1981

The Ability of Standard Cephalometric Techniques to Determine Accurately Repositioning of the Hyoid Bone Through the Use of a Tongue Crib

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THE ABILITY OF STANDARD CEPHALOMETRIC TECHNIQUES TO DETERMINE ACCURATELY REPOSITIONING OF THE HYOID BONE THROUGH THE USE OF A TONGUE CRIB

by

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A Thesis Submitted to the Faculty of the Graduate School
of Loyola University of Chicago in Partial Fulfillment
of the Requirements for the Degree of
Master of Science

June

1981

ACKNOWLEDGMENTS

I would like to take this opportunity to express my sincere thanks and deep gratitude to Dr. Douglas C. Bowman, my thesis advisor, for his tremendous help and guidance.

I also wish to express my gratitude to Dr. Bernard Pawlowski and Dr. Joseph Gowgiel for their steady support and guidance.

I will always be indebted to Loyola University and Dr. Milton Braun for making my graduate education possible.

I fondly acknowledge the inspiration of my parents to strive to better my knowledge.

Most important, I wish to acknowledge the support of my wife, Patricia, because without her understanding and love, none of this would have been possible.

VITA

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Dr. Inda is married to Patricia Louise and has three sons: Daniel 12, David 11, Douglas 8.

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INTRODUCTION AND STATEMENT OF PROBLEM

The purpose of this study was to determine if standard cephalometric techniques can be used to measure repositioning of the hyoid bone following forced distal displacement of the tongue through the use of a tongue crib.

In previous studies at Loyola University, Cuozzo and Bowman (1975), Gobeille and Bowman (1976), it was shown that hyoid bone position did influence tongue accommodation. In these studies it was hypothesized that subjects with the hyoid positioned near the mandible have greater potential for tongue adaptation than subjects presenting hyoids positioned farther from the mandible.

Augustson (1976), designed a study to test this hypothesis by dividing his subjects into two groups. One group had the hyoid positioned close to the mandible, another group had the hyoid positioned relatively farther away. His subjects were divided into the two groups by using both a lateral cephalogram and a cinefluorographic sequence of each subject's normal swallow sequence. Due to discrepancies between the lateral cephalogram and the cinefluorographic film of the hyoid bone at rest, he discarded the cephalogram as being inaccurate. The results of his study did show, though, that a statistically significant result could be obtained as to which subjects would get tongue adaptation and which would not, based on the position of the hyoid bone at rest relative to the lower border of the mandible.

This study was designed to test for two answers: (1) could the hyoid bone at rest be consistently captured with a lateral cephalogram, and (2) could subjects be predicted and categorized into groups that would adapt with forced posterior placement of the tongue and those that would not based on hyoid position to the lower border of the mandible. A group of twenty-five subjects was chosen. Both cinefluorographic swallow sequence and a specialized lateral cephalometric technique were used. Then a tongue crib was placed to distallize the tongue posteriorly and another cinefluorographic and special cephalometric technique were repeated. From the films prior to tongue crib placement predictions were made as to adaptation and a determination was made whether the tongue could be captured at rest on the cephalogram. As to the film taken twenty-four hours after crib placement, the predictions were tested for statistical significance.

REVIEW OF THE LITERATURE

A. The Hyoid Bone

The hyoid bone is shaped like a horseshoe and is referred to by Sicher as the skeleton of the tongue. It is suspended from the tips of the styloid processes of the temporal bones by the stylohyoid ligaments (Gray 1973). The bone consists of a body and paired greater and lesser horns. It is located just above the thyroid cartilage in the middle sagittal third of the neck between the third and fourth cervical vertebrae.

According to Orban (1966), the hyoid has its origins from the second and third branchial arches. The upper medial part of the body and the lesser cornua are derived from the second arch, while the greater cornua and the majority of the body come from the third arch. The bone is ossified from six centers: two within the body, and one within each horn. Ossification begins in the greater horn near the end of fetal life; in the body, shortly afterward; and in the lesser horns, during the first and second year after birth.

According to Gray (1973) the lesser horns are small conical eminences which arise superiorly at the junction of the body and greater horns. The attachment to the stylohoid ligament is at the apex of each cornua. The Chondroglossus muscle originates from the medial base. The body is quadrilateral in form and anteriorly is divided by a transverse ridge into superior and inferior portions. The superior surface serves for muscle attachments of the geniohyoid and genioglossus muscles. The inferior surface gives insertion for the sternohyoid, mylohyoid and omohyoid muscles on its anterior surface. The posterior surface of the body is smooth and separated from the epiglottis by the hyothyroid membrane and some loose areolar tissue. The superior border is rounded, and gives rise to the thyrohyoid membrane.

The greater cornua project back from the lateral borders of the body. Dorsolaterally, the stylohyoid, thyrohyoid, and digastric muscles insert into the anterior two-thirds of the greater horn. The greater horn, superiorly, gives origin to the middle pharyngeal constrictor; and, inferiorly, to the hyoglossus muscle.

The hyoid is a non-articulating bone, suspended entirely by ligaments and tendons attached to several structures (see Figure 1).

1. tongue (via the hyoglossus and genioglossus)
2. mandible (via the mylohyoid, geniohyoid, genioglossus and digastric muscles)
3. base of skull (via the stylohyoid ligament and digastric muscles)
4. sternum (via sternohyoid muscles)
5. scapula (via omohyoid muscles)

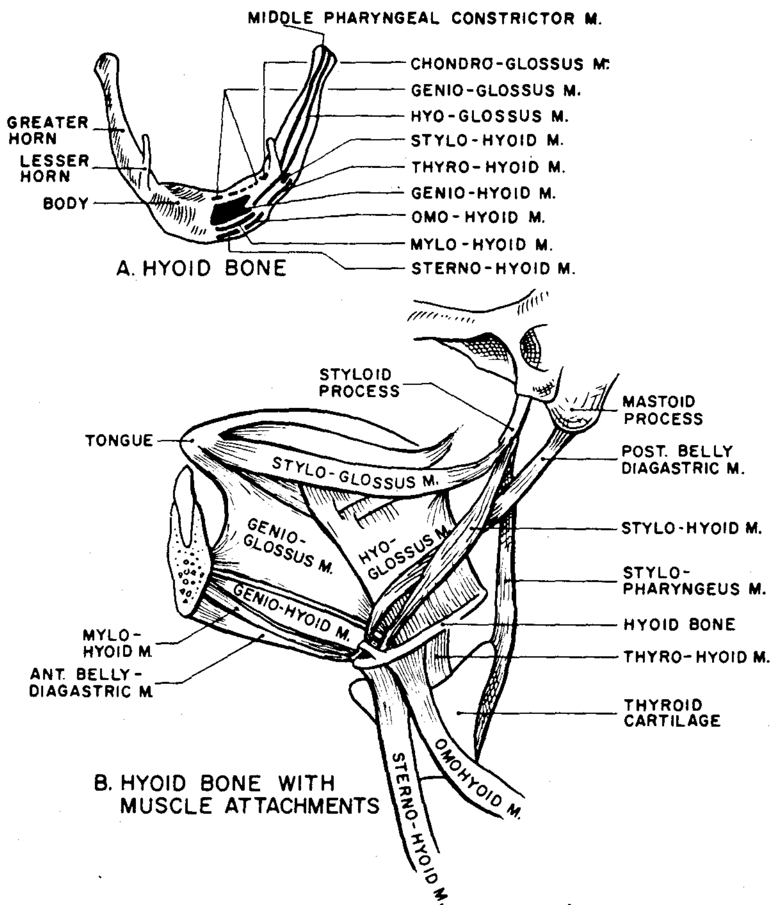


Figure 1

The Hyoid Bone and Attachments

6. thyroid cartilage (via hyothyroid membrane and ligament)
7. pharynx (via middle constrictor)

The genioglossus moves the tongue forward, backward, or downward. The hyoglossus depresses the tongue and draws its sides down. The styloglossus draws the tongue up and backward. The intrinsic muscles which consist of the longitudinalis superior, or the longitudinalis inferior, the transversus, and the verticalis, are mainly concerned with changing the shape of the tongue, i.e., shortening, narrowing, and curving actions.

In examining the group functions of the hyoid muscles they can be divided into two groups: suprahyoid and infrahyoid.

The group effect of the suprahyoid which consists of the digastric stylohyoid, mylohyoid, and geniohyoid act in combination in two important functions. During deglutition, the hyoid bone is raised along with the base of the tongue by the suprahyoids, and in mouth opening, when the hyoid is fixed by its depressors, the suprahyoids aid in opening the mouth. In the first stage of swallowing, the hyoid bone is raised up and forward by the combined action of the geniohyoid, anterior bellies of the digastric and the mylohyoid muscles. Once the bolus has passed through the pharynx, the posterior bellies of the digastric and the stylohyoid pull the hyoid posteriorly which assists in preventing the food from regurgitating.

The Infrahyoids (sternohyoids, sternothyroid and omohyoid) depress the larynx and hyoid following the superior anterior movement in swallowing. During mouth opening, this group fixes the hyoid enabling the suprahyoids to depress the mandible. The omohyoid not only depresses the hyoid, but also carries it backward to either side. This muscular control of the suspended hyoid bone lends it to ranges of physiologic adaptability through cooperative constriction and relaxation of muscles.

A major limiting factor on the hyoid is the stylohyoid ligament which is attached from the base of the temporal bone to the lesser cornua of the hyoid.

Thompson (1941) noted that change in position of the mandible influenced the hyoid position. He concluded that the hyoid moved only slightly during the opening rotation of the mandible. Mainland (1945) felt that the hyoid acted as a platform whereas fixing one set of muscles enabled the others to work off it.

Wood (1956) found direct correlation of the head and hyoid in that when the head was raised the hyoid was elevated and that the reverse was also true.

Sloan (1956) described two variations of hyoid movement during deglutition: circular and elliptical. Fink (1968) introduced a third pattern, observing that the hyoid moved in a triangular pattern during deglutition in some instances.

Ingervall (1970) felt that because the hyoid was free floating it would vary with different muscle pulls on it. He concluded that when the jaw is moved from the intercuspal to the retruded position the hyoid moves in an inferior direction due to the musculature's effect upon it. In a followup study (1970) he reported that: (1) The movements of the mandible between intercuspal position and retruded position and the associated movements of the hyoid showed no statistical significance. (2) That the movement of the mandible between intercuspal position and <u>postural</u> position and the associated movement of the hyoid was proved to be correlated with facial and dental morphology. (3) Also that the horizontal movement of the mandible between intercuspal position and <u>postural</u> position was positively correlated with the sagittal apical base difference between upper and lower jaw. (4) The vertical movement of the hyoid bone on movement of the mandible from intercuspal position to <u>postural</u> position was negatively correlated with the height of the face. This means that if the height of the face is small, the hyoid tends to move inferiorly on movement of the lower jaw from intercuspal position to postural position, while if the height is great the hyoid will move superiorly.

Brodie (1961) called attention to the fact that the hyoid's role is to maintain patent airspace during mandibular movements.

On observing Class I, II, and III malocclusions, Grant (1959) noted from cephalometric films that the hyoid maintained a constant position. He stated that the musculature, not the occlusion of the teeth, determines the position of the hyoid bone.

Bench (1963) found the hyoid moved downward in conjunction with cervical bone growth. He revealed that the hyoid descended gradually from the third cervical vertebra at age three to a position opposite the fourth cervical vertebra in adulthood.

Fink (1968), in a study of hyoid position in three types of individuals, normal occlusion, functional open bites, and skeletal open bites, reported that the hyoid positions were not significantly different for the three.

Durzo and Brodie (1962), in a longitudinal study involving cephalometrics reporting on five subjects with normal occlusion, found the hyoid to be positioned opposite the lower portion of the third cervical and the upper portion of the fourth cervical vertebrae. It was stated that the position anteroposteriorly depends on the relative length of the muscles running from the hyoid to the base of the cranium and the mandibular symphysis. They stated that during development the hyoid descends as the cervical vertebrae grow and as the posterior cranial base and mandible descend. But the relative position of the hyoid is invariable.

Sloan et al. (1967), in a study of comparative hyoid movement during swallowing in the Class I and Class II malocclusions, showed the anteroposterior location of the hyoid to be found near the anterior root of the pterygoid plates. He found that Class I malocclusions, even though exhibiting no skeletal difference from other malocclusions in this study, exhibited significantly lower and more posterior hyoid locations relative to the lower border of the mandible. The Class II cases showed the reverse to be true.

Cleall (1970) studied changes cinefluorographically that occurred in posture and function of the oropharyngeal structures during transition of dentition. He reported the ability of the oropharyngeal structures to adapt to dental changes. He found that the hyoid moved progressively downward through this transitional dentition period.

Yip and Cleall (1971), using cinefluorographic evaluation of the resting posture and the pattern of movement of the oropharyngeal structures before and after surgery of both tonsils and adenoids on twenty-eight children, concluded that the hyoid appeared to be in a more elevated and forward position both at rest and during all stages of deglutition after surgery.

Wickwire (1972) stated that if the mandible is set back in Class III correction, the tongue is carried lower in the mouth and is demonstrated by a change in the hyoid.

Cuozzo and Bowman (1975), in a study to determine the amount of change in the position of the hyoid following forced distal position with a tongue crib, used ten female subjects ranging from nineteen to thirty years of age. All had Class I occlusions. They judged accommodation in terms of hyoid repositioning measured from the inferior border of the mandible as evidenced both myometrically and with cinefluorography. Results showed strong correlation between placement of a tongue crib and hyoid repositioning. From these results they hypothesized that individuals with the hyoid initially close to the mandible can easily reposition the hyoid inferiorly or distally. Conversely, those with the hyoid held relatively distant from the mandible would find such accommodation difficult due to a postulated encroachment on the patent airway space.

In a followup, Gobeille and Bowman (1976) studied ten open bite, tongue thrust patients. Their methods as well as results supported the findings of subjects with normal Class I occlusion. They stated, "The hypothesis of hyoid mandibular plane distance was again borne out."

Augustson (1976), in a similar study to that of Cuozzo and Bowman, after screening forty-seven female adults with Class I occlusion into a sample of twenty-two, divided this sample into three groups: (1) subjects with mandibular plane-to-hyoid distance of 24-32 mm., (2) distances of 19-24 mm., (3) distances of 14-17 mm. to mandibular plane. His results, using the tongue crib, again reflected a significant difference vertically ($P. < .01$ level) using a cinefluorographic technique. He stated, "It appears hyoid adaptive potential is influenced by its spatial relationship to the mandibular plane." This offers statistical support for the theory first proposed by Cuozzo and Bowman (1973).

B. Deglutition

As in most modern literature, Magendie's (1783-1855) theory of deglutition immediately comes to the forefront. He divided the act of swallowing into three stages. Today, Magendie's theory of constant propulsion remains essentially correct as corroborated by modern cinefluorographic research, though many other theories such as Barclay's theory of negative propulsion have been disproved.

Magendie's three classic stages of swallowing are: (1) oral, (2) pharyngeal, and (3) esophageal. The oral stage is voluntary and conscious, the pharyngeal involuntary but still conscious, and the esophageal both involuntary and unconscious.

The oral or preparatory stage begins as the tongue collects the substance to be swallowed and forms the bolus. The bolus is contained in a cupped depression on the dorsum of the tongue and at this point is circumscribed by a peripheral seal. Anteriorly, the top of the tongue is positioned against the palatal mucosa behind the maxillary anterior teeth. Laterally, the seal is against the palatal surface of the posterior teeth and palatal mucosa. Posteriorly, the seal is formed by the tensor-depressed soft palate and the faucial pillars against the pharyngeal portion of the tongue.

Passage of the bolus into the oral pharynx is accomplished with two different actions. First, the lumen expands making room for the bolus to pass. Then the lumen narrows and closes behind the bolus, propelling it into the oral pharynx. Thus the pharyngeal stage is begun.

Saunders-Davis-Miller (1951), using cinefluorographic techniques, divide Magendie's second stage into the following phases:

(a) elevation of the larynx
(b) posterior thrust of the base of the tongue
(c) initial posterior-inferior movement of the epiglottis
(d) further elevation of the larynx
(e) final descent of the epiglottis
(f) spincteric closure of the laryngeal aditus
(g) passage of a peristaltic wave down the pharyngeal constrictor muscles
(h) opening of the superior end of the esophagus
(i) return (anteriorly) of the base of the tongue to resting position
(j) return of the epiglottis to an upright position
(k) descent of the larynx to the resting position

Ardran (1954) likened bolus propulsion to toothpaste being squeezed from a tube. Ramsay et al. (1955) calls the progressive narrowing and obliteration of the lumen behind the bolus a "stripping wave."

This entire pharyngeal state, according to Guyton (1975), takes one to two seconds. The sensory nerve stimulation of the pharyngeal state is through the glossopharyngeal and trigeminal nerves transmitting to the region of the medulla oblongata closely associated with the tractus solitarius, which receives almost all sensory impulses from the mouth. The successive stages of swallowing are controlled in the reticular substance of the medulla and lowest portion of the pons. These are collectively called the swallowing center.

The pharyngeal stage interrupts respiration for only a fraction of the respiratory cycle. The portion of the medulla responsible for respiration is inhibited by the swallowing center for this one to two second period.

The third stage, esophageal, is a five to ten second period conducting the bolus from the pharynx to the stomach. The peristaltic waves of the esophagus are controlled primarily by the vagal reflex.

Ramsay et al. (1955) showed that the timing and the order of swallowing events vary considerably in different people and even vary in the same individual under different circumstances. He also stated that there are persons who by habit or training showed marked variation from normal deglutition.

Straub (1960), though disproved in more recent literature, professed three criteria for a normal swallow: (1) teeth firmly together, (2) muscle of facial expression relaxed, (3) tongue remaining in oral cavity. Any variation from this was considered pathological and the most likely cause was improper bottle feeding. He further stated that this would lead to "serious malocclusions." Thus he advocated function determined form.

Subtelny (1965), in his review of literature, attacked Straub's hypothesis of bottle feeding causing tongue thrust. He quoted Tulley's work, who, using cinefluorography, showed no correlation between breast or bottle feeding and tongue thrust. In Subtelny's study he also showed that the tongue rests farther back and down after removal of tonsils and adenoids. His results of this experiment showed that more than fifty percent of subjects with normal occlusion had perioral contraction and seventeen percent had tongue thrust.

Rosenblum (1963), using motion picture analysis of deglutition of subjects with normal occlusion, showed perioral activity in more than fifty percent of subjects tested.

Wildman et al. (1964), in a study of fifty-two ten year old children, divided them equally into normal and tongue thrusters. Static tongue posture and oral coordination were investigated specifically. No significant difference between the two groups was found.

Hedges et al. (1965), studying children twelve to fourteen with normal occlusion and no speech problems, demonstrated two distinct swallowing patterns: one with teeth together and one with teeth apart. He therefore suggests the term "acceptable" instead of "normal" as practical and more inclusive when describing deglutition.

Peat (1968) claimed there were two postural positions for the tongue for each individual. The first, which exhibited tongue tip contact with the incisors and/or lips, was considered habitual. The second position was a relaxed postural position evidenced by increased convexity of the dorsum and contacted only the soft palate.

Hansen et al. (1970) used twenty-two factors on 193 subjects and found only two functionally associated with tongue thrust. These were enlarged tonsils and lingual cross-bites. His theory was that enlarged tonsils forced carriage of the tongue forward, and that lingual cross-bites forced a narrowing and elongation of the tongue.

In 1973, Hansen et al. performed a study of 178 children who at the start of the experiment ranged from four and a half to five years of age and who were followed for four years. Tongue thrusts were evaluated as to incidence and how long they retained this habit. Also, etiology was considered as was incidence of malocclusion. He found five behavioral factors and five structural factors associated with the persistence of tongue thrusting pattern. The five behavioral factors were: greater contractions of masseter and circumoral muscles during swallowing, more dentalized linguoalveolar consonants, fewer allergies, more digit sucking, and more mouth breathing. The structural factors were larger tonsils, higher and narrower palates, less buccal cross-bites, greater maxillary arch circumference, and less available anteroposterior space at the level of point A. He contended that there is a serious reciprocation between form and function and that myometric research makes it difficult to avoid the conclusion that the tongue does have the strength and persistence to cause malocclusion.

Cleall (1965) advocated function adapting to form. In this study he found that with a tongue crib the hyoid adapted back and down and that in the tongue thrust group the hyoid at rest was further back and down than in so-called normal swallowers. He also observed that among the subjects with normal occlusion forty percent swallowed with teeth apart, twenty percent no lip closure, and eleven percent protruded the tip of the tongue beyond the incisors.

In another study, Subtelny (1970) observed swallow pattern of ten normal subjects and thirty with malocclusions. The difference of tongue-tip function that he observed he attributed to functional adaptation of the anterior environment to achieve a seal during deglutition.

In 1973 Subtelny reaffirmed his belief of function adapting to form. But he mentioned three factors that contraindicate orthodontic treatment: abnormal skeletal relationships, neurological impairments, and abnormal tongue size. He summarizes,

> When form is modified by orthodontic and/or surgical procedures within the anatomical and phhsiological limitations of the patient and within the reference of anticipated changes incident to growth and development, stable adjustments in occlusion and favorable adaptations in orofacial muscle activity may be anticipated.

C. Cinefluorography

Cinefluorography is a production of an illusion of motion with the aid of the motion picture. Motion picture films are recorded in two different ways, direct and indirect. The direct method involves taking multiple, sequential exposures on x-ray films. These serial radiographs are then copied onto film. Since the film sequence is so low this is not very graphic. In the indirect technique the film is photographs of the fluorescent image onto the film. Since 1953, when the image intensifier was developed, there has been an improvement in film quality and a reduction of patient radiation.

To the author's knowledge the earliest work was reported in 1929 and done by Warren and Bishop at the University of Rochester. Many excellent studies have been conducted since. Some of these are: Ardran and Kemp (1954); Ramsay et al. (1955); Shelton et al. (1960); Wildman et al. (1964); Brauer and Holt (1965); Cleall (1965); Hedges et al. (1969); Sloan et al. (1969); Milne and Cleall (1970); Hansen et al. (1970); Subtelny (1970); Ingervall (1971); Yip and Cleall (1971); Cuozzo and Bowman (1975); Gobeille and Bowman (1976); Augustson (1976).

Sloan et al. (1964) stated that with cinefluorography you could analyze (1) motion, (2) variation of density radiographically, (3) a chronology of function. He also established eight basic steps necessary for correlation of cephalometric analysis to cinefluorography.

Cleall et al. (1966) stated that correction for magnification showed less error than tracing error but that loss of detail was a definite problem if viewing individual films.

Saunders et al. (1951) stated that "spot films" are inadequate as they may be incorrectly interpreted since their relation to the cycle remains unknown. He also felt that sixty frames/second were necessary to capture the complete deglutition cycle, especially movement of the epiglottis.

D. Hyoid Position and Cephalometrics

King (1952) followed the growth and position of the hyoid from six months of age to age sixteen. Using the Bolton Foundation's cephalometric roentgenograms at Western Reserve University, he found that the hyoid was well above the symphysis in the infant but below it in the adult. The downward progress of the hyoid was rapid during infancy and early childhood, followed by a slower descent afterwards. Then there was an accelerated rate of descent between the tenth and twelfth years in girls and between the twelfth and sixteenth year in boys. Also, the hyoid moved slightly forward at puberty. He also discussed hyoid and head position. He found that changes in head position in the same person lead to changes in hyoid position. Extend the head backward, and the hyoid moves back; tip the head downward and the hyoid moves forward. In this study only the body of the hyoid was traced and was related to the Frankfort plane and the symphysis (see Figure 2).

Wood (1956) also studied the movement of the hyoid with head movement. He found that with the head in dorsiflexion the hyoid is elevated and that when the head is in ventriflexion the hyoid is directed downward.

Smith (1956) studied hyoid position related to mandibular movements from centric to protrusion and from centric to maximum opening. He found the hyoid moves forward and slightly upward when going to protrustion and that it moves downward and backward in maximum opening (see Figure 3).

Grant (1959) studied hyoid in Class I, II, and III malocclusions. One cephalometric for each subject was selected from the school file. He concluded that hyoid position is constant in all three types of malocclusion. He hypothesizes that the musculature and not the occlusion of the teeth determines hyoid position. His work showed that hyoid position, in his teen-age sample, was midway between the third and fourth cervical vertebrae (see Figure 4).

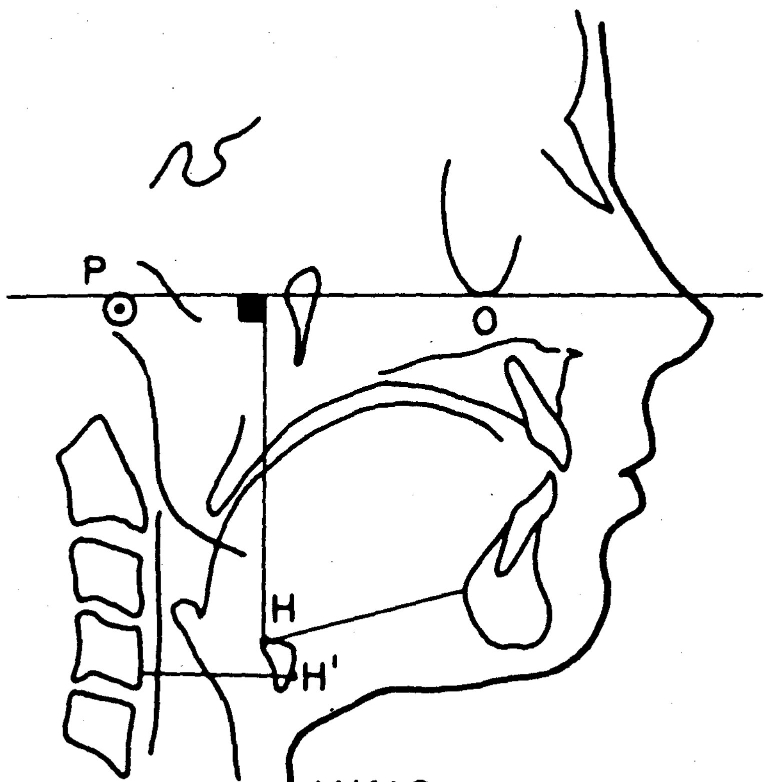


Figure 2

King Analysis

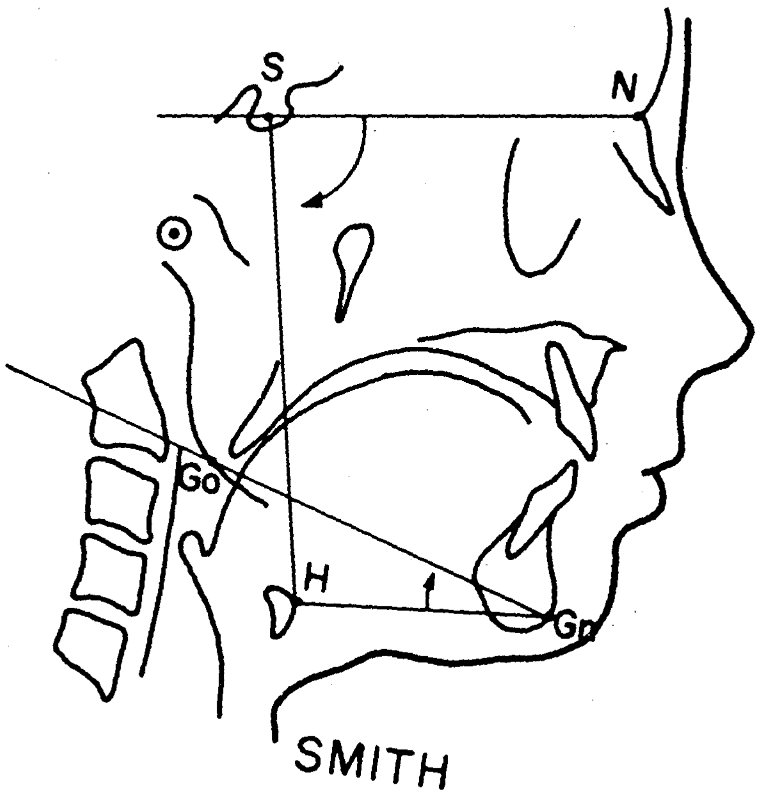


Figure 3

Smith Analysis

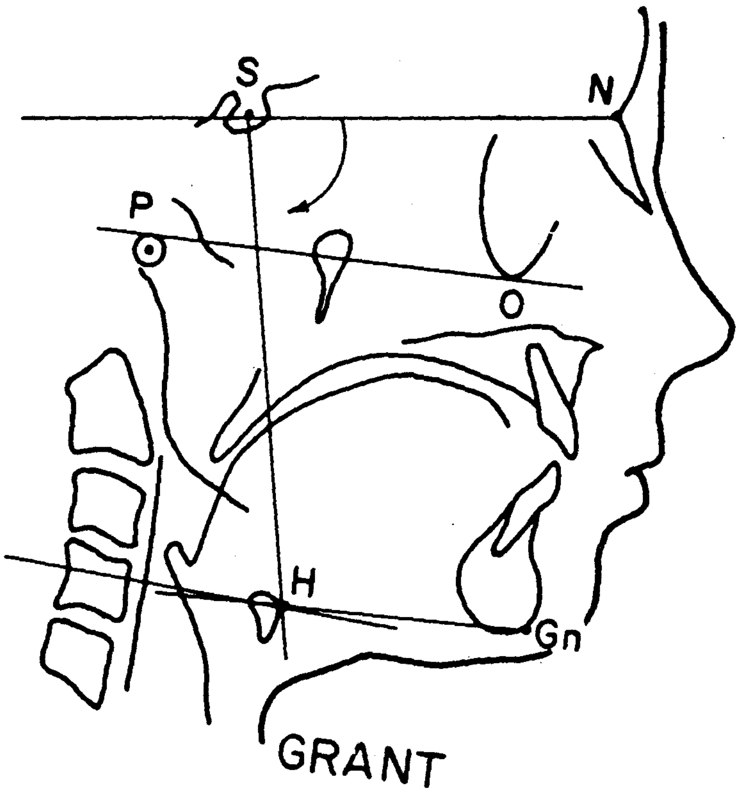


Figure 4

Grant Analysis

Durzo and Brodie (1962) showed descent of the hyoid with growth, and its position remained constant relative to these areas. They also showed changes in position of the hyoid with variation in head position.

Bench (1963) in his study followed hyoid position relative to the cervical vertebrae. He found the hyoid at age three at the level of the third cervical vertebra and its descent to the fourth cervical at adulthood. The cephalograms were taken with the head held in a natural position. No orbitale or nasion registration points were used in obtaining a Frankfort plane parallel to the floor, as a natural position of the tongue and vertebrae was sought after (see Figure 5).

Anderson (1963), in a study of tongue thrust, noted a tendency of patients to outgrow this syndrome. He tested with cephalograms whether the hyoid position was higher in tongue thrust than "normal" swallowers. He measured hyoid position by determining the height of the greater horns relative to the cervical vertebrae. He did not use lineal or angular measurements. He concluded that there was no relation between vertical height of the hyoid and tongue thrust (see Figure 6).

Stepovich (1965) in his study used twenty-eight male subjects ranging in age from thirteen to thirty-five. All had Class I occlusion and none had open bites. They also had an apparent tongue thrust. Although on all subjects

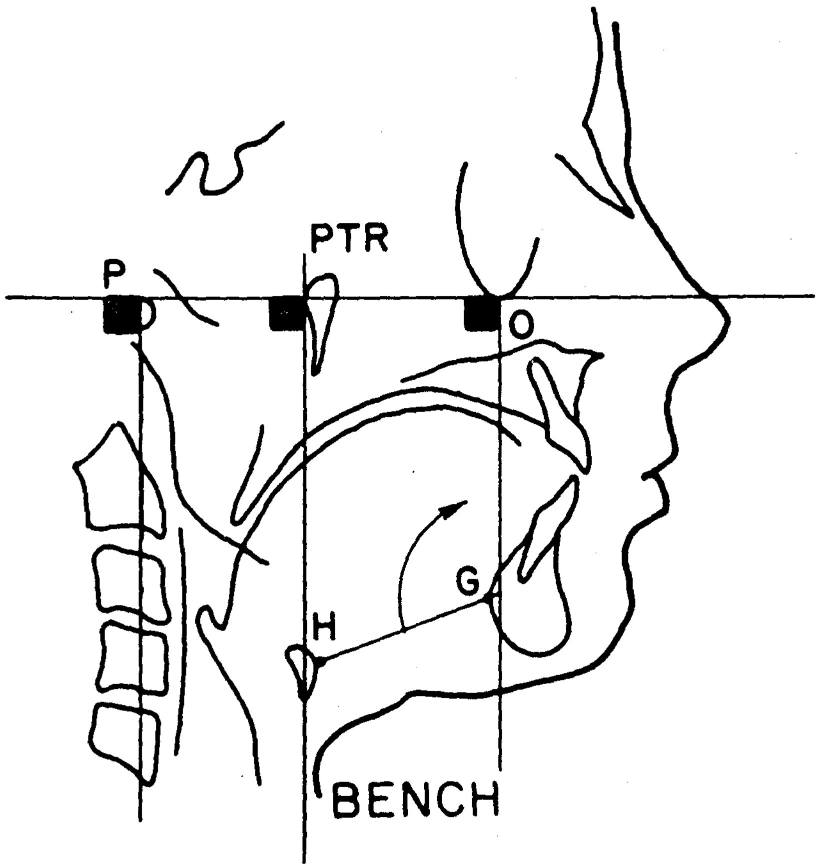


Figure 5

Bench Analysis

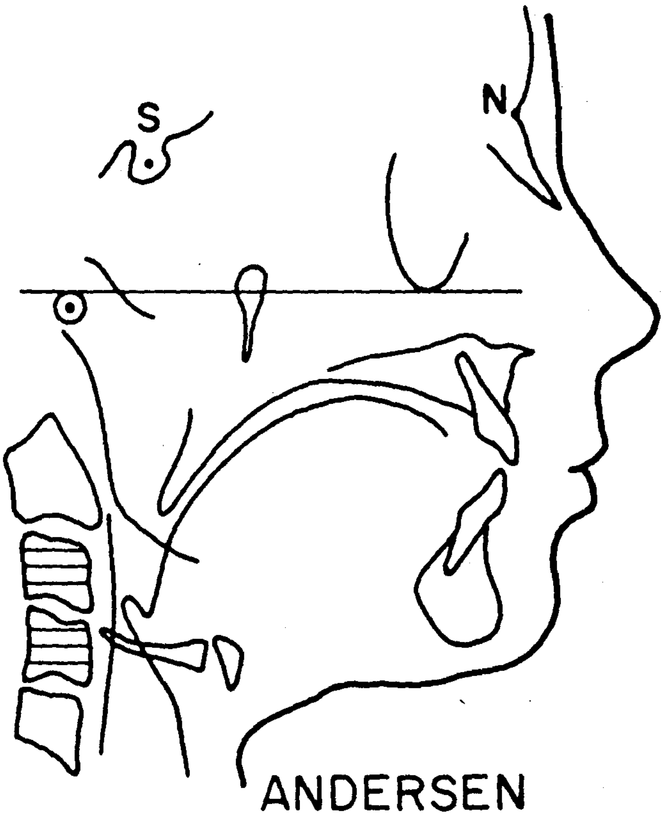


Figure 6

Andersen Analysis

standard cephalometric technique was used where the subject was seated erect and the head was positioned by the operator, with the Frankfort parallel to the floor and a positive downward pressure was exerted on the earrods, they were divided into three groups where four different variants were used.

The first group had eight different cephalograms taken on different days. Of these, five were taken with teeth occluded and three were taken after they were told to swallow and wait five seconds.

The second group had four different films taken at the same seating:

(a) standard technique

(b) one film with left shoulder raised

(c) one where they inhaled deeply and held it

(d) repeat of standard technique

The third group had three cephalograms taken on consecutive days. Standard technique was used but the tongue was stabilized by holding a small metal ring against the palate.

Stepovich (1965) measured both the position of the hyoid and the angle of rotation. In his results the range of deviation was of such an extent as to be statistically insignificant (see Figure 7).

Ingervall (1970) stated that the study of the hyoid offers greater difficulties from a physiological than from

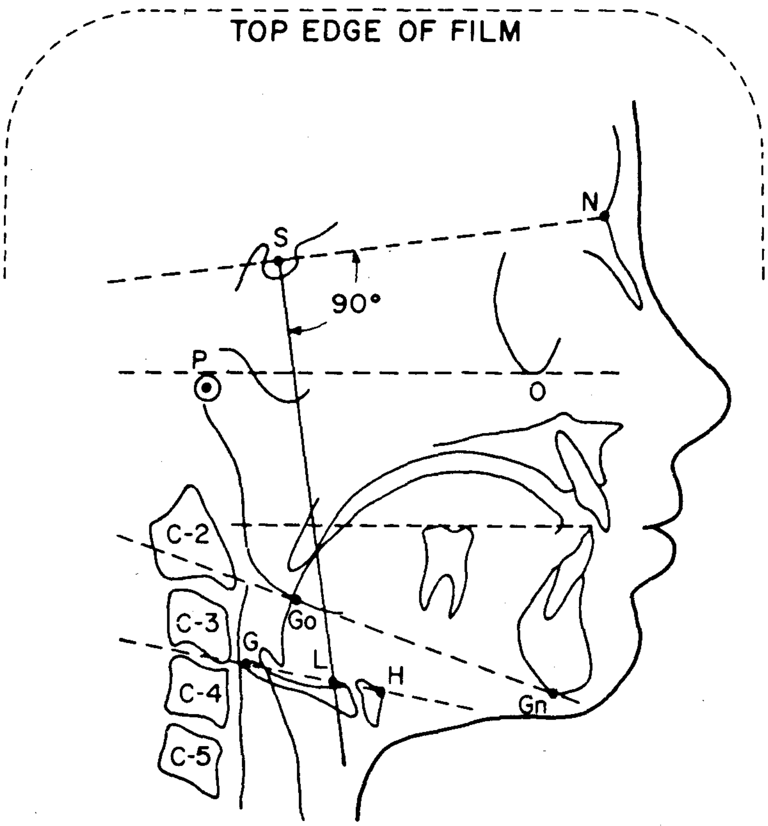


Figure 7

Stepovich Analysis

a purely methodical point of view. The fact that the hyoid is embedded entirely in soft tissue connected to various muscles means that it is influenced by a number of functions. He disagreed with Stepovich in that he felt Stepovich exaggerated the lack of precision. Also, by taking cephalograms in the postural rest position whereas Stepovich did not, Ingervall found significant reproducibility. The error also could be reduced further by limiting the recordings to the position of the body of the hyoid and not the bolus. In this study using F- value, Ingervall found the following results of hyoid position: Retruded position of mandible to postural position the effect on hyoid was F- value 4.10*. From intercuspal position of mandible to postural position as related to hyoid = F- value 3.30*. (*Significant limits = $0.001 > P > 0.01$).

Of the correlations tested he found a significant difference only in the vertical displacement of the hyoid when the mandible went from postural position to intercuspal position when correlated with age.

Further results of Ingervall's work were previously discussed in the Review of Literature under the heading of <u>Hyoid Bone</u>.

Augustson (1976) in his screening process used lateral cephalograms taken in the standard manner: teeth occluded, positive upward pressure on the earrods after placement, patient positioned by operator with the Frankfort parallel to the floor, and seated erect. He found significant difference between the cephalogram and the cinefluorographic film. He states, "For the clinician to utilize lateral cephalometric x-rays to monitor hyoid rest position, they should be taken with the mandible in postural position."

METHODS AND MATERIALS

A. General

1. Twenty-five adult female subjects ranging in age from nineteen to twenty-three with no TMJ dysfunction were selected. Existing malocclusions were not considered as criteria for dismissal from the sample, though when present they were not considered of a major order.

2. Description of procedure in order:

   a. A lateral cephalometric film taken after patient swallowed, waited three seconds, and again assumed postural rest position.

   b. A twelve-second cinefluorographic sequence of normal deglutition.

   c. Placement of a tongue crib forcing distalization of the tongue and wearing this for twenty-four hours.

   d. A repeat of lateral cephalometric film after swallowing, waiting three seconds, and assuming postural rest position with crib in place.

   e. Another cinefluorographic sequence of deglutition with tongue crib in place.

B. Crib Construction and Placement

The appliance used in this study was modeled after that of Augustson (1976) (see Figure 8). The crib superstructure was borne by a straight length of .040 inch diameter orthodontic wire soldered to a wire mesh or orthodontic band. The wire mesh, if used, was adapted to the palatal surface of the first maxillary premolars and attached with concise direct bond acrylic. If standard orthodontic bands were used, they were cemented in the standard way. Bands were used if the patient had fluorosed teeth or large restorations. The orthodontic wire used to support the superstructure was cut in the middle. This allowed constriction or expansion of the appliance palatally-buccally and therefore negated custom-made appliances for each subject.

The appliance was adjusted to span the palate approximately 15 mm. distal to the central incisors. The superstructure consisted of (1) a "U" shaped crib, and (2) an acrylic palate. Both the "U" shaped crib portion and the acrylic portion were attached to a length of .045 inside diameter orthodontic tubing which fitted over the transoral .040 inch wire. This allowed the entire superstructure to rotate around the transoral wire attached to the premolars.

The "U" shaped crib projected vertically from the tubing approximately 10 mm. When the subject occluded, the crib extended into the lingual aspect of the mandibular arch and served to prevent the tongue from slipping inferiorly and anteriorly during deglutition.

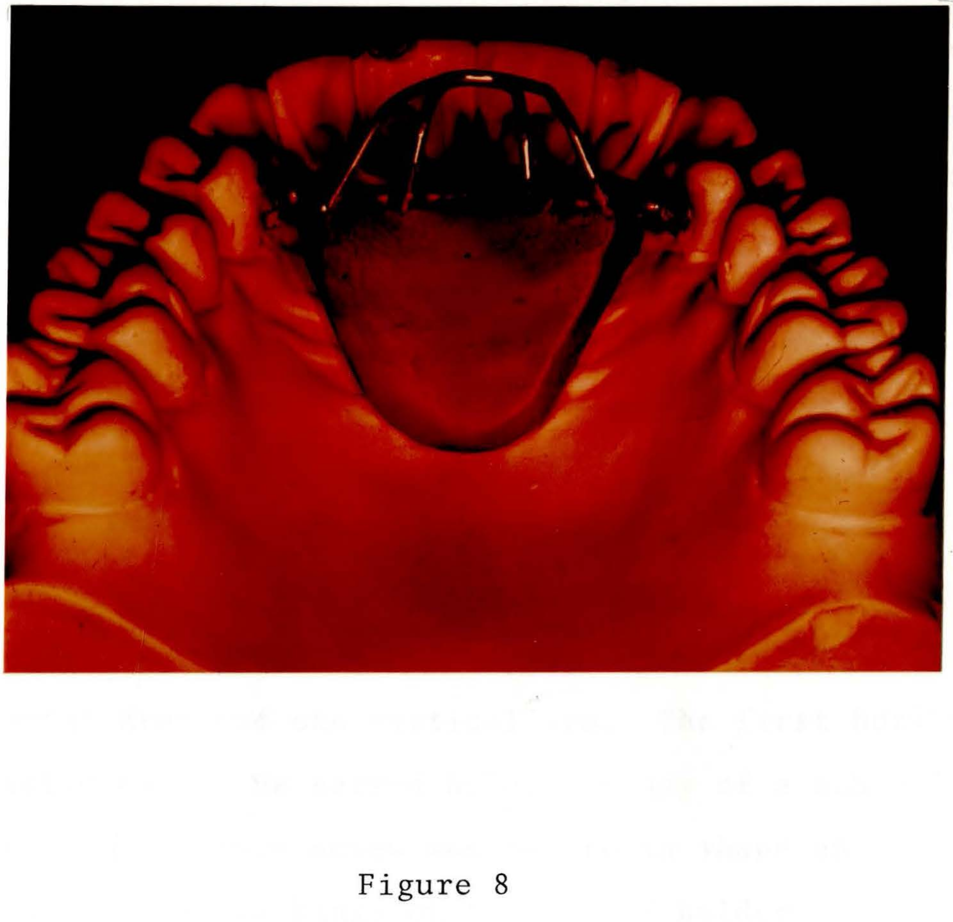


Figure 8

Tongue Crib Appliance

The acrylic portion extended anteriorly to near the cingulum of the maxillary incisors. Laterally it was cut away from the buccal segments. The posterior portion of the crib was trimmed to mimic the lingual aspect of the hard palate.

The crib design enabled the superstructure to rotate around the transoral wire in an attempt to allow for physiological feedback during deglutition. Anterior pressure was transferred to the incisor and anterior palate. This appliance was cemented on each subject for twenty-four hours.

C. Infraorbital Pointer Construction and Placement

A lightweight aluminum infraorbital pointer was custom made for transferring the subjects from the cephalometric appliance to the cinefluorographic machine with the head in the same sagittal, transverse, and horizontal position and to be able to reproduce this position repetitively and accurately (see Figure 9). The appliance consisted of two horizontal arms and one vertical arm. The first horizontal post attached to the earrod holder by way of a nub screw. The housing for this screw was square in shape and this allowed accurate markings on the earrod holder for reproducing its position. Prior to scribing the marks on the earrod holder, this first part was plumbed to the true horizontal. Also this first part, when in position, ran posteriorly-anteriorly in a sagittal view. This arm had 1 mm. increments scribed on it for duplication.

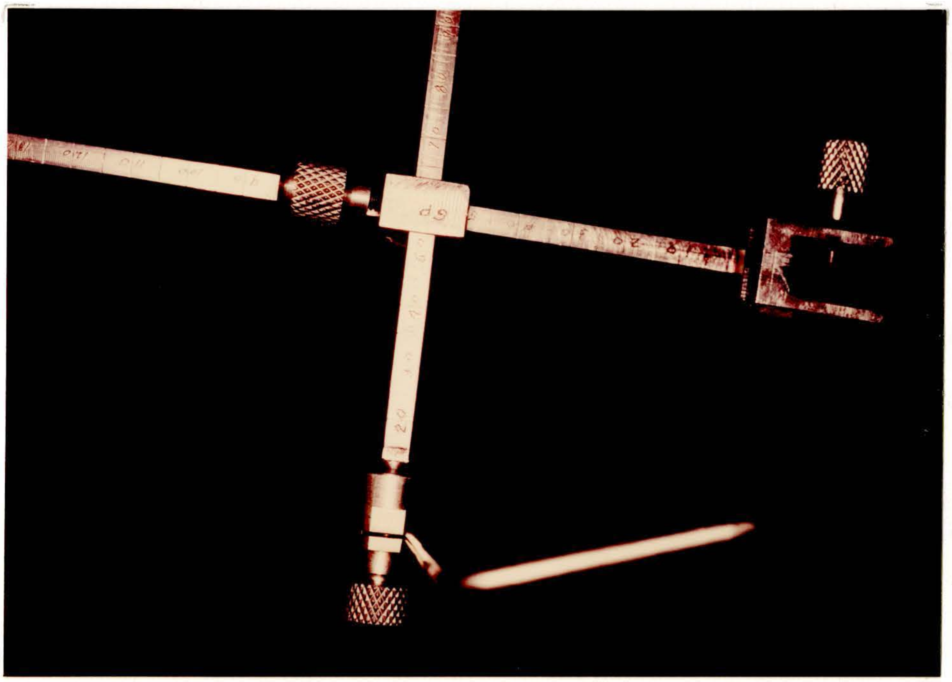


Figure 9

Infra Orbital Pointer

Over this arm slid a second horizontal part which ran transversely across the face and could be moved anteriorly-posteriorly and palatal-buccally. It too had 1 mm. increments for reproduction of position.

The third part was an "L" shaped vertical arm which when adjusted touched the face. It also had 1 mm. markings on it.

An indelible mark was placed on the subject's face for reorientation (see Figure 10).

D. Cephalometric Technique

The subject was seated in a relaxed position to reduce tension and any hypertonicity of the hyoid musculature. The patient was instructed to look "straight ahead" and then the earords were inserted gently after positioning the chair and not the patient. After this, the above-mentioned infraorbital pointer was placed and recordings made of its position (see Figure 11).

A cephalometric film was taken, as described under "Description of procedure in order."

After twenty-four hours of crib placement, the second cephalogram was taken.

These cephalometric films were then traced in the same manner as in Augustson's experiment, and this is described later in this section.

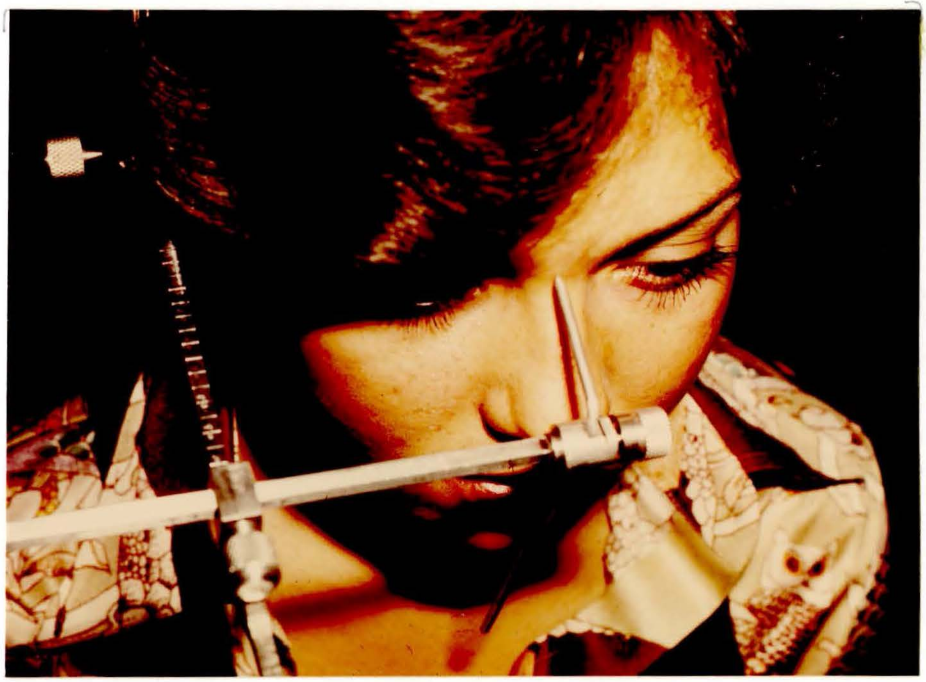


Figure 10

Pointer Positioned Subject

Figure 11

Subject Positioned for Cephalogram

E. Cinefluorographic Equipment, Technique and Analysis

A Picker cinefluorograph with a high image intensifying screen was used for the deglutition film sequence. The output phosphor on the machine had a diameter of 9 inches and the input phosphor had a diameter of 0.8 inches. The resulting demagnification was 11 to 1 and the brightness gain was about 3,000 to 5,000 X. On opposite ends of a "C" arm were the x-ray head and the image amplifier with a camera and optical system. The "C" arm was adjustable and capable of being locked in any vertical position. The cephalostat was attached to the "C" arm in close relation to the input phosphor of the image tube. The earrod nearest the image amplifier was fixed so that the subject-film distance was constant (see Figure 12).

The patient was placed in this cinefluorographic cephalostat, using the infraorbital pointer to duplicate the head position of the cephalometric machine.

Then 2 to 4 cc. of barium sulfate was introduced into the patient's mouth and she was instructed to swallow twice when the machine was activated. The sequence ran twelve seconds and exposure was run at 90 KVP and 13 MA. This procedure was repeated after twenty-four hours of crib placement but prior to its removal. It was estimated that total exposure per subject was approximately .75 R.

A sixty frame per second sequence was taken during the act of deglutition with 16 mm. Kodak Shellburst film and

Figure 12

Subject Positioned for Cinefluorographic Sequence a 35 mm. F. lens. The film was developed on a Profexray automatic film developing machine.

The films were analyzed on a Vanguard Motion Analyzer. The machine had manually operated cross hairs which superimpose on the film. Measurements with this Vanguard unit were accurate to .001 inch lineal and 1/4° angularly, but because of lack of detail on the film this accuracy could not be reached. A variable speed adjuster on the analyzer enabled viewing within a range of 5 to 30 frames per second. Single frame advancement and long term viewing was also possible. A metered frame counter allowed the viewer to identify individual frames.

Both the cinefluorographic and cephalometric film were traced in the same manner (see Figure 13) before crib placement and again after crib placement, with what was considered the hyoid at rest; that is, its most posterior and inferior position.

The landmarks that were used included: (1) hyoid bone (body only), (2) the mandibular symphysis, (3) lower border of the mandible, (4) upper and lower incisor teeth, (5) maxilla. Then two lines were traced. One was a tangent to the lower border of the mandible. The second line was a perpendicular to the line tangent to the lower border of the mandible and dividing the lower border into two equal halves. Measurements were then taken of the distance of the body of the hyoid from these two lines both vertically and

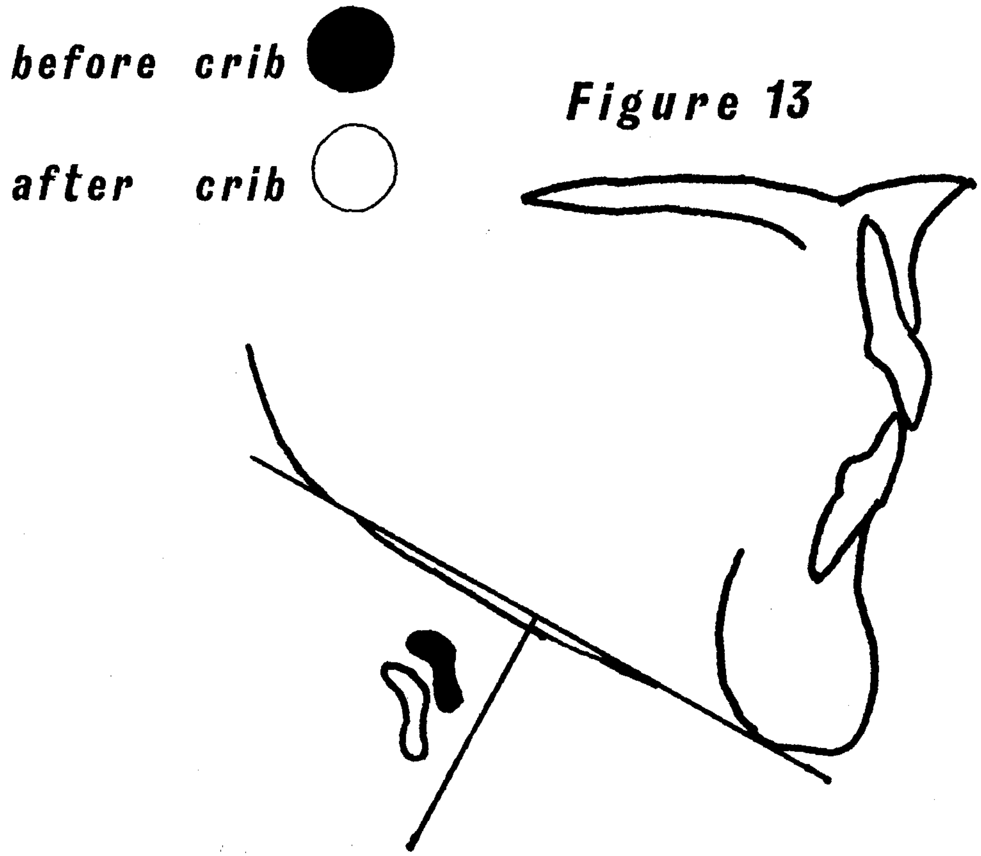


Figure 13

Traced Film

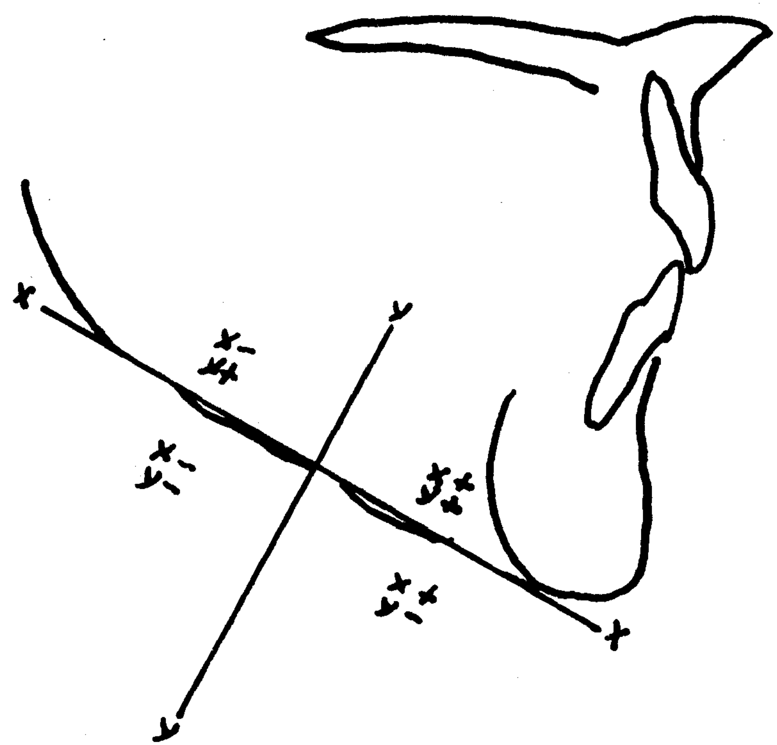
horizontally of before crib placement. After twenty-four hours of crib placement, the second tracing was done and this was superimposed on the first tracing using the two lines as reference, and the difference of hyoid position was noted.

RESULTS

The results as presented in Table 1 represent both cephalometric measurements taken with a controlled swallow before crib placement and again twenty-four hours after crib placement with a controlled swallow as described under "Description of procedure" in Methods and Material. The table also includes cinefluorographic data on the same subject of before and after crib placement of the deglutition cycle. The data on subjects 15, 16, 17, 23, and 24 was lost on the after crib placement cinefluorographic film, due to under exposure.

The vector analysis as used in Tables 2 through 5 was established in the following manner. A line was drawn tangent to the lower border of the mandible, extending from the gonial angle to menton on the symphysis of the mandible. This was considered to be the "x" axis. The "x" axis was divided into two equal halves by a vertical line drawn perpendicular to the "x" axis and assigned the "y" value. Plus and minus values were given to the "x" line measured on the horizontal, with plus values to any position of the hyoid mesial to the "y" axis. The plus values for "y" axis are those above the lower border of the mandible and minus for those plotted below the mandible (see Figure 14). The vector

Figure 14



Vector Analysis

was determined with the following formula: $\sqrt{x^2 + y^2}$ and subtracting the smaller square if the signs differed.

Tables 2 and 3 represent the vector analysis of the cephalometric film before and twenty-four hours after crib placement.

Tables 4 and 5 represent the vector analysis of the cinefluorographic film before and after crib placement and measured in the same manner as the cephalometric films. The rest position was considered to be at the most posterior and inferior point of the swallow cycle.

In the work of Cuozzo and Bowman (1975), Gobeille and Bowman (1976), and Augustson (1976), it was shown that if the hyoid bone was positioned in a relatively posterior and inferior position at rest, it would not adapt upon forced distallization of the tongue. Using their data, an arbitrary point was established to predict which subjects would not adapt. The predicted vector for cephalometric data in this study was established at $\sqrt{245}$ and for cinefluorographic data it was a vector $\sqrt{280}$.

Those subjects predicted not to adapt were different between the cephalometric and cinefluorographic groups. This was due, in part, to the difference of the image size on the cephalometric film and the cinefluorographic film.

Table 6 shows the cinefluorographic subjects predicted not to adapt. Of these, three subjects did in fact adapt, though as a group (using a paired T test) no statistically significant adaptation did occur. ($P > .05$ level and T value 0.8743).

In Table 7 are the results of the cephalometric vector. Subjects 2 and 3 adapted to a very slight degree but not enough to be significant. Again, the paired T test was used and as a group there was no significant change ($P > .05$ and T value 0.103).

Table 8 lists the results of those subjects, minus those predicted not to adapt, measured by cephalometric analysis. It shows at statistically significant levels using the paired T test ($P < 0.01$ and T value 5.981) that predictions can be made by cephalometric analysis as to which subjects would adapt.

Table 9 consists of subjects predicted to adapt by cinefluorographic analysis. Again using the paired T test high statistical significance was shown ($P < .01$ and T value of 6.009).

A significant correlation was found between x value cephalometric measurements and x value cinefluorographic measurements before crib placement ($r^2 = 0.211$ $P < .05$) and again after crib placement ($r^2 = 0.211$ $P < .05$).

Comparing the y measurements, significant correlation was found between the y value measurement after crib placement cephalometric and after cinefluorographic measurements ($r^2 = 0.344$ $P < .05$) but not before crib placement y cinefluorographic and before crib placement y cephalometric values.

TABLE 1

GENERAL DATA

	Cephalometric				Cinefluorographic			
	Control Swallow		Crib		Control Swallow		Crib	
	←x(mm)	↓y(mm)	←x(mm)	↓y(mm)	←x(mm)	↓y(mm)	←x(mm)	↓y(mm)
1.	-11	-11	-15	-14	- 4	-12	-16	-16
2.	-13	-11	-13	-13	- 4	- 8	- 6	-16
3.	-13	-10.5	-12	-14	- 9	- 8	-11	-16
4.	-16	- 8	-13.5	- 9	-10	-14	-10	-14
5.	-11	- 6	-10	-17	+ 2	-17	- 4	-24
6.	-21	- 3.5	-18.5	- 7	0	- 8	-16	-14
7.	- 3	-11.5	-14.5	- 8	+ 4	-10	- 4	-15
8.	+ 3	- 9	+ 2	-15	0	-16	-12	-20
9.	-15	- 1	-18	- 4	-16	-12	-14	- 8
10.	-12	-10	- 7	-15.5	- 4	-14	- 8	-16
11.	0	-11	- 1	-15.5	+ 2	-15	+12	-26
12.	- 4	+ 3	-12	- 4	- 6	- 6	-18	- 8
13.	-13	- 9	-19	-12	- 6	- 9	-22	-30
14.	-14	- 7	-11	- 9	- 6	-12	-14	-18
15.	- 5	- 5	-12	+ 1.5	- 2	- 6	*	*
16.	-15	- 6	-25	-10	-18	- 8	*	*
17.	------	------	------	------	------	------	------	------
18.	+ 3	-12	+ 5	-15	0	-11	- 2	-11
19.	- 3	- 9	- 1	-13	+ 9	-10	+ 2	-16
20.	-16	- 5	- 7	- 8	-30	- 2	-32	- 4
21.	- 7	-12.5	- 6	-13	0	-18	0	-18
22.	- 1.5	- 9	- 2	-12	-20	- 8	-22	- 9
23.	- 0.5	-21	- 3	-16	+ 6	-14	*	*
24.	-18	-11	-17.5	-13.5	- 8	-12	*	*
25.	+ 4	-23	+ 4	-22	+ 8	-16	+ 2	-22
26.	- 4	- 9	0	-12.5	+ 2	- 6	+ 5	-12

*lost data

TABLE 2

CEPHALOMETRIC VECTOR ANALYSIS
(Before Crib Placement)

	←x(mm)	↓y(mm)	$\sqrt{x^2 + y^2}$	Vector(mm)
1.	-11	-11	$\sqrt{121 + 121}$	15.556
2.	-13	-11	$\sqrt{169 + 121}$	17.029
3.	-13	-10.5	$\sqrt{169 + 110.25}$	16.71
4.	-16	- 8	$\sqrt{256 + 64}$	17.888
5.	-11	- 6	$\sqrt{121 + 36}$	12.529
6.	-21	- 3.5	$\sqrt{441 + 12.25}$	21.289
7.	- 3	-11.5	$\sqrt{9 + 132.25}$	11.884
8.	+ 3	- 9	$\sqrt{81 - 9}$	8.485
9.	-15	- 1	$\sqrt{225 + 1}$	15.033
10.	-12	-10	$\sqrt{144 + 100}$	15.62
11.	0	-11	$\sqrt{121}$	11
12.	- 4	+ 3	$\sqrt{12 - 9}$	1.732
13.	-13	- 9	$\sqrt{189 + 51}$	15.491
14.	-14	- 7	$\sqrt{196 + 49}$	15.652
18.	+ 3	-12	$\sqrt{144 - 9}$	11.618
19.	- 3	- 9	$\sqrt{9 + 81}$	9.481
20.	-16	- 5	$\sqrt{256 + 25}$	16.763
21.	- 7	-12.5	$\sqrt{49 + 156.25}$	14.326
22.	- 1.5	- 9	$\sqrt{2.25 + 81}$	9.124
25.	+ 4	-23	$\sqrt{529 - 16}$	22.649
26.	- 4	- 9	$\sqrt{16 + 51}$	8.185

TABLE 3

CEPHALOMETRIC VECTOR ANALYSIS
(After Crib Placement)

	←x(mm)	↓y(mm)	$\sqrt{x^2 + y^2}$	Vector(mm)
1.	-15	-14	$\sqrt{225 + 196}$	20.518
2.	-13	-13	$\sqrt{169 + 169}$	18.384
3.	-12	-14	$\sqrt{144 + 196}$	18.439
4.	-13.5	- 9	$\sqrt{182.25 + 81}$	16.224
5.	-10	-17	$\sqrt{100 + 289}$	19.723
6.	-18.5	- 7	$\sqrt{342.25 + 49}$	19.78
7.	-14.5	- 8	$\sqrt{201.25 + 64}$	16.56
8.	+ 2	-15	$\sqrt{225 - 4}$	14.866
9.	-18	- 4	$\sqrt{324 + 16}$	18.439
10.	- 7	-15.5	$\sqrt{49 + 240.25}$	17.0
11.	- 1	-15.5	$\sqrt{1 + 240.25}$	15.532
12.	-12	- 4	$\sqrt{144 + 16}$	12.649
13.	-19	-12	$\sqrt{361 + 144}$	22.472
14.	-11	- 9	$\sqrt{121 + 81}$	14.212
18.	+ 5	-15	$\sqrt{225 - 25}$	14.142
19.	- 1	-13	$\sqrt{169 + 1}$	13.038
20.	- 7	- 8	$\sqrt{49 + 64}$	10.63
21.	- 6	-13	$\sqrt{36 + 169}$	14.317
22.	- 2	-12	$\sqrt{4 + 144}$	12.165
25.	+ 4	-22	$\sqrt{484 - 16}$	21.633
26.	0	-12.5	$\sqrt{156.25}$	12.5

TABLE 4

CINEFLUOROGRAPHIC VECTOR ANALYSIS
(Before Crib Placement)

	←x(mm)	y(mm)	$\sqrt{x^2 + y^2}$	Vector(mm)
1.	- 4	-12	$\sqrt{16 + 144}$	12.649
2.	- 4	- 8	$\sqrt{16 + 64}$	8.94
3.	- 9	- 8	$\sqrt{81 + 64}$	12.04
4.	-10	-14	$\sqrt{100 + 196}$	17.2
5.	+ 2	-17	$\sqrt{289 - 4}$	16.88
6.	0	- 8	$\sqrt{64}$	8
7.	+ 4	-10	$\sqrt{100 - 16}$	9.165
8.	0	-16	$\sqrt{256}$	16
9.	-16	-12	$\sqrt{256 + 144}$	20
10.	- 4	-14	$\sqrt{16 + 196}$	14.56
11.	+ 2	-15	$\sqrt{225 - 4}$	14.866
12.	- 6	- 6	$\sqrt{36 + 36}$	8.48
13.	- 6	- 9	$\sqrt{36 + 81}$	10.81
14.	- 6	-12	$\sqrt{36 + 144}$	13.41
18.	0	-11	$\sqrt{121}$	11
19.	+ 9	-10	$\sqrt{100 - 81}$	4.35
20.	-30	- 2	$\sqrt{900 + 4}$	30.06
21.	0	-18	$\sqrt{324}$	18
22.	-20	- 8	$\sqrt{400 + 64}$	21.54
25.	+ 8	-16	$\sqrt{256 - 14}$	15.556
26.	+ 2	- 6	$\sqrt{36 - 4}$	5.65

TABLE 5

CINEFLUOROGRAPHIC VECTOR ANALYSIS
(After Crib Placement)

	←x(mm)	↓y(mm)	$\sqrt{x^2 + y^2}$	Vector(mm)
1.	-16	-16	$\sqrt{256 + 256}$	22.64
2.	- 6	-16	$\sqrt{36 + 256}$	17.08
3.	-11	-16	$\sqrt{121 + 256}$	19.41
4.	-10	-14	$\sqrt{100 + 196}$	17.2
5.	- 4	-24	$\sqrt{16 + 576}$	24.3
6.	-16	-14	$\sqrt{256 + 196}$	21.26
7.	- 4	-15	$\sqrt{16 + 225}$	15.52
8.	-12	-20	$\sqrt{144 + 400}$	23.32
9.	-14	- 8	$\sqrt{196 + 64}$	16.12
10.	- 8	-16	$\sqrt{64 + 256}$	17.88
11.	+12	-26	$\sqrt{676 - 144}$	23.065
12.	-18	- 8	$\sqrt{324 + 64}$	19.69
13.	-22	-30	$\sqrt{484 + 900}$	37.2
14.	-14	-18	$\sqrt{196 + 324}$	22.8
18.	- 2	-11	$\sqrt{4 + 121}$	11.18
19.	+ 2	-16	$\sqrt{256 - 4}$	15.87
20.	-32	- 4	$\sqrt{1024 + 16}$	32.24
21.	0	-18	$\sqrt{0 + 324}$	18
22.	-22	- 9	$\sqrt{484 + 81}$	23.76
25.	- 2	-22	$\sqrt{4 + 484}$	22.09
26.	+ 5	-12	$\sqrt{144 - 25}$	10.9

TABLE 6

CINEFLUOROGRAPHIC SUBJECTS
PREDICTED NOT TO ADAPT
(Using a Before Vector of $\sqrt{280}$ or More)

	Before	After	d	d^2
4.	17.2	17.2	0	0
5.	16.88	24.3	-7.42	55.056
9.	20	16.12	+3.88	15.054
20.	30.06	32.24	-2.24	5.017
21.	18	18	0	0
22.	21.54	23.76	-2.22	4.928
			= 8	= 80.055

T = 0.8743

$P > .05$

TABLE 7

CEPHALOMETRIC SUBJECTS
PREDICTED NOT TO ADAPT

(Using a Before Vector of $\sqrt{245}$ or more)

	Before	After	d	d^2
2.	17.029	18.384	-1.355	1.836
3.	16.71	18.439	-1.729	2.989
4.	17.888	16.224	+1.664	2.768
6.	21.289	19.78	+1.509	2.277
14.	15.652	14.212	+1.35	1.822
20.	16.763	10.63	+6.133	37.613
25.	22.649	21.633	+1.016	1.032
			= 8.588	= 50.337

T = 1.26

$P > .05$

TABLE 8

CEPHALOMETRIC SUBJECTS PREDICTED TO ADAPT
(Using a Before Vector of Less than $\sqrt{245}$)

	Before	After	d	d^2
1.	15.556	20.518	-4.962	24.621
5.	12.529	29.723	-7.194	51.753
7.	11.884	16.56	-4.676	21.864
8.	8.485	14.866	-6.381	40.717
9.	15.033	18.439	-3.406	11.6
10.	15.62	17.0	-1.38	1.90
11.	11	15.532	-4.532	20.539
12.	1.732	12.649	-12.649	119.18
13.	15.491	22.472	-6.981	48.734
18.	11.618	14.142	-2.524	6.37
19.	9.486	13.038	-3.552	12.616
21.	14.326	14.317	+0.009	0.00008
22.	9.124	12.165	-3.041	9.247
26.	8.185	12.5	-4.315	18.619
			= 65.602	= 387.76

T = 7.055

P < .01

TABLE 9

CINEFLUOROGRAPHIC SUBJECTS PREDICTED TO ADAPT
(Using a Before Vector of Less than $\sqrt{280}$)

	Before	After	d	d^2
1.	12.649	22.64	- 9.991	99.82
2.	8.94	17.08	- 8.14	66.259
3.	12.04	19.41	- 7.37	54.316
6.	8	21.26	-13.26	175.827
7.	9.165	15.52	- 6.355	40.386
8.	16	23.32	- 7.32	53.582
10.	14.56	17.88	- 3.32	11.022
11.	14.86	23.065	- 8.205	67.322
12.	8.48	19.69	-11.21	125.664
13.	10.81	37.2	-26.39	696.432
14.	13.41	22.8	- 9.39	88.172
18.	11	11.8	- .18	.032
19.	4.35	15.87	-11.52	132.710
25.	15.556	22.09	6.534	42.693
26.	5.65	10.9	- 5.25	27.562
			= 134.435	= 1681.799

T = 5.9469

$P < .01$

DISCUSSION

With the advent of cinefluorographic research, the swallowing cycle theory of Magendie (1822) has withstood the test of time and has been validated. Many recent experiments using this technique have examined the numerous movements of the tongue, head, oral and pharyngeal musculature, dentition, larynx, and underlying bony structures. In many of these experiments the correlation of the tongue and hyoid bone has been shown to be statistically significant. Some examples of this are the work of Saunders (1951) and Wildman (1964) in which it was postulated that since the hyoid bone serves as a posterior pedestal of the tongue, it would move in conjunction with the tongue through the swallow cycle. Cleall (1965) in an excellent work demonstrated a direct correlation between the position of the hyoid bone and the tongue at rest. With the tongue at rest it was shown that the hyoid bone was in its most retruded and downward position.

Using this established relationship of the hyoid bone to the swallow cycle, Bowman and Cuozzo (1975) demonstrated that the tongue could be positioned posteriorly in certain individuals with placement of a tongue crib and apparently adapt to this new position. This was again demonstrated, Gobeille and Bowman (1976), to be possible with different structural anomolies such as Class I, II, and III facial patterns. In 1976 Augustson, following up the work of Cuozzo and Bowman and Gobielle and Bowman, demonstrated with significant statistical data that the potential was there to predict which subjects would adapt and which would not to a forced distal placement of the tongue. In these three experiments the hyoid bone was measured in relationship to the lower border of the mandible, and all three studies used cinefluorographic apparatus.

King (1952) and Wood (1956), using cephalometric technique, found that changes in head position led to changes in the position of the hyoid bone. In another cephalometric study by Grant (1959), it was demonstrated that different malocclusions had no effect on hyoid position. He hypothesized that musculature and not the occlusion of the teeth determined the position of the hyoid bone. Stepovich (1956), using the standard cephalometric technique where the head was positioned by the operator with the Frankfort plane parallel to the floor, teeth held in centric occlusion, and positive pressure applied to the earrods, found such a deviation in the results as to be statistically insignificant. The taking of cephalograms in this manner was reported by Augustson (1975) with the same results. Ingervall (1970) disagreed with Stepovich in that he felt the study of the hyoid bone offers greater difficulties from a physiological rather than a methodical point of view. He believed that Stepovich exaggerated the lack of precision. He also demonstrated that, if the cephalogram was taken with the mandible held in postural rest position, a significant reproducibility could be attained. The possibility of error was reduced further by limiting the recording on the cephalogram to the body of the hyoid bone and not its horns.

Using Ingervall's method of taking cephalograms, we have been able to show statistically significant correlation between the "x" value cinefluorographic film and "x" value cephalometric film of the hyoid bone at rest both before crib placement and after crib placement. The same correlation was shown with the "y" vector measurements after crib placement between cinefluorographic film and cephalometric film but not before crib placement. As to the ability to predict which subjects would adapt and which would not using cephalometric films, a strong statistical significance was shown, thereby leaving no doubt that cephalograms can be used and still have accurate predictions. This applied only to the more extreme ranges of the hyoid bone at rest.

In a practical manner the cinefluorographic technique, though accurate, would not be feasible to most clinicians due to its expense. Therefore, in this study we have attempted to test whether by using cepahlometric films the same accurate predictions of adaptation of the tongue could be shown. Two major problems would, we hoped, be answered.

These were determining if we could capture the hyoid bone at rest since it is a free floating bone and subject to more stimuli and movement, and if we could predict with any certainty which subjects would adapt and which would not.

In our study the $\sqrt{245}$ for the vector of cephalograms was used. It was only an arbitrary point decided upon after evaluating the work in Dr. Augustson's unpublished thesis. Any vector larger than this was predicted not to adapt. Tables 2 and 3 give the vectors for cephalogram of before crib placement and twenty-four hours after. In Table 8, of the fourteen subjects which we predicted to adapt, only one subject, 21, showed no adaptation. In fact, the other thirteen showed fairly substantial adaptation (T value 7.055 $P < .01$).

The subjects predicted not to adapt, shown in Table 7, as a group showed no significant change. Two out of the group of seven did show some slight adaptation but nowhere near the adaptation of those in Table 8.

Though this initial study does show that predictions can be made at the extreme range, much further work needs to be done on the ability to predict the middle ranges of hyoid position. Also, even though Ingervall's technique of taking cephalograms in the postural rest position can reproduce the hyoid bone at rest in most instances, a more standardized technique would be of great value in clinical applications.

SUMMARY AND CONCLUSIONS

The purpose of this study was to determine if a standard cephalometric technique could be used to accurately measure repositioning of the hyoid bone at rest following forced distal displacement of the tongue through the use of a tongue crib.

This study was also to determine to what extent the repositioning of the hyoid bone, using the cephalometric technique, correlated with the ability to measure repositioning of the hyoid bone as had been determined by previous cinefluorographic technique.

Twenty-five adult female subjects were included in this study. Cinefluorographic and cephalometric films were taken to determine the hyoid bone rest position. Tongue crib appliances were placed on each subject. After twenty-four hours' wear, and prior to removal of the appliances, a duplication of the cephalometric and cinefluorographic film were repeated.

Conclusions:

(1) A strong correlation was shown to exist between cephalometric films and cinefluorographic film on the horizontal vector, both before crib placement and after crib placement.

(2) The same correlation was shown on the vertical vector _after_ crib placement between cinefluorographic film and cephalometric film but not before crib placement.

(3) Using Ingervall's method of taking a cephalogram (mandible held in postural rest position), a significant reproducibility of the hyoid bone at rest can be attained.

(4) Cephalograms can be used to determine at a statistically significant level which subjects would adapt to forced posterior positioning of the tongue based on the position of the hyoid bone at rest at the more extreme levels.

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The thesis is therefore accepted in partial fulfillment of the requirements for the degree of Master of Science.

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