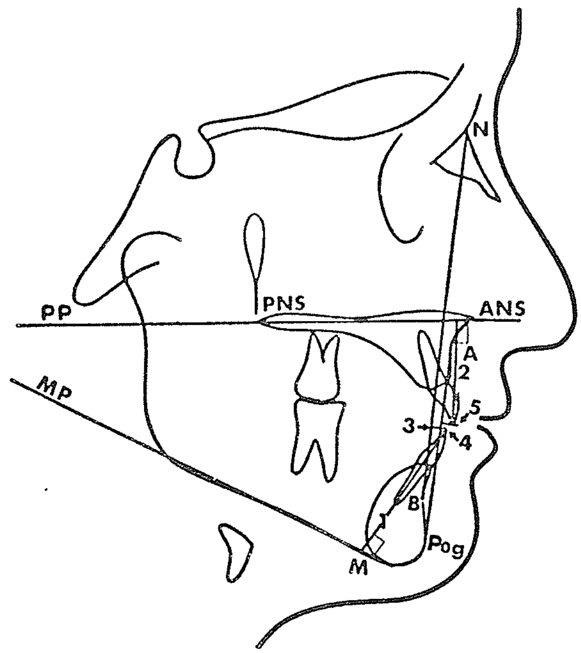


Figure 34. Illustration of the 5 cephalometric dental linear measurements used in the analysis.

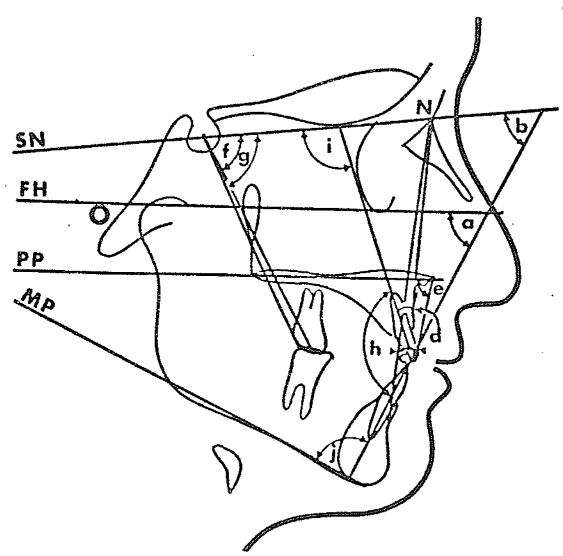


Figure 35. Illustration of the 10 (a-j) cephalometric dental angular measurements used in the analysis.

Angle i. The relation of the upper incisor to the cranial base (1-SN).

Angle j. The relation of the lower incisor to the mandibular plane ($\bar{1}$-Me-LBM).

IV. SOURCES OF ERROR

Magnification and Distortion

The correction factor in digitization was calculated for the cinefluorograph and the lateral cephalometric radiograph. Using a 5 cm. metal rod placed in the mid-sagittal plane at a focal spot-rod distance of 121.92 cm. (48 inches), the magnification at the ear rods was found to be .1 cm. for the cine and .92 cm. for the lateral cephalometric radiograph. The bellows on the Ruscom strip chart digitizer were adjusted to produce a 1:1 blow-up of the cine frame. It was not possible to adjust the bellows for the lateral cephalometric radiographs; consequently, the computer was programmed to adjust for the magnification. Therefore, all cine and cephalometric output data could be accepted as having no inherent magnification.

Measurement Error

To determine personal and overall errors in landmark selection the forty-eight lateral cephalometric radiographs were digitized once by the investigator and once by the research director*. Chebib et al (1972) measured the true errors inherent in these data and reported them as estimates of the

*Dr. J.F. Cleall

mean error and the maximum absolute error expected in a certain percentage of cases. The maximum error associated with 99% of the measurements for each of the thirteen parameters was as listed in Table I. For the linear distances it ranged between .97 mm. (UI-AP) and 1.63 mm. (Po-NB) and for the angular measurements between 1.11 degrees (ANB) and 6.51 degrees (UI-LI). It was also estimated that in order to reach a precision of 1 mm. in 99% of the Po-NB measurements, each subject in the sample should be measured three times; while it would be necessary to measure each subject forty-three times to reach a precision of one degree in the UI-LI angle in 99% of the subjects. The larger error associated with the interincisal angle was probably due to the difficulty involved in consistently selecting the apex of the lower incisor.

Other errors which could be calculated from the standard deviation of the error reported in Table I were the mean error and the accidental error.

Different measurements were obtained from the digitization of the mesio-buccal cusp of the maxillary first molar (landmark 5), and the superior and inferior points of the true vertical (landmarks 1 and 2, respectively), during the ten cinefluorographic mandibular movement stages. Since these points were fixed landmarks, the differences observed for the measurements were employed to estimate the measurement error.

From these measurements the standard deviation for

TABLE I

ACCIDENTAL ERROR, STANDARD DEVIATION OF ERROR, MEAN ERROR, 99% MAXIMUM ERROR AND THE NUMBER OF READINGS REQUIRED TO REACH THIS ERROR FOR 13 CEPHALOMETRIC SKELETAL AND DENTAL VARIABLES

Measure (degrees)	n	Accidental Error	Standard Deviation of Error (s)	Mean Error $\bar{e}$	99% Maximum Error	*Number of Required Readings (k)
Facial Plane	48	0.428	0.598	0.477	1.615	3
Convexity	48	0.583	0.816	0.651	2.203	5
SNA	48	0.570	0.797	0.636	2.152	5
SNB	48	0.468	0.655	0.522	1.768	4
ANB	48	0.295	0.413	0.329	1.114	2
Mandibular Plane	44	0.605	0.846	0.675	2.284	5
Interincisal	48	1.723	2.412	1.924	6.512	43
$\underline{1}$-SN	48	1.244	1.741	1.389	4.701	22
$\overline{1}$-mandibular plane	44	1.392	1.876	1.497	5.064	26
U-1-AP (mm)	48	0.257	0.360	0.287	0.972	1
L-1-AP (mm)	48	0.281	0.393	0.313	1.059	1
L-1-NB (mm)	48	0.277	0.388	0.310	1.048	1
Po-NB (mm)	48	0.431	0.603	0.481	1.627	3

* For a maximum error not exceeding 1° in 99% of points.

each X and Y coordinate was calculated according to the formula (Chebib and Burdick, 1972).

$$SD = \sqrt{\frac{\sum^{n}\sum^{m} (x - \bar{x})^2}{n(m-1)}}$$

where $\bar{x}$ was the mean of the m stages for each subject and n was the number of subjects.

It can be observed in Table II that the standard deviation of the error was slightly greater for the Y axis than for the X axis.

A template was not constructed for the true vertical. This explains the apparent larger error for points 1 and 2 as compared to point 5. Instead, it was plotted directly from the true vertical line which was superimposed on the cinefluorographic film. Therefore, plotting of the points utilizing a template has virtually no error as seen by point 5 in Table II.

Other systematic errors that may be inherent in the data were projecting errors depending upon the spherical form of the fluorescent screen or the camera film which was not perfectly flat in some instances. As suggested by Lundberg (1963), the size of the image on the cine films was smaller than 10 x 10 mm; therefore, these errors must be extremely small.

V. STATISTICAL ANALYSIS

The coordinates of the landmarks for the mandibular

TABLE II

CINEFLUOROGRAPHIC MEASUREMENT ERRORS CALCULATED FROM THE DETERMINATIONS OF THE SAME LANDMARK (mm)

		MEASUREMENT ERROR	
	Landmark	Horizontal (X)	Vertical (Y)
Standard Deviation of the Error	1	.258	.326
	2	.306	.340
	5	0.0	.004
Mean Error	1	.206	.260
	2	.244	.271
	5	0.0	.003
99% Maximum Error	1	.665	.840
	2	.788	.876
	5	0.0	.010

movement and swallowing stages, plus the coordinates of the landmarks from the lateral cephalometric x-rays were recorded in a set sequence and used as the data base for further statistical analysis. In order to calculate the standardized coordinates for the points of each subject, the coordinate template was superimposed mathematically on reference point 3, which was the junction on the palatal plane of a perpendicular dropped from the pterygo-maxillary fissure (PTM), and thus represented the origin. The template was then rotated in a given direction, reference point 4, which was the junction on the palatal plane of a perpendicular erected from A point (Cleall and Chebib, 1971). Calculated for each subject were the means and standard deviations of the standardized coordinates for each point, the intersite horizontal and vertical distances between points, the values for selected angles and the location of the centre of rotation for the mandibular movements mentioned, and their mean values.

The angles and distances calculated from the coordinate analysis were subjected to the following statistical analysis:

a) A T test was used to determine the differences between the sexes for all of the cephalometric variables.

b) Specific variables previously mentioned for the cinefluorographic mandibular movement sequence were subjected to a 2-way mixed analysis of variance, the factors being the two sexes and the ten stages. The degrees of freedom were allocated as follows:

Source of Variation	Degrees of Freedom
Sex	1
Error 1	29
Stages	9
Sex X Stages	9
Error 2	261
Total	309

Variables previously mentioned for the 5 stage deglutition sequence were subjected to a 3-way mixed analysis of variance; the factors being the two sexes, two conditions (water swallow and/or saliva swallow) and the 5 stages. The degrees of freedom were as follows:

Source of Variation	Degrees of Freedom
Sex	1
Conditions X Sex	1
Error 1	25
Stages	4
Conditions X Stages	4
Sex X Stages	4
Conditions X Sex X Stages	4
Error 2	100
Total	144

The differences and interactions were tested for significance by an F ratio against the mean squares.

c) A factor analysis was performed on the cephalometric matrix which contained 90 variables. The program was written by Dr. F.S. Chebib* and was designed to calculate each correlation coefficient from all pairs of observations independently because of some missing values. The object of the analysis was to reduce the number of cephalometric variables to a fewer number of components, each component being a linear function of the 90 variables. The scores of the individual patients on each of the more important components was then calculated and subjected to further statistical analysis.

The simple correlation matrix was computed and represented product-moment correlations between all pairs of the 90 cephalometric variables. The large matrix was reduced to a factor loading matrix by the principal component method, disregarding any factor accounting for less than five per cent of the total variability (Cooley and Lohnes, 1962). The significance of the factor loadings was tested using Harman's (1967) method of approximation of the standard error of the loadings adjusted for missing values as described in Young and Chebib (1970).

*Biostatistician, Faculty of Dentistry, University of Manitoba.

Figure 36. Duplicates of Figures 4,5,27,28,29,31,32,33, and 34.

This set of illustrations can be removed to assist the interpretation during the reading of the Results and Discussion.

MANDIBULAR MOVEMENT - STAGES

1. Rest.
2. Initial Contact.
3. Full Closure.
4. End to End.
5. Minimum Protrusion.
6. Maximum Protrusion.
7. Wide Open.
8. Initial Contact.
9. Full Closure.
10. Retruded Contact Position.

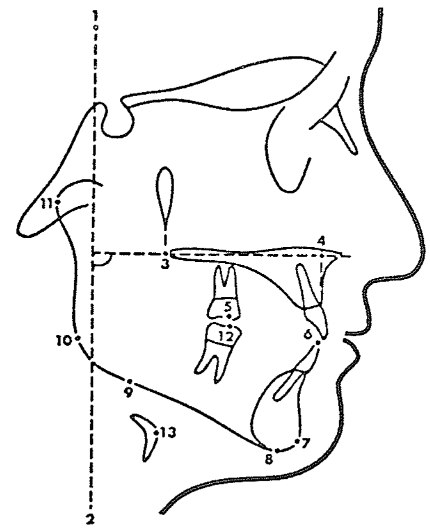


Figure 4. Landmarks, mandibular movement

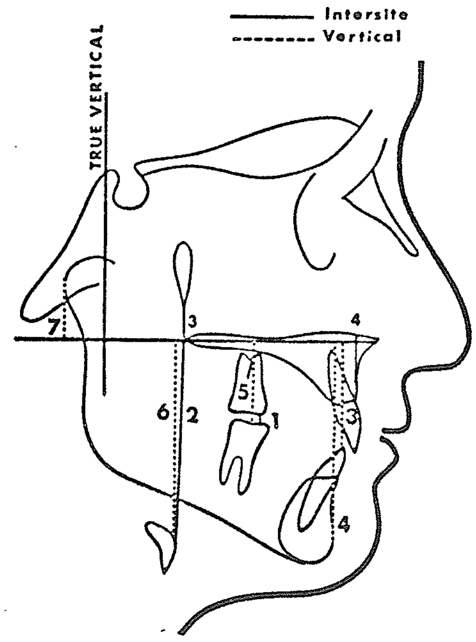


Figure 27. Linear measurements (1-7), mandibular movement.

A. MANDIBULAR MOVEMENT - STAGES

Stage 1. Rest.

Stage 2. Initial Contact.

Stage 3. Full Closure.

Stage 4. End to End.

Stage 5. Minimum Protrusion.

Stage 6. Maximum Protrusion.

Stage 7. Wide Open.

Stage 8. Initial Contact.

Stage 9. Full Closure.

Stage 10. Retruded Contact Position.

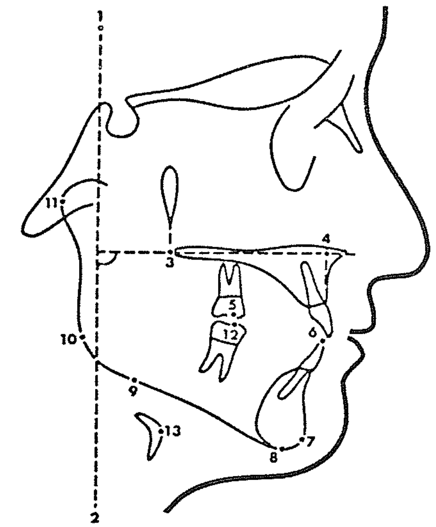


Figure 4. Landmarks, mandibular movement

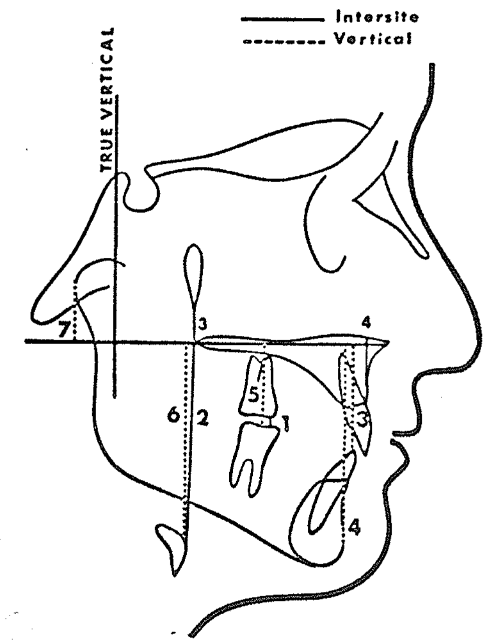


Figure 27. Linear measurements (1-7), mandibular movement.

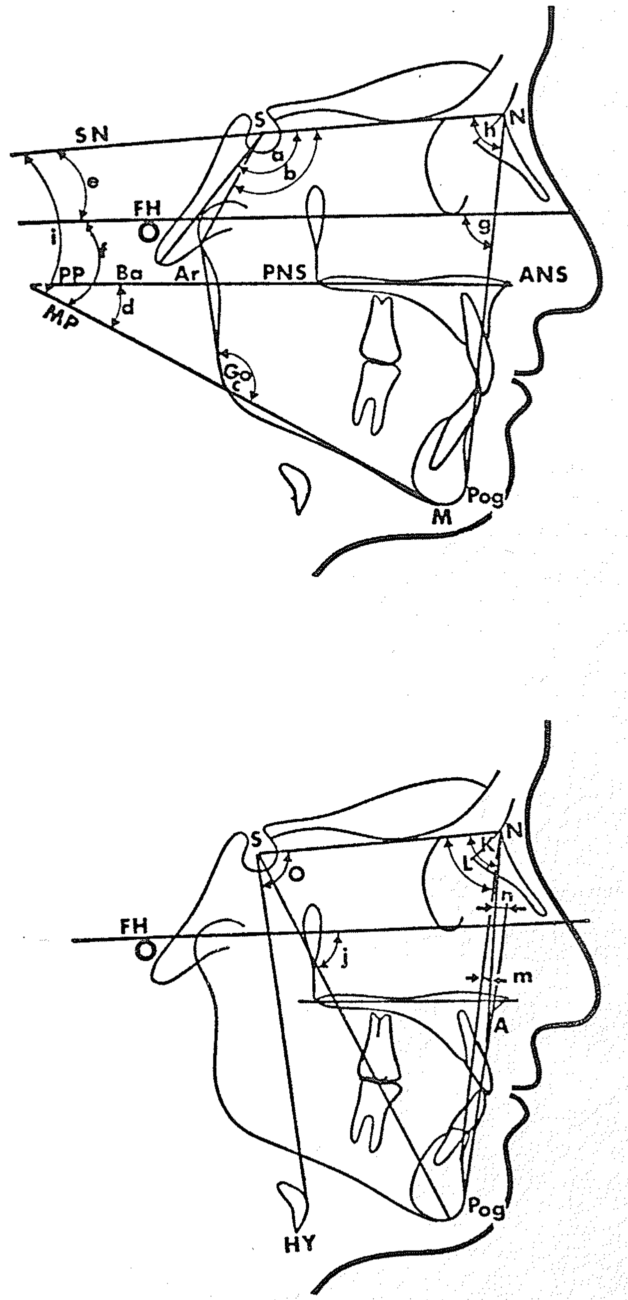


Figure 33. Angular measurements (a-o).

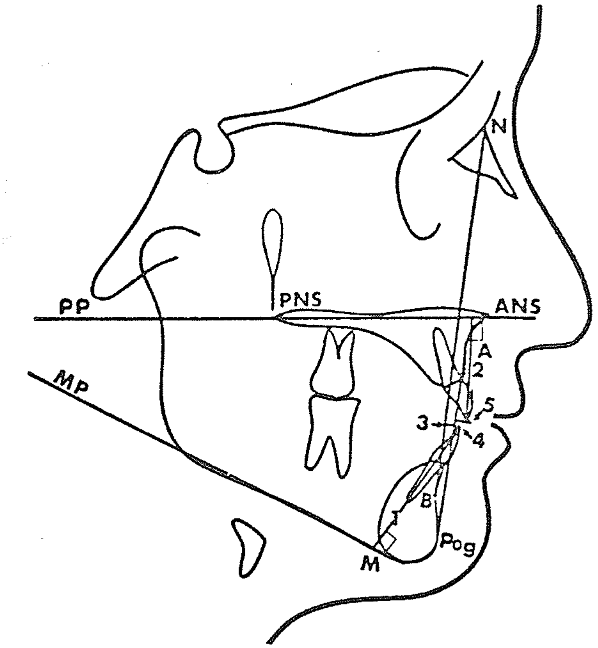


Figure 34. Dental linear measurements (1-5).

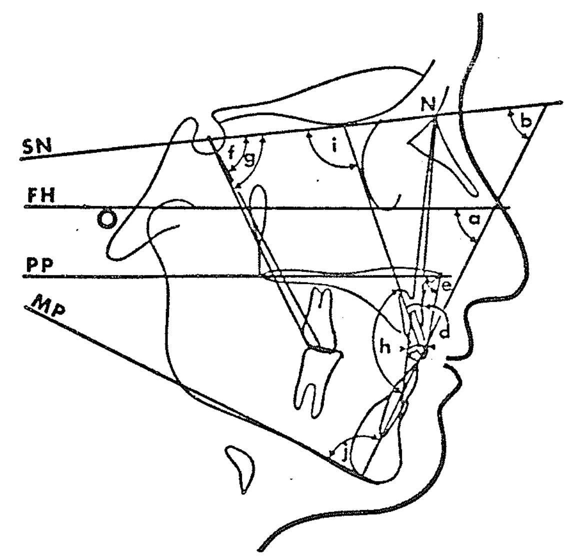


Figure 35. Dental angular measurements (a-j).

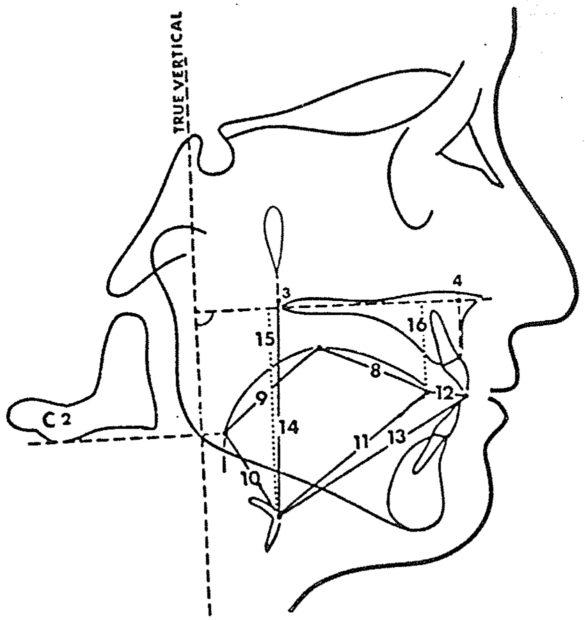


Figure 28. Linear measurements (1-16), deglutition.

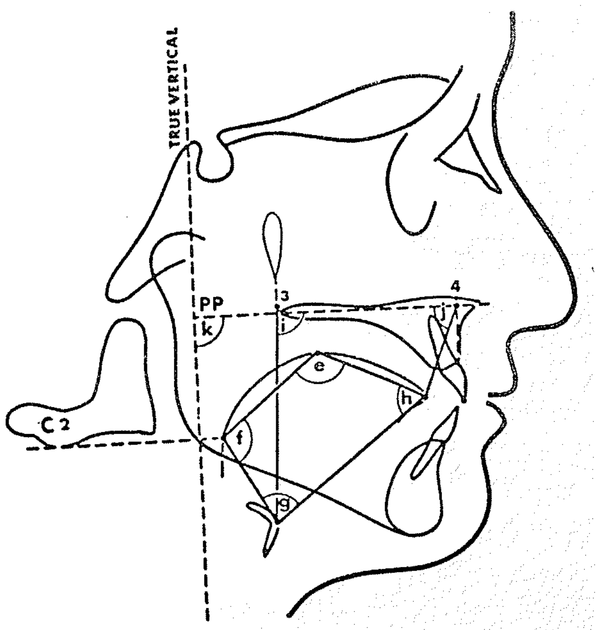
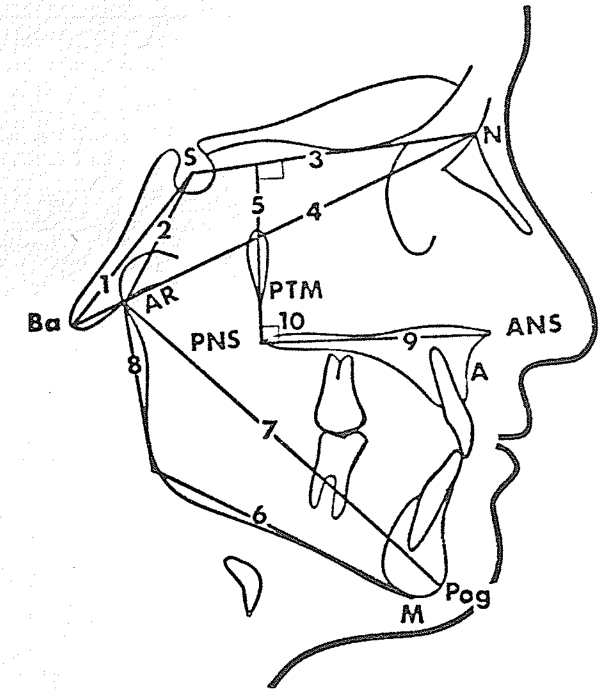


Figure 30. Angular measurements (e-k), deglutition.



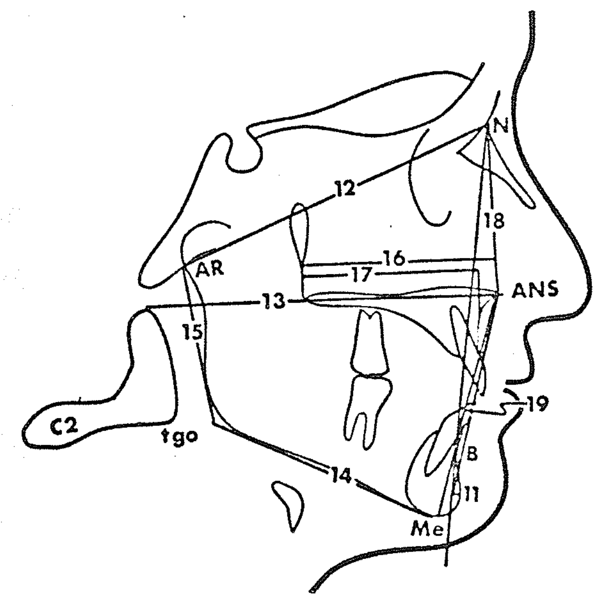


Figure 32. Linear measurements (1-19).

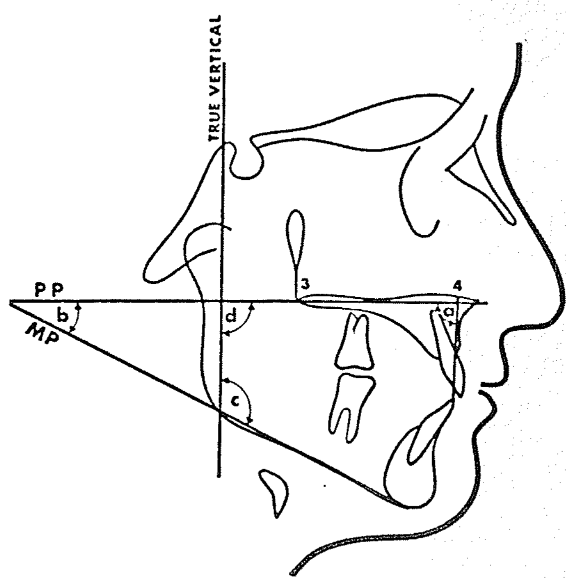


Figure 29. Angular measurements (a-d), mandibular movement.

DEGLUTITION STAGES

Stage 1.	Rest.
Stage 2.	When the tongue tip contacts the maxillary central incisor.
Stage 3.	When the dorsum of the tongue reaches the junction of the hard and soft palate.
Stage 4.	When the hyoid bone reaches its most anterior, superior position.
Stage 5.	The resting posture at the end of the swallowing sequence.

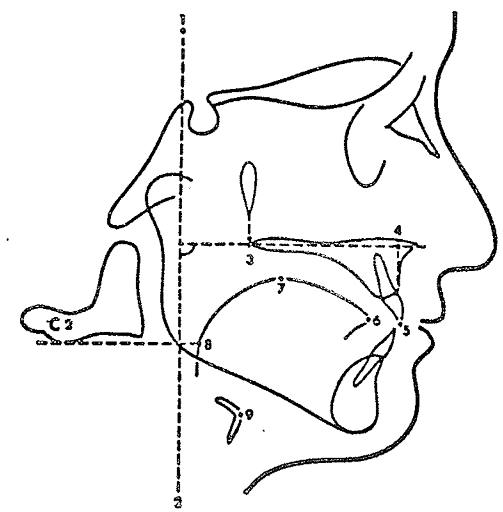


Figure 5. Landmarks, deglutition.

CHAPTER IV

RESULTS

The results will be presented in seven sections as follows:

I. The cephalometric appraisal of the skeletal and dental pattern.

II. The effect of restraining ear rods on the spatial position of the mandible and on head posture.

III. The centres of rotation of the mandible during seven mandibular movements.

IV. The change in head posture during the five stages of deglutition and the ten stages of mandibular movement.

V. The linear and angular measurements observed during mandibular movement.

VI. The linear and angular measurements noted during the swallowing sequence.

VII. The results of a factor analysis on ninety cephalometric variables.

Composite diagrams, graphs and tables are used to present the results. Complete statistical tables are presented in the Appendix. Abridged forms of these tables are presented diagrammatically in the text to clarify the results.

I. CEPHALOMETRIC RESULTS

Skeletal and Dental Analysis

The city of Winnipeg, Manitoba, Canada is composed of a heterogeneous population of basically middle Europeans and Anglo Saxons. The sample selected possessed Class I "normal" occlusions and manifested skeletal and dental patterns typical of this classification of occlusion. Due to the ethnic background of the population, it was suggested that the faces of the sample might not necessarily be in accord with the faces which provided the standards of Downs (1948), Riedel (1950), Steiner (1953) and Holdaway's (1956) analyses.

Mutual agreement among the staff of the orthodontic department at the University of Manitoba provided an analysis which included specific skeletal and dental components which were referred to most frequently in their diagnosis of malocclusions. The analysis was termed the "Manitoba Analysis" and is illustrated in Figure 37. A polygon shown in Figure 38 was developed from the means and standard deviations which were obtained from the present study.

The results of the Manitoba Analysis are listed in Table III. The table shows that the means and standard deviations of the skeletal variables of the Manitoba Analysis do not coincide but do fall within the ranges and standard deviations suggested by Downs, Holdaway, Riedel and Steiner.

CEPHALOMETRIC ANALYSIS

UNIVERSITY OF MANITOBA

Name________________________________ Case No.__________________

Standards for 48 Winnipeg school children with acceptable occlusion. Males and females combined.

Date_______________ Age________

Date_______________ Age________

Date_______________ Age________

Date_______________ Age________

Date_______________ Age________

Date_______________ Age________

SKELETAL PATTERN

	Mean	S.D.	A	B	C	D	P1*	P2*
Facial Angle	85.9	3.5						
Angle of Convexity	5.1	4.5						
SNA	82.0	3.3						
SNB	79.0	3.4						
ANB	2.9	1.6						
Mand. Pl. Angle	25.3	4.7						
SN to Pg.	79.6	3.6						
SN. to Mand. Pl.	31.7	5.5						
Pg. to NB (mm)	1.0	1.3						

DENTURE PATTERN

$\underline{1}$ to $\overline{1}$	126.7	9.0						
$\underline{1}$ to SN	103.8	5.6						
$\underline{1}$ to AP (mm)	5.9	1.7						
$\overline{1}$ to Mand. P.	7.6	7.2						
$\overline{1}$ to AP (mm)	2.6	1.6						
$\overline{1}$ to NB (mm)	4.8	2.0						

*P1 - First Progress Report
*P2 - Second Progress Report

Figure 37. An illustration of the Manitoba cephalometric skeletal and dental analysis.

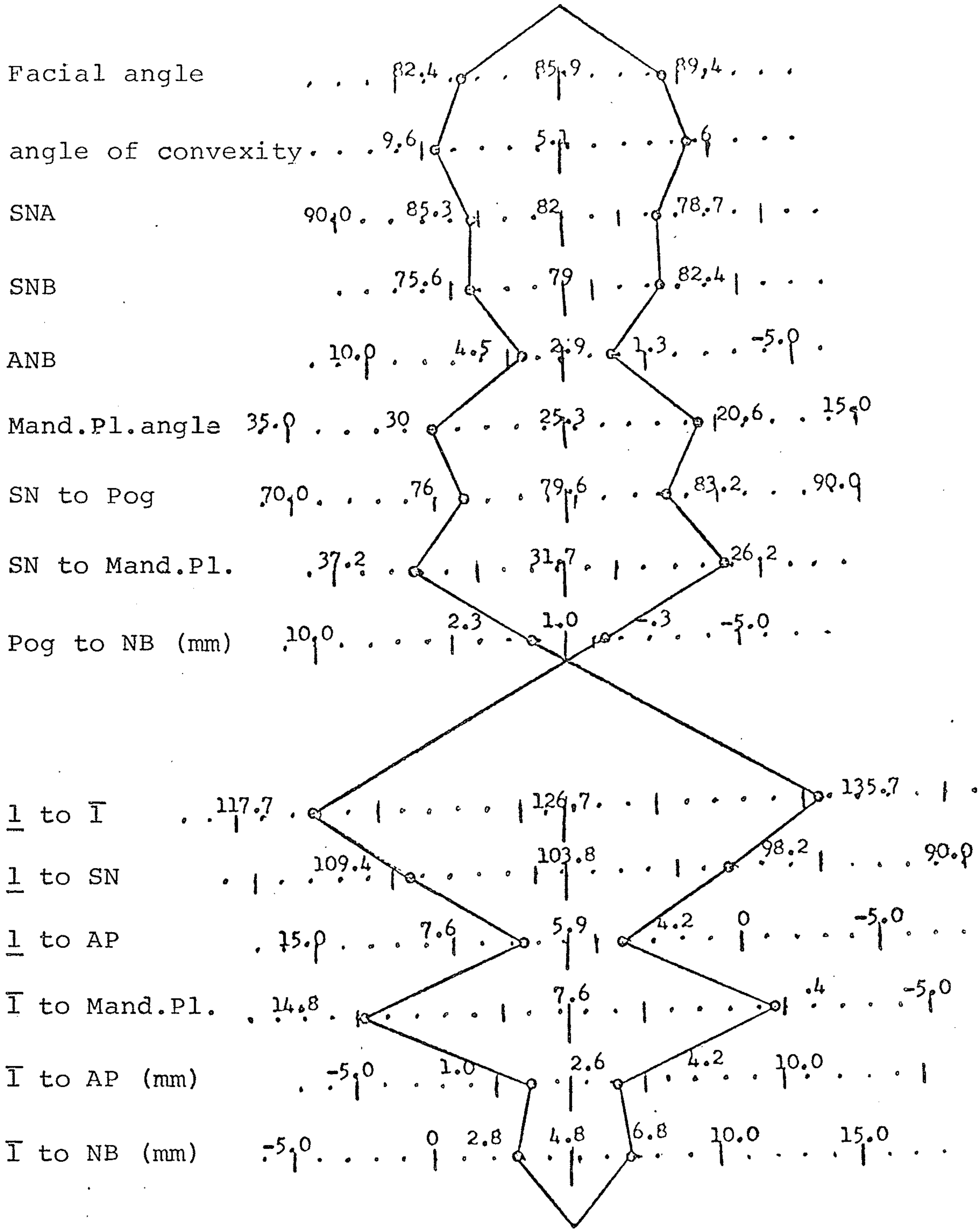


Figure 38. An illustration of the Manitoba Analysis polygon.

TABLE III

A COMPARISON OF THE MEANS, STANDARD DEVIATIONS AND RANGES OF THE SKELETAL AND DENTAL VARIABLES OF THE MANITOBA ANALYSIS TO THE ANALYSES OF DOWNS, HOLDAWAY, RIEDEL AND STEINER

VARIABLE	DOWNS			HOLDAWAY	RIEDEL	STEINER	MANITOBA
SKELETAL	MIN.	AVG.	MAX.				
Facial angle	82.0	87.8	95.0				85.9 ± 3.5
Convexity	-8.5	0.0	10.0		4.2 ± 5.4		5.1 ± 4.5
SNA					80.8 ± 3.9		82.0 ± 3.3
SNB					78.0 ± 3.1		79.0 ± 3.4
ANB					2.8 ± 2.3		3.0 ± 1.6
Mand.Pl.Angle	17.0	59.4	66.0				25.3 ± 4.7
SN-Pog							79.6 ± 3.6
SN-MPA					32.3 ± 4.7		31.7 ± 5.5
$\overline{1}$-NB:Pog-NB				1:1			4:1
Pog-NB (mm)							1.0 ± 1.3
DENTAL							
$\overline{1}$-NB (mm)						4-5.5	4.8 ± 2.0
$\underline{1}$-$\overline{1}$ angle	130.0	135.4	150.0		130.4 ± 7.2		126.7 ± 9.0
$\underline{1}$-SN					103.5 ± 5.0		103.8 ± 5.6
$\underline{1}$-AP (mm)	-1.0	2.7	5.0				5.9 ± 1.7
$\overline{1}$-Md.Pl.	-8.5	1.4	7.0		3.5 ± 5.8		7.6 ± 7.2
$\overline{1}$-AP (mm)	-2.0	0	3.0				2.6 ± 1.6

The results of the denture pattern showed an increased procumbency of the upper and lower incisors to the facial plane illustrated by the $\underline{1}$ to AP plane and $\overline{1}$ to AP plane measurements of 5.9 mm. ± 1.7 mm. and 2.6 mm. ± 1.6 mm., respectively. The lower incisor to mandibular plane angulation was 7.6 degrees ± 7.2 degrees compared to Riedel's mean of 3.5 degrees ± 5.8 degrees indicating an increased proclination of the lower incisors in the Manitoba sample. The differences in the dental pattern were probably due to a compensation by the denture for a more retrognathic convex skeletal pattern manifested by the sample. This latter point was illustrated by the decreased facial angle (85.9 degrees ± 3.5 degrees), increased angle of convexity (5.1 degrees ± 4.5 degrees), and the steeper mandibular plane angle (25.3 degrees ± 4.7 degrees) as compared to the standards suggested by Downs.

Tables XII, XIII and XIV (see Appendix) represent the means, standard deviations and range of the males, females and the two sexes combined. When the sex differences for the values listed in the Manitoba Analysis were tested for significance, it was found that no sex differences were significant.

It was noted that the angle of convexity was greater in the female (5.0 degrees ± 4.4 degrees) than in the male (4.9 degrees ± 4.7 degrees) and the mandibular plane angle was lower in the female (24.8 degrees ± 4.7 degrees) than in the male (26.6 degrees ± 4.8 degrees).

Due to the lack of significant differences, it was felt that for diagnostic purposes of the Manitoba Analysis, the combined means and standard deviations of the skeletal and dental values could be utilized.

Skeletal and dental linear measurements. The results of the complete cephalometric, skeletal and dental linear measurements observed in the study are found in Table XV. The measurement sella-nasion was found to be significantly larger in the male than in the female at the .01 per cent level. The measurements that were significantly larger for the male at the .05 per cent level were basion-nasion, articulare-nasion, atlas-anterior nasal spine, the vertical measurement of the lower incisor to the mandibular plane and the upper face height. The female skeletal and dental linear measurements were not found to be significantly larger than the male linear measurements.

Skeletal and dental angular measurements. Table XVI contains the complete list of the means and standard deviations of the male and female skeletal and dental angular measurements. No significant differences between the sexes were observed.

Additional measurements. The lateral cephalometric radiograph obtained in rest position on the cinefluorographic machine provided nine variables which were not measured on the cephalometric radiograph in habitual occlusion. Table XVII lists the means, standard deviations and significance of the differences between the two sexes. The angulation of the hyoid bone to the palatal plane (hyoid to reference point 3 to reference point 4) was significantly larger in the female at the $p < 0.05$ level. None of the male measurements were found to be significantly larger.

The lateral cephalometric radiograph obtained in habitual occlusion on the cinefluorographic machine provided twelve variables which were not measured on the cephalometric radiograph in rest position. The means, standard deviations and significance of the differences between the sexes are listed in Table XVIII. The angulation of the hyoid bone to the palatal plane was significantly larger in the female at the $p < 0.01$ level. None of the male measurements was significantly larger than those observed for the females; however, overbite, overjet and curve of Spee were observed to be larger in the male measurements. The means and standard deviations in millimeters of the latter three variables for the males and females combined were 3.06 ± 1.00, 2.80 ± 1.09, 0.82 ± 0.54, respectively.

II. EFFECT OF RESTRAINING EAR RODS

The effect of restraining ear rods on the position of the mandible was determined statistically by a mixed analysis of variance. The analysis was utilized to test the significance of the differences for the two sexes, the difference between the lateral cephalometric radiograph (ear rods) and the cine (no ear rods), and the interaction of the two sexes with and without restraining ear rods on each of the following eight variables:

A. Head posture in rest position (H.p.r.).

B. Head posture in habitual occlusion (H.p.occ.).

C.1. Mandibular displacement at the lower incisor (Md.dis.-$\overline{I}$).

2. Mandibular displacement at pogonion (Md.dis.-pog.).

D. Centre of rotation of the mandible from rest to habitual occlusion on the

1. Horizontal axis (X).

2. Vertical axis (Y).

The resultant analyses of variance are shown in Table IV.

TABLE IV

ANALYSIS OF VARIANCE FOR EIGHT VARIABLES ASSOCIATED WITH HEAD POSTURE

		Mean Squares					
				Md.displacement		Centre of Rotation	
Source of Variation	DF	H.p.r.	H.p.occ.	$\overline{I}$	Pog.	X	Y
Sex	1	62.1395	54.7398	0.1191	0.3743	162.5909	13.0470
Error 1	26	38.4503	38.1923	0.1955	0.2257	236.4491	88.1736
Ear Rods	1	248.3736**	439.6853**	0.5114*	0.0657	14.5613	59.5305
Sex X Ear Rods	1	9.0938	0.3756	0.7294*	0.3493*	33.8584	33.2594
Error 2	26	24.1256	21.4700	0.1009	0.0534	293.8462	92.1259
Total	55						

* Significant at the 0.05 level.
** Significant at the 0.01 level.

Head Posture in Rest Position

The flexion or extension of the head was measured by noting the change in degrees of the angle formed by the intersection of the palatal plane and the true vertical for both the lateral cephalometric radiograph (ear rods) and the cine (no ear rods). The difference in head posture between the two sexes was not statistically significant; however, the difference in head posture between the lateral ceph (ear rods) and the cine (no ear rods) was significant at the $p<0.01$ level. It was observed that when ear rods were inserted that the head extended from a mean angulation of 84.56 degrees ± 0.93 degrees to 88.77 degrees ± 0.93 degrees. This is diagrammatically illustrated in Figure 39.

Head Posture in Habitual Occlusion

The head posture in habitual occlusion was not statistically significant between the sexes, but the difference in head posture between the lateral ceph (ear rods) and the cine (no ear rods) was significant at the $p < 0.01$ level. The head was observed to extend from a mean angulation of 84.14 degrees ± 0.88 degrees to 89.74 degrees ± 0.88 degrees when the restraining ear rods were inserted. This is consistant with the extension noted at rest position and is diagrammatically illustrated in Figure 40.

Mandibular Displacement

Mandibular displacement with and without ear rods was observed at the incisal edge of the lower incisor and pogonion.

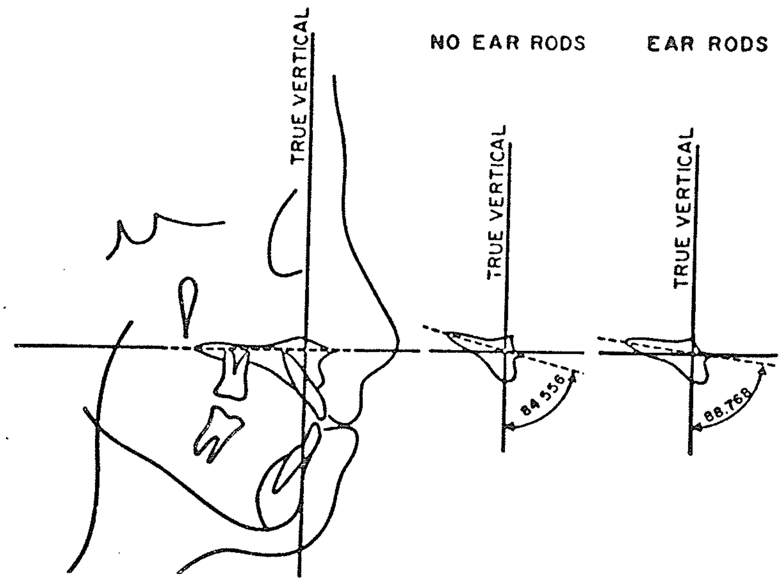


Figure 39. Illustration of the effect of ear rods on head posture when the mandible is in rest position.

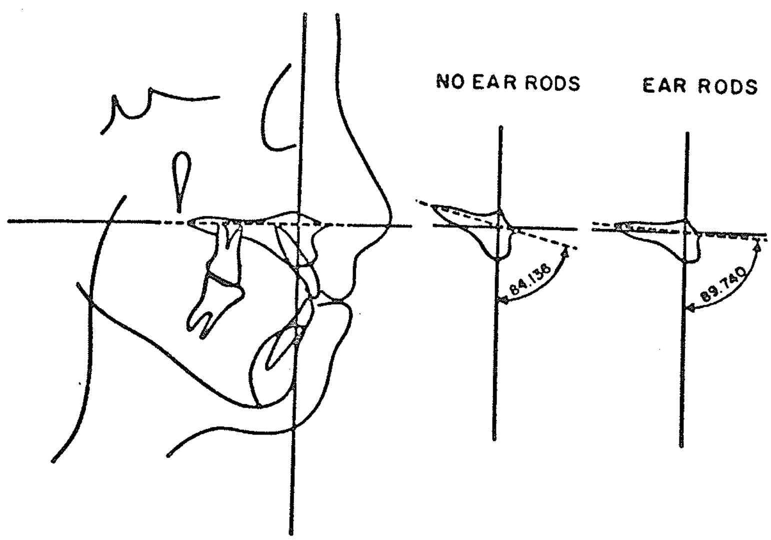


Figure 40. Illustration of the effect of ear rods on head posture when the mandible is in habitual occlusion.

<u>The lower incisor</u>. The displacement of the lower incisor between the ceph (ear rods) and the cine (no ear rods) was significant at the $p < 0.05$ level. The response between male and female was significantly different at the $p < 0.05$ level. In the male the tip of the lower incisor was displaced superiorly 0.40 mm. ± 0.92 mm. In the female the tip of the lower incisor was displaced inferiorly 4.22 mm. ± 0.79 mm.

<u>Pogonion</u>. The displacement of pogonion between the ceph and the cine was not observed to be significantly different. The interaction of the sexes to the displacement was significant at the $p < 0.05$ level. The mean displacement of the male's pogonion was 0.91 mm. ± 0.67 mm. in a superior direction. The mean displacement of the female's pogonion was 2.28 mm. ± 0.58 mm. in an inferior direction.

The displacement is described figuratively in Figure 41 by noting the change in position between a line joining the tip of the lower incisor and pogonion on the lateral ceph at rest, and the same line on the cine at rest. The superimposition of the ceph and the cine is made possible when the coordinates of the origin and direction of the ceph and cine are mathematically superimposed by the computer.

<u>Centre of rotation of the mandible from rest position to habitual occlusion</u>. The behaviour of the horizontal and vertical coordinates were tested statistically (Table IV) and no significant differences were observed. Figure 42

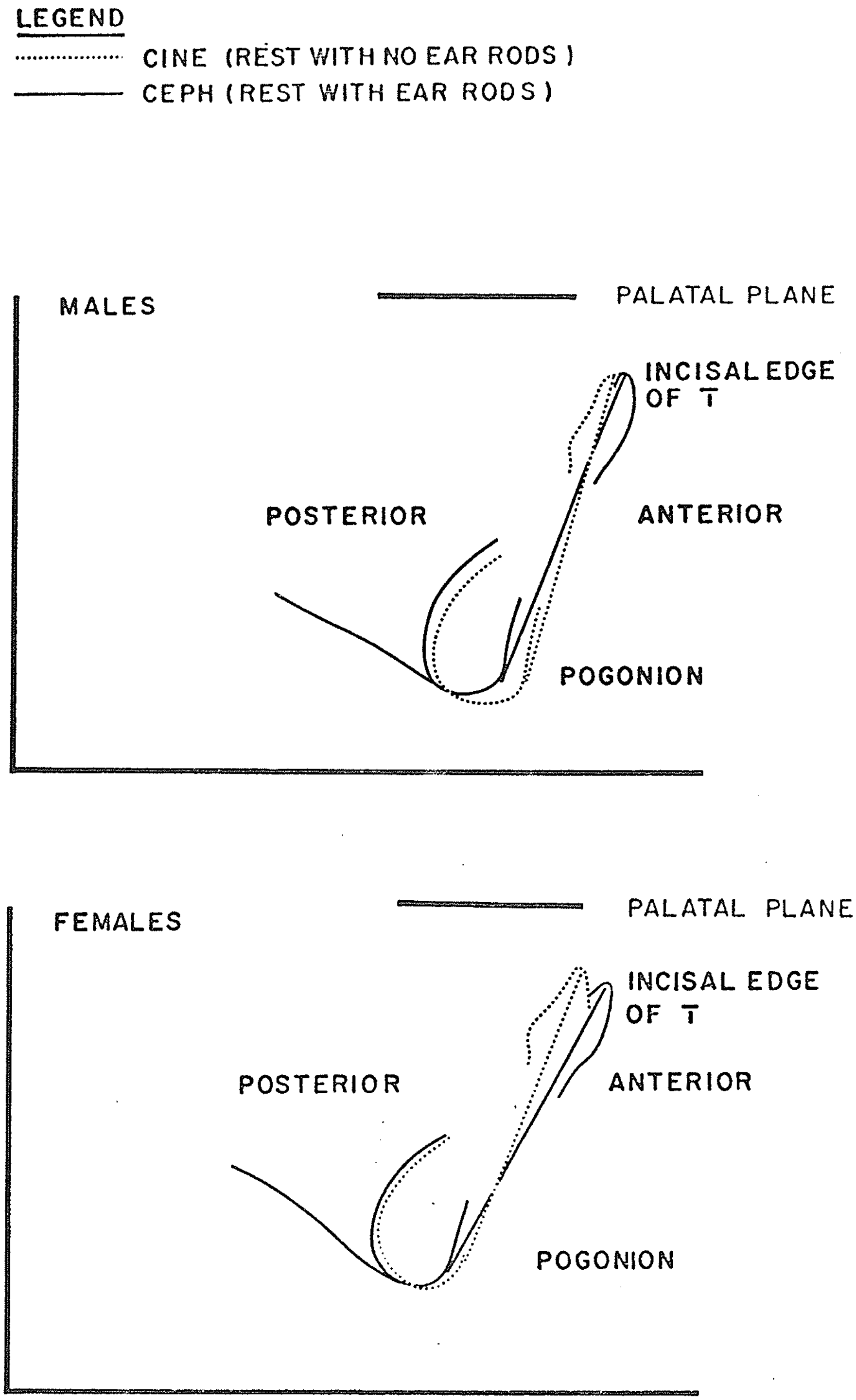


Figure 41. An illustration showing mandibular displacement caused by ear rods demonstrated by the change in position of a line joining the incisal edge of the lower incisor and pogonion.

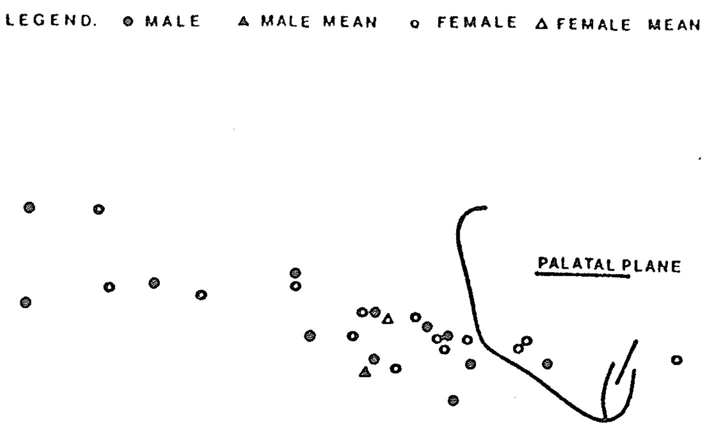


Figure 42. Illustration showing the male and female means and scatter of the rotation centres of the mandible during the cinefluorographic sequence from rest to occlusion.

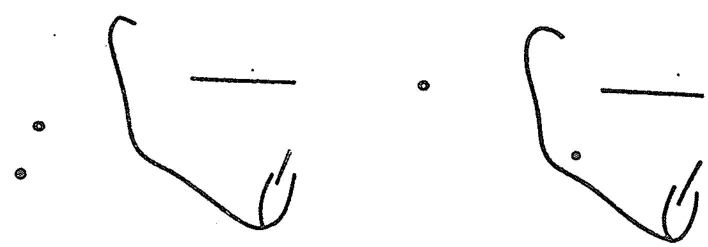


Figure 43. Illustration of the male and female mean rotation centres from rest to occlusion during a) the cinefluorographic sequence (no ear rods), b) the cephalometric sequence (ear rods).

shows the scatter of the centres of rotation and the male and female means as the mandible moved from rest to habitual occlusion in the cine. Figure 43a illustrates that the mean male and female centres of rotation in the cine lie closely grouped posterior to the ramus and inferior to the condyle. Figure 43b illustrates that in the ceph there was a wider separation between the male and female mean centres of rotation.

III. CENTRES OF ROTATION

The movement from rest to full closure was previously described in Section II of the results; however, the centre of rotation of the mandible was also calculated in methods for seven mandibular movements in the cinefluorographic analysis. Table XIX lists the mandibular movements, X and Y coordinates of the rotation centre, plus standard deviations for males and females. Figures 44 through 48 illustrate the male and female mean centres of rotation for the respective mandibular movements. The mandibles were drawn utilizing the mean coordinates of landmarks 6, 7, 8, 9 and 10 of the cinefluorographic analysis after registering on reference point 3 whose coordinates were designated zero, zero, by computer analysis.

Figure 44 is a diagrammatic illustration of the male and female mean centres of rotation as the mandible moved from rest position to initial contact to full closure.

Figure 45 represents the mean centre of rotation for

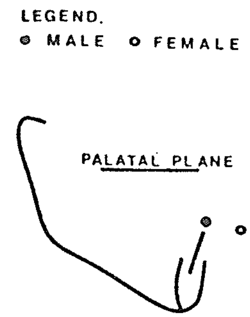


Figure 44. Illustration of male and female mean centre of mandibular rotation from rest position (Stage 1) to initial contact (Stage 2) to full closure (Stage 3).

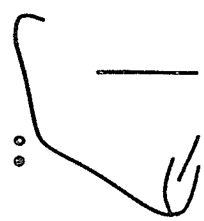


Figure 45. Illustration of male and female mean centres of mandibular rotation from maximum protrusion (Stage 6) to wide open (Stage 7)

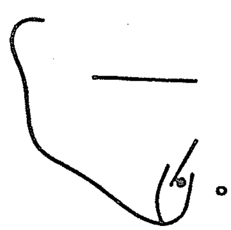


Figure 46. Illustration of male and female mean centres of mandibular rotation from wide open (Stage 7) to initial contact (Stage 8) to full closure (Stage 9)

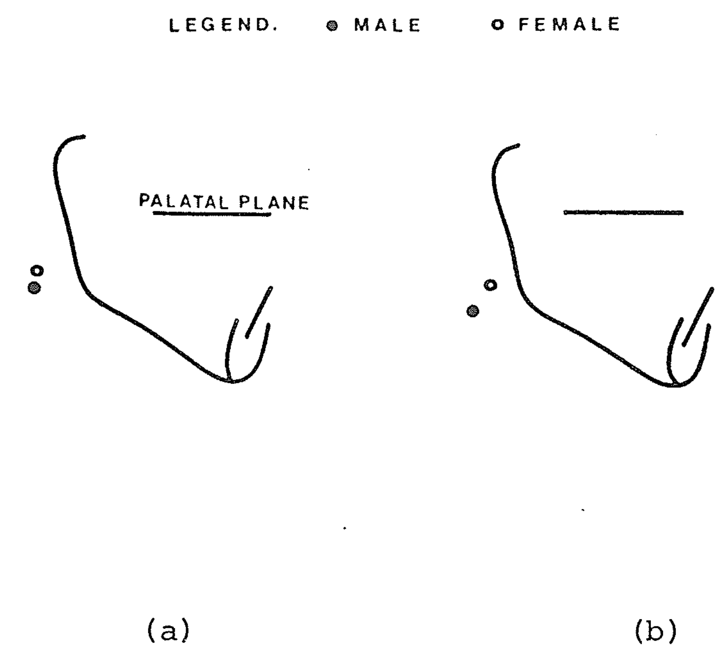


Figure 47. An illustration of the male and female mean centres of mandibular rotation from (a) wide open (Stage 7) to full closure (Stage 9) and from (b) wide open (Stage 7) to retruded contact position (Stage 10).

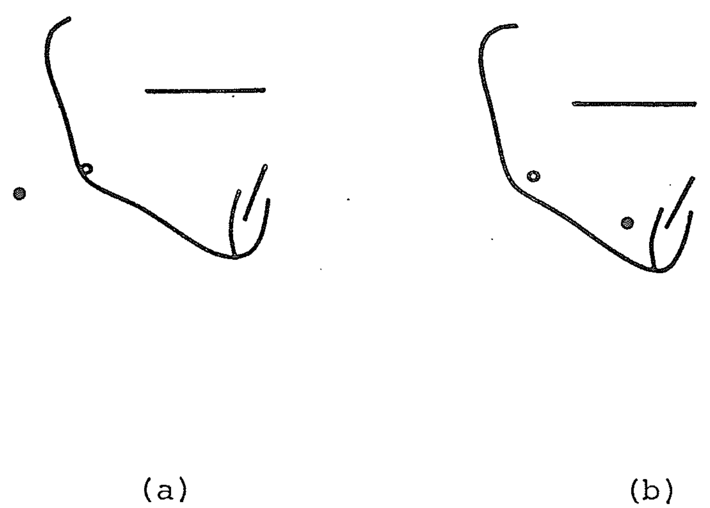


Figure 48. An illustration of the male and female mean centres of mandibular rotation from (a) rest position (Stage 1) to retruded contact position (Stage 10) and (b) habitual occlusion (Stage 9) to retruded contact position (Stage 10).

males and females as the mandible moved from maximum protrusion to wide open position. The mean centres are close together at the gonial angle.

Figure 46 represents the mandibular mean centre of rotation for males and females during the movement wide open to initial contact to full closure.

Figure 47a illustrates the male and female mandibular mean centres of rotation as the mandible moved from wide open to full closure. The movement was similar to that in Figure 43a. It can be seen by removing the initial contact movement by computer analysis that the centres of rotation cluster in the area posterior to the gonial angle.

Figure 47b represents the mean male and female centres of rotation as the mandible moved from wide open to retruded contact position. The mean centres cluster at the gonial angle for the movement from rest position to retruded contact position as shown in Figure 48a. The female mean centre is located in the body of the mandible while the male mean centre was found outside the body of the mandible.

The mean male and female centres of rotation as the mandible moved from full closure or habitual occlusion to retruded contact position are illustrated in Figure 48b. The female mean centre was found in the body of the mandible in the retromolar area while the male mean centre was found in the area of the mandibular bicuspids. On no occasion was the centre of rotation observed to be in the head of the condyle.

IV. HEAD POSTURE

The extension and/or flexion of the head was observed during the five stage swallowing sequence and the ten stage mandibular movement sequence for both males and females. A mixed analysis of variance was utilized to test the difference in head posture between the sexes, the differences in head posture between stages, and the interaction of the two sexes from stage to stage.

Deglutition

The resultant analysis of variance on head posture during the deglutition sequence is shown in Table V. The analysis of variance showed no significant differences. There was a slight flexion of the head from Stage 1 (85.50 degrees ± 2.61 degrees) to Stage 2 (85.30 degrees ± 2.61 degrees). During Stage 3 the head was extended (85.50 degrees ± 2.61 degrees) and then was flexed in Stage 4 (85.31 degrees ± 2.61 degrees). Stage 5 showed the head flexed to 80.05 degrees ± 2.61 degrees. The differences in head posture suggest trends which are diagrammatically illustrated in Figure 49.

Mandibular Movement

The resultant analysis of variance of head posture during the ten mandibular movement sequence is shown in Table VI. The change in head posture from stage to stage was significant at the $p < 0.01$ level. A slight flexion

TABLE V

ANALYSIS OF VARIANCE OF HEAD POSTURE DURING THE DEGLUTITION SEQUENCE

SOURCE OF VARIATION	DF	MEAN SQUARES
Sex	1	3.0639
Error 1	29	300.2021
Stages	4	177.8901
Sex and Stages	4	199.4471
Error 2	116	211.2296
Total	154	

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

TABLE VI

ANALYSIS OF VARIANCE OF HEAD POSTURE DURING THE MANDIBULAR MOVEMENT SEQUENCE

SOURCE OF VARIATION	DF	MEAN SQUARES
Sex	1	355.9063
Error 1	29	246.3579
Stages	9	85.3096**
Sex and Stages	9	4.2598
Error 2	261	3.6896
Total	309	

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

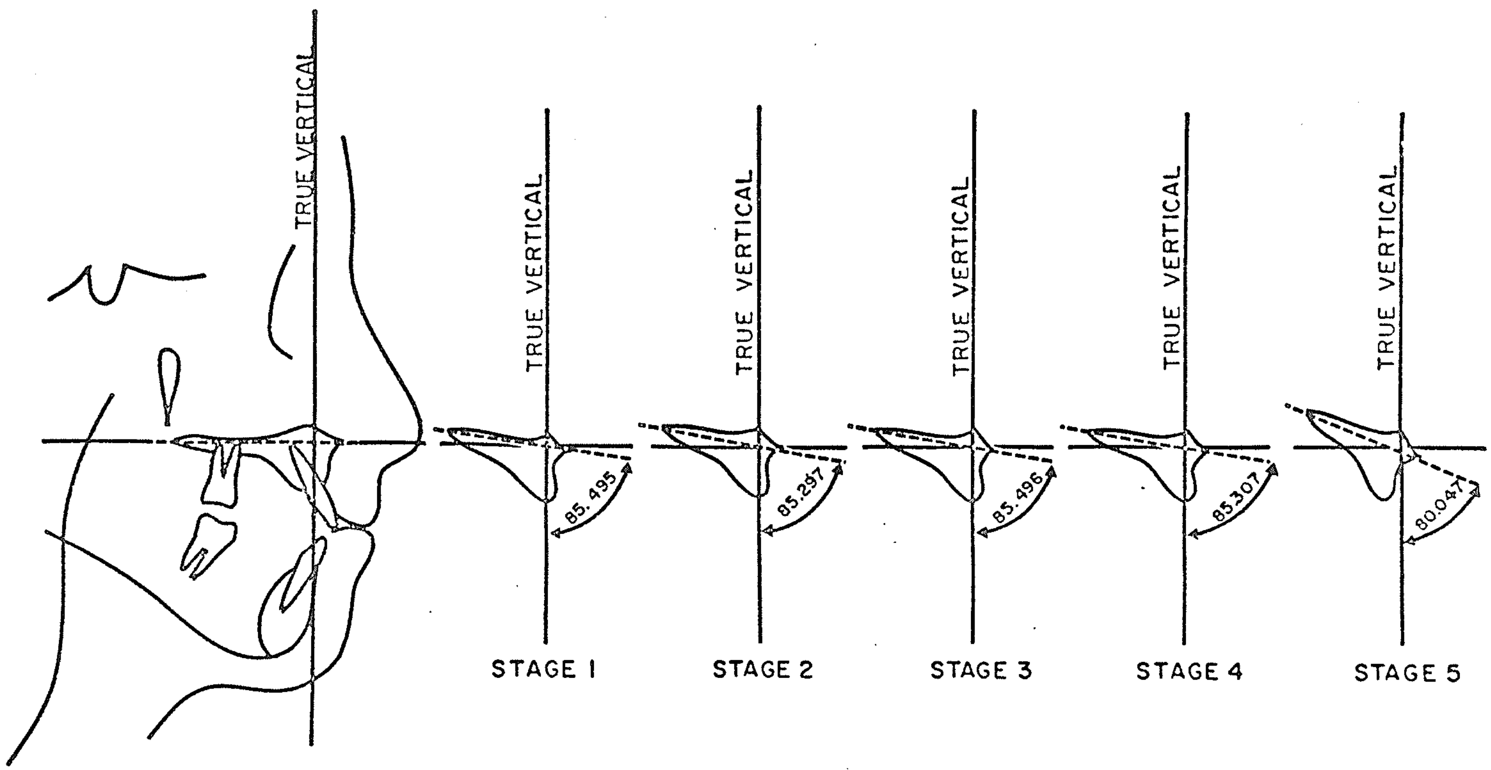


Figure 49. An illustration showing the change in head posture during the 5 stage deglutition sequence.

was observed as the mandible moved from rest (Stage 1, 84.64 degrees ± 0.35 degrees) to initial contact (Stage 2, 84.32 degrees ± 0.35 degrees). The head was extended in full closure (Stage 3, 84.44 degrees ± 0.35 degrees) and continued to extend as the mandible moved end to end (Stage 4, 84.57 degrees ± 0.35 degrees). Flexion was observed from Stage 4 to minimum protrusion (Stage 5, 84.45 degrees ± 0.35 degrees) to maximum protrusion (Stage 6, 84.09 degrees ± 0.35 degrees). The head extended considerably from Stage 6 to wide open (Stage 7, 89.13 degrees ± 0.35 degrees). Flexion of the head was observed from Stage 7 to initial contact (Stage 8, 87.25 degrees ± 0.35 degrees) to full closure (Stage 9, 86.48 degrees ± 0.35 degrees) to retruded contact position (Stage 10, 84.86 degrees ± 0.35 degrees).

The extension and flexion of the head during the ten stage mandibular movement sequence is diagrammatically presented in Figure 50.

V. MANDIBULAR MOVEMENTS

A mixed analysis of variance was utilized to test the differences between the sexes during the ten stage mandibular movement sequence, the differences between stages, and the interaction of the two sexes from stage to stage on each of the following variables:

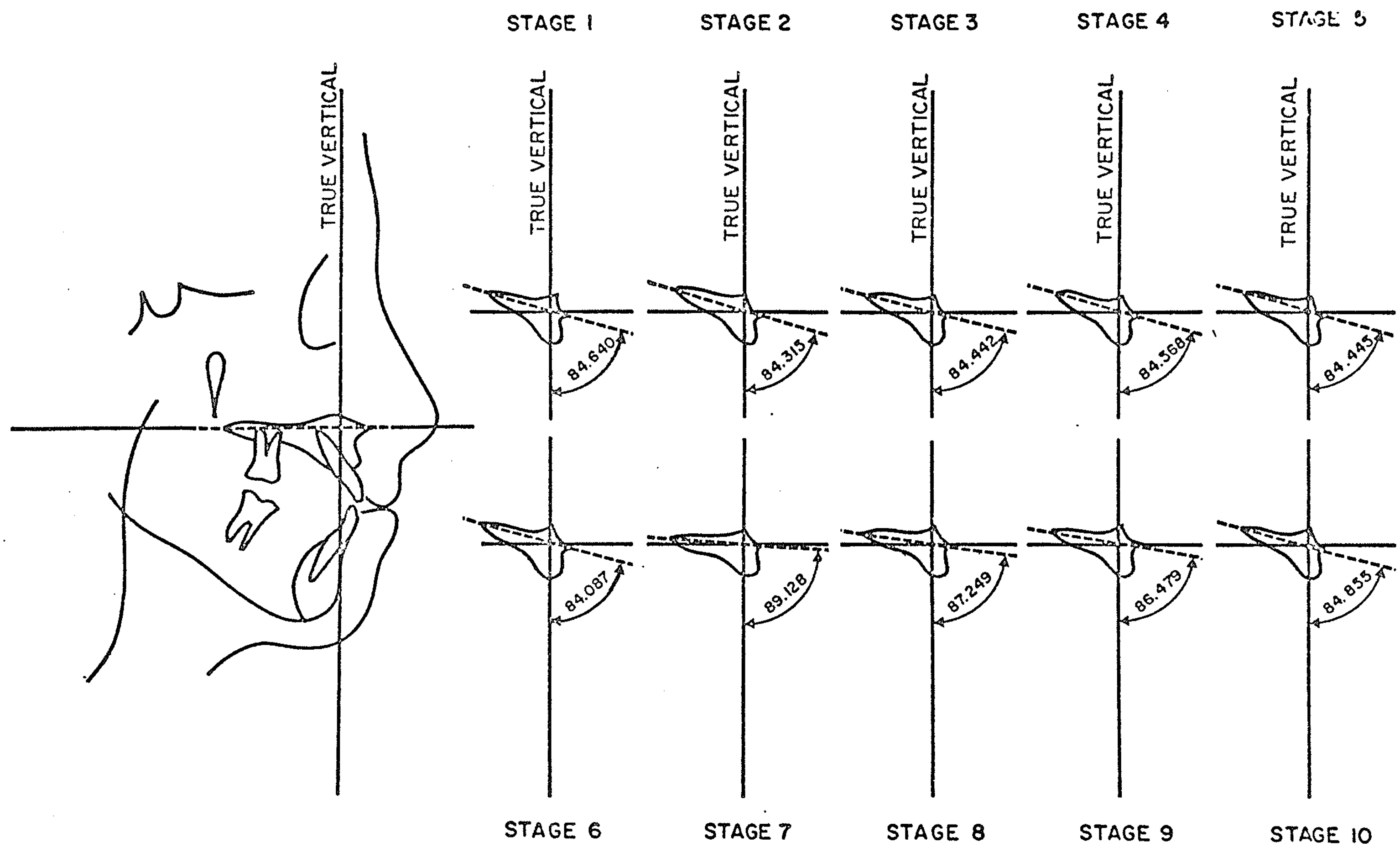


Figure 50. An illustration depicting the changes in head posture during the 10 stage mandibular movement sequence.

<u>Linear Measurements</u>

1. The intersite distance between the mesio-buccal cusp tip of the maxillary first molar and the buccal groove of the mandibular first molar represented by landmark 12 which was a point on the buccal groove which was directly superimposed by the tip of the mesio-buccal cusp of the maxillary first molar when the mandible was in full closure or habitual occlusion.

2. The intersite distance between the most anterior edge of the hyoid bone and reference point 3 on the palatal plane (PTM).

3. The vertical distance between the incisal edge of the mandibular central incisor and the palatal plane.

4. The vertical distance between the buccal groove of the mandibular first molar and the palatal plane.

5. The vertical distance from the anterior edge of the hyoid bone and the palatal plane.

6. The vertical distance from condylion to the palatal plane.

<u>Angular Measurements</u>

1. The change in the angle formed by the mandibular incisor to the palatal plane represented by reference point 4 to reference point 3.

2. The change in the angulation of the mandibular plane to the palatal plane.

The resultant analysis of variance of the linear and angular measurements are shown in Tables VII and VIII, respectively.

Linear Measurements

1. The intersite distance between the mesio-buccal cusp of the maxillary first molar and a point on the buccal groove of the mandibular first molar showed no significant differences between the two sexes, and thus they reacted in a parallel manner during the ten stages. The movement between stages was significant at the $p < 0.01$ level. The mean values for the combined male and female movement are graphically shown in Figure 51.

2. The difference between sexes in the intersite distance of the hyoid bone reference point 3 on the palatal plane was significant at the $p < 0.01$ level. The male mean measurement was 61.00 mm. ± 1.37 mm. and the female mean measurement was 55.08 mm. ± 1.32 mm. The change in position of the hyoid bone from stage to stage was significant at the $p < 0.01$ level; however, the difference in response of the two sexes from stage to stage was not significant.

The mean changes in distance from stage to stage of the hyoid bone to the palatal plane for males and females are graphically shown in Figure 52.

3. The change in the vertical distance from stage to stage between the incisal edge of the mandibular central incisor and the palatal plane was significant at the $p <$

TABLE VII

ANALYSIS OF VARIANCE FOR SIX LINEAR MEASUREMENTS DURING THE 10 STAGE MANDIBULAR MOVEMENT SEQUENCE

		MEAN SQUARES					
SOURCE OF VARIATION	DF	$\underline{6}-\overline{6}$	Hyoid-PTM	$\overline{1}$-palatal plane	$\overline{6}$-palatal plane	Hyoid-palatal plane	Condylion palatal plane
Sex	1	0.0760	27.0976**	1.4320	0.8695	29.5366**	0.9330
Error 1	29	0.0393	2.8056	0.3887	0.4004	2.7275	2.7595
Stages	9	20.7101**	6.6846**	65.6508**	17.1366**	5.0163**	1.3431**
Sex X Stages	9	0.0314	0.1379	0.0355	0.0114	0.2251	0.0344
Error 2	261	0.0245	0.1834	0.0355	0.0112	0.1690	0.0259
Total	309						

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

TABLE VIII

ANALYSIS OF VARIANCE FOR TWO ANGULAR MEASUREMENTS DURING THE 10 STAGE MANDIBULAR MOVEMENT SEQUENCE

SOURCE OF VARIATION	DF	MEAN SQUARES 1	MEAN SQUARES 2
Sex	1	5.4549	19.4909
Error 1	29	130.8069	209.2252
Stages	9	2504.0759**	2437.8970**
Sex X Stages	9	1.7897	4.7455
Error 2	261	6.7229	5.1861
Total	309		

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

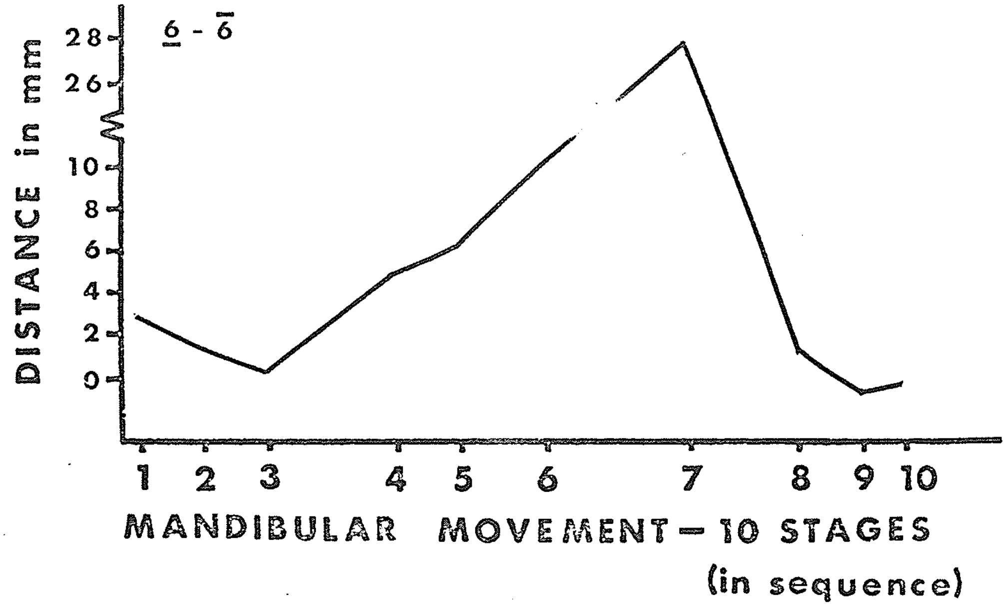


Figure 51. A graph illustrating the change in distance for the combined male and female mean values in mm. between 6 and 6 during the 10 stage mandibular movement sequence.

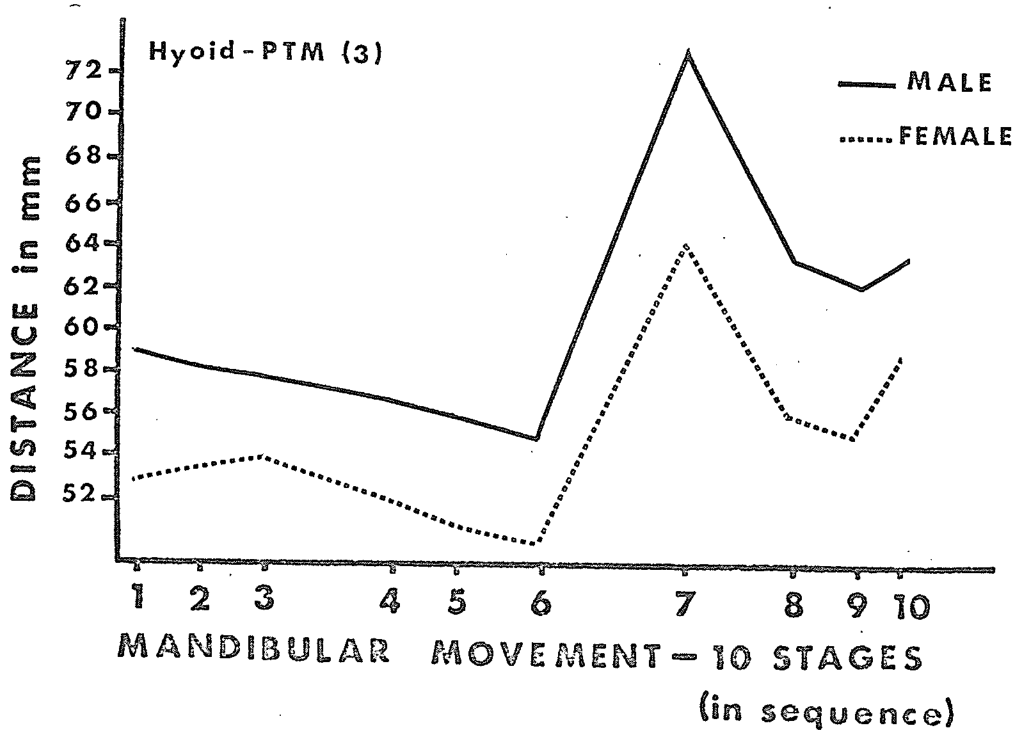


Figure 52. A graph showing the effect of sex on the hyoid-PTM measurement during the 10 stage mandibular movement sequence.

0.01 level. The differences between the sexes was not significant. It was noted that in relation to the palatal plane the lower incisor ($\overline{I}$) from rest position (Stage 1) moved upward to initial contact and then further upward to full closure. The movement of $\overline{I}$ from full closure to end to end (Stage 4) was downward from the palatal plane. The $\overline{I}$ from end to end went parallel to the palatal plane into minimum protrusion (Stage 5) and then continued to more down until at wide open (Stage 7) position the $\overline{I}$ was at its furthest position from the palatal plane. From wide open position to full closure (Stage 9) the movement was upward. When the mandible was moved into the retruded contact position from full closure the lower incisor was observed to move away from the palatal plane.

The combined mean values for the male and the female for the distance $\overline{I}$ to palatal plane are graphically represented in Figure 53.

4. The difference between the two sexes was not significant for the stage to stage change of the vertical distance between the buccal groove of the mandibular first molar and the palatal plane. The difference between the distances from stage to stage were significant at the $p < 0.01$ level. The male and female combined mean values are graphically shown in Figure 54.

5. The vertical distance between the anterior border of the hyoid bone and the palatal plane showed a significant difference at the $p < 0.01$ level between the two sexes.

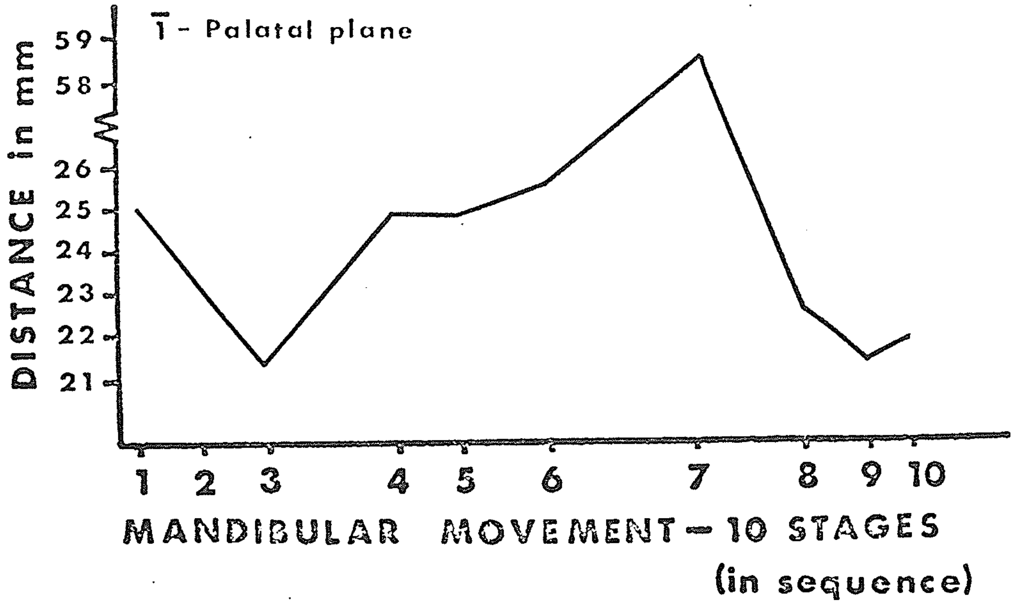


Figure 53. A graph showing the change in distance in mm. for the combined male and female mean values, of the lower incisor to the palatal plane during the 10 stage mandibular movement sequence.

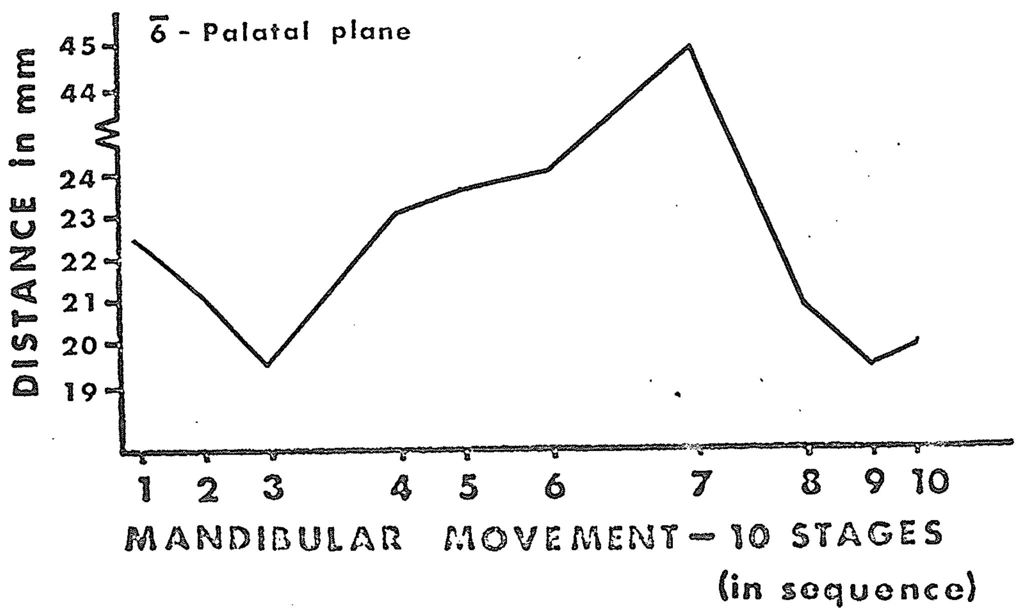


Figure 54. A graph showing the change in distance in mm., for the combined male and female mean values, of the lower first molar to the palatal plane during the 10 stage mandibular movement sequence.

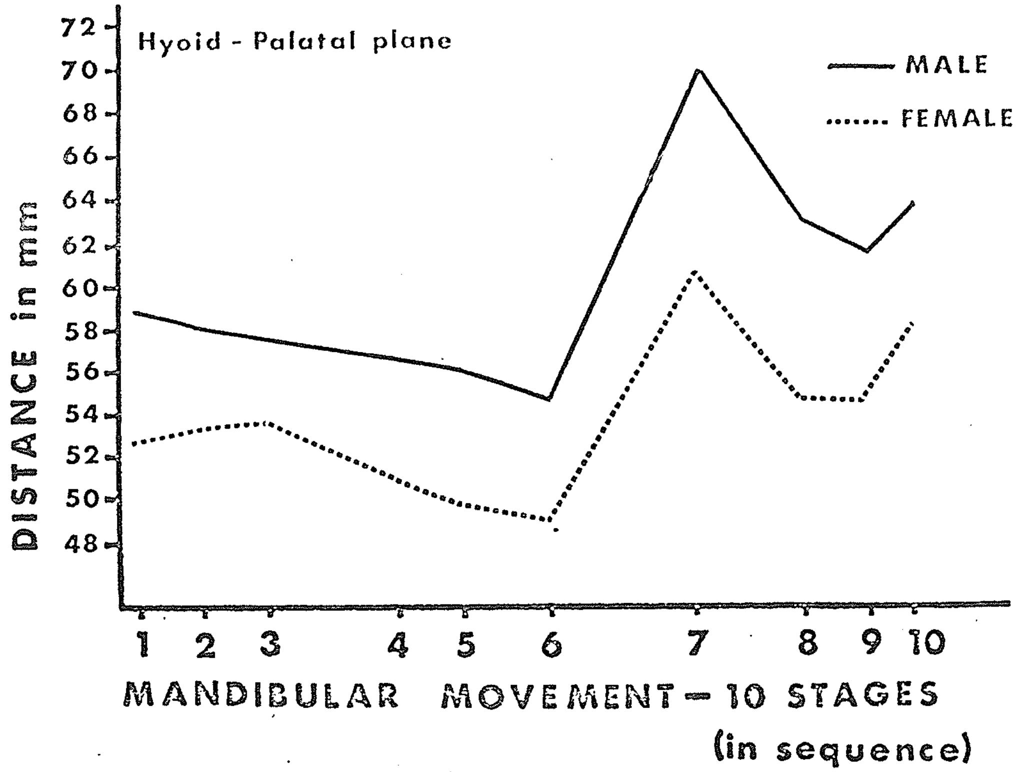


Figure 55. A graph showing the effect of sex on the distance from the hyoid bone to the palatal plane for males and females during the 10 stages of mandibular movement.

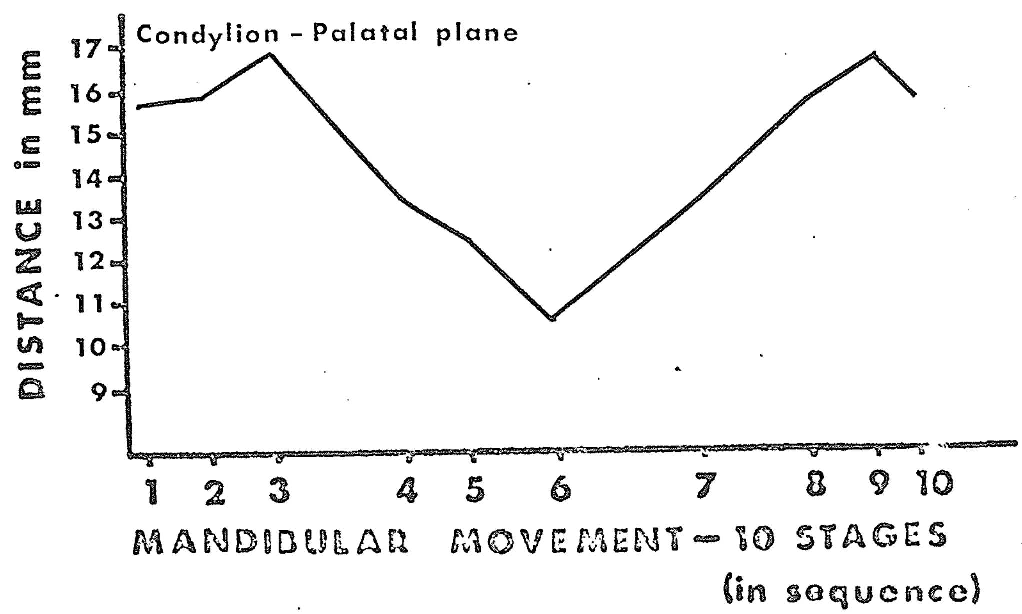


Figure 56. A graph showing the combined male and female mean movement in mm. from the condyle to the palatal plane during the 10 stage movement sequence.

The male and female mean vertical distances were 60.44 mm. ± 1.35 mm. and 54.26 mm. ± 1.31 mm., respectively. The change in the vertical distance between the ten stages was significant at the .01 per cent level; however, the interaction of the two sexes from stage to stage was not significant. Figure 55 shows the male and female mean changes in distance from stage to stage.

6. The vertical distance from stage to stage between condylion and the palatal plane was significant at the .01 per cent level. The differences between the sexes was not significant; therefore the male and female mean change in distance was combined and graphically represented in Figure 56.

<u>Angular Measurements</u>

1. The change in degrees of the angle formed by the incisal edge of the mandibular incisor and the palatal plane showed no significant differences between the sexes. The change in the angle from stage to stage was significant at the $p < 0.01$ level. The combined male and female mean angulations for the ten stages are graphically shown in Figure 57.

2. Differences between the sexes were not significant for the change in angulation from stage to stage between the mandibular plane and palatal plane. The differences in degrees between the mandibular plane and the palatal plane from stage to stage were significant at the .01 per

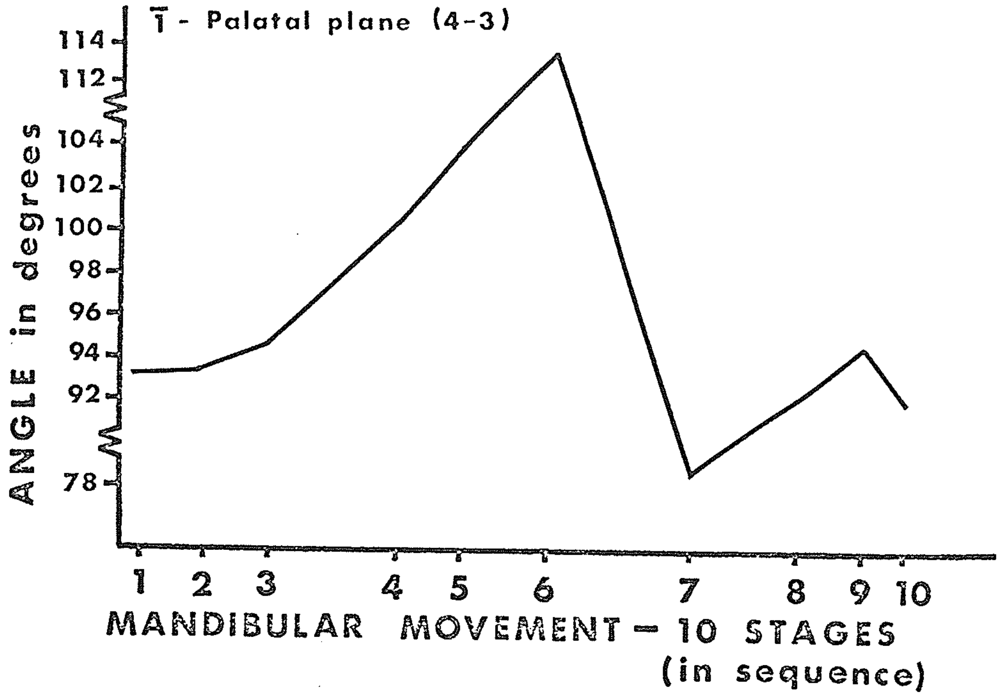


Figure 57. A graph illustrating the combined male and female mean change in angulation for the angle formed between Ī and the palatal plane (4-3) during the 10 stage movement sequence.

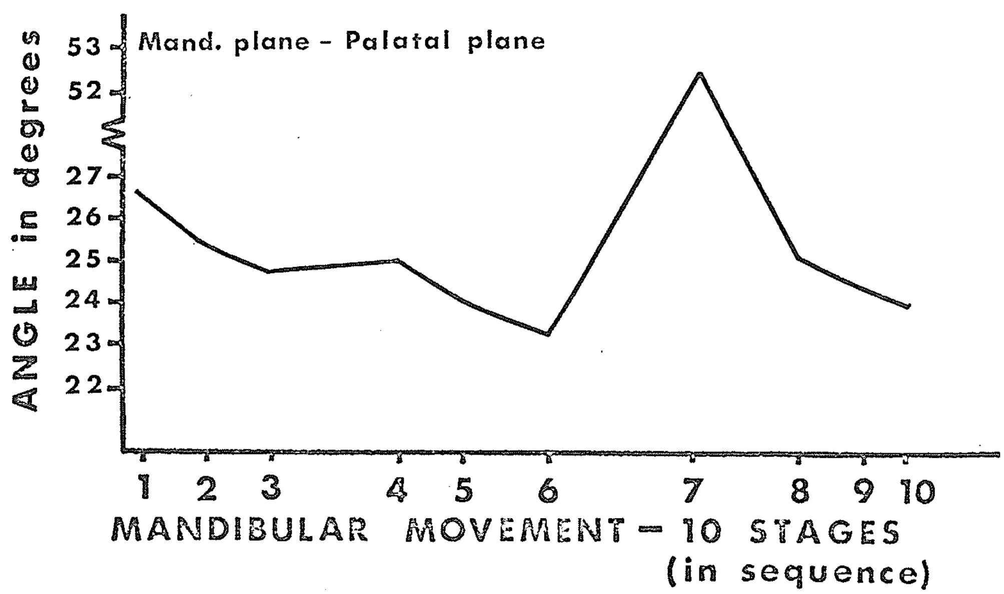


Figure 58. A graph showing the effect of the 10 stage movement sequence on the combined male and female mean change in angulation of the mandibular plane to the palatal plane.

cent level. These differences are graphically represented in Figure 58 by the combined male and female mean values.

VI. DEGLUTITION

A mixed analysis of variance was utilized to test the differences between two conditions, namely water swallows and saliva swallows. The differences between the two conditions and the differences between each of the two sexes and their interactions from stage to stage were noted on the following variables:

Linear Measurements

1. The intersite distance between the tip of the tongue and the most convex point on the dorsal surface of the tongue (tongue tip-dorsum) (line 8, Figure 28, page 64).
2. The intersite distance between the dorsal surface of the tongue and the posterior surface at a level tangent to the inferior surface of Cervical 2 (line 9, Figure 28).
3. The intersite distance between the posterior surface of the tongue and the anterior edge of the hyoid bone (line 10, Figure 28).
4. The intersite distance between the anterior edge of the hyoid bone and the tip of the tongue (line 11, Figure 28).
5. The intersite distance between the tip of the tongue and the incisal edge of the maxillary central incisor (line 12, Figure 28).
6. The intersite distance between the incisal edge of

the maxillary central incisor and the anterior edge of the hyoid bone (line 13, Figure 28).

7. The intersite distance between the anterior edge of the hyoid bone and the pterygo-maxillary fissure (PTM) represented by reference point 3 on the palatal plane (line 14, Figure 28).

8. The vertical distance between the anterior edge of the hyoid bone and the palatal plane (line 15, Figure 28).

9. The vertical distance between the tip of the tongue and the palatal plane (line 16, Figure 28).

Angular Measurements

1. The angle formed between the tip of the tongue, the dorsal and the posterior surface of the tongue (angle e, Figure 30).

2. The angle formed between the dorsal surface of the tongue, the posterior surface and the anterior edge of the hyoid bone (angle f, Figure 30).

3. The angle formed between the posterior surface of the tongue, the anterior edge of the hyoid, and the top of the tongue (angle g, Figure 30).

4. The angle formed between the anterior edge of the hyoid, the tip of the tongue, and the dorsal surface of the tongue (angle h, Figure 30).

5. The angle formed between the anterior edge of the hyoid bone and the palatal plane represented by reference points 3 and 4 (angle i, Figure 30).

TABLE IX

ANALYSIS OF VARIANCE FOR NINE LINEAR MEASUREMENTS IN THE CINEFLUOROGRAPHIC STUDY OF DEGLUTITION

		MEAN SQUARES								
SOURCE OF VARIATION	DF	Tongue Tip-Dorsum	Dorsum-Posterior	Posterior Hyoid	Hyoid Tongue Tip	Tongue Tip-1	1-Hyoid	Hyoid-PTM	Hyoid-Palatal Plane	Tongue Tip Palatal Plane
Conditions	1	1.1390	0.6970	0.2371	0.3895	0.2307	0.0650	0.0249	0.0163	0.6468
Sex	1	0.0853	0.2021	4.7902*	0.4914	0.0102	1.1108	5.7301*	6.3369*	0.2897
Conditions X Sex	1	1.7590	0.0628	1.0241	0.0	0.0071	0.1310	0.2170	0.2136	0.6172
Error 1	25	0.4236	1.2075	0.7201	0.6364	0.1984	0.6997	1.1013	1.0713	0.2738
Stages	4	2.2987**	4.5934**	2.8274**	6.0224**	3.4193**	6.0226**	4.0019**	3.8687**	1.3878**
Conditions X Stages	4	0.1616	0.5124	0.2765*	0.8355**	0.8463**	0.3233**	0.0504	0.0306	0.2923**
Sex X Stages	4	0.4594	0.5609	0.0772	0.1495	0.0699	0.0764	0.0179	0.0319	0.0084
Conditions X Sex X Stage	4	0.1510	0.6088	0.1731	0.2491	0.0773	0.1732	0.1646	0.1798	0.0568
Error 2	100	0.2073	0.2035	0.0872	0.1227	0.0848	0.0733	0.1047	0.0980	0.0336
Total	144									

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

TABLE X

ANALYSIS OF VARIANCE FOR SIX ANGULAR MEASUREMENTS IN THE CINEFLUOROGRAPHIC STUDY OF DEGLUTITION WITH TWO CONDITIONS, SALIVA SWALLOW (n-18) AND WATER SWALLOW (n-11)

		MEAN SQUARES					
SOURCE OF VARIATION	DF	Tip-Dorsum-Posterior	Dorsum-Posterior-Hyoid	Posterior-Hyoid-Tip	Hyoid-Tip-Dorsum	Hyoid-Palatal Plane	Tip-Palatal Plane
Conditions	1	175.5170	380.3945	490.3672	252.2840	12.1322	211.1801
Sex	1	670.0540*	4.8529	144.2789	1274.2124*	991.2810*	7.6851
Conditions X Sex	1	19.1038	84.2639	168.8443	67.3325	383.8806	16.4190
Error 1	25	104.5094	271.4197	490.2615	173.5730	135.4235	62.5079
Stages	4	1439.3379**	5502.4102**	5491.3906**	774.7947**	383.9260**	640.3315**
Conditions X Stages	4	106.4210	352.0950*	125.0540	62.8906	32.6026**	153.3557**
Sex X Stages	4	133.9726	201.6939	50.4254	167.2651**	17.9216**	3.2490
Conditions X Sex X Stages	4	62.0343	81.1792	53.1719	31.6378	17.2274**	1.2558
Error 2	100	68.2181	113.0018	90.2652	35.5919	4.0295	10.9233
Total	144						

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

6. The angle formed between the tip of the tongue and the palatal plane represented by reference points 4 and 3 (angle j, Figure 30).

The resultant analyses of variance for the linear and angular measurements are shown in Tables IX and X, respectively.

Linear

1. The intersite distance between the tongue tip and the most convex point on the dorsal surface of the tongue showed no significant differences between the sexes or conditions. The differences between stages were significant at the $P < 0.01$ level as shown in Figure 59.

2. No significant differences between the sexes or conditions were observed for the intersite distance between the most convex point on the dorsal surface of the tongue and the posterior point on the tongue at the level of a tangent to the inferior border of Cervical 2. The differences between stages were significant at the $p < 0.01$ level and are graphically illustrated in Figure 60.

3. The intersite distance between the most posterior point on the tongue and the anterior edge of the hyoid bone showed significant differences between sexes at the .05 per cent level as shown graphically in Figure 61. The male and female mean distances were 31.56 mm. ± 1.01 mm. and 27.92 mm. ± 0.98 mm., respectively.

There was a significant change at the $p < 0.01$

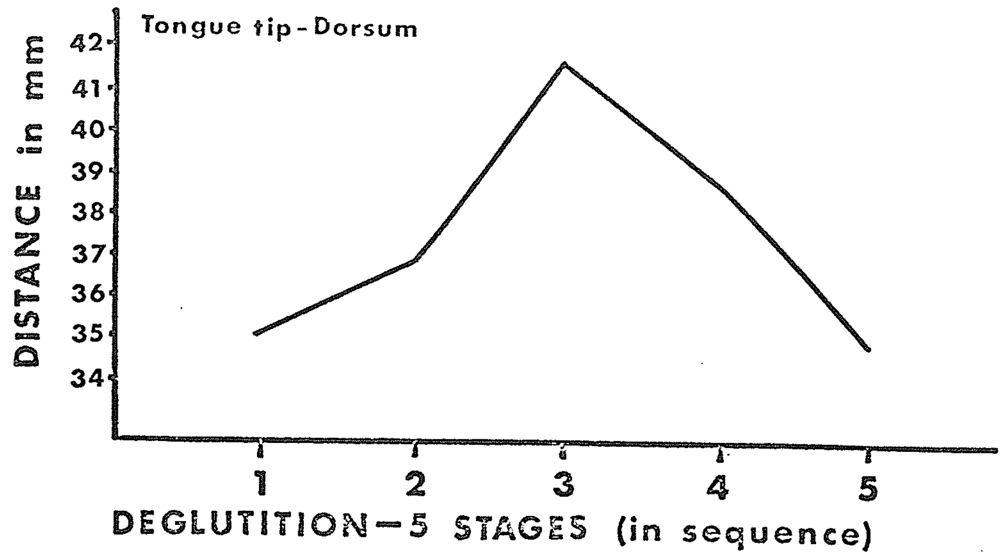


Figure 59. A graph illustrating the effect of the 5 stage swallowing sequence on the distance from the tongue tip (landmark 6) to the dorsal surface (landmark 7).

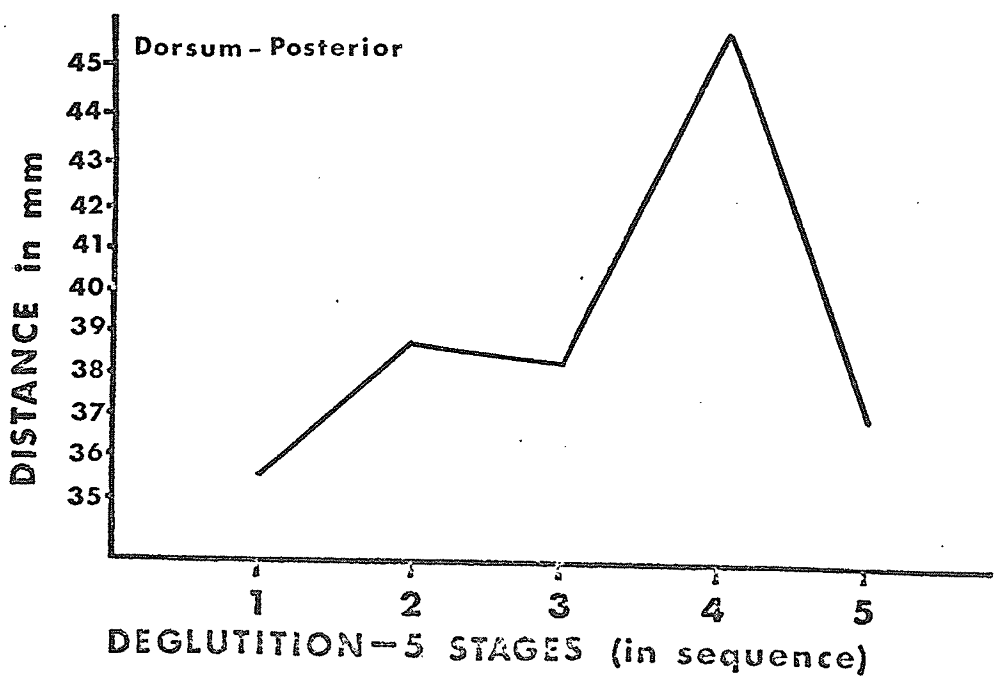


Figure 60. A graph showing the effect of deglutition on the change in distance from the dorsal surface of the tongue (landmark 7) to the posterior surface (landmark 8).

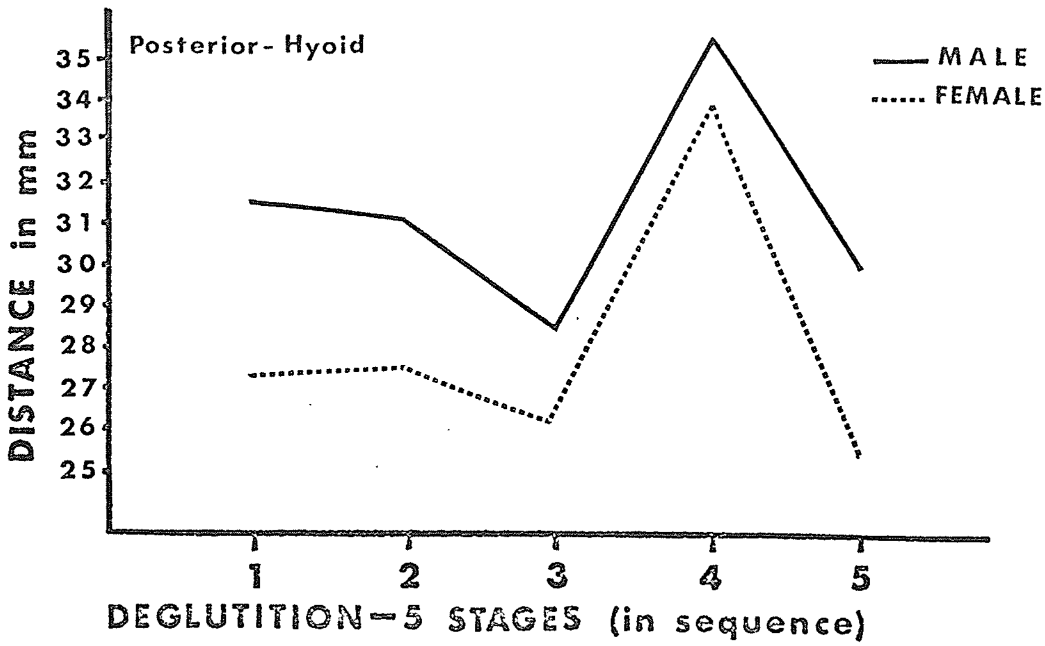


Figure 61. A graph illustrating the effect of sex on the measurement from the posterior tongue (landmark 8) to the hyoid bone (landmark 9) during the 5 deglutition stages.

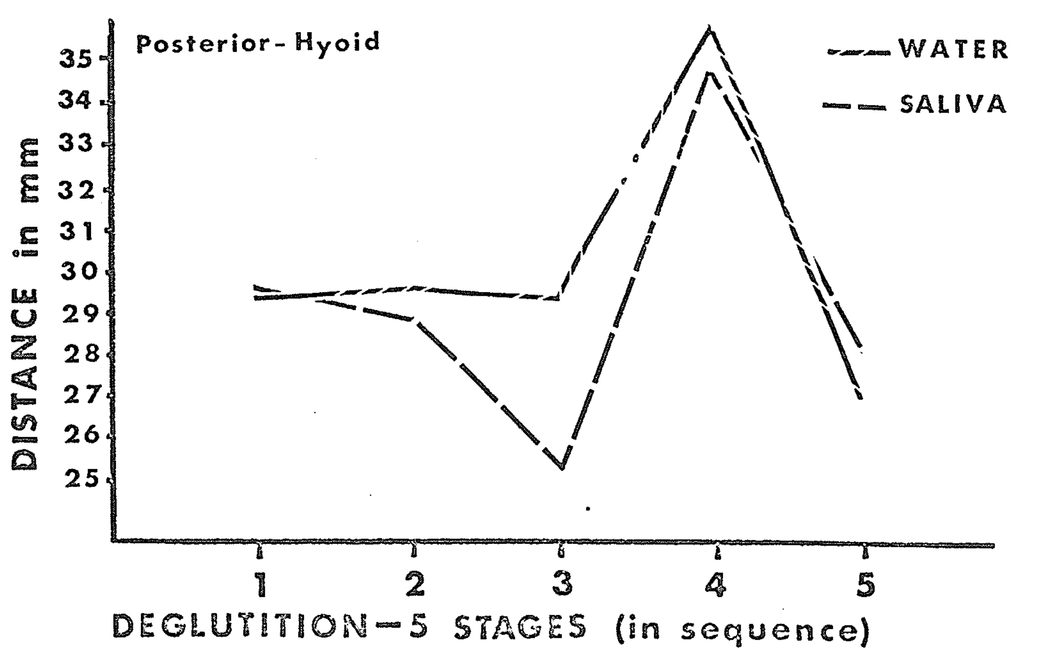


Figure 62. A graph showing the effects of water and saliva swallows on the measurement from the posterior tongue (landmark 8) to hyoid (landmark 9) during the 5 deglutition stages.

level from stage to stage and at the $p < 0.05$ level for the interaction between conditions and stages. These differences are illustrated in Figure 62.

4. A significant difference at the $p < 0.01$ level between stages was observed for the intersite distance from the anterior edge of the hyoid to the tip of the tongue. A significant difference at the $p < 0.05$ level was observed for the interaction between conditions and stages, however, no sex differences were observed. Graphically these differences are presented in Figure 63.

5. No significant sex differences were observed for the intersite distance between the incisal edge of the maxillary central incisor and the tip of the tongue. A significant change in the distance at the $p < 0.01$ level from stage to stage was observed. The interaction of the conditions and stages was significant at the $p < 0.01$ level. Figure 64 graphically presents the differences.

6. Differences were significant at the $p < 0.01$ level from stage to stage for the intersite distance between the incisal edge of the maxillary central incisor and the anterior edge of the hyoid bone. The interaction of the conditions and stages was significant at the $p < 0.01$ level, however, no significant differences between the sexes were observed. The differences are illustrated in Figure 65.

7. Differences between the sexes were observed at the .05 per cent level and between stages at the $p < 0.01$

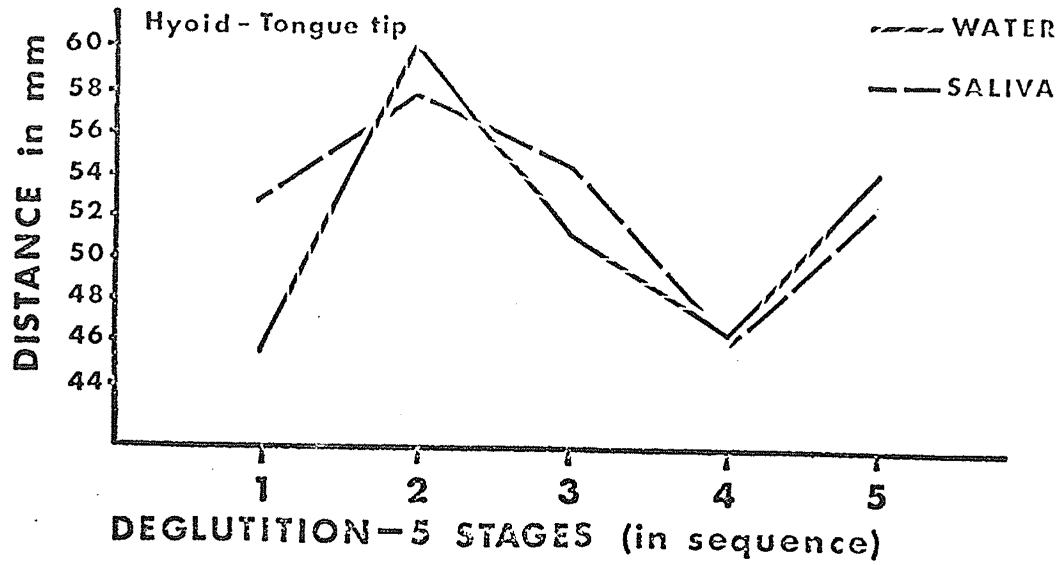


Figure 63. A graph illustrating the effect of water and saliva swallows on the distance from the hyoid bone (landmark 9) to the tongue tip (landmark 6)

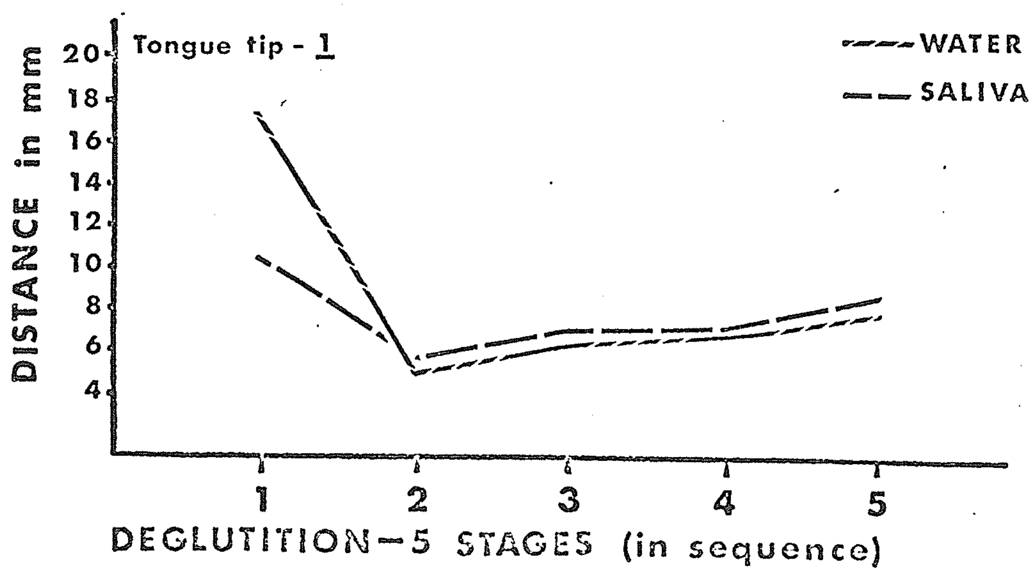


Figure 64. A graph illustrating the effect of water and saliva swallows on the distance from the tongue tip (landmark 6) to the incisal edge of 1 (landmark 5) during the 5 deglutition stages.

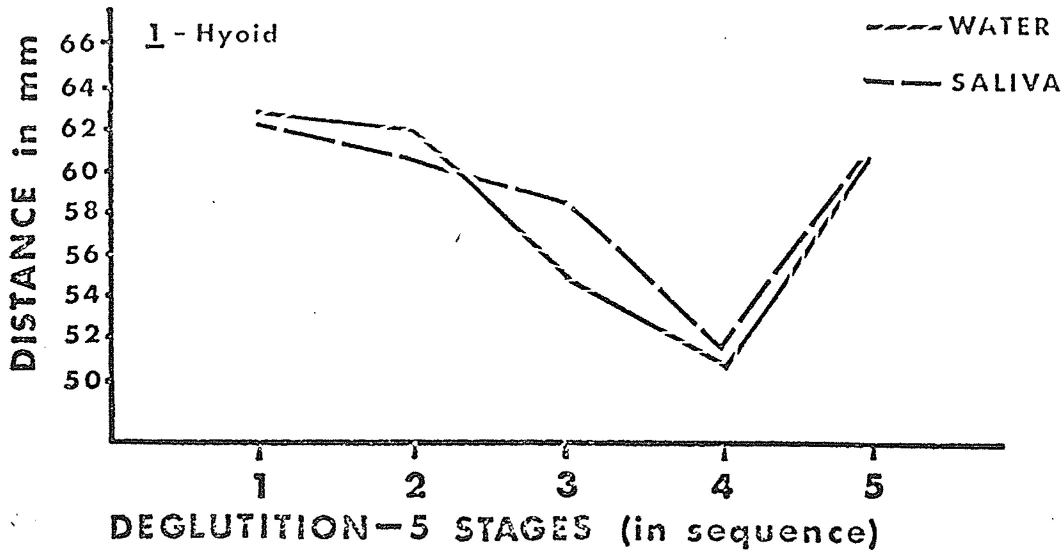


Figure 65. A graph illustrating the effect of water and saliva swallows on the distance from the 1 (landmark 5) to the hyoid bone (landmark 9) during the 5 stages of swallowing.

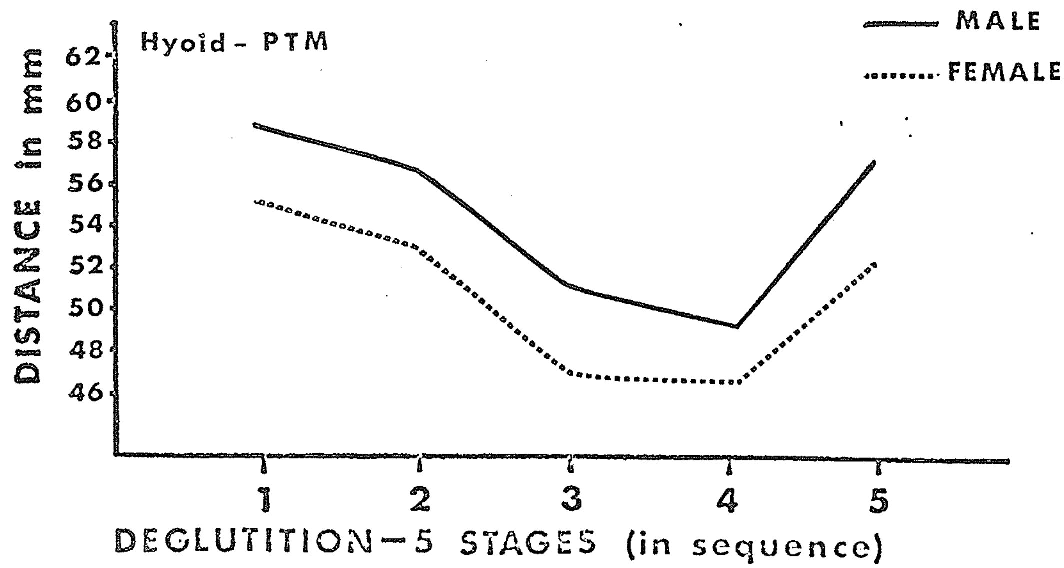


Figure 66. A graph presenting the effect of sex on the distance from the hyoid bone to PTM during the 5 stages of deglutition.

level for the intersite distance between the anterior edge of the hyoid bone and reference point 3 (PTM) on the palatal plane. The differences are illustrated in Figure 66. The male and female mean measurements were 54.73 mm. ± 1.25 mm. and 50.75 mm. ± 1.21 mm., respectively.

8. The vertical distance between the hyoid bone and the palatal plane showed differences between the sexes at the .05 per cent level. The male and female mean distances were 56.21 mm. ± 1.21 mm., and 49.82 mm. ± 1.13 mm., respectively. The differences between stages were significant at the $p < 0.01$ level. Figure 67 illustrates the differences.

9. The vertical distance from the tip of the tongue to the palatal plane showed no significant differences between the sexes, but the differences between stages and the interaction of the conditions and stages both showed significant differences at the $p < 0.01$ level. Figure 68 graphically shows the differences.

Angular

1. The angle formed between the tip, the dorsal surface, and the posterior surface of the tongue (angle e, Figure 30) showed a significant difference between the two sexes at the $p < 0.05$ level. The male and female mean angles were 109.99 degrees ± 1.22 degrees and 114.29 degrees ± 1.18 degrees, respectively. The differences between stages was significant at the $p < 0.01$ level. Figure 69

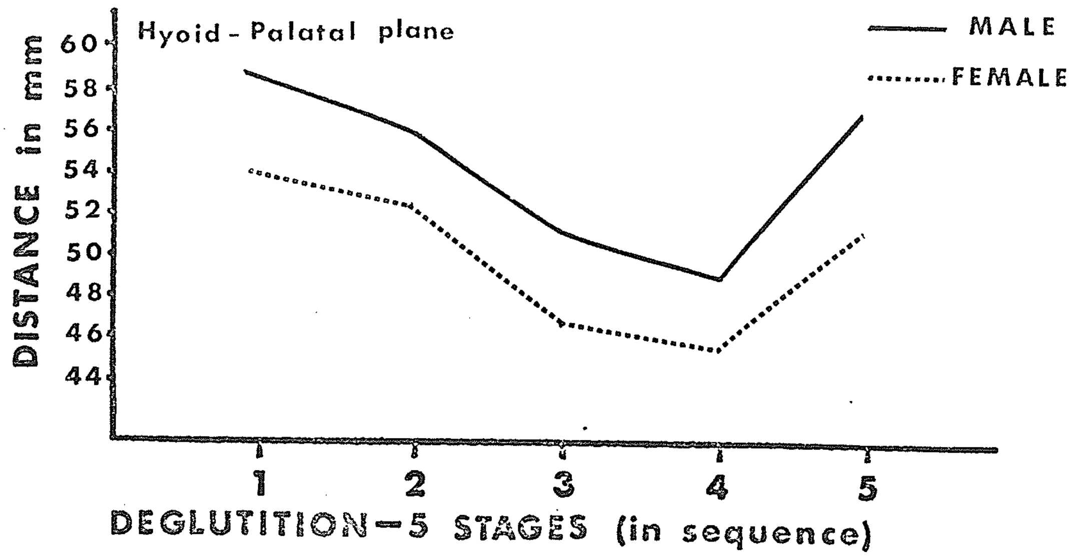


Figure 67. A graph showing the effect of sex on the distance from the hyoid to the palatal plane during the 5 swallowing stages.

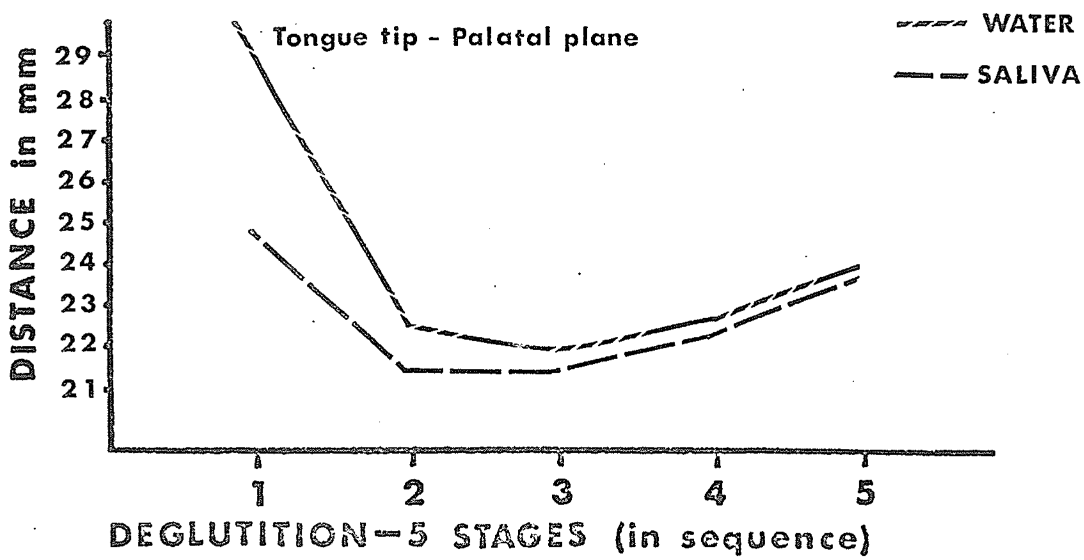


Figure 68. A graph presenting the effect of water and saliva swallows on the distance from the tongue tip to the palatal plane during the 5 stages of swallowing.

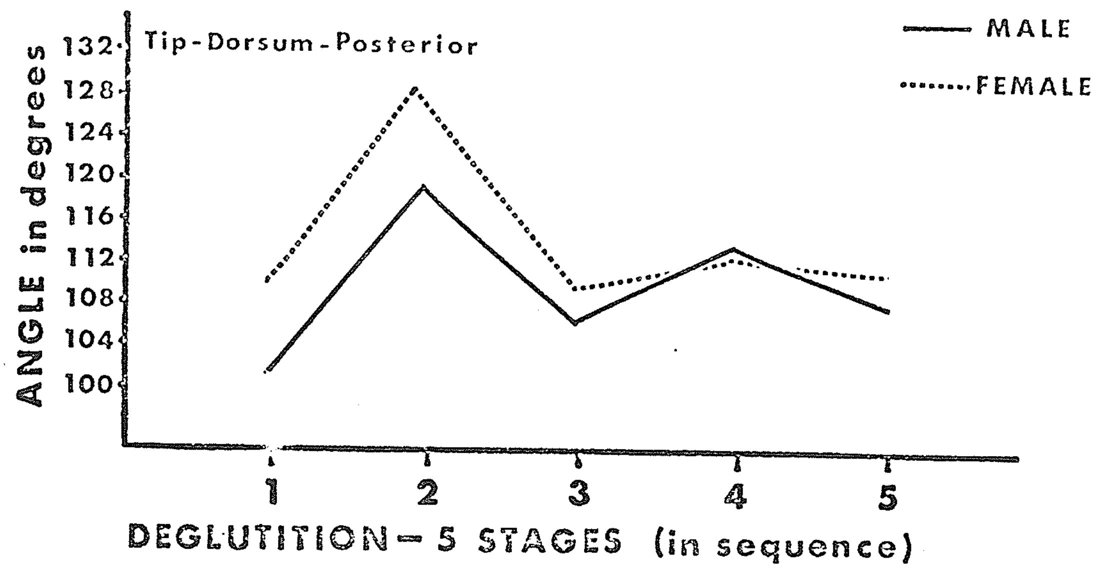


Figure 69. A graph showing the effect of sex on the angle formed by the tongue tip to the dorsal surface to the posterior surface of the tongue during the 5 stages of deglutition.

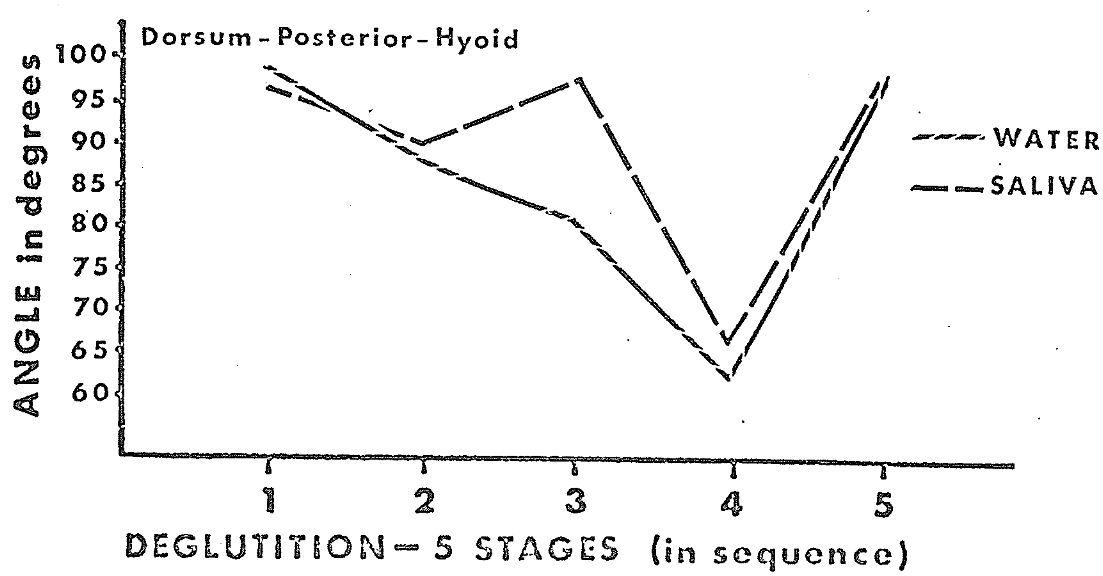


Figure 70. A graph illustrating the effect of water and saliva swallows on the angle formed by the dorsum of the tongue to the posterior to the hyoid bone during the 5 stages of swallowing.

illustrates the differences graphically.

2. The angle formed between the dorsal surface of the tongue, the posterior surface and the anterior edge of the hyoid bone (angle f, Figure 30) showed significant differences at the $p < 0.01$ level between stages. The interaction of conditions and stages showed significant differences at the $p < 0.05$ level. The differences are illustrated in Figure 70.

3. The posterior surface of the tongue, to the anterior edge of the hyoid, to the tip of the tongue formed angle g, Figure 30. No significant differences between the two sexes were observed for this angle, however, differences at the $p < 0.01$ level were observed for the angle change between stages. The differences are shown in Figure 71.

4. The angle formed between the anterior edge of the hyoid bone, and the tip of the tongue and the dorsal surface showed significant differences between the sexes at the .05 per cent level. The male and female mean angles were 64.36 degrees ± 1.57 degrees, and 58.42 degrees ± 1.52 degrees, respectively. The interaction between the sexes and the stages manifested significant differences at the $p < 0.01$ level. Figure 72 graphically shows the differences.

5. The angle formed between the anterior edge of the hyoid bone and the palatal plane represented by reference points 3 and 4 (Figure 30) showed significant difference in the interactions between the sexes, the two conditions and the stages at the $p < 0.01$ level. Figure 73

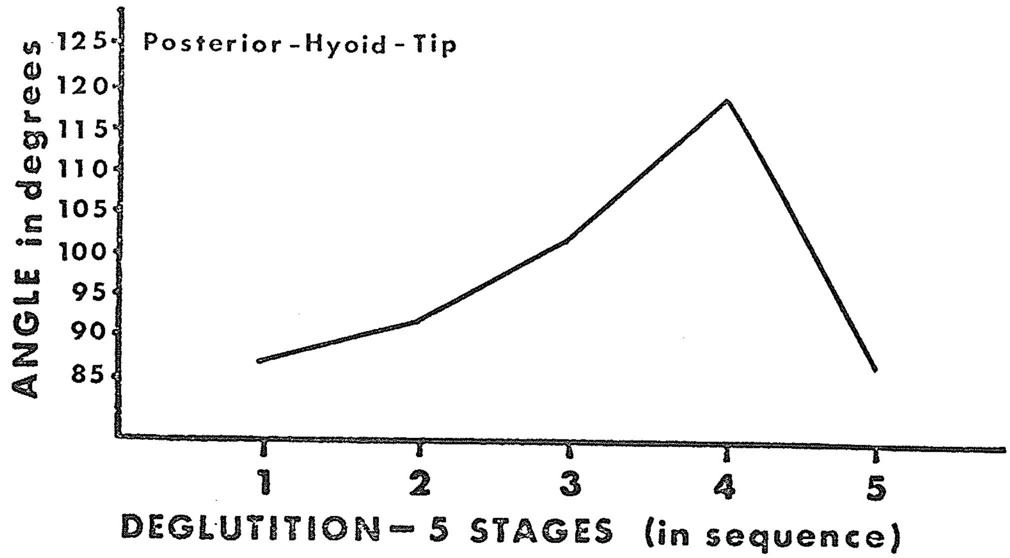


Figure 71. A graph showing the change in angulation between the posterior of the tongue, hyoid bone and tongue tip during the 5 stages of swallowing.

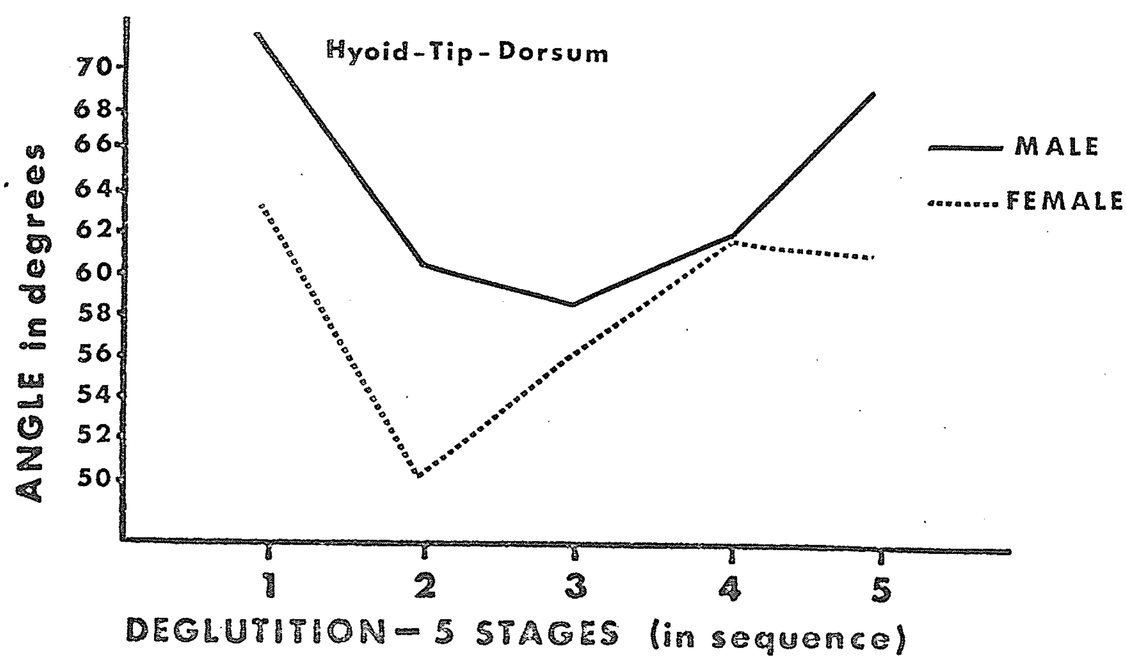


Figure 72. A graph showing the effect of sex on the angle formed by the hyoid bone, tongue tip and dorsum of the tongue during the 5 deglutition stages.

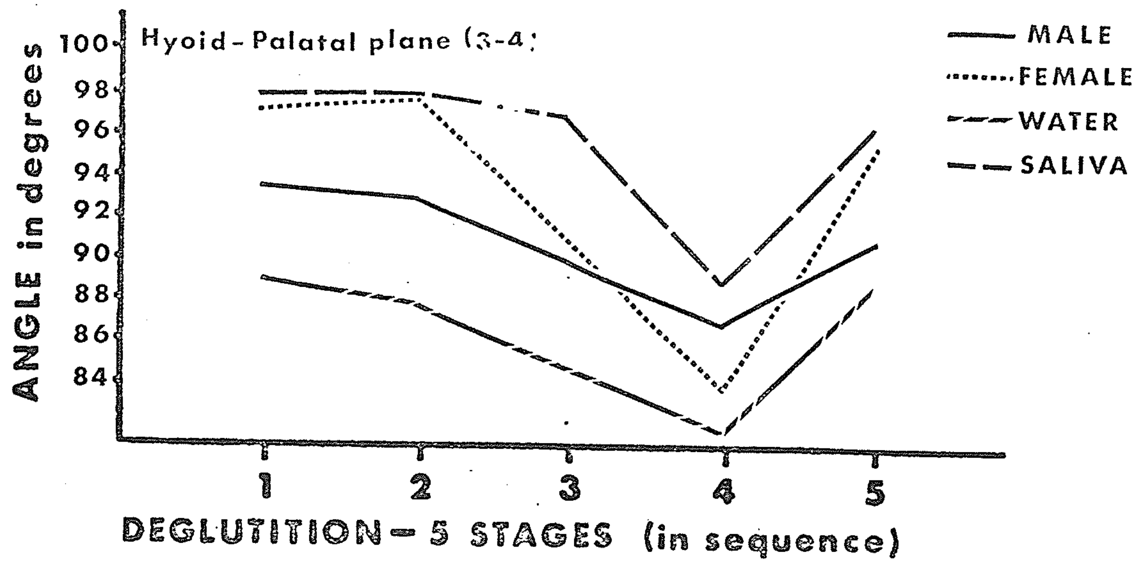


Figure 73. A graph illustrating the interaction of the sexes and the water and saliva swallows on the angle formed between the hyoid bone and palatal plane during the 5 stages of swallowing.

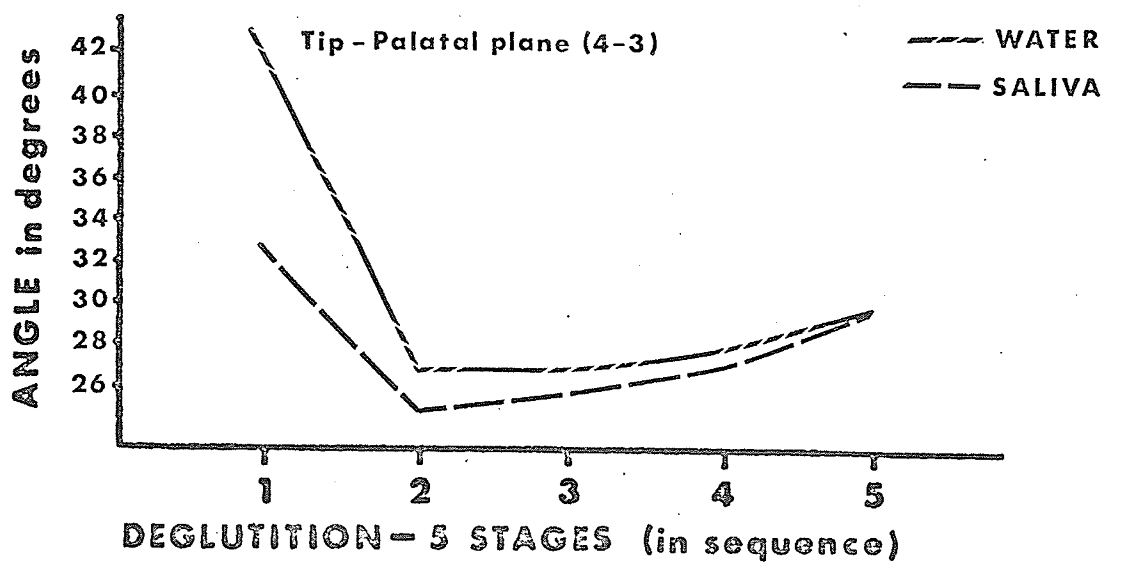


Figure 74. A graph illustrating the effect of water and saliva swallows on the angle formed by the tongue tip and the palatal plane during the 5 stages of deglutition.

graphically shows the differences.

6. The angle formed between the tip of the tongue and the palatal plane designated by reference points 4 and 3 (Figure 30) showed significant differences at the $P <$ 0.01 level between stages and between the interaction of the conditions and stages. The differences are shown in Figure 74.

VII. FACTOR ANALYSIS

The factor analysis performed on the 90 cephalometric variables yielded an average correlation of 0.23152. Six principal factors extracted from the 90 x 90 correlation matrix accounted for 65.501 per cent of the total variability. The sixth factor contained values of no biological significance and was discarded. The remaining five factors accounted for 59.762 per cent of the total variability explained by each factor. Only significant variables are shown and those with a standard error higher than .710 were significant at the $P < 0.01$ level.

The Factors

The first factor (F) had the highest loading (.857) on the Pog-N-A angle and therefore was most comprehensively defined as "profile type". It was the most important principal component since it was common to the largest number of variables (22 of 90), and its loadings on most of these variables were high (Table XI). Factor 1 accounted for over sixteen per cent of the total variability. Profile type, as defined by this factor, was related to the following (loadings are in parenthesis): a good relation of the chin to the cranium shown by a high facial angle (.679) and Sn-Pog angle (.657), a substantial chin button Pog-NB (.857), good mandibular length Me-Go (.676) and Ba-Pog (.646), an increased inclination of $\overline{1}$ as evidenced by the $\overline{1}$-SN angle (.803), the $\overline{1}$-FM angle (.689), harmony of the apical bases to each other as illustrated by a low ANB angle (-.701), harmony of the apical bases to each other and to the facial plane as shown by a small angle of convexity (-.748), a low mandibular plane angle (-.717), and SN-Mand.Pl. (-.596) and a shortened incisor to facial plane distance, $\underline{1}$-AP (-.615), $\overline{1}$-AP (-.582), $\overline{1}$-NB (-.619). The positive and negative loadings gave a very accurate picture of the direction of change in the response variables as they related to "profile type". Individuals with good profile types score highly on this factor.

Factor II accounted for 12.976 per cent of the total variability on the basis of its loadings. It was termed facial type because a high loading was observed for the position of the maxilla anteroposteriorly in the face, i.e. SNA (.697); the spatial position of the mandible, SNB (.661), the proclination of the maxillary incisors $\underline{1}$.SN (.719) and the $\underline{1}$-palatal plane distance also were loaded highly (.588). Highly loaded but related oppositely were decreased cranial base length (-.595), a low FH-SN angle (-.791) and a forward positioning of the alveolar processes illustrated by $\underline{6}$-SN angle (-.714), $\overline{6}$-SN angle (-.682). A patient who scored highly on this factor would have a convex facial type.

The third factor was described by nine biological variables and accounted for 12.861 per cent of the total variability. Factor III was defined as "retrognathic" from the high loadings which were observed for the distance $\overline{1}$ to mandibular plane (.615), in association with decreased measurements for $\overline{1}$-AP (-.600), $\overline{1}$-NB (-.611), posterior cranial base, Ba-S (-.619) and mandibular length (-.625). The $\overline{1}$ to mandibular plane angle was increased (.615) and associated with a decreased angulation of $\overline{1}$ to the facial plane NB (-.550). A high score on this factor would be indicative of a patient manifesting a degree of retrognathism.

Factor IV was common to six biological variables and accounted for 9.053 per cent of the total variability. The factor was identified as "head posture" from the high positive loading for the facial plane to true vertical angle (.819). This reading associated with the high negative loadings for the palatal plane to true vertical angle (-.818) and SN-true vertical angle (-.650) suggested that as the head was extended there was a decrease in the apparent facial angle. A patient scoring high on this factor would have well regulated upright head posture.

Factor V was defined by two highly loaded dental variables, the $\underline{1}$-NA angle (.576) and the $\underline{1}$-palatal plane angle (-.622). The positive and negative loading of these two variables suggests an increased proclination of 1, thus the factor was termed overjet. The increase in proclination of 1 was associated with a decrease in the cranial base angle N-S-Ar (-.541). Factor V was the least important variable and accounted for 7.957 per cent of the total variability. A patient with moderate overjet would score highly on this factor.

The subject described by the five factors would manifest a convex profile type, retrognathic facial type associated with good head posture and a minimum amount of overjet.

CHAPTER V

DISCUSSION

During the past twenty-five years investigators have produced many cephalometric analyses in an attempt to define specific skeletal and dental aberrations which contribute to malocclusion.

Utilizing the techniques of Tweed (1946), Downs (1948), Steiner (1953), and Holdaway (1956), to mention a few, orthodontists have attempted to define standards of the ideal or normal occlusion to which a malocclusion could be compared. As a result of these investigations, the value of cephalometrics as an adjunct to orthodontic diagnosis has become well established. The norms of Downs' and Steiner's analyses represent the composite findings of males and females within a range of ages. The question, however, remained whether or not such variables as sex differences, age discrepancies, and ethnic skeletal differences were of significance in cephalometric analyses. If so, it would necessitate separate sex and age norms, as well as separate norms for those geographic areas in which an ethnic group might predominate. In the present study these conditions were met by studying the skeletal and dental pattern of twenty-seven females and twenty-one males who possessed Angle's Class I normal occlusion. The ages ranged from eleven years, eleven months to fourteen years, two months, the mean age being thirteen years, five months. The age range thus compared well to the range within which most orthodontic treatment is undertaken.

Although there were no significant differences between the two sexes for the Manitoba skeletal and dental analysis, the results suggested that for this age group there was a tendency for the males to be more retrognathic than the females. A decreased facial angle and a higher mandibular plane angle was present in the male. This finding was in contrast to deKock et al. (1968) who observed the average sella-nasion mandibular plane angle to be significantly larger (by about 3 degrees) for girls than for boys at ages 5, 8, and 11. This being the case, it is conceivable that between ages 11-13 the female growth spurt is of such magnitude that the differential in growth between male and female allows the female mandible to simultaneously translate downward, forward, and rotate forward. The last movement would account for the flattening of the mandibular plane.

Factor I of the principal factor pattern, Table XI, supports the finding as high loadings were observed for the facial angle, length of chin Pog-NB, and $\bar{1}$-SN angle.

These variables were associated with a straight profile. Highly loaded but related oppositely in Factor I were the mandibular plane angle, the ANB angle and the angle of convexity. Negative loadings for these variables were also related to a straight profile. The loadings on the principal factor pattern were subjected to a T test and no significant differences between the two sexes were noted.

Giannelly (1970) noted little evidence of reduction of facial convexity with age. It is well established that the male mandible continues to grow into the late teens, and, as his sample ranged from ages 8-13 years, little validity can be given to his statement. It was also reported by Giannelly that there was little indication of a decrease in the slope of the mandibular plane with age. Although the present study was cross-sectional in nature, the results concur with Giannelly in that differences in the variables between the sexes were small (1 to 2 mm. or 1 to 2 degrees) and showed little consistency. In some cases the standard deviations were larger than the observed differences.

The maxillary incisors were observed to be slightly more procumbent in boys than in girls ($\underline{1}$-AP). It could be argued that at age thirteen pogonion was better developed in the females than in the males and therefore $\underline{1}$-AP was not a valid measurement. However, the difference between the two sexes for this measurement was only 0.4 mm. The reason for this finding was probably due to a maturation factor which allowed for the continuing growth of the male mandible, whereas the female mandible at age thirteen has all but completed its growth.

The overjet and overbite were observed to be slightly larger in the male. It is highly probable that the foregoing discussion on mandibular growth would also apply to these differences.

The Manitoba results resemble more closely Riedel's results (Table III). The fact that Riedel's sample pertained not only to ideal occlusion but also contained some Class II, Division 1 subjects would further suggest that in comparison to Downs, Steiner and Holdaway, the facial type and profile of the present sample was retrognathic and convex respectively.

In summary, the skeletal and dental variables contained in the Manitoba analysis showed no significant differences between the sexes. The values can, therefore, possibly be combined and used as a treatment guide. It should be remembered that so-called biologic norms represent the most common finding in the greatest number of individuals. Treatment objectives in orthodontics usually call for dental relationships that conform to a Class I normal occlusion and which relate harmoniously to the cranio-facial morphology. Few people possess either an ideal occlusion or an ideal skeletodental balance defined by the Manitoba analysis or the analyses of Downs', Steiner, Tweed, Riedel; consequently, treatment objectives are not necessarily biologic. Ideal values can be used as a guide for treatment to develop better harmony than would exist in a more biologically orientated definition of the pretreatment skeletodental relationship.

Effect of Restraining Ear Rods

The results showed that the difference in head posture between the sexes was not significant; however, the difference in head posture between the lateral ceph (ear rods) and the cine (no ear rods) in rest position and habitual occlusion was significant at the $p < 0.01$ level, seen in Figures 39 and 40, respectively, page 94 Upon insertion of the ear rods the head was extended approximately four degrees. This could probably be attributed to a reflex action of the patient to ease the minor discomfort caused by the ear rods as they were closed firmly into the external auditory meatus. In addition to the patient attempting to become more comfortable, there was some apprehension regarding the equipment and procedure which could result in a position of unnatural head posture. This observation was found to be in agreement with Cleall (1966) and Stone (1971) who suggested that the use of mechanical head posturing devices with ear rods appeared to cause an alteration in the physiological resting posture of the head and mandible.

In habitual occlusion, the head was extended from 84.14 degrees ± 0.88 degrees to 89.74 degrees ± 0.88 degrees when the ear rods were inserted. The clinical implication of this observation is that Downs (1956) noted occasional discrepancies between facial typing and photographic facial typing due to an upward tip of the Frankfurt plane of 1.30 degrees ± 5.00 degrees. The present study did not measure the angulation of the Frankfurt plane to the true vertical but did note the sella-nasion plane was tipped up 6.86 degrees

± 6.02 degrees to the true vertical. In Downs' study, the difference observed between the FH plane and the SN plane was 6.38 degrees ± 4.01 degrees. Thus, it can be concluded that the present sample did not differ greatly from Downs' sample with regard to the upward cant of the Frankfurt plane. In view of this similarity, a correction should be made for those individuals who do not possess a level Frankfurt plane and whose photographs were taken with ear rods in place and who show occasional discrepancies between photographic typing and facial typing. In addition to obtaining standard lateral cephalograms with ear posts, for dynamic analyses, facial photographs and lateral cephs should probably be obtained with no ear rods in natural head posture for those patients with photographic and facial typing discrepancies. This would allow for a closer correlation of the lateral head radiographs with the clinical appearance of the patient.

Perry (1960) has said that in order to accept the fact that mandibular displacement has occurred, it is necessary to demonstrate that movement of the mandible from rest to occlusion occurs along a path other than the accepted norm. The results of the present study show that when ear rods were inserted the displacement of the mandible in rest position was significantly different between the two sexes at the $p < 0.05$ level. In the male, the tip of the lower incisor was displaced superiorly .40 mm. ± .92 mm., whereas in the female, the lower incisor was displaced inferiorly

4.22 mm. ± 0.79 mm. The displacement observed at pogonion showed no significant differences between ear rods and no ear rods. The differences in reaction of the sexes to ear rods were significant at the $p < 0.05$ level. These differences were in the same direction as those observed for the lower incisor but of lesser magnitude. This diathesis between sexes could be due to the morphology of the external auditory meatus. The female being more diminutive would account for the more profound female reaction. This resulted in a downward and backward displacement of the mandible.

Sutcher and Laskin (1971) commented that since the portion of the mandibular condyle lateral to the post glenoid process lies immediately anterior to the cartilagenous external auditory meatus and is separated from it only by soft tissue, it seems likely that pressure from the ear rods would be transmitted to the condyle. It then becomes apparent that mandibular displacement could be a direct manifestation of this pressure.

It has been suggested that routine diagnostic lateral cephalograms be taken in rest position so that the patient's natural profile would be exposed in his usual facial posture. By so doing, the face would be completely unstrained, with the mandible in rest position and the lips relaxed, excepting the patient who has no freeway space and/or is a post freeway mouthbreather (McDowell, 1970). The post freeway mouthbreather is one whose mandible is held constantly open beyond rest position except for brief moments in swallowing, talking or chewing. In view of the results of the present study, McDowell's statement would appear even more plausible if restraining ear rods were not inserted provided the capability to reproduce the mandibular position could be ascertained for longitudinal analyses.

Centre of Rotation

In order to understand how teeth articulate, it is necessary to know the mechanics of jaw movement and function. McCollum and Stuart (1955) have said that the mandible functions as a Class III lever with the force (closing muscles of mastication) placed between the fulcrum (temporomandibular joint) and the load (teeth). Therefore, in a Class III lever with a given rod, force, load, and fulcrum point, and with all factors fixed except the load position, the force is constant. The influence of the force on the load and the fulcrum is inversely related to its distance between them. Clinically, the greater the distance between the load determining teeth and the muscle force, the less the effect of the force on the involved teeth, and the more the muscles will have to accentuate the bracing of the condyle against the skull.

Seitlin (1968) described the mandible as a lever and applied lever principles to the normal and abnormal physiology of dentures. The combination of bone and muscle action during mastication used leverage to obtain the desired results. The mandible functioned against a stationary skull while the moving mandible, the involved muscles of mastication, and the teeth represented the various parts of a lever, i.e. rod, fulcrum, force and load.

Load-determining teeth are those pairs of opposing teeth which primarily receive the muscle force. With the temporomandibular joint acting as the fulcrum and keeping within the physiological stress limits of the tooth-supporting tissues, it then follows that the more mesially placed the load, the more probable will be the toleration of the muscle force by the supporting tissue.

In habitual occlusion, the opposing teeth contact with no disproportionate pressures, with the tooth load anterior to the prime force exerted by the elevator muscles of mastication. The condyles are seated simultaneously and both temporomandibular joints act as a single fulcrum.

In rest position, the mandible is suspended with the condyles not held tightly against the glenoid fossa and with no tooth contact. From rest position to habitual occlusion the condyles are not firmly seated in their respective fossae until after tooth contact. Under these circumstances, the teeth momentarily become the fulcrum and the joints act as the load. Once the condyles are seated and stabilized, the functions are reversed, with the joint becoming the fulcrum and the teeth becoming the load.

The change in the centre of rotation of the mandible from rest to occlusion showed no significant differences between sexes or between ear rods and no ear rods. However, it was noted in Figure 43(a), page 97, that the male and female mean centres of rotation were clustered posterior and inferior to the condyle in the cine, in which no ear rods were inserted. In the ceph, in which ear rods were inserted, the rotation centres were more widely separated as shown in Figure 43(b). This would imply that for studies wishing to locate centres of rotation of the mandible, a cinefluorographic method utilizing no ear rods would likely be more accurate. It was noted that the standard deviations were very large which indicated that the subjects probably displayed much greater differences than the means might suggest.

The findings of the present study support the observations of Nevakari (1956) and Stone (1971) who found that in the movement from rest to habitual occlusion, the centre of rotation of the mandible was posterior to the ramus in the area of the mastoid process. Koski (1962) reviewed the origins and insertions of the masticatory musculature and showed that many of the muscles associated with the opening and closing of the mandible were either directly or indirectly related to the mastoid process region. It was pointed out that the mastoid process region was also the pivot for the movements of the skull, and, as functions of the cranial complex, should be considered interrelated. The mastoid region could well be the site of the axis during the initial opening movement of the mandible.

The centres of rotation observed during the cine mandibular movement sequence were interpreted as follows: The mean centres of rotation for the rest-initial contact-full closure movement were found to be clustered around the incisal edge of the mandibular incisors. This movement differed from rest to full closure because at initial contact the load was temporarily shifted to the condyles. The area of initial contact, which in most cases was the lower incisor region thus became the fulcrum and is illustrated in Figure 44, page 99.

When the mandible moved from maximum protrusion to wide open there was no tooth interference and the mean centres of rotation for both males and females were grouped posterior to the gonial angel shown in Figure 45, page 99. The movement from wide open (Stage 7)-initial contact (Stage 8)-full closure (Stage 9) produced mean centres of rotation in the area of the lower anteriors similar to the movement from rest-initial contact-full closure shown in Figure 46, page 99. The rotation centre was the point that the mandible rotated around from initial contact to full closure. This rotation can probably be attributed to the temporary change of the load to the temporomandibular joint and the fulcrum to the lower anteriors at the time of initial contact. When only the movement from wide open to full closure was considered, the mean centres of rotation were again clustered posterior to the gonial angle as illustrated in Figure 47(a), page 100.

There were no tooth interferences from rest to retruded contact position and wide open to retruded contact position. Movement was primarily rotatory, occuring in the area posterior to the gonial angle presented in Figures 48(a) and (b), respectively, page 100. For the movement from habitual occlusion to retruded contact position, there was an interchange between the functions of the condyles and the teeth involved in the guidance provided by the cusp inclines, as they were now used as lever components. The condyles were functioning against the mesially inclined distal surface of the glenoid fossa while the teeth were contacting the distal inclined planes of the buccal cusps of the mandibular posteriors and the mesial inclined planes of the palatal cusps of the maxillary posteriors. The end result was a small rotation and a large translation of the mandible. The resultant mean centres of rotation were in the area of the fulcrum provided by the cuspal inclines of the posterior teeth illustrated in Figure 48(b), page 100.

Head posture. The assumption was made by Cleall (1966) that the orofacial structures related to the many functions carried out by the stomatognathic system were in a state of neuromuscular balance. This inferred that the neuromuscular control of the head as a whole was integrated to some extent with the stomatognathic system. The present study was designed to test this hypothesis using three parameters: (1) various anatomical planes and lines were related to the true vertical to assess head posture in rest position (Table XVII, see Appendix), (2) the differences in head posture between the two sexes as well as the interrelation of the sexes and head posture during the 5 stages of deglutition, and (3) the differences in head posture between the sexes including the interrelation of the two sexes and head posture during the 10 sequential stages of mandibular movement.

The results of the present study showed no significant differences between the two sexes for the above variables. The angulation of palatal plane to the true vertical was 87.10 degrees ± 5.85 degrees and 91.24 degrees ± 5.13 degrees for the male and female, respectively. The male mean value compared closely to the 87.70 degrees ± 4.30 degrees which Cleall observed for a normal sample. Interestingly, the female values corresponded closely to the 90.30 degrees ± 4.60 degrees which were observed for the tongue thrust group of Cleall's sample. Due to the differences in sample (age and sex) no great significance can be attributed to this observation.

The findings which showed the angle formed by the facial plane to the true vertical of -5.29 degrees ± 5.03 degrees for the males and -2.82 degrees ± 5.58 degrees for the females further illustrate the degree of retrognathism that was present in the author's sample. The observation also showed the tendency for the males to be slightly more retrognathic at age thirteen. This was desirable as it has been well established that male mandibular growth proceeds into the late teens.

The degree of variation between the anatomical (linear) and the true vertical as noted in Table XVII (see Appendix) was noted to be quite consistant between the two sexes. Notwithstanding this observation, the female values were all higher than the male values, though not significantly. This observation suggested that there was a female trend to a more upright head posture. A study utilizing this parameter in an older age group would be of interest to determine whether or not this is a maturation factor.

Cleall (1966) observed during the deglutition sequence in a normal sample that as the tongue tip moved forward and upward to contact the upper incisor, the head was extended and the chin point moved slightly upward and forward. As saliva was being swallowed, the head returned to its normal resting posture. In the tongue thrust sample, Cleall noted that as the tongue moved from rest position to contact the upper incisors the head flexed and the chin point dropped downwards and slightly distally. As the swallowing sequence progressed the head extended to its normal resting posture.

The results of the study under discussion showed no significant changes in head posture from stage to stage or between the two sexes. The Class I normal occlusion group tended to flex the head slightly in Stage 2 followed by an extension as the swallow entered the "visceral phase" in Stage 4 as shown in Figure 49, page 104. This action resembled the flexion and extension observed by Cleall for the tongue thrust group. The present study showed a flexion when the resting states were compared before and after swallowing. Cleall (1965) found these positions were related directly to what had preceded and succeeeded the swallow. The swallow patterns in this study were a combination of water swallows and saliva swallows, the saliva swallows being more numerous. In the cinefluorographic sequence, the water swallow was followed by a speech sequence resulting in the tongue assuming a resting position from which it could more readily move to the required position for sound production. Similarily, the saliva swallow was followed by the mandibular movement sequence resulting in the tongue and head assuming the necessary postural position. The necessity of standardizing the type of cinefluorographic analysis and the sequences involved becomes obvious when the study of head positions, swallows, speech sequences and mandibular movements are contemplated. These findings further substantiate the assumption that the mandible, hyoid, tongue and postural muscles of the head work as an integrated unit both in function and in rest and were generally in agreement with the observations of Cleall (1965), Yip (1969), and Milne (1970).

The differences between stages were significant at the $p < 0.01$ level for the changing linear and angular morphology of the tongue for water swallows and saliva swallows.

Cleall (1965) noted a comparison between the clearance of 5 ml. of water, and the saliva clearance swallows showed it took slightly longer for the tongue tip to move from rest to initial tooth contact when water was being swallowed. Although the timing of the sequences were not recorded in the present study, the positional data of the tongue tends to support this finding. The results showed that when water was being swallowed the intersite distance between the tip of the tongue and the anterior edge of the hyoid was shorter. This is graphically shown in Figure 63, page 125. The vertical distance between the tip of the tongue and the palatal plane was greater in rest position as seen in Stage 1, Figure 68, page 128. This suggested that the resting tongue was positioned more distally and inferiorly while 5 ml. of water was contained in the mouth, and by having further to move to contact the maxillary incisor, required more time. Further support for this observation was shown in Stage 1 by the increased distance from the tip of the tongue and the maxillary central incisor when water was being swallowed. This is shown in Figure 64, page 125. Figure 68, page 128 illustrates that the tongue tip was further from the palatal plane in all stages during the water swallow.

A difference between the sexes during the five stage deglutition stages for water and saliva swallows at the $p < 0.05$ level was shown for the intersite distance between the posterior point on the tongue and the anterior edge of the hyoid bone seen in Figure 62, page 123. However, during Stages 2, 3, and 4, the intersite distance between the posterior edge of the tongue and the anterior edge of the hyoid was greater when water rather than saliva was being swallowed. Interestingly, it can be seen in Figure 62, page 123, that when water was being swallowed, the hyoid was closer to the posterior surface of the tongue in Stages 1 and 5 which represented the resting posture of the tongue.

The intersite distances between the tip of the tongue and the hyoid bone, shown in Figure 63, page 125 the tip of the tongue and the 1, illustrated in Figure 64, page 125, and the 1 and the hyoid bone presented in Figure 65, page were significantly different at the $p < 0.05$ level between water and saliva swallows for the five stages of deglutition.

The hyoid bone to palatal plane angulation was noted to be significantly different between the sexes at rest position and between stages and is shown graphically in Figure 67, page 128. The decreased angulation noted for the males, in association with a longer vertical distance between the hyoid bone and the palatal plane, suggested that the hyoid bone was situated lower and more anteriorly than in the female. As was previously mentioned, the skeletal pattern of the male seemed more retrognathic; therefore, this observation appears to be in contradiction to the higher and more posteriorly placed hyoid during Stages 2, 3, and 4 which were observed by Cleall (1965) in his Class II retrognathic facial type group. A possible explanation lies in the fact that the author's sample was

Class I in which mandibular growth was not terminated. Consequently, the retrognathic appearance was of temporary duration, as opposed to the Class II skeletal pattern of Cleall's sample.

Mandibular Movement

During the ten stage mandibular movement sequence, seen in Figure 58, page 116, it was statistically shown that there were no significant differences in head posture between the sexes; however, the differences between stages were significant at the $p < 0.01$ level. There was an immediate flexion of the head from the initial rest position (Stage 1) to Stage 2. This flexion was followed by an extension of the head through Stages 3 and 4 as the mandible glided forward to end to end position. When positive contact between the anterior incisors was lost in Stage 5 and 6, where the mandible passed through minimum and maximum protrusion, the head again flexed. The subject was aware that the following stage (Stage 7) was wide open. The flexion occuring prior to this movement could be a preparatory movement as Stage 7, wide open was characterized by a large extension. The extension of the head was a good example of the integration and functional balance of the muscular components involved in mandibular movements to allow for maintenance of the airway. Subsequent to Stage 7 there was a gradual flexion until Stage 10 when there was a return to the pre-mandibular movement resting head posture.

An interesting implication can be drawn from the fact that during swallowing, differences in head posture between stages were not significant, yet during mandibular movements the differences in head posture between stages were significant. This suggests that the degree of head movement during deglutition was less than during certain mandibular movements. For example, the extension of the head noted from maximum protrusion to wide open position is probably necessary to balance the shift in the centre of gravity of the head when the jaw is protruded as well as to prevent impingement on the airway as the mandible is depressed.

Aside from the previously mentioned, more anterior, inferior positioning of the hyoid bone in the male compared to the female, the intersite and vertical distances and angles observed during the ten stage mandibular movement sequence showed no significant differences between the sexes. The change in the distances and angles between stages was significant for all stages at the $p < 0.01$ level. It can, therefore, be concluded that for both males and females, the pattern of movement of the jaw responds in a parallel manner to the neuromuscular impulses guiding the mandible through the ten stages. An example of this parallel reaction is shown in Figure 55, page 114, which illustrates the differences between the two sexes for the vertical distance from the hyoid to the palatal plane.

Posselt (1968) described the protrusive path of the mandible commencing at retruded contact position (Stage 10) and passing through full closure (Stage 3), end to end (Stage 4), minimum protrusion (Stage 5), and terminating in maximum protrusion (Stage 6). In the sagittal plane a comparison of the movement paths of the lower incisor and condylion through the above stages is illustrated in Figure 75. From retruded contact to full closure the condylar guidance was slightly steeper than the incisal guidance. However, from full closure to end to end the condylar and incisal guidances appear parallel. It is interesting to note that as the incisal guidance is lost when the mandible moves from end to end to minimum protrusion the condylar guidance remains at the same grade and then tapers off until maximum protrusion position is attained.

Although Ingervall (1972) found no correlation between the inclination of the condyle path and the incisal path, the results of the present study suggest that in Class I normal occlusions with minimum overbite, the incisal path inclination and the condylar path inclination are equal. This may not be true of malocclusions, as Posselt (1968) stated that to have parallel inclination paths is uncommon and either the incisal path inclination was steeper than the condylar path inclination or the opposite. Regarding the etiology of Class I normal occlusions it is interesting to speculate that apart from a favourable skeletal pattern,

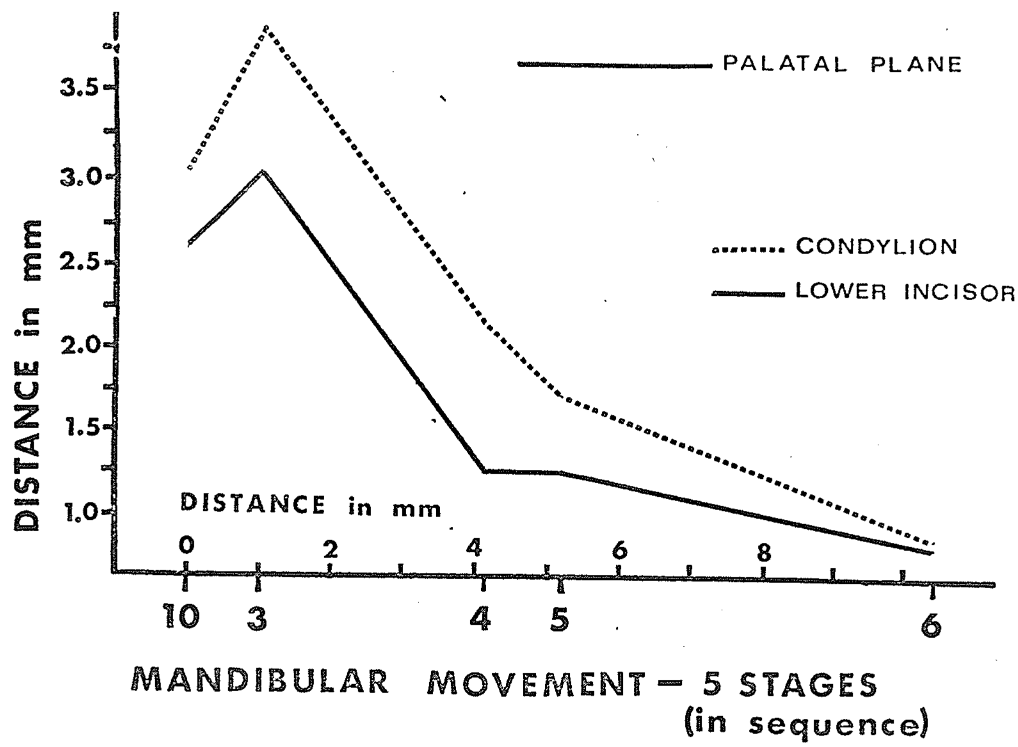


Figure 75. A graph comparing the incisal and condylar guidances in man from retruded contact position (Stage 10) to maximum protrusion (Stage 6).

a contributing factor may be that in the early mixed dentition where the articular eminence is not fully developed (Ricketts, 1966), the presence of a minimum overbite results in a shallow incisal guidance. This produces greater attrition, and consequently, the late mesial shift of the lower molars could occur with greater physiological facility. Thus, through the years of developmental growth, the incisal guidance may have a definite influence upon the contours of the glenoid fossa and the pattern of the movements of the condyles when the teeth are in function.

The results of the anterior border opening movement showed that the mean opening from maximum protrusion to wide open was 33.13 mm. ± .48 mm. Although the difference was not significant, the females showed a trend to opening wider than the males, 33.73 mm. ± .47 mm., and 32.52 mm. ± .49 mm., respectively. The conclusions of the present study do not agree with the findings of Sheppard and Sheppard (1965), who noted a larger opening capacity between the ages of eleven and fifteen than that in adults. The adult mean opening capacity was approximately 50 mm. for twenty to thirty year old adults. Nevakari (1960) noted no significant differences between sexes in the opening capacity of the six to twelve year range, however, in the twenty to twenty-five year range, the mean opening capacity was 56 mm. with the males opening wider than the females. The author's results was 33.13 mm. ± .48 mm. Notwithstanding the fact that the present study was cross-sectional, the results tend to agree with that of Nevakari who found the maximal opening capacity increased steadily to approximately 55 mm. from 7 to 20 years of age.

The assessment of the range of the anterior border opening movement can be used to assess functional disorders and/or evaluate the effect of various therapeutic measures.

Many investigators have shown that movement occurs from maximum intercuspation to retruded contact position. Bjork (1947), Heath (1949), and Posselt (1952) stated that movement ranged from 1-1½ mm. Bjork did not clearly state his methodology, Heath used plaster casts and Posselt had the subject's head secured in a cephalostat while radiographs were taken in retruded contact and intercuspal position. Donovan's study (1953) also utilized cephalometry but, as the patient was not touched, the result was more physiological. He observed the distance moved to be 1.03 mm. ± .43 mm.

The results of the present study showed a mean movement between maximum intercuspation and retruded contact position of .65 mm. ± .34 mm. with the male and female movements being .70 mm. ± .49 mm. and .59 mm. ± .47 mm., respectively. These results tend to agree with more recent studies, namely Sicher (1960) who stated at least ninety per cent of healthy young adults with a full complement of teeth and normal occlusion could retrude the mandible 0.5 mm. to 1.0 mm. from maximum intercuspation. In addition, Ingervall (1964) noted a mean difference in the sagittal plane between the maximum intercuspation and the retruded contact positions of 0.85 mm. ± 0.35 mm. and a gnathological study by Hodge (1965) determined the distance of the slide to be 0.44 mm. ± 0.54 mm. in the anteroposterior direction. The concept of Stuart (1955) which stated that for condylar centricity a slide from retruded contact to maximum intercuspation was pathologic, does not appear tenable considering the results of subsequent investigators.

In spite of these findings, orthodontists, in general, have been blamed by the rest of the dental profession for many of the occlusal problems found in mature patients who had undergone orthodontic treatment during the teenage years. The accusation has been that the basis of the orthodontist's understanding of occlusion was based on the establishment of a normal mesial-distal relationship of the posterior teeth, with ideal overbite and overjet. "Orthodontic occlusion",meaning the establishment of the cusp-to-marginal ridge interdigitation of the premolars, is considered abnormal by gnathologists such as Stuart and Stallard (1960). Although the subject of occlusion is controversial, the goal of many clinicians treating occlusal problems is the elimination of discrepancies between retruded contact position and habitual occlusion.

There are many variables which can affect the result of an orthodontic case, such as maxillomandibular disproportions, neuromuscular and occlusal abnormalities and individual variations between patients, etc. The objective of synchronizing retruded contact position and habitual occlusion is particularly difficult in skeletal Class II extraction cases. Roth (1969) indicated that as the maxillary molars were moved distally and the mandibular molars were moved mesially, there was a tendency on the part of the patient to anteriorize the mandible in an attempt to coordinate the arch widths. This helped contribute to a centric slide. It must be remembered that as the maxillary molars were moving distally, they were also moving buccally, in order to remain in the alveolar trough. In contrast, the lower molars moving mesially were also moving lingually for the same reason. Although there is some buccal lingual leeway in the alveolar trough there is a limitation; therefore, to expect that all orthodontic cases can be corrected to Class I occlusion with no centric slide is not realistic. The limiting factors could be the width of the respective alveolar processes and the degree of deviation from the skeletal norm. Roth has stated that severe skeletal-facial deformities represent problems which provide limitations not only to what can be accomplished orthodontically, but also to what can be accomplished functionally.

Whether orthodontists approve or disprove, the success or failure of orthodontic treatment is often evaluated by other clinicians who observe the patient years after orthodontic treatment has been terminated. Where possible, every effort should probably be made to produce or maintain a centric slide in the range of normalcy which is .65 mm. ± .34 mm. according to the observations of the present study.

Ingervall (1964) showed that the retruded contact position of the mandible can be recorded accurately for ten year old children. The mean difference observed between habitual occlusion and retruded contact position in the sagittal plane was 0.85 mm. ± .06 mm. It was also illustrated that the sagittal difference between the two positions was the same for children and adults. As a result, the retruded contact position can be used as a reference position in orthodontic treatment, thus allowing the principles of functional analysis of occlusion based on retruded contact position, to be utilized instead of the most commonly used rest position.

This study has endeavoured to describe the skeletal and dental characteristics as well as some of the functional patterns of a Class I "normal" occlusion group of thirteen year old children in order to provide a base from which to assess those subjects possessing malocclusions and/or aberrant functional patterns. A similar study for other classifications of malocclusions would be useful.

Although no immediate comprehensible answers are available, the foregoing discussion has raised such questions as: Do growth and development changes affect learned functional patterns? How limited is the degree of adaptation regarding the ability of the neuromuscular mechanism to function in an environment which has been altered orthodontically?

Timms (1964) has said that orthodontic treatment is a qualitative and/or quantitative morphological change, and success or failure will depend on whether or not the change is within the permissible range of adaptation.

CHAPTER VI

SUMMARY AND CONCLUSIONS

A cross sectional cinefluorographic and cephalometric radiographic study was undertaken utilizing linear and angular measurements. The study endeavoured to evaluate whether a sex diathesis existed regarding the relationship of the craniofacial, skeletal and dental components and to assess certain functional movements of the stomatognathic mechanism during a swallowing and mandibular movement sequence.

The sample consisted of 27 female and 21 male school children who possessed Angle's Class I "normal" occlusion. The mean age of the sample was 13 years, 5 months, while the ages ranged from 11 years, 11 months to 14 years, 2 months.

An evaluation of the significant differences between males and females and the interaction of the two sexes during the different stages of deglutition and mandibular movement were determined utilizing a mixed analysis of variance. The multitude of variables which were measured for the study were subjected to a factor analysis in order to reduce the number of cephalometric variables to a smaller number of components. The statistical and subjective assessment of the results suggests the following conclusions:

1. The facial and profile type for a Class I "normal" occlusion sample in Winnipeg, Manitoba appears to be retrognathic and convex.

2. Separate sex norms for routine orthodontic cephalometric radiographic diagnosis are probably not indicated.

3. The significant differences between the two sexes observed for all the variables involving the hyoid bone in both the cephalometric study and the deglutition sequence suggest the sexes should probably be separated for future studies in which that anatomical component is involved.

4. The use of mechanical restraining ear rods in rest position appears to alter head posture, resulting in an extension of the head in relation to a horizontal plane. In addition, the mandible was displaced in a rotatory manner downward and backward in the female and translated forward and superiorly in the male.

5. Differences in head posture were observed during the ten stage mandibular movement sequence, yet were not observed during the five stage deglutition sequence. This suggests that a greater degree of neuromuscular integration probably exists between the postural muscles of the head and the oropharyngeal mechanism than between the postural muscles of the head and the muscles of mastication.

6. Cinefluorography, rather than cephalometric radiography, appears to be a more accurate method of determining the centres of rotation of the mandible from rest position to habitual occlusion. This conclusion is founded on the mandibular displacement caused by the restraining ear rods used in the lateral cephalometric radiograph. Nevertheless, the standard deviations for both the cine and the ceph were

very large, indicating that the subjects probably presented much greater differences than the means might suggest.

7. The condylar and incisal guidance paths appear to be parallel from habitual occlusion to end to end position in Class I "normal" occlusion where there is a minimum overbite and overjet.

8. The presence of a slide from habitual occlusion to retruded contact position observed in the present sample suggests that for 13 year old Class I "normal" occlusions the absence of condylar centricity should not be considered pathologic.

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A P P E N D I X

TABLE XI

PRINCIPLE FACTOR PATTERN SHOWING LOADINGS OF 5 FACTORS EXTRACTED FROM CORRELATION MATRIX IN 90 CEPHALOMETRIC VARIABLE FACTORS*

No.	Variable	Facial type I	Profile type II	Retro-gnathism III	Head Posture IV	Overjet V
1	Facial angle	679				
2	Convexity	-748				
3	SNA		697			
4	SNB		661			
5	ANB	-701				
6	Md.Pl. Angle	-717				
8	$\underline{1}$-SN		719			
10	$\underline{\underline{\bar{1}}}$-AP	-615				
11	$\bar{1}$-AP	-582		-600		
12	$\bar{1}$-NB	-669		-611		
13	Pog-NB	857				
14	Ba-S			-619		
16	S-N				553	
17	Ba-N		-595			
19	Me-Go	676				
20	Ba-Pog	646		-624		
23	Atlas-ANS			-564		
24	Pog-NB	857				
27	$\bar{1}$-Md.Pl. (mm)			615		
28	$\underline{1}$-P.P. (mm)		588			
33	$\bar{N}$-S-Ar (degrees)					-541
34	Gonial Angle				-661	
36	FH-SN Angle		-791			
37	Hyoid-SN Angle		-622			
38	Y-Axis Angle	-666				
39	Pog-N-A Angle	-826				
40	SN-Pog Angle	657	569			
41	SN-Md.Pl. Angle	-596				
42	$\bar{1}$-FH Angle	689				
43	$\bar{1}$-SN Angle	803				
44	$\underline{1}$-PP (angle)					-622
45	$\underline{\bar{1}}$-NA Angle					576
46	$\bar{1}$-NB Angle	-595		-550		
47	$\underline{6}$-SN Angle		-714			
48	$\bar{6}$-SN Angle		-682			
49	Me-tgo-distance	645				
55	Lower Lip Thickness	568				
61	LFH			-683		
62	Length of Lips			-641		
63	Nose to Chin			-764		
69	Pog-P.P.(rest-mm)			589		

(Continued)

TABLE XI (CONTINUED)

No.	Variable	Facial type I	Profile type II	Retro-gnathism III	Head Posture IV	Overjet V
70	SN-TV (rest)				-624	
71	PP-TV (rest)				-766	
73	$\bar{I}$-PP (rest-mm)					-586
75	Na-Ba-TV (rest)				-642	
76	Me-tgo (rest)	592				
77	$\bar{I}$-PP (occlusion)			614		
78	Pog-PP (occlusion)		547	675		
80	SN-TV (occlusion)		-546		-650	
81	PP-TV (occlusion)				-818	
82	Facial plane-TV (occlusion)				819	
85	Na-Ba-TV (occlusion)				-641	
86	Me-tgo (occlusion)	605				
	% Variability Accounted for	16	13	12	9	7

* Only significant loadings are reported (decimal points are dropped).

TABLE XII

MEANS, STANDARD DEVIATIONS AND RANGES OF THE SKELETAL COMPONENTS FOR 21 MALES AND 27 FEMALES WITH CLASS I "NORMAL" OCCLUSION

SKELETAL PATTERN	SEX	MEAN	S.D.	RANGE
Facial Angle (Down's)	M	85.6	± 3.5	82.1 - 91.6
	F	86.2	± 3.6	78.6 - 92.9
Facial Angle (SN-Pog)	M	79.5	± 3.2	73.9 - 86.1
	F	79.5	± 3.8	72.0 - 86.9
Angle of Convexity	M	4.9	± 4.7	-3.7 - 12.7
	F	5.03	± 4.4	-8.4 - 13.4
SNA	M	81.9	± 3.0	74.2 - 88.1
	F	81.9	± 3.7	74.2 - 87.8
SNB	M	78.9	± 3.0	73.1 - 85.1
	F	78.9	± 3.7	71.5 - 85.9
ANB	M	2.9	± 1.7	0.3 - 5.9
	F	2.9	± 1.5	-1.0 - 6.0
Mandibular Plane Angle	M	26.6	± 4.8	14.9 - 35.1
	F	24.8	± 4.7	15.8 - 34.8
SN to Mandibular Plane	M	32.7	± 4.8	21.1 - 39.2
	F	31.4	± 5.8	19.5 - 42.9
Pog to NB (mm)	M	0.9	± 1.1	-1.7 - 3.6
	F	1.0	± 1.4	-1.7 - 5.5

TABLE XIII

MEANS, STANDARD DEVIATIONS AND RANGES OF THE DENTAL COMPONENTS FOR 21 MALES AND 27 FEMALES WITH CLASS I "NORMAL" OCCLUSION

DENTURE PATTERN	SEX	MEAN	S.D.	RANGE
$\underline{1}$ to $\overline{1}$	M	127.4	± 9.0	104.7 - 144.3
	F	126.9	± 9.3	108.3 - 142.7
$\underline{1}$ to SN	M	103.4	± 5.2	95.2 - 110.7
	F	103.5	± 5.8	89.9 - 111.3
$\underline{1}$ to AP	M	6.1	± 1.8	3.0 - 9.9
	F	5.7	± 1.7	1.1 - 8.2
$\overline{1}$ to Mand. Plane	M	6.3	± 6.7	-5.2 - 19.8
	F	8.0	± 7.3	-1.5 - 27.0
$\overline{1}$ to AP (mm)	M	2.8	± 1.6	0.3 - 4.8
	F	2.6	± 1.8	-1.6 - 5.7
$\overline{1}$ to NB (mm)	M	4.9	± 2.2	.9 - 1.1
	F	4.7	± 1.8	- .2 - 8.4

TABLE XIV

MEANS, STANDARD DEVIATIONS AND RANGES OF THE SKELETAL AND DENTAL COMPONENTS FOR 21 MALES AND 27 FEMALES WITH CLASS I "NORMAL" OCCLUSION

SKELETAL PATTERN	MEAN	S.D.	RANGE
Facial Angle (Down's)	85.9	3.5	78.4 - 92.9
Facial Angle SN Pog	79.6	3.6	72.9 - 87.7
Angle of Convexity	5.1	4.5	-8.4 - 13.5
SNA	82.0	3.3	73.8 - 88.1
SNB	79.0	3.4	71.5 - 86.6
ANB	2.9	1.6	-1.2 - 6.7
Mandibular Plane Angle	25.3	4.7	14.2 - 35.1
SN to Mandibular Plane	31.7	5.5	20.3 - 39.6
Pog to NB (mm)	1.0	1.3	-2.5 - 5.5
DENTAL PATTERN			
$\underline{1}$ to $\overline{1}$	126.7	9.0	103.9 -139.1
$\underline{1}$ to SN	103.8	5.6	89.6 -113.9
$\underline{1}$ to AP (mm)	5.9	1.7	1.0 - 9.9
$\overline{1}$ to Mandibular Plane	7.6	7.2	-5.2 - 28.7
$\overline{1}$ to AP (mm)	2.6	1.6	-1.9 - 6.5
$\overline{1}$ to NB (mm)	4.8	2.0	- .9 - 9.0

TABLE XV

MEANS, STANDARD DEVIATIONS AND SIGNIFICANCE OF THE DIFFERENCES BETWEEN THE CEPHALOMETRIC AND DENTAL LINEAR MEASUREMENTS FOR 21 BOYS AND 27 GIRLS WITH CLASS I NORMAL OCCLUSION

VARIABLE	UNIT	BOYS			GIRLS			SIG.
Ba-S	mm.	44.21	±	2.36	42.96	±	2.10	
Ar-S	mm.	33.42	±	2.93	32.31	±	2.86	
S-N	mm.	67.95	±	2.78	65.70	±	2.86	**
Ba-N	mm.	101.94	±	3.76	99.21	±	3.58	*
Ar-N	mm.	90.71	±	3.47	88.39	±	4.17	*
Me-Go	mm.	74.73	±	3.81	73.14	±	4.79	
Ba-Po	mm.	101.53	±	5.41	99.41	±	4.95	
Ar-34	mm.	32.51	±	3.90	32.28	±	3.50	
ANS-PNS	mm.	44.43	±	4.58	44.75	±	2.82	
Atlas-ANS	mm.	93.46	±	4.27	90.72	±	4.14	*
Po-NB	mm.	.98	±	1.16	1.03	±	1.46	
Ptm-SN (vertical)	mm.	28.76	±	3.49	26.87	±	3.39	
Ptm-palatal plane (vertical)	mm.	14.72	±	3.62	15.74	±	3.39	
$\overline{1}$-mand. plane (vertical)	mm.	38.65	±	2.21	37.16	±	2.37	*
$\underline{1}$ palatal plane (vertical)	mm.	26.62	±	2.11	26.01	±	1.85	
Me-tgo	mm.	68.27	±	3.46	66.63	±	4.29	
Ar-tgo	mm.	42.82	±	4.78	43.32	±	4.49	
Ptm-ANS	mm.	48.58	±	2.50	47.60	±	3.30	
Ptm-"A" point	mm.	44.47	±	1.97	43.38	±	3.49	
UFH	mm.	50.09	±	2.57	48.27	±	3.34	*
LFH	mm.	57.19	±	3.82	55.59	±	3.47	

* - Significant at the 0.05 level.
** - Significant at the 0.01 level.

TABLE XVI

CRANIOFACIAL, SKELETAL AND DENTAL ANGULAR MEASUREMENTS IN 21 MALES AND 27 FEMALES WITH CLASS I "NORMAL" OCCLUSION

VARIABLE	MALES	FEMALES	SIG.
N-S-Ba	129.17 ± 4.20	130.95 ± 5.02	
N-S-Ar	123.33 ± 4.44	125.41 ± 4.66	
Gonial Angle	228.03 ± 3.87	229.12 ± 7.00	
Palatal Plane to Mandibular Plane	24.89 ± 4.72	24.78 ± 5.85	
FH-SN	6.13 ± 3.60	6.64 ± 4.42	
Hyoid-S-N	88.76 ± 4.09	91.39 ± 5.48	
Y-axis	58.77 ± 3.76	58.34 ± 3.96	
Po-N-A	2.38 ± 2.26	2.41 ± 2.13	
SN-Po	79.54 ± 3.27	79.56 ± 3.86	
SN-MP	32.79 ± 4.88	31.47 ± 5.87	
$\overline{1}$-FH	57.03 ± 7.56	57.14 ± 8.17	
$\overline{1}$-SN	50.89 ± 7.33	50.49 ± 7.27	
$\underline{1}$-palatal plane	111.15 ± 4.85	110.28 ± 4.59	
$\underline{1}$-NA	21.56 ± 4.43	21.61 ± 3.97	
$\underline{1}$-NB	28.10 ± 6.41	28.49 ± 6.81	
$\underline{6}$-S-N	68.15 ± 2.42	69.43 ± 3.20	
$\overline{6}$-S-N	66.79 ± 2.40	68.07 ± 3.20	

TABLE XVII

CRANIOFACIAL, LINEAR AND ANGULAR MEASUREMENTS OBTAINED IN REST POSITION ON THE LATERAL CEPHALOMETRIC RADIOGRAPH FOR 13 MALES AND 25 FEMALES

VARIABLE	UNIT	MALES	FEMALES	SIG.
$\bar{1}$-palatal plane	mm.	25.97 ± 3.09	26.46 ± 2.58	
Pog-palatal plane	mm.	58.94 ± 4.99	57.88 ± 3.88	
Me-tgo	mm.	67.87 ± 4.13	65.96 ± 4.82	
SN-True Vertical	degrees	95.73 ± 4.70	97.99 ± 7.35	
Palatal Plane—TV	degrees	87.10 ± 5.85	91.24 ± 6.33	
Facial Plane-TV	degrees	-5.29 ± 5.03	-2.82 ± 5.58	
$\bar{1}$-palatal plane	degrees	92.96 ± 5.47	91.44 ± 5.13	
Hyoid-palatal plane	degrees	92.32 ± 7.91	98.61 ± 6.39	*
Na-Ba-TV	degrees	116.36 ± 5.05	118.19 ± 6.34	

* Significant at the 0.05 level.

TABLE XVIII

CRANIOFACIAL, LINEAR AND ANGULAR MEASUREMENTS OBTAINED IN HABITUAL OCCLUSION ON THE LATERAL CEPHALOMETRIC RADIOGRAPH

VARIABLE	UNIT	MALES n-16	FEMALES n-25	SIG.
$\overline{1}$-palatal plane	mm.	22.91 ± 2.37	22.81 ± 2.35	
Pog-palatal plane	mm.	56.44 ± 4.41	54.66 ± 3.68	
Curve of Spee	mm.	0.84 ± 0.59	0.80 ± 0.49	
SN-TV	degrees	97.18 ± 4.87	98.29 ± 7.81	
Palatal plane-TV	degrees	88.54 ± 4.78	91.63 ± 5.94	
Facial plane-TV	degrees	3.53 ± 4.57	2.30 ± 5.56	
$\overline{1}$-palatal plane	degrees	98.31 ± 5.43	91.94 ± 5.27	
Hyoid-palatal plane	degrees	93.41 ± 8.30	100.48 ± 6.25	**
Na-Ba-TV	degrees	117.68 ± 3.27	117.63 ± 5.58	
Me-tgo	mm.	68.04 ± 3.85	66.52 ± 5.03	
Overjet	mm.	2.99 ± .90	2.62 ± .72	
Overbite	mm.	3.11 ± .94	3.00 ± 1.05	
Centre of Rotation	X-coordinate	11.79 ±24.38	19.19 ±16.63	
Centre of Rotation	Y-coordinate	19.73 ±16.31	17.18 ± 6.81	

** Significant at the 0.01 level.

TABLE XIX

HORIZONTAL (X) AND VERTICAL (Y) COORDINATES REPRESENTING THE CENTRE OF ROTATION OF THE MANDIBLE DURING EIGHT MANDIBULAR MOVEMENTS

MOVEMENT	COORDINATE	MALES	FEMALES	SIG.
rest-f.c.	X	20.70 ± 27.84	13.65 ± 7.11	
	Y	15.44 ± 6.70	17.86 ± 1.52	
rest-i.c.-f.c.	X	24.78 ± .97	26.09 ± 5.65	
	Y	17.66 ± .21	17.49 ± .93	
Mx.Pro-W.O.	X	16.86 ± .66	16.81 ± .50	
	Y	16.35 ± .82	16.91 ± .58	
W.O.-i.c.-f.c.	X	24.09 ± 17.26	25.89 ±25.95	
	Y	15.97 ± 6.99	15.27 ±11.87	
W.O.-f.c.	X	15.71 ± 1.05	15.99 ± .59	
	Y	17.08 ± 1.04	17.47 ± .54	
W.O.-retruded contact	X	15.95 ± .86	16.16 ± .62	
	Y	16.92 ± .94	17.36 ± .64	
rest-retruded contact	X	15.42 ± 13.79	17.96 ±13.19	
	Y	16.56 ± 1.11	17.20 ± 2.94	
f.c.-retruded contact	X	27.76 ± 15.92	18.68 ±11.23	
	Y	15.64 ± 1.68	17.27 ± 1.83	*

* Significant at the 0.05 level.

TABLE XX

MEANS AND STANDARD ERRORS OF SIX CINEFLUOROGRAPHIC VARIABLES FOR 15 MALE AND 16 FEMALE SUBJECTS COMBINED DURING THE 10 STAGE MANDIBULAR MOVEMENT SEQUENCE

STAGE	VARIABLES					
	$\underline{6}$ TO $\overline{6}$ (mm)	$\overline{I}$ TO PALATAL PLANE (mm)	$\overline{6}$ TO PALATAL PLANE (mm)	CONDYLION TO PALATAL PLANE (mm)	$\overline{I}$ to PALATAL PLANE (degrees)	PALATAL PLANE TO MAND. PLANE (degrees)
1	3.17 ± 0.28	25.01 ± 0.34	22.56 ± 0.19	15.77 ± 0.29	93.25 ± 4.66	26.73 ± 4.09
2	1.76 ± 0.28	23.07 ± 0.34	21.20 ± 0.19	15.98 ± 0.29	93.73 ± 4.66	25.53 ± 4.09
3	0.23 ± 0.28	21.36 ± 0.34	19.71 ± 0.19	16.98 ± 0.29	94.55 ± 4.66	24.95 ± 4.09
4	4.96 ± 0.28	24.94 ± 0.34	23.32 ± 0.19	13.40 ± 0.29	101.07 ± 4.66	25.01 ± 4.09
5	6.16 ± 0.28	24.95 ± 0.34	23.57 ± 0.19	12.49 ± 0.29	104.40 ± 4.66	24.33 ± 4.09
6	10.09 ± 0.28	25.46 ± 0.34	24.32 ± 0.19	10.78 ± 0.29	113.37 ± 4.66	23.53 ± 4.09
7	27.27 ± 0.28	58.59 ± 0.34	44.70 ± 0.19	13.31 ± 0.29	78.89 ± 4.66	52.89 ± 4.09
8	1.78 ± 0.28	22.80 ± 0.34	21.05 ± 0.19	15.84 ± 0.29	93.11 ± 4.66	25.17 ± 4.09
9	0.21 ± 0.28	21.11 ± 0.34	19.65 ± 0.19	16.88 ± 0.29	94.62 ± 4.66	24.85 ± 4.09
10	1.38 ± 0.28	22.01 ± 0.34	20.52 ± 0.19	15.76 ± 0.29	92.64 ± 4.66	24.59 ± 4.09

TABLE XXI

MEANS AND STANDARD ERRORS OF TWO CINEFLUOROGRAPHIC VARIABLES DURING THE 10 STAGE MANDIBULAR MOVEMENT SEQUENCE

MALES n-15	VARIABLES	
STAGE	HYOID TO PTM (ref. point 3) (mm)	HYOID TO PALATAL PLANE (mm)
1	59.22 ± 1.11	58.92 ± 1.06
2	58.81 ± 1.11	58.51 ± 1.06
3	58.40 ± 1.11	58.11 ± 1.06
4	57.18 ± 1.11	56.86 ± 1.06
5	56.74 ± 1.11	56.34 ± 1.06
6	55.74 ± 1.11	55.16 ± 1.06
7	72.60 ± 1.11	70.56 ± 1.06
8	63.96 ± 1.11	63.58 ± 1.06
9	62.63 ± 1.11	62.30 ± 1.06
10	64.69 ± 1.11	64.08 ± 1.06
FEMALES n-16		
1	53.16 ± 1.07	52.77 ± 1.03
2	53.86 ± 1.07	53.39 ± 1.03
3	54.02 ± 1.07	53.57 ± 1.03
4	52.25 ± 1.07	51.96 ± 1.03
5	51.28 ± 1.07	50.99 ± 1.03
6	49.83 ± 1.07	49.64 ± 1.03
7	63.99 ± 1.07	60.67 ± 1.03
8	56.33 ± 1.07	55.38 ± 1.03
9	56.24 ± 1.07	55.33 ± 1.03
10	59.85 ± 1.07	58.96 ± 1.03

TABLE XXII

MEANS AND STANDARD ERRORS OF 3 CINEFLUOROGRAPHIC VARIABLES TABLED FOR 14 MALE AND 15 FEMALE SUBJECTS COMBINED DURING THE 5 STAGE DEGLUTITION SEQUENCE

STAGE	VARIABLES		
	TONGUE TIP TO DORSUM OF TONGUE (mm)	DORSUM OF TONGUE TO POSTERIOR OF TONGUE (mm)	POSTERIOR-HYOID-TONGUE TIP (degrees)
1	35.03 ± 0.85	35.37 ± 0.84	87.28 ± 17.64
2	36.99 ± 0.85	38.73 ± 0.84	92.35 ± 17.64
3	41.59 ± 0.85	38.29 ± 0.84	103.88 ± 17.64
4	38.59 ± 0.85	45.78 ± 0.84	119.66 ± 17.64
5	34.76 ± 0.85	37.08 ± 0.84	87.66 ± 17.64

TABLE XXIII

MEANS AND STANDARD ERRORS OF FIVE CINEFLUOROGRAPHIC VARIABLES DURING THE 5 STAGE DEGLUTITION SEQUENCE

STAGES	VARIABLES				
	POSTERIOR OF TONGUE TO HYOID (mm)	HYOID TO PTM (mm)	HYOID TO PALATAL PLANE (mm)	TONGUE TIP TO DORSUM TO POSTERIOR (degrees)	HYOID TO TIP TO DORSUM (degrees)
MALES n-14					
1	31.45 ± 0.79	58.72 ± 0.86	58.42 ± 0.84	101.84 ± 22.07	72.00 ± 15.94
2	31.26 ± 0.79	56.70 ± 0.86	56.40 ± 0.84	119.73 ± 22.07	60.45 ± 15.94
3	28.61 ± 0.79	51.74 ± 0.86	51.53 ± 0.84	106.56 ± 22.07	58.58 ± 15.94
4	36.47 ± 0.79	49.73 ± 0.86	49.16 ± 0.84	113.66 ± 22.07	62.11 ± 15.94
5	30.00 ± 0.79	56.75 ± 0.86	56.54 ± 0.84	108.14 ± 22.07	68.66 ± 15.94
FEMALES n-15					
1	27.16 ± 0.76	54.82 ± 0.84	54.03 ± 0.81	110.75 ± 21.33	63.46 ± 15.40
2	27.32 ± 0.76	53.03 ± 0.84	52.31 ± 0.81	128.15 ± 21.33	49.36 ± 15.40
3	26.24 ± 0.76	47.64 ± 0.84	47.30 ± 0.81	109.82 ± 21.33	56.66 ± 15.40
4	33.70 ± 0.76	46.28 ± 0.84	45.97 ± 0.81	112.49 ± 21.33	62.29 ± 15.40
5	25.17 ± 0.76	51.99 ± 0.84	51.52 ± 0.81	110.25 ± 21.33	60.37 ± 15.40

TABLE XXIV

MEANS AND STANDARD ERRORS OF SEVEN CINEFLUOROGRAPHIC VARIABLES FOR 14 MALES AND 15 FEMALES DURING THE 5 STAGE DEGLUTITION SEQUENCE

	VARIABLES						
	POSTERIOR OF TONGUE TO HYOID (mm)	HYOID TO TONGUE TIP (mm)	TONGUE TIP TO 1 (mm)	1 TO HYOID (mm)	TONGUE TIP TO PALATAL PLANE (mm)	DORSUM TO POSTERIOR TO HYOID (degrees)	TONGUE TIP TO PALATAL PLANE (degrees)
WATER (n-11)							
1	29.20 ± 0.89	47.08 ± 1.06	17.57 ± 0.88	63.11 ± 0.82	29.79 ± 0.55	99.62 ± 32.05	43.14 ± 9.97
2	29.67 ± 0.89	59.92 ± 1.06	4.99 ± 0.88	62.08 ± 0.82	22.68 ± 0.55	85.25 ± 32.05	26.77 ± 9.97
3	29.48 ± 0.89	51.54 ± 1.06	6.31 ± 0.88	54.83 ± 0.82	22.14 ± 0.55	82.45 ± 32.05	26.86 ± 9.97
4	35.45 ± 0.89	46.45 ± 1.06	6.98 ± 0.88	50.97 ± 0.82	22.89 ± 0.55	63.59 ± 32.05	28.29 ± 9.97
5	26.97 ± 0.89	54.53 ± 1.06	8.00 ± 0.88	60.35 ± 0.82	23.98 ± 0.55	99.24 ± 32.05	30.28 ± 9.97
SALIVA (n-18)							
1	29.41 ± 0.70	53.17 ± 0.83	10.57 ± 0.69	62.07 ± 0.64	24.78 ± 0.43	97.77 ± 25.06	32.24 ± 7.79
2	28.91 ± 0.70	57.87 ± 0.83	5.78 ± 0.69	60.64 ± 0.64	21.54 ± 0.43	89.34 ± 25.06	25.65 ± 7.79
3	25.36 ± 0.70	54.59 ± 0.83	6.73 ± 0.69	58.87 ± 0.64	21.87 ± 0.43	98.17 ± 25.06	26.62 ± 7.79
4	34.73 ± 0.70	46.69 ± 0.83	6.88 ± 0.69	51.60 ± 0.64	22.59 ± 0.43	66.54 ± 25.06	27.64 ± 7.79
5	28.20 ± 0.70	52.53 ± 0.83	9.79 ± 0.69	60.34 ± 0.64	23.83 ± 0.43	98.02 ± 25.06	30.76 ± 7.79

TABLE XXV

MEANS AND STANDARD ERRORS OF ONE CINEFLUOROGRAPHIC VARIABLE

STAGE	VARIABLE: HYOID TO PALATAL PLANE (degrees)	
	WATER n-11	SALIVA n-18
MALES		
1	93.64 ± 8.98	89.01 ± 6.69
2	93.42 ± 8.98	88.50 ± 6.69
3	90.13 ± 8.98	89.43 ± 6.69
4	87.48 ± 8.98	80.97 ± 6.69
5	91.79 ± 8.98	88.77 ± 6.69
FEMALES		
1	97.18 ± 8.20	97.93 ± 6.69
2	97.62 ± 8.20	97.71 ± 6.69
3	90.71 ± 8.20	97.61 ± 6.69
4	84.44 ± 8.20	89.79 ± 6.69
5	95.86 ± 8.20	96.61 ± 6.69

G L O S S A R Y

GLOSSARY

Cinefluorographic landmarks - mandibular movement.

Landmark:

1. The superior termination of the true vertical.
2. The inferior termination of the true vertical.
3. Origin.

   A reference point represented by the intersection on the palatal plane of a perpendicular dropped from the most inferior point on the pterygo-maxillary fissure (PTM).
4. Direction.

   A reference point represented by the point of intersection on the palatal plane of a perpendicular erected from "A" point.
5. The most inferior occlusal point on the mesio-buccal cusp of the maxillary first permanent molar.
6. The incisal edge of the mandibular central incisor.
7. Pogonion (Pog).

   The most anterior point on the contour of the chin.
8. Menton (Me).

   The most inferior point on the symphysis menti of the mandible.
9. The most inferior point on the posterior one third of the lower border of the mandible.
10. Gonion (Go).

    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.

11. Condylion.

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

12. The point on the buccal groove of the mandibular permanent first molar which in habitual occlusion is superimposed by the occlusal edge of the mesiobuccal cusp of the maxillary first molar (landmark 5).

13. The most anterior point on the hyoid bone.

Cinefluorographic landmarks - deglutition.

Landmark:

Landmarks 1,2,3, and 4 are similar to the cinefluorographic landmarks 1,2,3, and 4 (mandibular movement) previously described.

5. The incisal edge of the maxillary central incisor.

6. A point tangent to the anterior tip of the tongue.

7. A point tangent to the dorsal surface of the tongue.

8. A point on the posterior border of the tongue at a level tangent to the inferior border of Cervical 2.

9. A point tangent to the anterior edge of the hyoid bone.

Cephalometric landmarks.

Landmark:

1. Occipital point.

   The most posterior point on the occipital bone.

2. Porion.

   The mid-point on the upper edge of the external auditory meatus. As a cephalometric radiograph landmark it is located 4 millimeters directly superior to the mid-point of the metal ear rods.

3. Frontale.

   The most anterior point on the frontal bone determined by a perpendicular line from the S-N line.

4. Nasion.

   The mid-point of the frontonasal suture at its most anterior margin.

5. Nasal tip.

   The most anterior inferior point on the nasal bones.

6. Orbitale.

   The deepest point on the infraorbital margin of the bony orbit.

7. Soft tissue nasion.

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

8. Pronasale.

   The most anterior point on the contour of the soft tissue nose as measured from the N-Pog line.

9. Soft tissue A point.

   The most posterior point of the philtrum of the upper lip.

10. Labrale superius.

    The most prominent point on the upper lip measured perpendicular to the N-Pog line.

11. Stomion.

    The lowest point on the upper lip or the highest point on the lower lip (Burstone, 1952).

12. Labrale inferius.

    The most prominent point on the lower lip measured perpendicular to the N-Pog line.

13. Soft tissue B point.

    The most posterior point on the contour between the labrale inferius and the soft tissue pogonion.

14. Soft tissue pogonion.

    The most prominent point on the contour of the soft tissue covering of the chin.

15. Menton (Me).

    The most inferior point on the symphysis menti of the mandible.

16. Pogonion (Pog).

    The most anterior point on the contour of the chin.

17. B point (B).

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

18. The apex of the mandibular central incisor.

19. The incisal edge of the mandibular central incisor.

20. The incisal edge of the maxillary central incisor.

21. The apex of the maxillary central incisor.

22. A point (A).

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

23. Anterior nasal spine (ANS).

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

24. Posterior nasal spine (PNS).

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

25. Pterygomaxillary fissure (PTM).

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 radiographic point is the most posterior point on the posterior wall of the maxillary tuberosity.

26. Sella (S).

The centre of the sella turcica (pituitary fossa).

27. Basion (Ba).

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

28. Articulare (Ar).

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

29. The point of intersection of a tangent to the superior border of the odontoid process of Cervical 2.

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

31. A point tangent to the anterior edge of the hyoid bone.

32. Distobuccal cusp tip of the maxillary left first molar.

33. Distobuccal cusp tip of the mandibular left first molar.

34. Gonion (Go).

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.

35. The buccal cusp tip of the lower left first bicuspid.

36. Direction.

A reference point on the palatal plane formed by the intersection of a perpendicular erected from A point.

37. Origin.

A reference point on the palatal plane formed by the intersection of a perpendicular dropped from the most inferior point on the pterygomaxillary fissure (PTM).

38. The most inferior point on the true vertical.

39. The most superior point on the true vertical.