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A Cinefluorographic, Electromyographic, and Myometric Study of Muscular Activity During Swallowing in Patients with Mandibular Resection

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A CINEFLUOROGRAPHIC, ELECTROMYOGRAPHIC, AND MYOMETRIC STUDY OF MUSCULAR ACTIVITY DURING SWALLOWING IN PATIENTS WITH MANDIBULAR RESECTION

by

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AUTOBIOGRAPHY

Dr. Roger Wolk was born on July 6, 1942 in Boston, Massachusetts, the second child of Dr. and Mrs. Eliot Wolk. At an early age the family moved to Los Angeles, California and has resided there ever since.

As an orthodontic patient in high school, Dr. Wolk became interested in the profession and has pursued the goal since that early age.

After graduation from North Hollywood High School in June 1959, he entered U.C.L.A. to complete his pre-dental training and from there he went to the University of Southern California School of Dentistry where he graduated in June, 1967.

Soon after graduation, Dr. Wolk enrolled in the Orthodontic and Oral Biology Departments at Loyola University in Chicago. After completion of the graduate curriculum, Dr. Wolk will return to Los Angeles to practice orthodontics and teach.

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CHAPTER I

REVIEW OF THE LITERATURE

A. Cinefluorographic Literature

Research in developing the cinefluorographic technique began as early as 1929 by Warren and Bishop at the University of Rochester. The bulk of research, however, has occurred since 1946. Many studies have been made concerning the anatomy and physiology of the normal and abnormal heart, the urinary tract, the esophagus, the stomach, and cerebral circulation. In addition to routine clinical studies, special investigations have been made of the swallowing mechanism, the production of sounds by laryngectomized patients, and the function of the organs of speech. The majority of studies have been concerned with the mechanism of swallowing, the function of the heart, and urinary tract.

1. Methods of Quantitative Cinefluorography: Berry and Hoffman (1959) made a cinefluorographic study of the movement of the TMJ. In order to determine the degree of the roentgenographic enlargement and thereby calibrate the actual anatomic excursions, a metal ball bearing of known diameter was attached to the face directly above the joint to be examined. This ball bearing becomes magnified to the

same extent as the joint structures. A wire grid of 10mm. mesh was placed in contact with the receiving screen of the image amplifier and is not subject to enlargement. Therefore, on the finished film, a simple ratio between the size of the shadow of the ball bearing and the grid meshes determines the actual anatomic measurements. All of the quantitative methods of cinefluorographic analysis of motion have been based on the development of analytical projectors which enable the viewer to preview the cine sequences by means of slow motion and pulse viewing, and select a cine frame representing the limit of motion in some direction. This selected frame is then projected for an unlimited period of time while its image is traced or compared to a subsequently prepared tracing. The unlimited dwell of the selected frame is made possible by means of a fine gate shutter or accessory blower so as not to damage the film.

Recently, Cleall (1966) has used the Vanguard Motion Analyzer in his study of head posture in relation to swallowing. The analyzer consists of a vertical projecting analytical projector attached to a projection stand or rear projection screen. On the face of the screen are cross hairs in the X and Y axes which can be moved and are accurate to .001 inch. The theta or angle measuring device is also available. The motion analyzer can be coupled to an automatic readout device which will activate an IBM punch card and magnetic tape equipment for computer analysis.

Men investigating swallowing and speech patterns, as well as hyoid movement, have developed methods to quantitatively measure movements with respect to fixed cranial landmarks, Sloan, et al (1963) presented an analysis originally described by Bench (1962) wherein cephalometric tracings of fixed cranial landmarks were superimposed over a cenofluorographic image. After making corrections for magnification errors, the patient's movement on the cine record could be shown with respect to the cephalometric tracing.

Since the hyoid bone has a characteristic cycle of movement during swallowing, comparisons can be made by relating the hyoid to certain fixed landmarks and plotting the changes in position during movement. The cephalometric analysis of hyoid position considers the following landmarks: a) cranial base (represented by the saddle angle, which is measured from nasion-sella turcica-basion, an indication of the relationship between the anterior and posterior cranial base.), b) facial angle (the angle between Frankfurt Horizontal and the facial plane, which represents maxillary and mandibular position in the anterio-posterior direction), c) mandibular plane (plane of the lower border of the mandible), d) facial convexity (a measure of procumbency of jaws), 3) facial height (linear measurement between nasion and menton), f) the height of cervical vertebrae 1-5, g) vertical height of the dens, h) distance from the hyoid bone to the mandible, i) distance of hyoid bone to the genial tubercle, j) level of hyoid bone with respect to the cervical vertebrae, k) the distance of hyoid point to a vertical line drawn from the pterygoid root.

The cinefluorographic analysis considers the following measurements: a) hyoid bone to posterior nasal spine at rest, b) hyoid bone in posterior-most position to posterior nasal spine, c) hyoid bone in anterior-most position to posterior nasal spine. Angular measurements were made at these positions using the hyoid as the apex and PNS as one leg and the vertical line from the orbit upon the palatal plane as the other leg.

Cleall (1966) used a cinefluorographic analysis somewhat different than Ricketts et al. He considered the following angular measurements: a) tongue tip to palatal plane at PNS, b) hyoid to palatal plane at PNS, c) soft palate to hard palate at PNS, d) tongue tip to palatal plane, e) lower incisor to palatal plane at point a intersection, and f) pogonion and palatal plane. The following linear measurements were considered: a) tongue tip to palatal plane, b) lower incisor to palatal plane, c) dorsum of tongue to palatal plane, d) hyoid to palatal plane, e) lip separation, f) molar separation, g) tongue tip to lower incisor (horizontal), h) hyoid to posterior pharyngeal wall.

2. Studies of Swallowing Patterns: Saunders, et al (1951) using high speed cinefluorography studied the mechanism of swallowing. Their paper is summarized by Grant and Basmagian: "Swallowing begins as a voluntary movement and continues as an involuntary one. Thus the lips are closed and the buccinators are pressed against the teeth. The lingual muscles pass the bolus of food backward on the dorsum of the tongue to the palato-glossal arch, and there, at the entrance of the pharynx it may rest, the voluntary stage being completed."

When saliva or a bolus of food enters the pharynx, the involuntary stage is started. The jaws are held closed by the masseter and temporalis, while the hyoid and larynx rise. The tongue thrusts the bolus upward and backward against the soft palate thus beginning the reflex activity. A peristaltic wave passes the bolus down the esophagus. These movements are too rapid for the eye to perceive, therefore, high speed cinefluorography as employed by Saunders is necessary to trace the movements of the swallowing reflex.

Cleall (1965) studied deglutition through cinefluorographic analyses of twenty-eight adolescents with skeletal and normal Class II, Div. I cases, and twenty-seven tongue thrust cases with Class II and Class I malocclusions, including several open bites. In this analysis, a cinefluorographic sequence was studied during the saliva swallow on demand and motion was compared by means of an analytical projector.

Cleall states "The assumed interrelationship between the tongue, lips, and mandible during swallowing, and the form of the surrounding hard tissues has given rise to the concepts of 'normal' and 'abnormal' when the behavior is such that an adverse effect on the dentition can be demonstrated or assumed to be present." However, in this study of the normal sample, he found that in approximately twenty percent there was an actual lip separation and also forty percent showed no occlusal contact during the swallowing process.

In the Class II group, the hyoid bone was found to be higher and more posterior, and the posterior aspect of the tongue with the soft palate resting upon it was also found to be in dorsincranial position. When related to the lower incisor, the tongue tip was also observed to be further forward in the Class II group. At rest, the lips were parted in about twice as many subjects in the Class II group as in the normal sample. Most of the important differences appeared to be related to the marked dental disharmony present in the Class II group. Sixty percent of these children did not have occlusal contact.

Hedges, et al (1965) state that the evidence concerning the frequency of the teeth-together swallow is not well documented and simultaneous lip movement during deglutition is vague. Tulley (1956) attributed this to the difficulty in obtaining a true lateral view of a subject without a head positioner. Cleall (1963) refrained from using a head positioner in his study and had the patient watch a small light positioned at eye level. He stated that fixation of the head during swallowing is unphysiologic, since the head moves slightly during swallowing. In the study of tongue patterns in function by Hedges et al, a cephalostat was used and they found that fifty-three percent of the non-demand saliva swallows were with teeth apart.

3. <u>Hyoid Bone Patterns During Swallowing</u>: The hyoid bone is a horse-shoe shaped bone located high in the neck. The legs of the bone encircle the larynx just above the thyroid cartilage. Sicher (1960) states that the hyoid bone can be designated as the skeleton of the tongue. Orban (1957)

states that the hyoid develops from the second and third branchial arch. The posterior portion of the tongue also develops from these two arches. Brodie (1950) related the action of the hyoid, suprahyoid muscles, and mandible to the maintenance of an airway during mandibular movements, and called attention to the fact that the hyoid's role as a functional part of the skeleton is an evolutionary development associated with those with an upright posture.

The relative lengths of the sets of muscles attaching to the hyoid bone determines the A-P relationship of it to the vertebral column and the superio-inferior relation to the sternum and mandible of maxilla. Thompson (1941) noted that mandibular movements were influential upon the position of the hyoid. Cleall (1960) noted a definite statistical correlation between movements of the tongue tip, mandible, and hyoid bone during swallowing in normal patients. Sloan (1963) et al, prescribed methods of quantitative analysis of hyoid movements which is discussed above. They studied forty-five subjects averaging twelve years old; equal groups of Class I, Class II, Div. I, and Class II, Div. II, were presented. Two distince hyoid movement patterns were found; a circular pattern and an oblique pattern (elliptical). In all three groups, the anterio-posterior location of the hyoid bone was found consistently near the anterior root of the pterygoid plates. The Class I malocclusions showed significantly lower and more posterior hyoid locations. The Class II's showed higher and more forward hyoid position with greater ranges of movement than the Class I subjects.

Sloan, et al (1965), showed that the elliptical pattern of hyoid movement was associated with tongue thrust swallowing. Cleall (1965) noted that the hyoid in Class II subjects was higher and more posterior than the normal patients.

Shelton, et al (1960), found in their cinefluorographic study that the hyoid bone moved cephalad, the larynx elevated and the pharyngeal portion of the tongue moved dorsally during the first phase. The second phase shows the hyoid anterio-superiorly with elevation and closure of the larynx. The pharyngeal portion of the tongue was obscured by the bolus. In phase three, the hyoid descended either obliquely postero-inferiorly or more directly inferiorly. Anterior movement of the pharyngeal portion of the tongue and descent and opening of the larynx also was observed.

Durso and Brodie (1962) concluded that the hyoid bone is positioned superiorly and inferiorly at a level opposite the third and fourth cervical vertebrae. Its position is determined by the suspending muscles which run from the cranial base bilaterally to the mandibular symphysis. Thus it is controlled by a three point suspension. During the period of growth, the hyoid descends as the cervical vertebrae increase their height while the posterior cranial base and the mandible descend and move away from each other. This descent, however, is of such a nature that the relative position of the bone does not change.

B. Electromyographic Literature

The action of the muscles of mastication during chewing and swallowing cannot be measured directly. The electrical activity of the muscle can afford an indirect measure of the force exerted by an individual muscle and the time of its activation.

The impetus for applying electromyography to problems in dentistry is credited to Moyers. In 1949, he studied temporomandibular contraction patterns in Class II, Div. I, malocclusion cases. Among the findings, he noted that the suprahyoid muscles aided in stabilizing mandibular movements. Since then, a number of articles have appeared describing a variety of problems studied with the aid of electromyography. In 1950, Moyers published a second paper dealing with the electromyographic analysis of the synergistic action of the muscles involved in the temporomandibular articulation. He found that movements of a joint are affected by the interaction of several muscles.

In addition to Moyers, Carlson (1952), studied the muscles of mastication electromyographically and has confirmed that the action of the muscles are based on their anatomy.

Geltzer (1953), studied the activity of the temporal muscles during forceful contraction. He found that increasing loads on the temporalis resulted in changes in ampliture, but not in frequency. Therefore, he surmised that amplitude was the most useful parameter to be measured.

Recordings obtained during maximal bite were taken by MacDougall and Andrews (1953), Greenfield and Wyke (1956), Latif (1957), Woeful (1960), and Okum (1960). These studies showed that the elevators were activated differently according to where the mandible was placed in the sagittal plane; as compared to biting in the normal intercuspal position. Biting on the incisors involved activation mainly of the masseter muscles whereas biting in a retruded position involved activation mainly of the posterior temporal fibers.

Schlossberg (1954), performed an EMG investigation of the functioning perioral and suprahyoid musculature in patients with normal and abnormal occlusion. He found early in his experiment that a general pattern of muscle activity could be established with characteristics for each group. Although variations within each group were noted, he observed a definitely discernible pattern between the two groups.

Karau (1955) concluded with the aid of EMG studies that abnormal muscle patterns could be altered favorably by the elimination of occlusal disharmonies.

Grossman (1961) compared pre- and post-treatment muscle function of patients undergoing orthodontic care and found abnormal muscle activity to be related to malocclusion.

Jarabak (1956) used electromyography to analyze muscular and TMJ disturbances due to occlusal imbalances. He found that malfunction of one of the muscles which control mandibular movements leads to malfunction of the others, resulting in disturbances within the joint.

Caldwell and Letterman (1954) introduced the vertical osteotomy of the ramus. In this procedure, the ramus is exposed through an extra-oral incision at the angle of the mandible. A cut is made in the ramus from the sigmoid notch to the angle so as to preserve the integrity of the structures in the mandibular canal. This is done bilaterally and the the mandible repositioned posteriorly in its new relationship. The segments are wired together and intra-oral fixation is maintained for three to six weeks.

Robinson (1956) and Hinds (1960) advocated the subcondylar osteotomy technique for this reduction. The surgical approach was through a sub-mandibular incision. With this procedure, the hazards of post-operative open bite was felt to be eliminated.

Obwegeser (1962) in his intraoral surgical technique states that the possibility of relapse anteriorly is greatly reduced. Egyedi (1962) suggests surgical reduction of the tongue in certain cases to prevent relapse. This suggests that the tongue and suprahyoid muscles play a large role in the untoward forces on the mandible after surgery.

Tulley (1953) and Baril and Moyers (1960) studied the muscles of the lips and the elevators during swallowing. In a number of their subjects the pattern of activity conformed neither to the normal or abnormal patterns of activity observed by Gwynne-Evans (1954); thus these patterns cannot serve as basis to classify the muscle activity during swallowing.

Findlay and Kirkpatrick (1960) showed that the activity during swallowing in the temporal and masseter differed significantly in amount and duration from subject to subject. These men found no evidence of discernible differences in activity in normal patients and those with malocclusion. They found the individual variation to be too great.

Krazer (1960), Kydd and Neff (1964) and Ahlgren (1966) agreed with this conclusion.

C. Relation of Muscle Activity to Skeletal Types

Moyers (1949) as mentioned earlier, studied Class II, Div. I, patients. He found the predominance of activity in the posterior temporalis when the mandible was at rest and during movements. The coordination of the masseter and temporalis during biting depends on where the mandible is placed in the sagittal plane. Grossman and Greenfield (1956), Timms (1960), Grossman, Timms and Greenfield (1961) found, using the EMG, that the sagittal relationship of the mandible could be found in patients with malocclusion by measurement of the maximal bite.

Perry and Harris (1954) and Perry (1961) found the masseter muscles in unilateral chewing to be activated earlier in individuals with Class II, Div. 1, than in subjects with normal occlusions. Garrett (1964) showed that the masseter had increased activity in patients with Class II, Div. 1, than those with normal occlusion in experiments with biting forces.

As to the shape of the mandible, Witt (1963) reported that a small gonial angle was associated with strong masticatory activity in the masseter; Ahlgren (1966) found a tendency of a similar association between the activity both in the temporalis and masseters during chewing as related to the gonial angle.

Moller (1966), in an excellent study of chewing muscles, reported the following information: in contrast to chewing, swallowing was characterized by a synergistic activation of all the muscles he studied. The degree of activation varied from patient to patient. The elevator muscles (internal pterygoid, temporalis, masseter) are less active during swallowing than chewing. They are activated in the above order.

The depressor muscles (external, pterygoid, mylohyoid) were activated before the anterior temporalis in some, simultaneously in others. The temporalis and digastric were synchronous in their onset. The external pterygoid was less active during swallowing than chewing. The digastric and mylohyoid showed greater activity during swallowing. Those who swallowed with tooth contact had more activity of the anterior temporalis, masseter, and orbicularis oris, while the others showed no changes with or without tooth contact.

Experiments during maximum biting force with the mandible in different positions showed: 1) the two divisions of the temporalis were active only in intercuspal position, 2) the temporalis was passive during biting on the incisors; the mandible was fixed by the pterygoids and the masseter,

3) the external pterygoids were strongly activated in all experiments, but mostly during the protrusion.

Moller also categorized the activity of the masticatory muscles as related to cranio-facial morphology. His conclusions are of great significance for this study.

1) A curved cranial base was associated with a) late activation of the masseter relative to the anterior temporalis during chewing, b) strong activity in the anterior and posterior temporalis during swallowing; in addition, the action of the masseter during swallowing was correlated to facial prognathism; strong activity was found in patients with prognathism and anterior inclination of both jaws.

2) A curved mandibular base and prognathism and anterior inclination of the mandible was associated with a) strong activity in the anterior temporalis and masseter during maximal bite in the inter-cuspal position and b) a prolonged initial phase of low activity in the mylohyoid during swallowing.

2) Retroclination of the lower incisors and reduced alveolar, mandibular prognathism was associated with a) strong activity in the external pterygoid during swallowing and rest position, and b) strong activity in the lips during swallowing.

4) A large overbite was associated with a) strong

activity in the posterior temporalis during chewing and biting, b) strong postural activity in the upper lip during swallowing and chewing, c) low activity of the mylohyoid during swallowing.

Ware and Taylor (1968) stated that when the mandible was positioned posteriorly, there is a slight increase in the mandibular plane angle. Within a year following surgery, an anterior relapse of 2-3mm. at pogonion was noted and the mandibular plane angle returned to the pre-surgical value. They suggested that the external pterygoid caused the condylar fragment to displace anteriorly after surgery and the resulting tension caused growth of bone at the condylar head. This they theorized was the reason that relapse occurred in their study. These surgical procedures were done without interosseous wiring. It is not known if wiring would prevent this result. Baume and Derichsweiller (1961) found in monkeys that the mandibular condyle is responsive to physiologic forces.

D. <u>Studies on Intraoral Forces of the Tongue</u>

To date, no specific research has been done in an effort to measure the force of the tongue upon the lower anterior teeth before and after mandibular repositioning as a means of evaluating change taking place in tongue activity.

Neff and Kydd (1966) studied the tongue pressure on the lower anteriors in open bite cases. Although they did not study magnitude, they determined that tongue-thrusters may cause open bite malocclusion not primarily from tongue pressure during swallowing, but chiefly from the tonic passive position of the tongue in these children.

Proffit, et al (1964), showed that tongue pressure during swallowing ranged from 10gm/cm to more than 100gm/cm, depending on the child. The tongue forces were measured by means of a strain gauge mounted on a stainless steel cantilever beam which was mounted to the teeth by dental compound. The leads from the strain gauge were connected to a Wheatstone bridge and recorded on a four channel recorder. Command swallows of water or saliva showed slightly greater pressure than involuntary swallows.

Gould and Picton (1962) studied the force acting upon the teeth from the lips, cheeks, and tongue. They found that in order to assure an accurate result the pressure transducers should be no more than 2mm. from the surface of the tooth, otherwise the force will be higher than normal.

Winders (1958) found that resistance transducers and recorders on the teeth were best suited for recording myometric pressures. He also found that the tongue is not in contact with the lower anteriors during rest except in

Class III open bite malocclusions. There was no significant difference between the pressures incurred during swallowing and the anterior-posterior position of the teeth. The tongue in function, exerted a much greater force upon the teeth than the perioral muscles.

Winders (1962) showed that resting pressures of the tongue ranged from 0 to 15 gm/cm. Swallow-ng pressures ranged from 10 to 150 gm/cm. Lingual pressure on the maxillary central has been measured as high as 207 gm in a tongue thruster. Maximum effort pressures have been measured up to 2,000 gm/cm.

CHAPTER II

PURPOSE

The purpose of this investigation was to study the changes which took place, during swallowing, in the activity of the tongue, the hyoid bone, and the temporalis and masseter muscles after surgical resection and repositioning of the mandible.

The study is threefold:

A. Cinefluorographic sequences of deglutition were taken before surgery and a few months after surgery to evaluate changes in hyoid bone and tongue movement due to the surgical procedure.

B. An electromyographic study was done to compare changes which took place in the masseter, anterior temporalis, and posterior temporalis as a result of repositioning of the mandible and its associated musculature. These changes were compared to activity patterns shown by Moller (1966) for prognathic and normal patients.

C. A myometric study of the anterior force of the tongue during swallowing was done to compare pre- and post-surgical tongue thrust pressure on the mandibular incisor teeth.

CHAPTER III

METHODS AND MATERIALS

Six patients with clinical characteristics of mandibular prognathism were selected from the Orthodontic Clinic and Hines V.A. Hospital. The diagnosis was confirmed by means of a lateral cephalometric headplate using the Sassouni and Bjork analyses, which were traced on acetate paper. Post-surgical headplates were also taken and tracings made to evaluate skeletal changes which occurred.

Impressions were taken and models constructed in order to assess the present occlusion and determine the proper occlusion to be sought after surgery. Midline deviations, arch length discrepancies, arch form, and amount of anterior and posterior crossbite were also considered when planning surgical treatment.

Frontal and lateral photographs were taken with Kodak Panatomic-X 35mm. film from a distance of about three feet.

A. <u>Cinefluorographic Film Sequence</u>

A Picker cinefluorograph with an image intensifying tube was used for the film sequences. The x-ray head and the image amplifier with the camera and optical system are mounted on each end of a "C" arm which is adjustable and capable of being locked in any vertical position. The cephalostat is attached to the "C" arm in close relation to the input phosphur of the image tube. An aluminum profile shield is attached to the cephalostat in order to produce a soft tissue outline while definite skeletal contrast is preserved.

The patients were positioned loosely in the ears in order to allow free movement of the head during swallowing. The patients were allowed to assume natural head position while looking straight ahead. Free movement of the head is necessary in order to allow for a completely physiologic swallow. The patients were viewed under fluoroscopy first in order to be sure that the necessary skeletal and soft tissue structures were visible. In areas where excessive radiation would strike the input phosphur, small pieces of lead were taped onto the input phosphur to block this potential radiation. An adjustable mirror was used to view the patient's image.

The tip, dorsal, and ventral surface of the tongue was dried with gauze squares and a mixture of barium sulfate crystals and Orobase was applied to the tongue with a cotton swab. Barium sulfate (Esophotrast) was used to outline the tissue by placing a line down the middle of the face.

A small amount of Esophotrast was introduced into the mouth and the patients were asked to remain at rest. At this time, the cinefluorograph was adjusted for radiation and cinema. The patients were asked to swallow the radiopaque bolus. A sixty-frame-per-second cinefluorographic film of the swallowing mechanism was recorded several times for each patient. The Esophotrast, when swallowed, produced a radiopaque coating on the tongue and soft palate, which aided in identifying the structures. After the initial swallow of Esophotrast, the patients were given a smaller amount of barium sulfate and a sip of water. This was done to enable them to swallow more easily and to reduce the size of the radiopaque bolus which obscures the tongue.

The film recordings were taken with Kodak Plus X 16mm. film at a film speed of sixty-frames-per-second, using a 35mm. F_1 lens.

The one hundred foot films were developed with a Kindermann developing apparatus using normal x-ray developing and fixing solutions. Safelights were not to be used in the darkroom during developing.

B. Film Analysis

The analysis of the film was accomplished with the aid of the Vanguard Motion Analyzer. The motion analyzer is a general purpose portable unit which will show qualitative information and still gather quantitative data. This unit provides X and Y measurements on the image projection screen, as well as an adjustable theta axis for easy angular measurements. Measurement is made from manually positioned cross hairs which appear superimposed on the film image. The measurements are accurate to .001 inch linearly and 1/4° angularly. Due to the lack of detail of the skeletal landmarks, it was unnecessary to measure to that degree of accuracy. The metered frame counter enables the operator to record the duration of the sequences. The motion analyzer has a variable speed adjustment which allows for speeds of five to thirty frames per second in forward or reverse. A single frame advance is also present.

Each patient's film sequences were viewed repeatedly until several uninterrupted swallows could be found. These swallows were noted by frame number. Each swallow was analyzed separately. The swallow was divided into five stages so that the hyoid and tongue movement could be plotted accurately. Stage 1 - Rest; Stage 2 - Hyoid bone in posterior superior position; Stage 3 - The tongue contacting the hard palate and the bolus passing the Posterior Nasal Spine on its way to the pharynx; Stage 4 - The hyoid bone in its most anterior and superior position. The bolus usually is at the level of the epiglottis; Stage 5 - Hyoid returns to rest.

Each swallowing sequence was projected slowly until the frame which represented the stage of swallowing desired was reached. Tracings were made of these frames by placing acetate paper over the image and tracing the tongue, hyoid bone, mandibular symphysis, facial profile, palatal plane, incisor teeth, and nasion. By superimposing the tracings of successive stages of deglutition with reference to a fixed plane, it was possible to follow the hyoid and tongue movements visually, and compare each sequence to others pre- or post-surgically. It was also possible to compare stages with one another and in addition, the hyoid movement pattern could be compared visually to others of the patient. Changes in hyoid and tongue position post-surgically can be thought to be directly related to the change in the muscular environment due to surgery.

The inferior border of the body of the hyoid bone was used to plot movement because it was the most easily distinguishable part of the bone.

C. Electromyographic Methods

The equipment used for this phase of the study consists of a G.M.E. eight channel polygraph which has been modified for electromyographic recordings, and eight Grass monopolar silver disc surface electrodes. The electromyograph was calibrated in order to have six millimeters of pen deflection with fifty microvolts of input. The paper speed was adjusted to 1.5 cm. per second for some swallows, and 6.0 cm. per second for others. The best ten recordings were selected for analysis.

The muscles observed in this study were the bilateral masseters, anterior temporals and posterior temporals. The anterior and posterior temporals were recorded separately as their individual function differs. The posterior fibers run almost horizontally and are a retracting component. The anterior fibers run vertically and elevate the mandible. These muscles are also anatomically convenient for electrode placement. Electromyographic recordings were made before and after surgery.

The subject was seated in a chair in a secluded room where there was a minimal amount of electrical interference from lights, typewriters, machines, etc. The electromyograph was located approximately six feet away. The location of electrode placement was determined by having the patient clench his teeth together. Thus the bulge of the masseters and anterior and posterior temporals could be palpated easily. The anterior temporalis electrode was usually placed about four centimeters superior to the outer canthus of the eye. The posterior temporalis electrode was usually placed superior to the external ear at the hairline. The masseter was found to be most prominent slightly anterior and superior to the gonial angle.

The sites for electrode placement were cleaned and a small amount of electrode jelly was rubbed on the area with a finger. Approximately one-half inch strip of Grass Conductive Electrode Paste was then applied to the area. The electrode was then placed at the site and held securely while a gauze square wet with collodion was placed over the electrode and pressed tightly to the skin. A jet of air was used to harden the collodion. The electrodes were therefore making good contact to the skin. Electrodes were placed on all six muscles because they were to be recorded simultaneously. A reference electrode was then placed on the left ear lobe in the usual manner. The patients were grounded by means of an electrode placed on the left mastoid bone.

The electrode leads were plugged into the terminal board of the electromyograph in the following order: Left Masseter, Right Masseter, Left Anterior Temporalis, Right Anterior Temporalis, Left Posterior Temporalis, Right Posterior Temporalis. The reference electrode was plugged into the terminal board in a socket which was wired to all channels, so that one electrode could be used for all muscle electrodes. The ground electrode was placed in the ground socket of the terminal board.

After the electrodes were properly placed and the amplifiers were calibrated so that fifty microvolts would produce a six millimeter pen deflection, the patients were given a sip of water to swallow. The pens were watched in order to follow the activity of the muscles. When twenty swallows were accomplished with noticeable activity, the electrodes were removed and the patients were dismissed.

The name, date, age and sex of the patient was noted on the recording paper. This procedure was repeated after surgery in order to compare the results.

Two surgical techniques were used with these patients, the intraoral sagittal splitting of the ramus as advocated by Obwegeser, (Fig. 1) and the extraoral bilateral vertical osteotomy of the ramus. (Fig. 2) An attempt will be made to discern any muscular effects of these techniques.

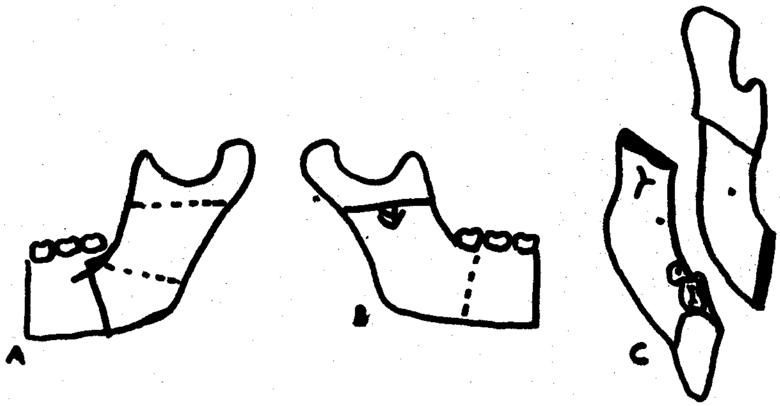
D. Electromyographic Analysis

Pre-operative and post-operative electromyograms were compared for each subject. This study did not lend itself to group evaluation because of individual variations in the degree of prognathism, surgical technique, cranio-facial morphology, and occlusion.

Each series of electromyographic records were carefully evaluated and the ten best swallowing sequences were selected for each patient. The duration and amplitude was

FIGURE 1

Obwegeser's Sagittal Splitting Technique of the Ramus



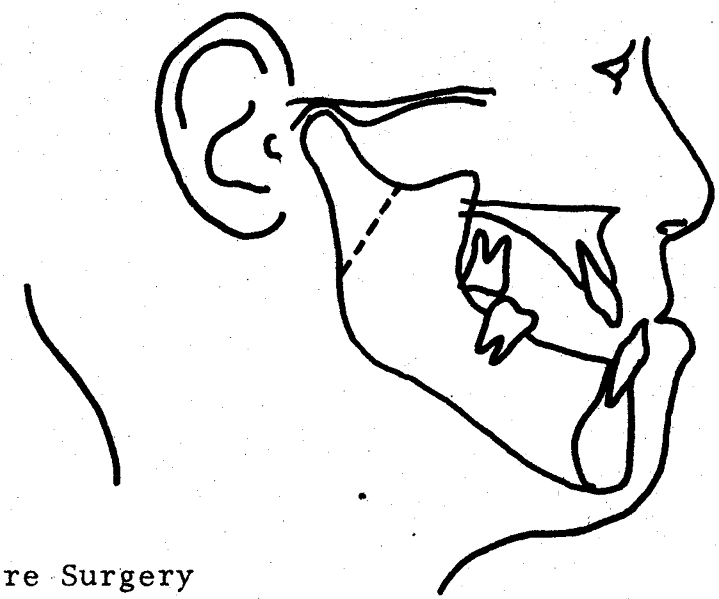
A. External View

B. Internal View

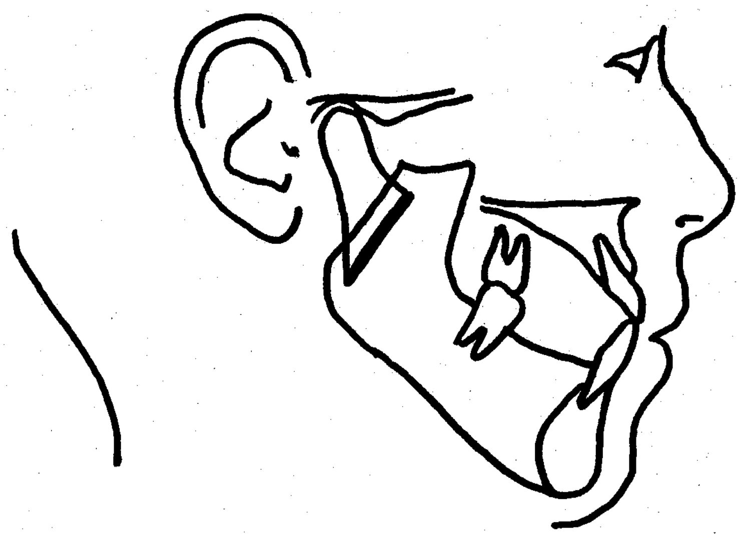
C. After Splitting

FIGURE 2

Bilateral Osteotomy of the Ramus



Before Surgery



After Surgery

measured for each muscular envelop. The duration was measured in millimeters with respect to the paper spread. To measure amplitude, the vertical height of the three largest spikes were measured and averaged. If any wobble was present in the pens before swallowing started, it was subtracted from the average amplitude. This was done for each muscle on every swallow.

The average amplitudes for each muscle was recorded in a table for each swallow. These figures, as well as the duration values, were then ready for statistical analysis.

E. Myometric Method

In order to measure the force of the tongue on the lower anterior teeth a pressure sensitive gauge must be used which is of small enough size to place on the lingual of these teeth and remain in place during successive swallowing pressure. The lower anterior region was selected to measure tongue force because prognathic patients have a low tongue position and usually swallow with a tongue thrust. In addition, tongue pressure upon these teeth is to be evaluated post-surgically to determine if any significant force increase is present to effect post-surgical occlusion.

In order to provide accurate information with relative ease of calibration, strain gauges were selected which have the property of linear variation. Due to the inability of the patients from the Veterans Administration to be present at the Physiology laboratory of the dental school, it was necessary to use two types of pressure sensitive strain gauges.

Three patients were tested by means of a strain gauge unit which operates by interrupting the beam of a photo cell. This unit is made by the E & M Co., Houston, Texas, and is made to be used with the E & M Physiograph located in the Physiology laboratory of the dental school. A five gram deflection of the cantilever beam produced a pen deflection of one millimeter. The forces have the property of linear variation, so calibration was easily attained by hanging a known weight on the cantilever beam which provided a measurable deflection on the paper.

Since this strain gauge is an extraoral device, it was necessary to construct a pressure plate which could be connected to the cantilever beam without distortion. A piece of stainless steel band material was adapted to the lower anterior central incisors on the lingual surface. A short piece of .016 round wire was welded to the plate and extended beneath the contact of the lower centrals to the labial. If necessary an offset bend was made in the wire if necessary to pass between the lips without interference.

The wire, as it passed through the lips, was connected to an extension arm of the strain gauge. Thus any pressure applied to the lingual pressure plate was transferred to the strain gauge and a pen deflection was produced.

It was imperative that the head was stabilized by means of a portable dental headrest which was attached to the back of a sturdy chair. Small amounts of water were introduced into the mouth by means of a medicine dropper. The pressure plate was adjusted so that it was not allowed to extend lingually more than two millimeters. More than this amount would produce undue impingement upon tongue space and a possible lack of accurate recordings. The wire lead from the pressure plate was stabilized by threading it through a small wire loop attached on the labial of the anteriors. This prevented dislodging of the pressure plate.

Approximately twenty swallows were recorded and after calibration, the patient was dismissed.

The three Veterans Administration patients were tested by means of a resistance gauge mounted on a metal beam, and attached to the lingual surface of the lower lateral incisor so that the deflection end of the beam would lie approximately in the midline. The Baldwin-Lima-Hamilton weldable gauge SR-4, FAB-25-35-6 was selected in these cases. This gauge is advocated by Brodie (1966).

It consists of a short length of very thin conductive foil attached to the deflective element in such a manner that the filament is strained equally with the carrier. This gauge is manufactured with the foil element embedded in a bakelite layer. The gauge was mounted on a steel beam .005 inches thick and 4mm x 8mm in size and was attached with Eastman 910 adhesive.

Small diameter flexible wire was soldered to the lead wires of the gauge and the soldered portion was embedded in a small piece of Kerr's dental compound. A small amount of dental compound was warmed and placed at the stationary end of the beam and adapted to the lingual of the lateral incisor of the patient's dental case. This created a template for positioning in the mouth.

The gauge was used as one leg of a four leg Wheatstone bridge. The output current of the bridge, induced by changes in resistance of the strain gauge was measured by the polygraph. Calibration was adjusted to effect a one mm deflection a five gram force.

The strain gauge assembly was attached to the lateral incisor by Eastman 910 adhesive. The compound was adapted so that the end of the beam was two mm from the lingual of the central incisors. When stability was assured, the wire leads were brought out at the corner of the mouth and the terminals were connected to the control board of the recorder.

About twenty swallows of water was performed and the pen deflection was noted. The patient was then dismissed.

F. Myometric Analysis

The myometric recordings were carefully studied for each patient pre- and post-operatively, and the ten most representative swallows were chosen for analysis.

Each swallow produced a pen deflection of various amounts. The amplitudes were measured in millimeters with respect to the base line and recorded. The figures were then ready for statistical analysis.

CHAPTER IV

RESULTS

A. Cinefluorographic Results

After evaluation of the cinefluorographic records, the most significant finding was the fact that the position of the hyoid bone in Stage 4 (the most anterior and superior position of the hyoid during swallowing, which marks the end of the pharyngeal phase of deglutition when the bolus is at the level of the epiglottis) is at the same antero-posterior position relative to the symphysis as before surgery. This means that when the mandible is repositioned, the hyoid and all its associated musculature is also repositioned posteriorly. All other stages in the hyoid cycle were moved posteriorly. Indeed, the whole hyoid cycle was repositioned.

1. Subject #1 Patient M.C. See Figures 3 and 4

All stages of the swallowing cycle show a posterior and inferior location of the hyoid bone when compared to the same stage presurgically. The entire hyoid cycle is posterior and inferior to the pre-surgical cycle. The rest position was not positioned posteriorly as far as the amount of mandibular reduction (as was Stage 4), and the position at Stage 3 did not move downward as in other stages. In this patient, Stage 2, which represents the posterior and superior limits of the cycle, did not move posteriorly with respect to rest position as in other cases.

The shape of the pre-surgical hyoid cycle shows more forward movement than upward, while post-surgically the movement was more equivalent. In both cases, the cycle was triangular in shape.

Tongue thrust was present both pre- and post-surgically with the tip protruding through the anterior teeth in both cases. A low tongue position was present in each case.

2. <u>Subject #2 Patient P.W. See Figures 5 and 6</u>

The hyoid cycle was positioned posteriorly the same amount as the reduction of the mandible, with all stages slightly superior to the pre-surgical positions, except in Stage 4, which was inferior. This is in opposition to the other cases which show inferior repositioning. The post-surgical rest position was superior to the pre-surgical rest, which indicates higher initial tongue position.

The hyoid cycle showed more forward movement than upward in both pre- and post-surgical swallows. Therefore, the cycles remained of similar type. The tongue pattern remained of the tongue-thrust variety, only a slightly higher tongue position was noted.

3. <u>Subject #3 Patient C.S. See Figures 7 and 8</u>

The entire hyoid cycle was repositioned posteriorly and inferiorly in all stages. The amount of posterior repositioning of the hyoid, though, did not represent the complete amount of surgical reduction.

The hyoid pattern showed a more superior than anterior movement and this cycle was similar post-surgically.

Pre-surgically, a noticeable tongue thrust was present with the tongue tip protruding well beyond the maxillary incisors. Post-surgically, the tongue contacted the maxillary anteriors showing some evidence of a changing swallowing pattern, but it still must be classified as a tongue thrust due to the observed lip activity in the cinefluorographic film.

4. <u>Subject # 4 Patient G.J. See Figures 9 and 10</u>

The hyoid cycle was repositioned posteriorly and inferiorly. Stage 1 and Stage 4 hyoid positions were relocated backward the equivalent amount of the mandibular reduction. Except for Stage 2 hyoid position, the pattern of movement was the same. The shape of the cycle was superiorly about the same distance as anteriorly.

A tongue thrust was present pre- and post-surgically. The tongue tip protruded beyond the maxillary anteriors prior to surgery, but was confined afterwards.

5. Subject #5 Patient T.Y. See Figures 11 and 12

This patient exhibited two distinct post-surgical hyoid patterns. One cycle was superior and posterior to the pre-surgical, while the other was inferior and posterior. The difference in the level of the cycles appears to be related to tongue position prior to swallowing. A low tongue produced a low hyoid cycle, while a high position produced a high cycle. In both instances though, the cycle was repositioned posteriorly the equivalent amount of the mandibular reduction. Although trajectories differed, they remained of similar type, superior movement and anterior movement approximately equal.

Tongue thrust swallowing remained present post-surgically.

6. Subject #6 Patient D.B. See Figures 13 and 14

This patient was the only one in the study which showed a distinctly different hyoid movement pattern although the location of the hyoid stages were still positioned posteriorly and inferiorly. Stage 4 hyoid position showed relocation approximately equal to mandibular reduction. Rest position was not as far back and was above pre-surgical rest, but all others were inferior.

In both cases superior movement was about equal to anterior movement, although the cycles were different.

The tongue thrust, which was present pre-surgically, persisted at the time post-surgical records were taken, although the tongue did not protrude beyond the teeth after surgery as they did before.

TABLE 1

Summary of Subjects

Patient	Age	Technique	Amount of Resection	Date: Pre Surgical	Date: Post-Surgical
M.C.	45	Extra-oral	7mm	10/68	3/69
P.W.	16	Intra-oral	6mm	12/68	3/69
C.S.	16	Intra-oral	18mm	12/68	3/69
G.J.	22	Extra-oral	15mm	1/69	3/69
T.Y.	16	Intra-oral	10mm	12/68	3/69
D.B.	25	Extra-oral	6mm	7/68	3/69

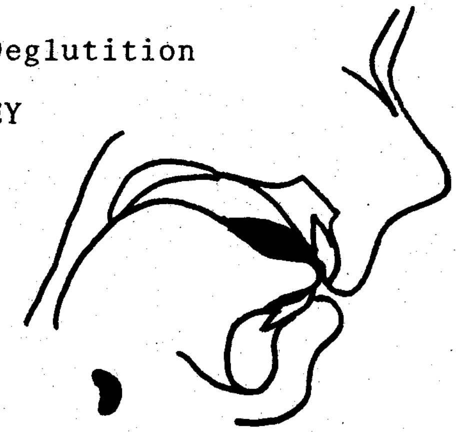
TABLE 2

Stages of Deglutition

KEY

Stage 1 - BLUE

a) Rest position of hyoid and tongue



Stage 2 - RED

a) Hyoid superior and posterior in position
b) Soft palate beginning to move toward pharynx
c) Bolus begins move backward

Stage 3 - PURPLE

a) Dorsum on tongue at Posterior Nasal Spine
b) Soft palate contacting posterior pharynx
c) Hyoid moving forward

Stage 4 - GREEN

a) Hyoid in anterior and superior-most position
b) Bolus at level of epiglottis
c) End of Pharyngeal Phase

FIGURE 3

Comparison of Hyoid Position During Swallowing - Patient M.C.

Amount of resection -- 7mm.

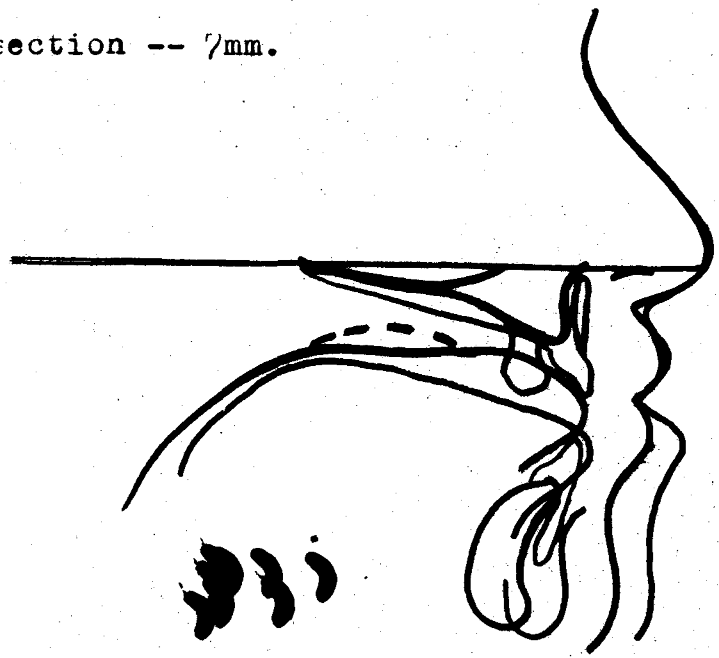


FIGURE 4

Comparison of Hyoid Cycle During Swallowing - Patient M.C.

BLUE-- Stage 1

RED-- Stage 2

PURPLE-Stage 3

GREEN--Stage 4

FIGURE 5

Comparison of Hyoid Position During Swallowing - Patient P.W.

Amount of resection -- 6mm.

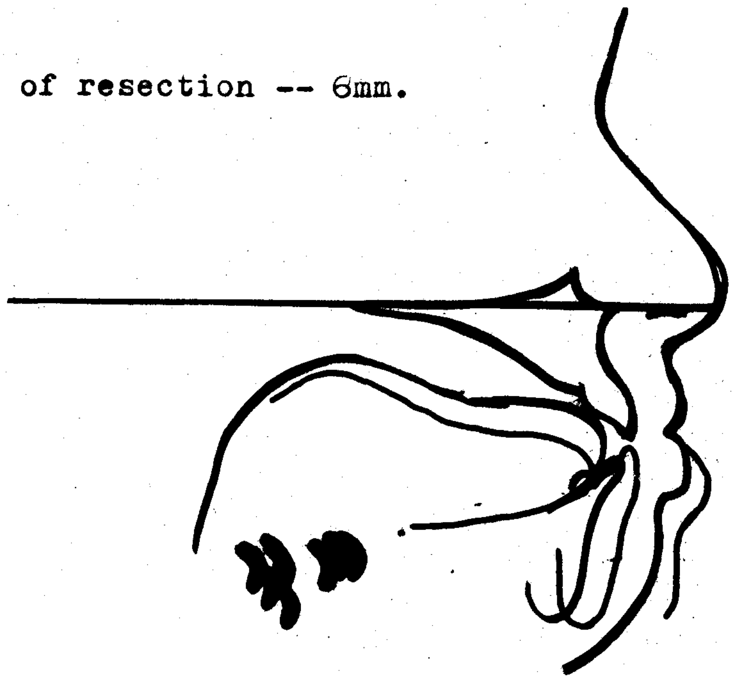


FIGURE 6

Comparison of Hyoid Cycle During Swallowing - Patient P.W.

BLUE --- Stage 1
RED ---- Stage 2
PURPLE - Stage 3
GREEN -- Stage 4

FIGURE 7

Comparison of Hyoid Position During Swallowing - Patient C.S.

Amount of resection -- 18mm.

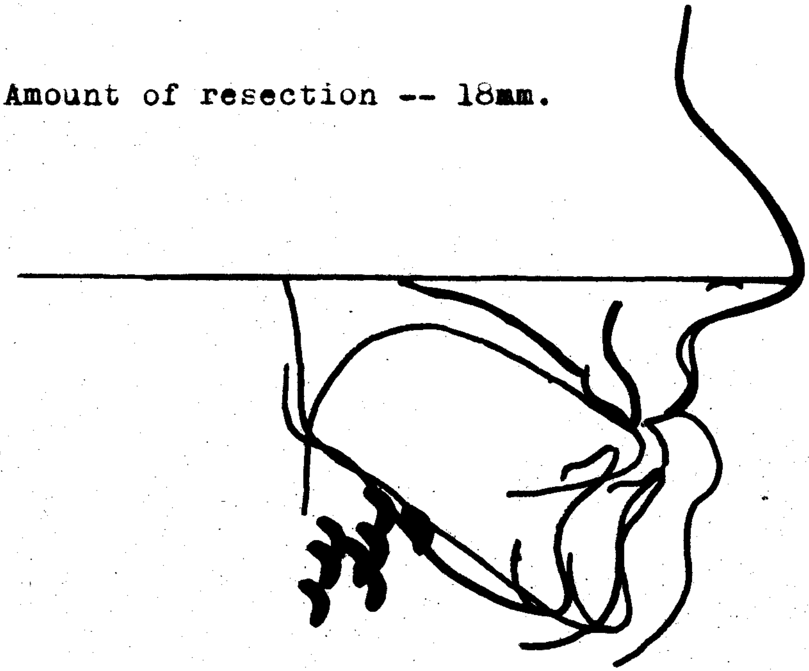


FIGURE 8

Comparison of Hyoid Cycle During Swallowing - Patient C.S.

BLUE --- Stage 1

RED ---- Stage 2

PURPLE - Stage 3

GREEN -- Stage 4

FIGURE 9

Comparison of Hyoid Position During Swallowing - Patient G.J.

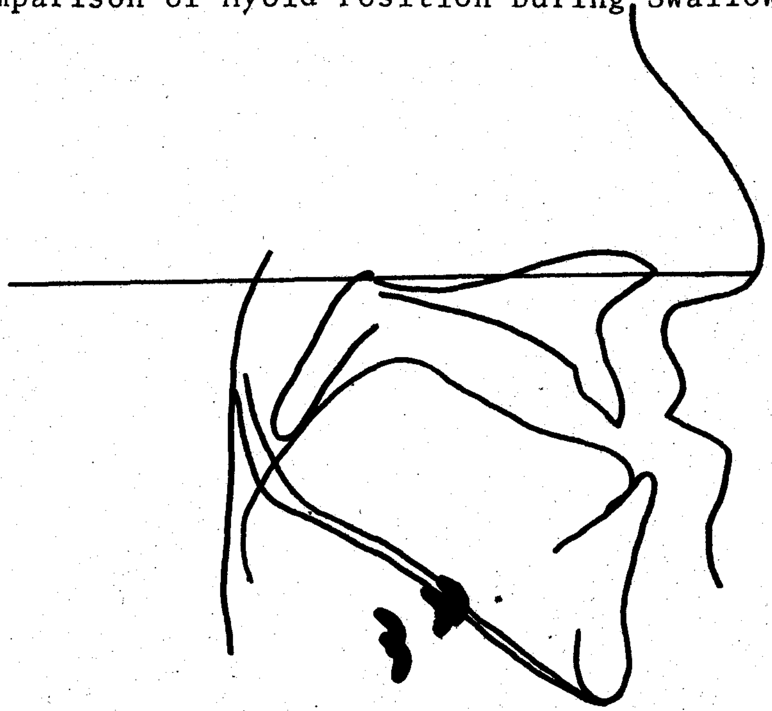


FIGURE 10

Comparison of Hyoid Cycle During Swallowing - Patient G.J.

FIGURE 11

Comparison of Hyoid Position During Swallowing - Patient T.Y.

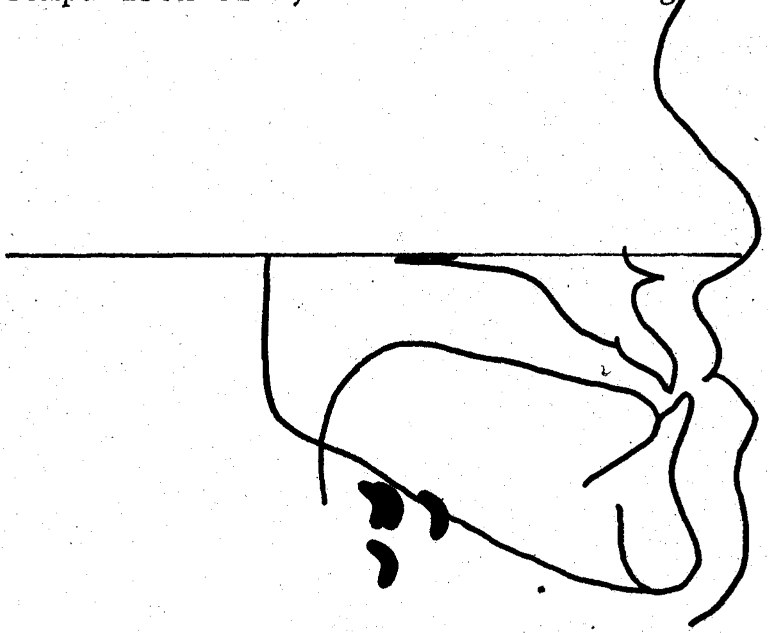


FIGURE 12

Comparison of Hyoid Cycle During Swallowing - Patient T.Y.

FIGURE 13

Comparison of Hyoid Position During Swallowing - Patient D.B.

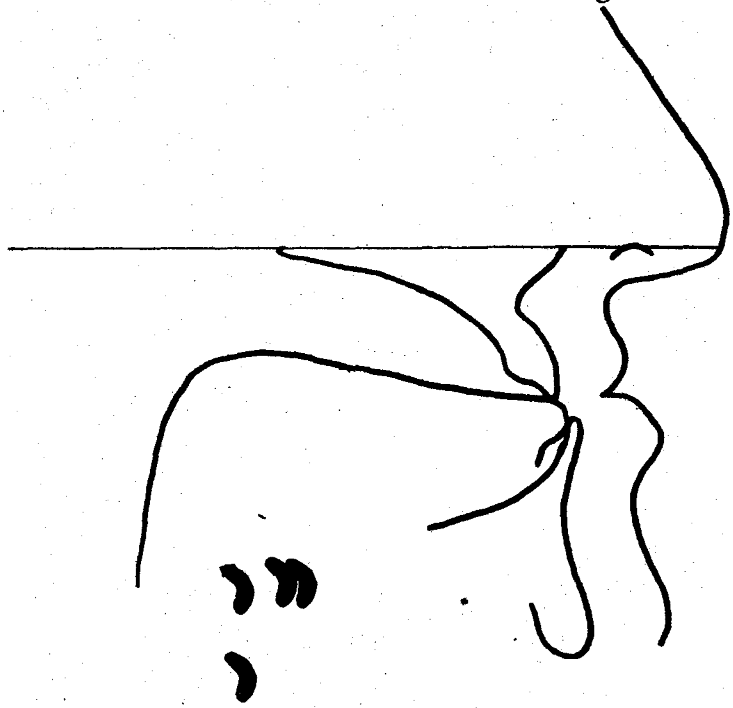


FIGURE 14

Comparison of Hyoid Cycle During Swallowing - Patient D.B.

B. Electromyographic Results

The following observations were made:

1. Subject #1 Patient M.C. Table 3

Amplitude --

A comparison of pre- and post-surgical electromyograms show a predominance in activity of the right side muscles over the left side. All right side muscles increased their activity post-surgically while only the left posterior temporalis increased. The magnitude of activity showed the masseters most active, followed by the anterior temporalis and the posterior temporals. Statistically, only the Right Posterior Temporalis showed a significant increase.

Duration --

The duration of activity of three muscles remained relatively constant, but the Right Masseter and Left Anterior Temporalis exhibited a slight, but statistically significant, increase in duration.

2. Subject #2 Patient P.W. Table 4

Amplitude --

Pre-surgically, the anterior temporals showed more activity than the masseters, followed by the posterior temporals. The masseters, though, were most active post-surgically. The left side showed more activity

TABLE 3

Subject #1 Patient M.C.

(Amplitude (50 microvolts = 4 mm)

Muscle	Pre-Surgical	S.D.	Post-Surgical	S.D.	"t" Test
Left Masseter*	4.07	0.94	3.56	0.68	1.31
Right Masseter	4.92	2.27	6.40	1.52	1.62
Left Anterior Temporalis	1.07	0.42	0.90	0.20	1.10
Right Anterior Temporalis	1.43	0.42	2.68	1.17	3.02*
Left Posterior Temporalis	0.50	0.00	0.64	0.35	1.22
Right Posterior Temporalis	1.0	0.70	2.13	0.85	3.07*
Duration (seconds)					
Left Masseter	1.07	0.05	1.08	0.14	0.20
Right Masseter	1.00	0.05	1.23	0.18	3.69*
Left Anterior Temporalis	1.10	0.05	1.17	0.08	2.22*
Right Anterior Temporalis	1.10	0.07	1.07	0.07	0.91
Left Posterior Temporalis	1.05	0.10	1.05	0.10	0.00
Right Posterior Temporalis	1.05	0.08	1.07	0.08	0.53

Based on 10 measurements

*Statistical Significance less than .05
**Statistical Significance less than .01

TABLE 4

Subject #2 Patient P.W.

Amplitude (50 microvolts = 6 mm)

Muscle	Pre-Surgical	S.D.	Post-Surgical	S.D.	"t" Test
Left Masseter	4.31	1.18	2.80	0.53	3.50*
Right Masseter	3.64	1.47	4.45	0.95	1.41
Left Anterior Temporalis	5.50	3.83	2.10	0.66	2.62*
Right Anterior Temporalis	5.10	1.57	3.25	0.89	3.07*
Left Posterior Temporalis	2.76	1.70	0.90	0.49	3.15*
Right Posterior Temporalis	2.33	1.57	2.55	2.45	2.26*

Duration (seconds)

Muscle	Pre-Surgical	S.D.	Post-Surgical	S.D.	"t" Test
Left Masseter	1.31	0.15	0.81	0.19	6.19**
Right Masseter	1.33	0.18	0.77	0.12	7.76**
Left Anterior Temporalis	1.23	0.15	0.78	0.13	6.80**
Right Anterior Temporalis	1.17	0.15	0.74	0.15	6.08**
Left Posterior Temporalis	1.26	0.16	0.78	0.03	8.89**
Right Posterior Temporalis	1.25	0.17	0.67	0.07	9.46**

Based on 10 measurements

*Statistical significance less than .05

**Statistical significance less than .01

pre-surgically while the right side was more active post-surgically.

All muscles showed a decrease in activity post-surgically, except the Right Masseter and the Right Posterior Temporalis. All results were statistically significant except the Right Masseter.

Duration --

All muscles statistically showed a decrease in duration of activity post-surgically. The masseters showed a slightly longer duration than the temporals.

3. <u>Subject #3 Patient C.S. Table 5</u>

Amplitude --

This data indicates dominance of the masseters over the anterior and posterior temporals pre- and post-surgically, with the Right Masseter being more dominant than the Left Masseter. All muscles showed an over-all increase in activity post-surgically except the Right Posterior Temporalis. Only the Right Masseter and Left Posterior Temporalis showed statistically significant results.

Duration --

All muscles showed an overall increase in duration post-surgically. The masseters had a longer duration than the temporals pre-surgically, but post-surgically, all muscles

TABLE 5

Subject #3 Patient C.S.

Amplitude (50 microvolts - 6 mm)

Muscle	Pre-Surgical	S.D.	Post-Surgical	S.D.	"t" Test
Left Masseter	3.0	0.63	2.83	0.45	0.66
Right Masseter	5.27	1.22	4.03	1.29	2.10*
Left Anterior Temporalis	2.99	1.02	1.67	0.47	1.98
Right Anterior Temporalis	2.96	1.20	1.77	0.53	1.67
Left Posterior Temporalis	3.38	1.20	1.69	0.76	3.56*
Right Posterior Temporalis	1.50	1.10	1.77	0.22	0.72

Duration (seconds)

Muscle	Pre-Surgical	S.D.	Post-Surgical	S.D.	"t" Test
Left Masseter	0.83	0.20	1.11	0.13	3.58*
Right Masseter	0.96	0.22	1.22	0.15	3.02*
Left Anterior Temporalis	0.76	0.10	1.12	0.14	6.12**
Right Anterior Temporalis	0.77	0.14	1.12	0.13	5.55**
Left Posterior Temporalis	0.75	0.16	1.15	0.11	6.18**
Right Posterior Temporalis	0.75	0.16	1.13	0.11	6.16**

Based on 10 measurements

*Statistical Significance less than .05
**Statistical Significance less than .01

showed similar durations. Pre- and post-surgical figures indicate statistically significant results.

4. Subject #4 Patient G.J. Table 6

Amplitude --

Pre-surgically, the masseters showed the greatest activity followed by the Right Anterior Temporalis and the Left Posterior Temporalis. The right side was predominant over the left side, except for the posterior temporals. Post-surgically, all right side muscles showed greater activity over the left side muscles, with the masseters, anterior temporals and posterior temporals active in that order. Except for the Left Anterior Temporalis and Right Posterior Temporalis, all muscles decreased in activity, but no results showed statistical significance.

Duration --

This patient showed the longest average duration of all the patients studied. Post-surgically, the duration of activity of the masseters decreased slightly, but was still longer than the other patients. The temporal muscles increased in duration, with significant results. The order of duration post-surgically was masseters, posterior temporals, and anterior temporals.

TABLE 6

Subject #4 Patient G.J.

Amplitude (50 microvolts = 4 mm)

Muscle	Pre-Surgical	S.D.	Post-Surgical	S.D.	"t" Test
Left Masseter	4.93	1.20	4.41	1.60	0.78
Right Masseter	5.81	1.47	5.25	1.90	0.67
Left Anterior Temporalis	1.38	0.33	1.66	0.55	1.41
Right Anterior Temporalis	2.78	1.37	2.50	1.15	0.47
Left Posterior Temporalis	1.91	0.58	1.58	0.92	0.91
Right Posterior Temporalis	1.40	0.40	1.80	0.64	1.85

Duration (seconds)

Muscle	Pre-Surgical	S.D.	Post-Surgical	S.D.	"t" Test
Left Masseter	2.13	0.21	2.00	0.15	1.50
Right Masseter	2.13	0.21	2.00	0.15	1.50
Left Anterior Temporalis	1.70	0.23	2.00	0.10	3.50*
Right Anterior Temporalis	1.67	0.25	2.00	0.11	3.61*
Left Posterior Temporalis	1.78	0.14	2.10	0.12	5.25**
Right Posterior Temporalis	1.75	0.15	2.00	0.15	3.55*

Based on 10 measurements

*Statistical significance less than .05

**Statistical significance less than .01

5. <u>Subject #5 Patient T.Y. Table 7</u>

Amplitude --

The masseters showed the greatest activity pre-surgically, while all temporals showed similar activity. The right temporals predominated over the left ones. Post-surgically, a significant decrease in activity was noted in the masseters and the Right Posterior Temporalis, while the left temporals showed an increase in activity. The Right Anterior Temporalis showed no appreciable change.

Duration --

All muscles showed a slight increase in duration of activity with the masseters having the shortest duration and the posterior temporals having the longest. Only the Right Anterior Temporalis and Left Posterior Temporalis showed statistically significant changes though.

6. <u>Subject #6 Patient D.B. Table 8</u>

Amplitude --

The masseters showed the greatest activity pre-surgically, followed by the posterior temporals and the anterior temporals. Post-surgically the masseters lead in activity, followed by the anterior temporals and the posterior temporals. All muscles showed a decrease in activity post-surgically except the left anterior temporalis. All figures

TABLE 7

Subject #5 Patient T.Y.

Amplitude (50 microvolts = 6 mm)

Muscle	Pre-Surgical	S.D.	Post-Surgical	S.D.	"t" Test
Left Masseter	4.59	1.36	2.73	0.61	3.76*
Right Masseter	4.49	1.55	2.86	0.68	2.88*
Left Anterior temporalis	1.77	0.90	2.84	0.97	2.42*
Right Anterior Temporalis	2.20	0.93	2.23	0.46	0.09
Left Posterior Temporalis	1.23	0.36	1.46	0.49	1.13
Right Posterior Temporalis	2.25	0.75	1.50	0.34	2.73*

Duration (seconds)

Muscle	Pre-Surgical	S.D.	Post-Surgical	S.D.	"t" Test
Left Masseter	0.75	0.12	0.79	0.15	0.62
Right Masseter	0.74	0.08	0.81	0.11	1.54
Left Anterior Temporalis	0.82	0.16	0.92	0.18	1.28
Right Anterior Temporalis	0.81	0.11	0.88	0.09	2.33*
Left Posterior Temporalis	0.89	0.09	1.02	0.07	3.42*
Right Posterior Temporalis	0.92	0.29	0.99	0.12	0.66

Based on 10 measurements

*Statistical significance less than .05

**Statistical significance less than .01

TABLE 8

Subject #6 Patient D.B.

Amplitude (50 microvolts = 6 mm)

Muscle	Pre-Surgical	S.D.	Post-Surgical	S.D.	"t" Test
Lest Masseter	5.80	0.18	4.07	0.76	6.66*
Right Masseter	5.00	2.00	3.33	0.75	2.34*
Left Anterior Temporalis	1.20	0.50	2.40	1.08	2.26*
Right Anterior Temporalis	2.25	0.75	1.88	0.76	1.03
Left Posterior Temporalis	3.5	0.5	0.7	0.45	12.48**
Right Posterior Temporalis	3.3	0.7	0.76	0.21	10.42**

Duration (seconds)

Muscle	Pre-Surgical	S.D.	Post-Surgical	S.D.	"t" Test
Left Masseter	1.47	0.07	0.77	0.11	16.15**
Right Masseter	1.47	0.07	0.96	0.05	17.85**
Left Anterior Temporalis	1.3	0.10	0.80	0.11	10.09**
Right Anterior Temporalis	1.3	0.10	0.82	0.11	9.68**
Left Posterior Temporalis	1.1	0.10	0.75	0.06	9.00**
Right Posterior Temporalis	1.1	0.10	0.82	0.12	5.45*

Based on 10 measurments

*Statistical significance less than .05
**Statistical significance less than .01

showed statistical significance except the Right Anterior Temporalis.

The Left Masseter and Posterior Temporalis were predominant over their right counterparts presurgically, while post-surgically all left muscles showed greater activity over their respective right muscles.

Duration --

All muscles showed a significant decrease in duration after surgery. Pre-surgically, the masseters had the longest duration followed by the anterior temporals and the posterior temporals. Post-surgically, the Right Masseter had the longest duration, but the Left Masseter had the shortest.

C. Cephalometric Results - See Table 9

Moller (1966) correlated the electromyographic activity in the masseter and temporalis muscles with craniofacial types. He used Bjork's Analysis to measure the curvature of the cranial base. The saddle angle (nasion-sella turcica-articulare) measures the angle which the anterior cranial base makes with the posterior cranial base. Angles SNA and SNB measure the location of the maxilla and the mandible with respect to the cranial base in the antero-posterior direction. These measures are indications of facial prognathism. A smaller than average saddle angle and a larger

TABLE 9

Cephalometric Changes Due to Surgery

Patient	Landmarks	Pre-Surgical	Post-Surgical	Mean
M.C.	Saddle angle	127°	127°	123° ± 5
	SNA	81°	81°	80° ± 1
	SNB	85°	81-1/2°	78° ± 1
	Difference	-4°	-1/2°	2°
P.W.	Saddle Angle	135°	135°	
	SNA	84°	84°	
	SNB	86-1/2°	82°	
	Difference	-2-1/2°	+2°	
C.S.	Saddle angle	114°	114°	
	SNA	85°	85°	
	SNB	90°	80°	
	Difference	-5°	+5°	
G.J.	Saddle angle	123°	123°	
	SNA	84°	84°	
	SNB	93°	77°	
	Difference	-9°	+7°	
T.Y.	Saddle angle	113°	113°	
	SNA	91°	91°	
	SNB	101°	93°	
	Difference	-10°	-2°	
D.B.	Saddle angle	119°	119°	
	SNA	83°	83°	
	SNB	87°	83°	
	Difference	-4°	0°	

than average SNB angle indicates mandibular prognathism.

Moller showed that the anterior and posterior temporalis and masseter exhibit activity during swallowing which is greater in prognathic patients than in normal patients. The saddle angle and the SNB angle were used as measures of prognathism.

The electromyographic results in this study support Moller's conclusions. All masseter muscles except two showed a decrease in activity as the mandibular prognathism was reduced. Nine of twelve anterior temporals reduced in activity subsequent to reduction and six of twelve posterior temporals reduced in activity after reduction. The posterior temporalis results were inconclusive.

D. Myometric Results - See Table 10

The intra-oral transducer and its mounts showed strength and stability throughout all recordings. Due to the fact that the solder joints attaching the lead wires and cable were embedded in the dental compound, there was no problem with breakage of the assembly.

The extra-oral strain gauge posed more of a problem in stabilizing the apparatus. It was necessary that the head be stable against the headrest in order to prevent disengaging the wire extension. Also, the mandible could not be

TABLE 10

Comparison Thrust (Magnitude)

Tongue Thrust Pre-Surgically and Post-Surgically

Patient		Pre-surgical Grams	S.D.	Post-surgical Grams	S.D.	"t"
#1	M.C.	141*	31.3	155*	46.3	.752
#2	P.W.	68.8	8.8	60.7	19.5	1.135
#3	C.S.	43	15.4	28	18.2	1.8
#4	G.J.	98.4	7.2	95.4	12.5	.623
#5	T.Y.	61.6	13.9	68.4	22.6	.768
#6	D.B.	98.3	15.0	101	24	.286

Duration

Patient		Pre-surgical Seconds	S.D.	Post-surgical Seconds	S.D.	"t"
#1	M.C.	.62*	.13	.60*	.11	.352
#2	P.W.	1.5	.26	1.33	.22	1.49
#3	C.S.	.48	.15	.51	.12	.468
#4	G.J.	1.95	.21	1.84	.38	.696
#5	T.Y.	.90	.41	.82	.34	.025
#6	D.B.	.45	.11	.52	.13	1.233

*Based on 10 measurements

opened more than slightly for the same reason. Water had to be introduced with a medicine dropper. After some practice, the patient was able to accommodate to the apparatus and proper recordings were made.

Each swallow recorded by the transducers appeared as a deflection from the base line of various magnitudes and durations. Magnitude was determined by measuring the height of the highest peak in millimeters and converting the figure into grams by using the calibration ratio. Duration was calculated by measuring the length of the curve in millimeters and using the paper speed to compute time.

No attempt was made to correlate the pressure of all the patients due to their individual differences, but only to compare changes for each patient due to surgery. Since the patients in the study were tongue thrusters due to their prognathic mandible, they all constantly produced pressure against the lower anterior teeth during swallowing. Pressures ranged from 40.2 grams to 125 grams. A sip of water was used for all swallows.

1. <u>Subject #1 Patient M.C.</u>

This patient showed the greatest tongue force pre- and post-surgically. The mean force increased slightly post-surgically, and the duration decreased, but no statistical significance was shown.

2. Subject #2 Patient P.W.

The tongue force decreased post-surgically as well as the duration, but no significant results were noted.

3. Subject #3 Patient C.S.

The tongue force decreased post-surgically as well as the duration, but not significantly.

4. Subject #4 Patient G.J.

The force of tongue thrust decreased slightly as did the duration. This patient showed the longest duration of thrust of all patients. There was no statistical significance in these figures.

5. Subject #5 Patient T.Y.

The tongue thrust increased slightly post-surgically while the duration decreased. No statistical significance was noted.

6. Subject #6 Patient D.B.

The tongue thrust increased slightly post-surgically, as did the duration. No significance was noted statistically.

The duration of tongue force was inconclusive, with two patients showing slight increase and four showing slight decrease as compared to pre-surgical data. The three patients with a mean decrease in tongue pressure showed evidence cinefluorographically of more pressure against the maxillary incisors post-surgically. This might have an influence on the result as it must be remembered that force was measured only on the mandibular anterior teeth.

CHAPTER V

DISCUSSION

An attempt was made in this study to correlate the cinefluorographic, electromyographic, and myometric results so as to arrive at more meaningful results regarding changes in perioral muscular activity. It was hoped that all three testing procedures would produce parallel results which would confirm or deny current thinking in the literature on this subject.

The fact that all six subjects were tongue thrusters gave us the opportunity to compare hyoid pattern with those described for tongue thrusters in the literature. It was found that in the subjects studied each patient had his own characteristic pattern of movement, although some were similar. Two patients (P.W. and M.C.) exhibited a forward movement with little upward movement; two others (G.J. and T.Y.) showed roughly equivalent upward and forward movement; and one patient showed a circular movement. These pre-surgical hyoid patterns did not confirm the belief that all tongue thrusters exhibited a predominately forward movement.

It was also shown cinefluorographically that the rest position of the tongue in these cases pre-surgically was usually low in the oral cavity with the hyoid bone correspondingly low. In the cases where the tongue was held higher at rest, the hyoid was also higher, thus, the hyoid movement could be thought to be directly related to the tongue position.

Myometrically, a wide variation of tongue thrust pressure was found between patients. Values ranged from 28 to 155 grams. Clinically, it was my impression that the patients with large muscular tongues had larger tongue thrust pressures. It was also found that no significant changes in pressure occurred as a result of surgery regardless of the amount of mandibular reduction.

Similarly, the duration of tongue thrust showed a wide variation among patients, with time ranging from 0.45 seconds to 1.95 seconds. Each patient, though, stayed within the same range post-surgically with no statistically significant results noted.

The myometric results leads me to believe that after surgical repositioning, when the size of the oral cavity is reduced, the tongue thrust pressure is not appreciably changed, even though the tongue has less operating space. This theory is borne out by the post-surgical cinefluorographic tracings, which show that as the mandible is positioned backward, the hyoid bone, together with all of its muscular attachments, is also repositioned posteriorly to approximately the same amount. Therefore, the relationship of the base of the tongue to the anterior mandible remains relatively the same. I believe the mylohyoid is largely responsible for carrying back the hyoid, due to its anatomic relation to mandibular hyoid bone.

It was also shown that, with one exception, the hyoid pathway during swallowing was not changed appreciably as a result of surgery. Rather, it was bodily moved backward and downward. One patient, T.Y., showed two separate locations for hyoid position post-surgically. One was posterior and inferior to pre-surgical location, and the other was posterior and superior. The low hyoid position corresponded to low tongue location. This case was the only one which showed dual characteristics. The lowering of the hyoid complex might be explained by the readaptation of the infrahyoids as a result of surgery.

The most accurate phase of swallowing to reproduce on cinefluorographic film was found to be Stage IV, which represented the most anterior and superior position of the hyoid during deglutition. This phase marks the end of the pharyngeal stage of swallowing when the bolus is at the level of the epiglottis and about to enter the esophagus. It was found that the hyoid positions at rest and at Stage II were not as repeatable due to the fact that the size of the bolus in part dictated the tongue position at rest. If the bolus was large, it was usually located on the dorsum in a cup-shaped fossa and correspondingly, the tongue and hyoid was low. If the bolus was small, it was usually found in the anterior part of the mouth near the incisor teeth. Thus the tongue and hyoid position was slightly higher.

But, at Stage IV, the tongue was always in the same position. The correct frame for Stage IV was easier to select because it represented the end of the active phase of deglutition while during the rapid oral phase the hyoid moves forward in its full distance in less than one-fourth second.

The only meaningful change in tongue movement post-surgically was in anterior placement of the tongue tip. The four patients who exhibited a large negative overjet demonstrated the tip protruding well anter-or to the maxillary incisors during swallowing while the other two patients showed the tongue confined within all the anterior teeth. Post-surgically, the four above patients did not protrude their tongues as before, but kept it confined within the anterior teeth even though they still retained the tongue thrust pattern. This adaptation is explainable because post-surgically the patient no longer had the necessity of sealing the opening in the anterior region due to the negative over-jet.

Whether or not the tongue thrust pattern will eliminate itself at a later date is open to further study. The need for a tongue thrust pattern is no longer necessary, but the neuromuscular pathways have been established.

Tongue thrust swallowing was easily detected in these patients when viewing the cinefluorographic film. Hyper-activity of the lip musculature was seen along with lack of tooth contact and a protruding tongue. These are classical signs of tongue thrust.

An overall view of the electromyographic tracings reveals a low activity in all muscles tested when compared to a slight biting force. It is understandable that the masseters and temporals would have much less activity during swallowing, especially during a tongue thrust swallow, where it is well-known that the buccinator and orbicularis muscles predominate over the masticatory muscles.

The presurgical records show that generally the masseter muscles predominated over the anterior temporals with the posterior temporals the least active. One side was usually dominant over the other side. Occlusion, as well as habit, plays an important part in the dominance of one side over another; therefore, this fact was not considered important.

Post-surgically, the muscle activity decreased in most cases, but the masseters continued to possess the greatest activity. Three patients showed statistically significant changes in activity of all muscles, two showed significant changes in some muscles, and one patient showed no statistically significant changes at all. It was evident, though, that the pattern of post-surgical changes in muscular activity was similar in all patients, with a few exceptions.

These findings support the results of Moller (1966) who found that a small cranial base angle (saddle angle), and a large SNB angle, which indicate a tendency toward prognathism, corresponds to greater activity in the masseter and temporalis muscles.

In this study it was shown that masseter and temporalis activity decreased as a result of surgically reducing the prognathism. It is thought that the direction of force of these muscles are in a more vertical direction in prognathic patients which predisposes to stronger activity. As the mandible is repositioned posteriorly, the attachments of these muscles to the gonial angle and coronoid process are positioned posteriorly, thus changing the force vector to a more oblique direction. Surgical stripping and repositioning of selected muscle attachments would alter the force values post-surgically. These procedures have been advocated in cases of abnormal cranio-facial development.

Two patients (P.W. and D.B.) showed a significant decrease in duration of all muscles post-surgically while one patient revealed a significant increase in duration of all muscles. Of other patients, most muscles increased slightly in duration, some decreased and a few remained the same. The duration values ranged from 0.75 seconds to 2.13 seconds.

The duration figures for the electromyographic readings were not compared to those for the myometric tests because they represented measurements of different muscles. The tongue thrust duration does not represent the total activity of all muscles during swallowing, and neither does the activity of the masseters and temporals. Thus, these figures were treated separately.

CHAPTER VI

SUMMARY AND CONCLUSIONS

Six candidates for resection were selected for study of swallowing activity.

Prior to surgery, all patients were tested for tongue thrust and electromyographic activity of the masseter and temporal muscles, and cinefluorographic sequences of several normal swallows were recorded.

Comparison of the pre- and post-surgical records reveals the following conclusions:

1) Tongue thrust pressure against the mandibular anterior teeth is not increased due to posterior repositioning of the mandible.

2) Electromyographic activity of the masseters and anterior and posterior temporals is decreased due to the reduction of the prognathism. This fact is in support of Moller's view that greater activity of these muscles is present with greater prognathic tendencies.

3) Duration of activity of these muscles increased with some patients and decreased with others.

4) The surgical repositioning resulted in a

repositioning of the hyoid bone and its associated muscles to the approximate amount of the reduction. Thus the tongue and its relation to the anterior portion of the mandible does not change after surgery to any significant degree.

5) The hyoid cycles exhibit three distinct types of movement even though all patients were tongue thrusters. This finding is in opposition to some investigators who describe all tongue thrust cycles as similar in character. Post-surgically, the hyoid cycles do not change in general character.

6) All patients retained the tongue thrust pattern at the time post-surgical records were taken. Future records are indicated to determine if changes occur at a later date.

7) Hyoid position is related to tongue position at rest.

This study indicates that the tongue and its associated musculature has a limited role, if any, in the anterior relapse frequently seen in mandibular resection cases. The tongue is related to the anterior aspect of the mandible in the same relative way after surgery as prior to surgery.

Therefore, tongue pressue does not increase during swallowing to cause undue force upon the anterior mandible.

Electromyographic evidence indicated that the activity of the masseter and temporalis muscles during swallowing were not great enough to cause any untoward anterior force on the mandible.

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APPROVAL SHEET

The thesis submitted by Dr. Roger S. Wolk has been read and approved by members of the Department of Oral Biology.

The final copies have been examined by the director of the thesis and the signature which appears below verifies the fact that any necessary changes have been incorporated and that the thesis is now given final approval with reference to content, form, and mechanical accuracy.

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

5/26/69	Douglas C. Bowman
Date	Signature of Advisor