Adaptability of Muscles and Hence Hyoid Position Following Forced Distal Repositioning of the Tongue in Open Bite Patients

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ADAPTABILITY OF MUSCLES AND HENCE HYOID POSITION
FOLLOWING FORCED DISTAL REPOSITIONING OF THE
TONGUE IN OPEN BITE PATIENTS

by

David H. Gobeille D.D.S.

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

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The most profound gratitude I can express goes to my wife, Carolyn, for having offered the greatest support and encouragement through my last six years of education and who has blessed me with two fantastic sons. I also thank my family for being understanding of my frequent absence due to the great demands of my professional life.
AUTOBIOGRAPHY

David Manning Gobeille was born in San Francisco, California on December 13, 1945. He was the first of four children, with brothers, Scott and Tom, and a sister, Suzanne, who is the youngest child. He moved with his family to Milwaukee, Wisconsin, in 1947 and then to Park Ridge, Illinois in 1953. In 1957, his family moved to Mt. Prospect, Illinois, where he was graduated from Prospect High School in 1964. That same year, he began attendance at Miami University, Oxford, Ohio, where he graduated with an A.B. degree in 1968. In July of 1968, the author was married to Carolyn Louise Dudley. In the fall of 1968, he began studies at the University of Illinois, College of Dentistry where he received a B.S. degree in dentistry in 1970 and the degree of Doctor of Dental Surgery in 1972. On April 6, 1972, the author's first son, Matthew David, was born. The following July, he began his studies at the Graduate School of Orthodontics, Loyola University, School of Dentistry, and in the Postgraduate program in Oral Biology. On February 8, 1974, Todd William, the author's second son was born.
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INTRODUCTORY REMARKS AND STATEMENT OF THE PROBLEM

The purpose of this study was to determine to what extent the hyoid bone and thus the tongue re-adapts its position during the swallowing pattern in an anterior open bite, tongue thrust patient, when the tongue is forced to a new distal position in the oral cavity.

The tongue position and adaptability are intimately related to the hyoid position and adaptability, due to the muscular and ligamentous attachments providing a precision balance between these two anatomical structures. If the dimensions of the oral environment are altered, as with orthodontic therapy, these structures must either adapt or damage themselves and/or the surrounding structures.

Two basic analysis techniques were used to perform this study. Cinefluorographic films were taken, and measurements of the tongue pressure was recorded by the myometric method. These procedures were done on the selected open bite subjects before and immediately after placing an appliance which forced the tongue to a more distal position. These same measurements were also taken 24 hours after placing the appliance - a time which was deemed ample for muscle adaptation.
REVIEWS OF THE LITERATURE

I. Tongue Thrust and Open Bite Defined:

All informed authors will agree that closing the open bite orthodontically is a clinically significant problem. The difficulty seems to rest with maintaining the desired overbite. Musculature is the main culprit of relapse in open bite cases, consequently, in recent years much attention has been given to areas such as tongue thrust and the "perverted" swallowing habit, which are quoted as often contributing to the open bite problem.

Open bite as related to tongue thrust is defined by this author as occurring when the lower incisors do not contact any opposing soft or hard tissue when the buccal teeth are in occlusion.

Jann (1960) described the tongue thrust habit as a neuromuscular syndrome that is largely overlooked and unrecognized in the fields of speech therapy, pediatrics, and dentistry. He postulated that perverted swallowing and tongue thrust habits in children have a direct causal relationship with open bite type of malocclusion. The neuromuscular dynamics of the basic biological speech functions of the oral cavity have much to do with its formation, indicating the need to examine the mouth both dynamically as well as statically.

Fletcher, Casteel, and Bradley (1961) described the deviate swallowing pattern to include these clinical characteristics:

a. extreme tension in the perioral musculature
b. decrease in the palpable contraction of the muscles of mastication during the act of swallowing

c. forward thrust of the tongue causing it to protrude between the incisors.

These authors found that the tongue thrust swallow was statistically related to age with the incidence of the tongue thrust swallow numerically decreasing with an increase in age.

In their sample of 1,615 school children they found that 668 children had a tongue thrust swallow, whereas, 947 children were without the tongue thrust swallow.

Moyer (1963) said that tongue thrusting often accompanies, or is a residuum, of thumb-sucking, but it may also originate from enlarged or hypersensitive tonsils. He described normal swallowing thusly: as the child swallows, the teeth are brought together, the lips close and the tongue is held against the palate back of the anterior teeth. In addition to being the result of prolonged thumb-sucking, Moyer said that the tongue thrust may be a result of swollen or sore tonsils due to the fact that the root of the tongue encroaches on the enlarged faucial pillars. This produces discomfort, and reflexly the mandible is dropped, the teeth become separated, and the tongue is thrust between them during the last stages of swallowing. Thus a new swallowing reflex is established and the teeth accomodate to new pressure provided by the new swallowing pattern.

Brauer and Holt (1965) had devised a classification system for tongue thrust based on the resulting deformity rather than on the etiology, since the etiology is often obscure and difficult to determine.
The following is the classification system which they devised:

Type I - Nondeforming Tongue Thrust

Type II - Deforming Anterior Tongue Thrust
Subgroup 1 - Anterior Open Bite
Subgroup 2 - Associated Procumbency of Anterior Teeth
Subgroup 3 - Associated Posterior Crossbite

Type III - Deforming Lateral Tongue Thrust
Subgroup 1 - Posterior Open Bite
Subgroup 2 - Posterior Crossbite
Subgroup 3 - Deep Overbite

Type IV - Deforming Anterior and Lateral Tongue Thrust
Subgroup 1 - Anterior and Posterior Open Bite
Subgroup 2 - Associated Procumbency of Anterior Teeth
Subgroup 3 - Associated Posterior Crossbite

All of these types and subgroups were reportedly seen in an examination of a random sample of approximately two hundred grade school and junior high school students.

Their criteria for tongue thrust were any movement occurring around the lips and observation of the tongue itself as the swallowing was commencing. They said that it was difficult to observe the tongue itself in many cases due to the active part the mentalis and orbicularis oris muscles played in the atypical swallowing pattern. Brauer and Holt concluded that because the resistance that the tongue encounters in swallowing is different in most individuals, we would expect to see many types of swallowing patterns, hence the many variations in deformities seen with tongue thrust problems.
Hoffman and Hoffman (1965) describe the extrinsic muscles of the tongue as the depressors, protractors, and retractors and change the position and extent of the tongue. The muscles which change the tongue's shape are the intrinsic muscles which lie within the body of the tongue.

The authors stated that the hyoid bone was important because most extrinsic muscles of the tongue are attached to it and it also helps to maintain the pharyngeal airway which is essential for life.

Some of the conclusions which Hoffman and Hoffman reached in their study are:

1. Tongue thrust may be a temporary developmental phenomena occurring during the growth and development of the lower face of some individuals. But, it may persist as a habit after growth and development are complete particularly if growth and development are inadequate when completed.
2. The clinician must differentiate between tongue thrusting as a temporary developmental manifestation and as a permanent persistently faulty habit. Only the latter may need therapy of any kind.
3. Swallowing is a complex reflex action and is not likely to be retrained successfully and permanently.

Norton and Gellin (1963) described digital sucking and tongue thrusting as the etiology of various forms of open bite. They said that some tongue thrusts are subtle and produce only a lack of occlusal contact in the lower incisal to upper anterior cingulum area.

According to Graber (1969) there is usually an overeruption of posterior teeth and little or no interocclusal clearance between the postural and rest position in anterior open bite patients. In addition,
the tongue becomes interdental in the anterior segment of the dentition upon swallowing.

Graber restated the fact that the abnormality of anterior open bite can be apparent in all three Angle malocclusion classifications at one time or another. He said that abnormal deglutition and improper tongue function may contribute to the open bite phenomenon, and in fact in some instances, may be the primary etiologic factor in anterior open bites.

Fletcher (1971) wrote an extremely comprehensive article on deglutition. He attempted to bring all the published material together in an attempt to explain normal tongue activity and present it on a theoretical framework so that it could be further evaluated. He said that in spite of the inconsistencies and unanswered questions, that most experimental and clinical evidence suggest that the tongue-thrust pattern is a very meaningful behavior worthy of further scrutiny and investigation.

Fletcher in dealing with the neurologic aspects of tongue thrust in the developing child. Even though there was some evidence suggested that it could represent either a form of developmental arrest or a regression to a less mature phase of physiologic function. In either case, the developing child is left with an extensor thrust-like, immature swallowing pattern. At the same time, if the neurologic development progressed normally, but the size and shape of the oral cavity or the tongue did not develop properly to develop a new set of sensory cues, the swallow pattern would remain at some less-than-mature level.

Subtelny and Subtelny (1973) defined abnormal swallowing on the basis of lip, jaw and tongue activity. Abnormal swallowing, then can
be indicated by 1) lip (circumoral) contraction 2) by failure of the buccal segments or molars to contact and, 3) by tongue protrusion between the incisor and/or the buccal teeth during the act of deglutition. They based this on the generally accepted definition of normal swallowing which states: 1) during swallowing, the muscles of facial expression are not used 2) the muscles of mastication bring the teeth and jaws together during the entire act of deglutition and, 3) the tongue mass remains within the confines of the oral cavity. They conclude, however, that not enough attention has been focused on normal swallowing.

In attempting to explain forceful tongue activity the authors cited large tonsillar masses as being causative of tongue thrust. Enlarged tonsils may cause anterior open bite resulting primarily from physiological respiratory need and secondarily from deviate tongue posture and activity. A similar situation can be seen when blockage of the normal respiratory passage by excessive development of adenoid tissue in the nasopharyngcal area. Even though these lymphatic tissues usually atrophy but this recession of tissue may occur too late to avoid a dentoalveolar deformity. However, these open bite situations may respond spontaneously to judicious removal of tonsillar tissue.

The authors also considered impaired neurologic control of the tongue. Patients with cerebral palsy, and have impaired neurologic control of the tongue, often display anterior open bite. However, they stated that neurologic impairment of lesser extent may not be easily identified. It is important, clinically, to recognize these patients from those with an abnormal swallowing habit.
Representative Subject With Anterior Open Bite

Tongue Position During Deglutition
II. Description of Hyoid Bone, Hyoid Musculature and Tongue Musculature

Harwick and Williams (1973) described the developing hyoid cartilage from the second and third visceral arches. The mesenchyme of the hyoid arches develops into the skeletal elements including the hyoid bone. The remainder of the core of the mesenchyme develops into striated muscle, some of which become the hyoid musculature, and others of which migrate and may lose all connection with their original respiratory function.

The hyoid bone is U-shaped and is suspended from the styloid processes of the temporal bone by the stylohyoid ligaments. The bone is made up of a body, two greater horns or cornua, and two lesser horns or cornua. The greater horns can be palpated in the living subject just above the thyroid cartilage and it can be moved from side to side. The lesser horns are connected to the body of the bone by fibrous tissue and occasionally to the greater horns by synovial joints. These joints usually persist throughout life but occasionally become ossified.

The geniohyoid muscle attaches to anterior surface of the body. The lower part of its surface provides the insertion of the mylohyoid and below this the sternohyoid inserts medially and the omohyoid laterally.

The superior border of the body provides the attachments for the genioglossus, the hyoepiglottic membrane, and to the thyrohyoid membrane. The upper surface of the greater horns provides the origin to the middle constrictor of the pharynx, and more laterally, to the hyoglossus. Where the horns join with the body, the stylohyoid ligament
inserts lateral to the hyoglossus. Posterior to this are the tendonous loops through which the digastric muscles run. The lateral border provides the insertion for the thyrohyoid muscle in the anterior portion.

The lesser horns give rise to the middle constrictor of the pharynx. The chondroglossus muscle arises from the medial aspect.

Hoffman and Hoffman (1965) gave the origin and insertion of the extrinsic muscles of the tongue in their anatomical description. The following is a summary:

<table>
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<tr>
<th>Muscle</th>
<th>Origin</th>
<th>Insertion</th>
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<tbody>
<tr>
<td>Genioglossus muscle</td>
<td>Posterior region of mandibular symphysis</td>
<td>Body of the tongue</td>
</tr>
<tr>
<td>Styloglossus muscle</td>
<td>Styloid process of the temporal bone</td>
<td>Body of the tongue running to the tip on both sides</td>
</tr>
<tr>
<td>Hyoglossus muscle</td>
<td>Hyoid bone</td>
<td>Upwards to the sides of the tongue</td>
</tr>
<tr>
<td>Palatoglossus muscle</td>
<td>Oral surface of the palatine aponeurosis</td>
<td>Sides of the tongue</td>
</tr>
</tbody>
</table>

Woodburne (1965), indicated movements of the tongue by describing traction of the individual muscles. He pointed out that to understand complex tongue movements one must understand complex actions involving combinations of extrinsic and intrinsic muscles.

Protrusion of the tongue is accomplished by the genioglossus. The superior fibers draw the tip back and down into the mouth, the middle fibers depress the middle region of the tongue, producing a hollow on the dorsum.

The styloglossus muscle retracts and elevates the tongue, while the superior fibers of the genioglossus help to retract the tip.
The palatoglossus muscle aids in elevating the tongue and the hyoglossus flattens the tongue and draws down its sides.

In tongue movements the hyoid bone is stabilized by the infrahyoid and suprathyoid musculature so that the extrinsic tongue muscles which are attached to the hyoid bone may have a solid "platform" from which to function.

The intrinsic muscles act in all these movements and aid the extrinsic muscles. The other related extrinsic muscles of the tongue aid in all of the movements depending on which combinations are called into function.
After Cunningham (1957)

Extrinsic and Associated Tongue Musculature

a. Styloglossus        f. Omohyoid
b. Digastric           g. Sternohyoid
  c. Stylohyoid        h. Mylohyoid
  d. Hyoglossus        i. Digastric
  e. Thyrohyoid

k. Geniohyoid
After Dickson (1970)

Hyoid Musculature Including:

- a. Hylohyoid m.
- b. Hyoid bone
- c. Sternohyoid m.
- d. Omohyoid m.
- e. Digastric m.
- f. Mastoid Process
- g. Thyrohyoid m.
- h. Sternocleidomastoid m. (cut)
- i. Thyroid Cartilage
- j. Sternothyroid m.
III. Cinefluorographic Literature:

Library research indicates that as early as 1929, Warren and Bishop at the University of Rochester began developing the cinefluorographic technique. Most of the research in this area, however, has occurred since World War II. Studies can be cited dealing with heart rhythm, cerebral circulation, the esophagus, the stomach, and the urinary tract, as well as deglutition. Cinefluorography has come to be used for diagnosis and treatment of several medical disorders and has undergone considerable refinement over the last 20 or more years. A number of those cinefluorographic studies have dealt with normal and abnormal swallowing patterns.

Saunders, Davis and Miller (1951) in their cineradiographic study of the "second stage" of swallowing indicated that this technique was an essential prerequisite for analyzing this part of deglutition. They attempted to indicate which muscles were responsible for the cyclic movement of the hyoid, larynx, and tongue by visual means.

Rushmer and Hendron (1951) said that even though swallowing is divided into three stages purely on anatomical grounds, their impression through cinefluorographic study, is that the actual functional act of swallowing cannot be fitted into such a rigid framework. They were perhaps the first to effectively describe the anterior displacement of the hyoid bone associated with elevation of the larynx through cinefluorography.

Ramsey, Watson, Gramiak, and Meinberg (1955) demonstrated various methods of using cinefluorographic apparatus to study swallowing. They
demonstrated regularity of response in movement of the hyoid bone upon swallowing a radio-opaque bolus and thus established the significant role of cinefluorography in deglutition studies.

Ardran and Kemp (1955), studied deglutition in 250 normal young adults with cineradiographic films. They claimed to disprove the theory that a negative pressure must be developed by the swallowing complex in order to swallow a bolus of food. They stated that for the most part in normal subjects, the bolus descends into the pharynx while it still contains air and while the larynx is still open. They state that the body of the hyoid bone is usually lifted to the level of the lower border of the mandible as the tongue rises in the forepart of the mouth and is drawn forwards as the main mass of the bolus descends through the nasopharynx. In some subjects, these movements seem to be combined, the body of the hyoid moving diagonally upward and forward.

Andran, Kemp and Lind (1953) in their paper on the evaluation of deglutition in bottle fed babies stated that the swallowing process was initiated by a muscular compression of the teat and not by a "suckling" function. They felt that the hard rubber material that most bottles were made of would not allow the tongue and jaws to compress the teat enough to express the liquid and that this would interfere with normal behavior, consequently disturbing growth and thereby resulting in deformities of the orofacial complex.

These same authors (1952) in another article concerning breast feeding made the following conclusions. The infant "sucked" the nipple back in the mouth and in this manner formed a teat. The tongue then compresses the teat against the hard palate and thus expresses the milk.
The authors were not able to evaluate the influence of "sucking" but felt the liquid was probably expressed from the breast by a combination of sucking and compression by the tongue.

Shelton, Bozma, and Sheets (1960) studied hyoid and larynx displacement by means of cinefluorographic observations. They concluded that it appeared as though the same motions were used in phonation and deglutition although the range of movement was greater in swallowing. They concluded, therefore, that the performance of swallowing is more useful as an indication of motor performance in the pharyngeal region.

Cleall (1965) defined normal swallowing as when the lips remain in repose, the posterior teeth make contact, and the tongue remains within the confines of the oral cavity. He defined abnormal swallowing as when the behavior is such that an adverse effect on the dentition can be demonstrated or assumed to be present.

He divided swallowing into four stages through cinefluorographic tracings based on the results from his sample of subjects. The first stage was the "rest position" from which the tongue and hyoid moved. The second stage was when the tongue tip had moved forward from rest to establish contact with the upper incisors or palatal mucosa. The third stage was when the dorsum of the tongue had rolled back and had reached the junction of the hard and soft palates. The fourth stage was when the hyoid was in its most superior and forward position. Finally, the last stage was the "rest position" at the end of swallowing.

Cleall noted that each subject had a characteristic swallowing pattern and the group as a whole showed great variation in patterns. Eleven per cent of his sample displayed a "tooth apart" swallow with
the tip of the tongue between the incisor teeth.

His study included 27 adolescents who displayed severe tongue thrust on swallowing. In this group, the oropharyngeal movements were jerky and inconsistent when compared to other subjects. These individuals did not show the same pattern from one swallow to the next. This group showed a low tongue tip posture and a longer period of time was required to move the tongue tip from the "rest position" to the second stage of swallowing. The hyoid was reported to be more posterior in the tongue thrust group than in the normal.

Cleall concluded that the "normal" swallowing in which the teeth came together, and the lips remain in repose, and the tongue remains in the oral cavity is no longer an acceptable description. Further, normal hyoid patterns cannot be expected in open bite subjects due to the marked change in morphology of the encasing soft and hard tissue structures.

Stepovich (1965) in his comprehensive review of hyoid position discussed the various methods that have been employed to measure the hyoid bone. He cites techniques by King (1952), Smith (1956), Grant (1959), Andersen (1963), and Bench (1963). Besides Andersen, Stepovich is the only author in the literature to trace the greater horns of the hyoid bone, and he is the only author to make measurements of these structures in space. In his discussion, Stepovich admitted that hyoid position could not be duplicated in successive roentograms of the same person. Thus we can see the need once again for cinerouurography. Stepovich felt that the change of head position may be the biggest reason why the hyoid position cannot be duplicated from film to film.
on the same individual. He summarizes by saying that accurate measurement of hyoid position remains unsolved on lateral head films due to the fact it does not articulate with other bones.

Cleall and co-workers (1966), however, concluded that movement of oropharyngeal structures within the individual could be quite reproducible with cinefluorographic radiography.

Ingervall et al (1969) felt that Stenovich (1965) exaggerated the lack of precision in recording the position of the hyoid bone.

Hedges et al (1965) described hyoid movement in the pharyngeal stage of swallowing. During this phase there is a strong contraction of the mylohyoid muscle, evidenced by the swift upward and forward movement of the hyoid bone and placement of the tongue finally against the posterior pharyngeal wall. The simultaneous contraction of the infra and suprahypoid musculature lifts the larynx up and forward under the root of the tongue and the epiglottis folds over the laryngeal opening to protect the airway and open the esophagus.

Sloan et al (1967), in conjunction with complimentary cephalometric studies developed a method for quantification of hyoid movement. The authors found the hyoid bone more inferior and posterior in class I malocclusions as related to class II malocclusions. The class II malocclusions demonstrated the greatest range of movement of the hyoid bone in deglutition.

Fink (1958) in his investigation of anterior open bite described a triangular cycle of hyoid position with a definite horizontal component. He felt this cycle was directly related to the movement of the larynx
which had to move up and forward to make room for an expanding esophagus and passing food bolus.

Volk (1969) found in his subjects that the hyoid repositioned, in class III surgery patients, the approximate amount of the reduction. In his conclusions, he stated that hyoid position is related to tongue position at rest.

Hassengill and co-workers (1972) used a cinefluorographic camera to confirm the visual diagnosis of tongue thrust. It was suggested that the cinefluorograph can be a good diagnostic tool to aid in the diagnosis of tongue-thrusting by showing the position of the tongue during the swallowing cycle, a phenomena impossible to actually see visually and clinically.

Cuozzo (1973), in his study of hyoid adaptation during distal tongue positioning in class I "normal" occlusions, found a variety of results with both the cinefluorographic and myometric parts of his study. He divided his subjects into three groups after evaluating the results. The first group showed horizontal and vertical adaptation of the hyoid bone during its swallowing cycle and adaptation of tongue force after 24 hours. The second group showed no change in hyoid cycle and a variety of responses in tongue force. The third group showed some adaptation of hyoid cycle but at the same time an increase in tongue pressure after 24 hours.

He concluded that the subjects who had a higher hyoid position in relation to the lower border of the mandible had a greater potential to accommodate in an inferior posterior direction. The subjects whose
initial hyoid position was a greater distance from the lower border of the mandible were not able to accommodate by distal positioning of the tongue. Cuozzo felt that the failure of these subjects to accommodate may be due to potential encroachment on a patent airway by the base of the tongue which is attached to the hyoid.

In his overall summary, Cuozzo felt that certain individuals have the definite ability to make this accommodation while others do not. This could be very important to clinical diagnosis of orthodontic patients.
IV. Myometric Literature:

Several attempts have been made in the literature to evaluate the influence of the tongue and perioral musculature on the dentition.

Kydd in his study in 1956 demonstrated that as much as five pounds of pressure could be exerted in the anterior region of the mouth in a 30 year old subject. This would be enough force to not only cause tooth movement but to also bring about an orthopedic change in the upper and lower jaws.

Hinders (1953), demonstrated that the tongue exerted greater forces on the dentition than did the perioral musculature. This was done by means of a pressure transducer and the physiograph recording system. In 1962, he showed that tongue thrusters had tongue pressure of as much as 207 gm/cm on the dentition. The normal swallowing pressure for the rest of the study ranged from 10 to 150 gm/cm.

Gould and Picton (1962) also studied these forces exerted by the tongue and perioral musculature in the dentition. In their study they found that if the pressure transducer was more than 2 mm from the teeth the basic forces would be greater than normal.

Kydd and co-workers (1963) used a pressure transducer to measure tongue pressure on swallowing and found the mean tongue pressure for the anterior open bite group to be twice that of the controls. The pressures in this group on swallowing were also exerted for a longer period of time.

Adlulty et al (1966) used prosthetic patients to place anterior teeth in different labio-lingual positions to measure the labio-lingual
forces of the lips and tongue. They found that the pressure increased on the side to which the teeth were moved initially, but that within as little as 24 hours the musculature had adapted to the new hard tissue architecture.

Neff and Kydd (1966) demonstrated two types of tongue thrusters. One showed a "teeth together" swallow and the other showed a "teeth apart" swallow. They felt that since both groups were tongue thrusters that these results were evidence that the tongue between the teeth alone is not enough to induce open bites, but there has to be an active force applied around a relatively passive tongue to produce an open bite distortion. This force, they felt, was provided by the muscles of mastication during swallowing.

McG lone and Proffit (1972) illustrated quite effectively that tongue pressure against the anterior part of the oral cavity was most significant during deglutition. In their sample, they found by means of a resistance strain gauge transducer that anterior tongue pressure was at least three times greater during swallowing as compared to the speech function. Length of time in a pressure-time comparison showed that tongue pressure during swallowing exceeded speech by at least eight times.

Nickle, White, and Proffit (1972) stated that the stability of the surgical result after mandibular osteotomy appears to be related to the stability of the hyoid position. In their surgery subjects, they found the initial postoperative position of the hyoid to be backward and down from its original position. However, this was followed by a
tendency for the hyoid to return to its original position. The thought that there may have been an actual change in tongue morphology as a response to the surgery which allowed the root of the tongue to be repositioned upward. They found also that small changes in horizontal mandibular position were accompanied by strong tendencies for anterior posterior hyoid repositioning. The forward repositioning of the hyoid can mean increased tongue pressure which can be imposed upon the teeth and cause surgical relapse.

As previously mentioned, Cuozzo, (1973) also used the myometric method to measure tongue pressure after forced distal repositioning of the tongue. He found a variety of tongue pressure results which were related to the hyoid distance from the inferior border of the mandible in the initial "rest" position.
V. Swallowing and Hyoid Cycle:

Straub (1951) described normal deglutition thusly: "Individuals whose teeth are in good or fairly close to normal occlusions close their teeth firmly in centric as the first step. The next action is the depression of the tip of the tongue and then placing the tongue in the palate well back in the mouth with the tip placed at the posterior part of the rugae. The tongue pressure is exerted backward and upward, the tip of the tongue in position and moving slightly distally."

Naffzinger, Davis and Bell stated, "The soft palate closes off the nasopharynx, the larynx rises and the opening is covered by the epiglottis as the material passes into the upper portion of the esophagus."

Straub also describes three stages of swallowing. Stage 1 is the voluntary and conscious stage when the food is gathered in a bolus and carried to the isthmus of the fauces. Stage 2 is involuntary and at the same time conscious (reflex mechanism). In this stage, the bolus passes through the oral and laryngeal portions of the pharynx. The third stage is both involuntary and unconscious as the bolus passes through the esophagus and into the stomach. The swallowing of the bolus then, is accomplished by negative pressure built up by the muscular function.

Straub suggested as one etiology that the perverted swallow may be the direct result of improper bottle feeding. Other significant causes according to the author are: a) a high, narrow palate which does not allow room for normal tongue position, b) a seeming female dominance.
c) unusually large tongues.

He felt the tongue habit usually caused anterior open bites and unless this habit could be corrected one could not expect normal development of the jaws and dentition nor could one expect successful treatment of malocclusion where this perverted swallowing habit presents itself.

Brodie (1955) pointed out that on mouth opening, the suprahypoid muscles, which suspend the hyoid, larynx, pharynx, and tongue, and are attached at the symphysis must contract to keep from blocking the airway. Therefore, they become part of the postural system.

Ricketts, (1953) observed extreme variations in the position of the hyoid bone in certain cases with tongue problems, such as open bite. He mentioned the extremely high position of the tongue and hyoid bone in many cases of open bite, possibly as an atavistic tendency.

Straub (1960) described how normal deglutition involved the use of some twenty muscles. The muscles of expression are never involved. When these muscles of expression appear to be active it's generally an indication of a perverted swallowing habit. He reported that a person swallows twice a minute while they are awake and once a minute while they are asleep. This emphasizes the importance of the tongue. Open bite cases, in Straub's experience, are sometimes corrected spontaneously with habit therapy. He further noted that breast fed babies almost never display a tongue thrust. Of 478 tongue thrusters observed in his practice only two were breast fed and in both cases the mothers admitted to having an exceptionally large quantity of milk. He states that abnormal swallowing does not correct itself with age. Straub
also feels that open bite is often a direct symptom of the abnormal swallowing habit which caused it.

Durzo and Brodie (1962) in their investigation of the hyoid bone found that even though the bone is entirely suspended by musculature, it is surprisingly stable in position with growth and development. They found that it generally maintained a position at a level between the bottom of the third and the top of the fourth cervical vertebrae. They also pointed out that with upright posture, man's larynx and trachea were no longer held away from the upper respiratory tract by gravity. Patency of the airway, then, could only be maintained by the geniohyoids and mylohyoid muscles which were anterior to the vital airway. They concluded that even though the hyoid was suspended by a three point system and that its relative position anteroposteriorly depends on the relative length of those muscles and that its position may be further modified by gravity acting on the larynx as well as pharyngeal and infrahyoid muscles, its growth and development is such that the overall relative position of the bone does not change during the development of breathing, swallowing, phonation and development of the tongue.

Andersen (1963) developed a quadrant grid related to the third cervical vertebrae to measure hyoid position in tongue thrusters (anterior open bite subjects) and non thrusters. He found no difference in hyoid position for these two groups. However, the vertebrae are not necessarily stable for measurement of hyoid position. He also found, as Straub did, that bottle fed children had a higher incidence of open bite and tongue thrust than did breast fed children.
Bench (1963) points out that the mandible develops from the first branchial arch and that the hyoid complex is associated with the second branchial arch. The tongue develops from both of these structures and therefore, is very closely related. He points out that a close association of the hyoid bone to the cartilage of the larynx suggests the importance of hyoid and tongue function to performance of both respiration and deglutition.

Bench found the hyoid to be midway between the third and fourth cervical vertebrae on the average. He also stated that the hyoid drops in a more rapid descent than the cervical vertebrae during development and thus a lowering of the hyoid bone in later life. Cases of tongue thrust and anterior open bite were outside of the normal statistical range and did not show the hyoid to move back and down with development. The behavior of the hyoid seemed to be more consistent with the behavior of the neck than that of the chin, although both seem to be important.

Harrington and Breinholdt (1963) raised the question of whether orthodontic therapy would enhance the tongue pattern, or whether the swallowing pattern would improve the dental arch morphology after therapy. They emphasized the need for more work in this area. The authors felt that the velopharyngeal complex was the key to the normal swallowing pattern. They pointed out that open mouth posture upsets lip and tongue balance. Thumb and finger sucking are often primary etiology in leading to the open mouth swallow. The authors also felt that the actual tongue size could be reduced with exercise by improving muscle tonus. A flacid tongue as well as a flacid velopharyngeal mechanism can lead to the tongue tip sliding forward on swallowing and
eventually cause anterior open bite dental morphology.

Subtelny and Sokuda (1964) measured hyoid position and compared normal subjects with those that displayed anterior open bite. They concerned themselves with its vertical position relative to the lingual aspect of the mandibular symphysis. In their study, no significant difference was found between the two groups. The subjects used in their study, however, were mainly skeletal open bites and not just dental open bites. There is a significant developmental and morphological difference between dento-alveolar open bites as a result of tongue thrust and a skeletal open bite which may be caused by a number of other factors including pathology and genetics.

Cleall (1965) has been previously discussed in this review. It will be remembered that he divided swallowing into four phases by his evaluations of the cinefluorographic results of his study.

He further reported that adolescents with severe tongue thrusts on swallowing displayed jerky and inconsistent movements of the oropharyngeal complex. They did not appear to have the same pattern from one swallow to the next indicating poor neuromuscular control.

Several other investigators, such as Ricketts (1955), Harvold (1953), and Brasch (1956) feel the soft tissues and particularly the tongue play the most important role in dental arch morphology, and, therefore, tongue position may be an important etiology of anterior open bite.

Hanson, et al (1969) in the first part of their five year study, found an extremely high incidence (as high as 80% for solid swallowing)
of tongue thrust in preschool children. This emphasizes the significance of the problem.

Richardson (1969) showed a correlation between facial morphology and development of open bites. Although he does not say so, one can extrapolate to say that morphology also determines muscle attachment and position which affects both form and function of the tongue.

Tulley (1969) seemed to feel that only a very small percentage of orthodontic problems are ultimately complicated by tongue behavior. He felt that the "tongue thrust as an adaptive behavior" was the category that orthodontists should concern themselves with. Other categories of tongue thrust are as follows:

1. "Tongue thrusting as a habit." - The author felt that placement of an appliance or placing teeth in their proper place would be sufficient to eliminate this problem.

2. "Tongue thrust which is possibly endogenous or innate." - The author felt that this would not respond to any kind of therapy.

3. "Pathologic and grossly abnormal tongue problems." - The author felt that tongue size may be significant etiology in tongue thrust but states that true macroglossia is extremely rare.

Guyton (1969) defined the automatic muscular movements of normal swallowing in a stepwise fashion thusly:

1. The soft palate is pulled upward to close the posterior part of the nose from the mouth.

2. Vocal cords and larynx close strongly, and the epiglottis swings backward to prevent food from going into the trachea.
3. The sphincter which normally closes the esophagus relaxes, and the larynx immediately pulls upward to open the esophagus.

4. The pharyngeal muscles then constrict and force the bolus from the pharynx into the esophagus.

The swallowing center of the nervous system is located in the medulla oblongata and stimulus from the posterior part of the mouth is transmitted to this center via the trigeminal nerve. When this center has been activated the series of muscular activities is initiated and usually cannot be stopped.

The motor stimulus is transmitted via the glossopharyngeal and vagus nerves to the pharyngeal and laryngeal regions to move the bolus of food into the esophagus. The motor function of the intrinsic muscles of the tongue, as well as the genioglossus, styloglossus and hyoglossus muscles, is controlled by the twelfth cranial nerve (hypoglossal nerve).
MATERIALS AND METHODS:

I. Selection of Subjects:

Ten subjects were selected through diagnosis of new patients to be started in active treatment in the orthodontic clinic. Eight of the subjects were female and two were male. They ranged in age from 11 to 15 years. They were selected for the fact that they presented with anterior open bite malocclusions and were obvious tongue thrusters upon swallowing.

II. General Procedures:

The purpose of the study was to determine the adaptability of the tongue and hyoid musculature upon forced distal repositioning of the tongue.

Therefore, an appliance was fabricated, incorporating two cuspid orthodontic bands as attachments. A straight piece of .045" wire in an .045" tube was soldered to the lingual aspect of these cuspid bands to go transorally, approximately 15 mm lingual to the central incisors. Acrylic was then added to the tubing and was shaped to duplicate the inclination of the lingual surfaces of the maxillary anterior teeth, and at the same time rest against these teeth and the rugae of the hard palate. The entire acrylic structure had the ability to pivot around the .045" wire and in this manner, when the tongue forced itself against the appliance, the pressure could be transmitted to the anterior superior portion of the palate and the maxillary incisor teeth. A
View From Lingual

View From Anterior

Appliance Used to Distally Reposition the Tongue
"U-shaped" crib also projected inferiorly from the .045" tube and projected into the lingual aspect of the mandibular arch when the teeth were in occlusion. This was positioned to approximate the angulation of the lingual aspects of the mandibular incisor teeth. This crib was designed to prevent the tongue from slipping inferiorly and anteriorly to the appliance during deglutition. The appliance was cemented to the subjects maxillary canine teeth for a period of 24 hours, a time deemed sufficient for muscle adaption.

Tongue pressure was measured before placing the appliance by means of a pressure transducer connected to a physiograph and results were calibrated in grams of force. A cinefluorographic film sequence was taken to determine the patients normal hyoid path in the act of swallowing. A lateral cephalometric film was taken also to check the patients normal hyoid "rest position." These procedures were repeated immediately after placing the appliance and then again 24 hours later before removal of the appliance.

III. Tongue-Pressure Recordings by the Hyometric Method:

A stainless steel button was soldered to a wire which was then slipped through a short piece of .045" tubing, providing as friction-free a system as possible, and was then attached to the extension arm of a pressure transducer. This particular transducer is manufactured by Marco-Sio Systems and is a hyograph & tiltel capable of recording in the range of 0-500 grams. The recordings of this transducer were transferred to a physiograph manufactured by Marco Instrument Company and were recorded on graph paper by means of a deflecting pen. Calibrations were done using standard 50 and 100 gram weights hung from the
transducer following each recording. The stainless steel button was placed 1-2 mm distal to the incisor teeth initially and 1-2 mm distal to the appliance after its placement. There was no interference from incisor teeth while recording due to the presence of anterior open bite in all subjects.

The subjects were stabilized by means of a dental chair and headrest. They were given water by means of an eye dropper in between swallows to keep adequate moisture in the oral cavity and a volume of liquid for deglutition.

The subjects were told to swallow with adequate rest intervals in between until ten representative swallows were recorded. A mean was taken to give an average representative figure for each sitting.

IV. Hyoid Position Recorded by Cinefluorography:

The equipment used was a Picker Cinefluorograph with an image intensifier and a Vanguard Motion Analyzer for evaluation of the films.

The cinefluorograph consists of an X-ray head with a lead plate collimator and image intensifier with a motion picture camera and optical system mounted on a "C" arm which is fully adjustable vertically. There is a head holder at a fixed distance between the X-ray source and the camera.

The subjects were placed in a chair of fixed height for each recording. Their heads were stabilized by ear rods from the head holder and they were oriented so that Frankfort Horizontal Plane was parallel to the floor. A wooden stand was fabricated with an extensive arm for the subjects chin to rest on so that the head would not move during swallowing.
The films were shot at 60 frames per second for approximately 15 seconds and were recorded on 16 mm Kodak Shellburst film. The X-ray control was set for 90 kvp and 13 ma which gave the best results. The total radiation received for each subject was approximately .90 R.

Each subject was given approximately 4 cc of barium sulfate to swallow at each sitting. They were instructed to hold the barium in their mouths until the camera was started and two swallows were recorded at each sitting.

The 16 mm film was processed and then examined in the Vanguard Motion Analyzer. Accuracy of this equipment was quite sufficient to analyze the films with good results. The speed of the motion analyzer was adjustable from 5 to 30 frames per second and frames could be set to examine one at a time.

Tracings of each subject were made on acetate paper and morphology and "rest position" of the hyoid was checked with the lateral cephalometric films which were also taken at each sitting. The hyoid bone and incisor teeth were duplicated by means of a template. Superimpositions of the tracings were made by superimposing the lower border of the mandible and the mandibular symphysis.

The hyoid measurements were made by making a graph type grid using the mandibular plane as the X axis. The Y axis was constructed by bisecting the mandibular plane and drawing a vertical axis at this point perpendicular to the mandibular plane. All measurements appear as negative numbers because the hyoid position remained in the negative X and negative Y quadrant.
RESULTS

The results of the myometric measurements on the physiograph are presented in Table I. Each subject is denoted in the first column by initials. The recordings of tongue pressure during normal deglutition before the appliance was inserted are presented in column two. The third column gives the results of tongue pressure immediately after placing the appliance. The fourth column shows tongue pressures 24 hours after the appliance was placed.

The most significant comparisons are those between columns two and four. These columns indicate the degree of adaptation by the subject over the stated period of time.

It should be noted from Table I, that the first four subjects evidenced good tongue accommodation to the distal positioning. The last six subjects appear to demonstrate an increase in tongue pressure over the 24 hour period.

Tables II and III present the millimetric measurements of hyoid positioning utilizing the previously described grid system. The X-axis represents the distance from the mandibular plane, and the Y-axis represents the distance from the vertical bisection of the mandibular plane. The most significant comparisons are those between the column labeled "Before Placing the Appliance" and the column labeled "24 hours After Placing the Appliance." It is felt that these figures give the best indication of hyoid bone repositioning, and therefore, subject accommodation.
Table II presents the measured results for the hyoid bone in the "rest position" (before deglutition was initiated). The measured results of the hyoid bone position in its most anterior-superior portion of the hyoid cycle during deglutition are shown in Table III.
These results show that the hyoid bone did move significantly inferiorly and/or posteriorly in five of the subjects (L.C., H.C., S.M., P.C., and T.F.) indicating good accommodation by these subjects to distal positioning of the tongue.

Further, it should be noted that those subjects who held the hyoid bone 20 mm or less from the mandibular plane were able to reposition the hyoid bone inferiorly and/or posteriorly, while those subjects whose initial hyoid position was greater than 20 mm from the mandibular plane were not able to significantly reposition the hyoid bone.

K.B. was the only exception to this general rule. The rest position of the hyoid bone was 20 mm from the mandibular plane and the subject did seem to accommodate in terms of tongue pressure. However, the subject did not reposition the hyoid bone inferiorly and/or posteriorly.

Two subjects (A.A. and C.L.) did appear to have changed hyoid position inferiorly and posteriorly, but this was considered to be too small to be significant. This change can be attributed to variations in head positioning at each sitting as well as tracing error.

Table IV summarizes the results of the first three tables, bringing them into perspective.

It can be seen that subjects K.B., L.C., H.C., S.M., P.C., and T.F. had an initial hyoid position of 20 mm or less from the mandibular plane. Four of these subjects (K.B., L.C., H.C., and S.M.) showed a return to initial tongue pressure during the 24 hours the appliance was worn. All of these subjects, except K.B., were able to reposition the
hyoid bone inferiorly and/or posteriorly during the 24 hours the appliance was worn.

Subjects A.A., C.C., C.L., and J.H. initially held the hyoid more than 20 mm from the mandibular plane in the rest position. All of these subjects showed an increase in tongue pressure over the 24 hours the appliance was worn, and none of them showed a significant amount of accommodation in the repositioning of the hyoid.
<table>
<thead>
<tr>
<th>SUBJECT</th>
<th>BEFORE INSERTION OF APPLIANCE</th>
<th>IMMEDIATELY AFTER INSERTION OF THE APPLIANCE</th>
<th>24 HOURS AFTER INSERTION OF THE APPLIANCE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. K.B.</td>
<td>118</td>
<td>96</td>
<td>94</td>
</tr>
<tr>
<td>2. L.C.</td>
<td>229</td>
<td>136</td>
<td>154</td>
</tr>
<tr>
<td>3. M.C.</td>
<td>206</td>
<td>133</td>
<td>162</td>
</tr>
<tr>
<td>4. S.M.</td>
<td>138</td>
<td>121</td>
<td>97</td>
</tr>
<tr>
<td>5. A.A.</td>
<td>200</td>
<td>211</td>
<td>217</td>
</tr>
<tr>
<td>6. C.C.</td>
<td>137</td>
<td>155</td>
<td>197</td>
</tr>
<tr>
<td>7. C.L.</td>
<td>94</td>
<td>96</td>
<td>131</td>
</tr>
<tr>
<td>8. J.N.</td>
<td>79</td>
<td>215</td>
<td>199</td>
</tr>
<tr>
<td>9. P.C.</td>
<td>83</td>
<td>237</td>
<td>113</td>
</tr>
<tr>
<td>10. T.F.</td>
<td>62</td>
<td>219</td>
<td>273</td>
</tr>
<tr>
<td>Patient</td>
<td>Before Placing The Appliance</td>
<td>After Placing The Appliance</td>
<td>24 Hours After Placing the Appliance</td>
</tr>
<tr>
<td>---------</td>
<td>------------------------------</td>
<td>----------------------------</td>
<td>--------------------------------------</td>
</tr>
<tr>
<td>1. K3</td>
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<td>-9.0</td>
<td>-3.5</td>
</tr>
<tr>
<td>2. LC</td>
<td>-10.5</td>
<td>-13.5</td>
<td>-13.0</td>
</tr>
<tr>
<td>3. MC</td>
<td>-10.0</td>
<td>-15.5</td>
<td>-15.0</td>
</tr>
<tr>
<td>4. SM</td>
<td>-8.0</td>
<td>-14.5</td>
<td>-12.5</td>
</tr>
<tr>
<td>5. MA</td>
<td>-10.5</td>
<td>-11.5</td>
<td>-10.0</td>
</tr>
<tr>
<td>6. CC</td>
<td>-10.5</td>
<td>-9.5</td>
<td></td>
</tr>
<tr>
<td>7. CL</td>
<td>-9.0</td>
<td>-13.0</td>
<td>-10.5</td>
</tr>
<tr>
<td>8. JN</td>
<td>-3.5</td>
<td>-3.5</td>
<td>-3.5</td>
</tr>
<tr>
<td>9. PC</td>
<td>-9.0</td>
<td>-19.5</td>
<td>-12.0</td>
</tr>
<tr>
<td>10. TF</td>
<td>-19.5</td>
<td>-15.5</td>
<td>-22.5</td>
</tr>
</tbody>
</table>

**Distance From Y Axis**

<table>
<thead>
<tr>
<th>Patient</th>
<th>Before Placing The Appliance</th>
<th>After Placing The Appliance</th>
<th>24 Hours After Placing the Appliance</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. K3</td>
<td>-20.0</td>
<td>-23.0</td>
<td>-13.0</td>
</tr>
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<td>2. LC</td>
<td>-16.5</td>
<td>-22.0</td>
<td>-20.5</td>
</tr>
<tr>
<td>3. MC</td>
<td>-19.0</td>
<td>-25.5</td>
<td>-21.5</td>
</tr>
<tr>
<td>4. SM</td>
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<td>5. MA</td>
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<td>-37.5</td>
<td>-34.5</td>
</tr>
<tr>
<td>6. CC</td>
<td>-27.5</td>
<td>-24.0</td>
<td>-12.0</td>
</tr>
<tr>
<td>7. CL</td>
<td>-21.5</td>
<td>-27.0</td>
<td>-22.5</td>
</tr>
<tr>
<td>8. JN</td>
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<td>-23.5</td>
<td>-23.0</td>
</tr>
<tr>
<td>9. PC</td>
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<td>-23.0</td>
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<tr>
<td>10. TF</td>
<td>-20.0</td>
<td>-19.5</td>
<td>-20.5</td>
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</tbody>
</table>

Grid - **X Axis=mandibular plane**

**Y Axis=perpendicular bisection of the mandibular plane**
### TABLE III
MOST ANTERIOR-SUPERIOR POSITION OF HYOID AT THREE MEASUREMENT PERIODS

<table>
<thead>
<tr>
<th>Patient</th>
<th>Before Placing The Appliance</th>
<th>After Placing The Appliance</th>
<th>24 Hours After Placing the Appliance</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. KB</td>
<td>- 1.0</td>
<td>- 1.5</td>
<td>0</td>
</tr>
<tr>
<td>2. LC</td>
<td>- 6.0</td>
<td>-10.0</td>
<td>- 7.5</td>
</tr>
<tr>
<td>3. MC</td>
<td>- 6.0</td>
<td>- 9.5</td>
<td>- 9.0</td>
</tr>
<tr>
<td>4. SM</td>
<td>- 6.0</td>
<td>- 8.5</td>
<td>- 7.0</td>
</tr>
<tr>
<td>5. AA</td>
<td>- 7.0</td>
<td>- 6.5</td>
<td>- 6.5</td>
</tr>
<tr>
<td>6. CC</td>
<td>-12.5</td>
<td>- 6.5</td>
<td>-11.0</td>
</tr>
<tr>
<td>7. CL</td>
<td>- 2.0</td>
<td>-10.0</td>
<td>- 5.0</td>
</tr>
<tr>
<td>8. JH</td>
<td>- 1.0</td>
<td>- 2.5</td>
<td>- 1.0</td>
</tr>
<tr>
<td>9. PC</td>
<td>- 7.0</td>
<td>- 4.0</td>
<td>- 8.0</td>
</tr>
<tr>
<td>10. TF</td>
<td>-10.0</td>
<td>-14.0</td>
<td>-21.0</td>
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</tbody>
</table>

**M1 Distance From the Y Axis**

<table>
<thead>
<tr>
<th>Patient</th>
<th>Before Placing The Appliance</th>
<th>After Placing The Appliance</th>
<th>24 Hours After Placing the Appliance</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. KB</td>
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<td>-13.0</td>
</tr>
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<td>- 9.0</td>
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<td>3. MC</td>
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<td>8. JH</td>
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<td>- 9.0</td>
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<tr>
<td>9. PC</td>
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<td>-19.0</td>
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</tr>
<tr>
<td>10. TF</td>
<td>- 9.0</td>
<td>- 5.5</td>
<td>- 5.5</td>
</tr>
</tbody>
</table>

**Grid**: *X Axis=mandibular plane

**Y Axis=perpendicular bisection of the mandibular plane*
<table>
<thead>
<tr>
<th>SUBJECT</th>
<th>HYOID DISTANCE FROM MANDIBULAR PLANE</th>
<th>AVERAGE MAXIMUM TONGUE PRESSURE DURING SHALLOWING OVER 24 HOUR PERIOD</th>
<th>HYOID REPOSITIONING IN 24 HOUR PERIOD</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. K.B.</td>
<td>20.0 mm</td>
<td>Decreased</td>
<td>No</td>
</tr>
<tr>
<td>2. L.C.</td>
<td>16.5 mm</td>
<td>Decreased</td>
<td>Yes</td>
</tr>
<tr>
<td>3. M.C.</td>
<td>19.0 mm</td>
<td>Decreased</td>
<td>Yes</td>
</tr>
<tr>
<td>4. S.M.</td>
<td>19.5 mm</td>
<td>Decreased</td>
<td>Yes</td>
</tr>
<tr>
<td>5. A.A.</td>
<td>32.5 mm</td>
<td>Increased</td>
<td>No</td>
</tr>
<tr>
<td>6. C.C.</td>
<td>27.5 mm</td>
<td>Increased</td>
<td>No</td>
</tr>
<tr>
<td>7. C.L.</td>
<td>21.5 mm</td>
<td>Increased</td>
<td>No</td>
</tr>
<tr>
<td>8. J.N.</td>
<td>24.5 mm</td>
<td>Increased</td>
<td>No</td>
</tr>
<tr>
<td>9. P.C.</td>
<td>17.0 mm</td>
<td>Increased*</td>
<td>Yes</td>
</tr>
<tr>
<td>10. T.F.</td>
<td>20.0 mm</td>
<td>Increased</td>
<td>Yes</td>
</tr>
</tbody>
</table>

*P.C. showed an overall increase in average maximum tongue pressure when comparing the figures from "Before Placing the Appliance" to "24 Hours After Placing the Appliance" in Table I. However, it should be observed in Table I that in the 24 hour period from the time the appliance was inserted there was a large decrease in tongue pressure.
DISCUSSION:

This study was inspired by Cuozzo (1973) and is an attempt to see if the hyoid position can be changed to accommodate forced distal positioning of the tongue. Cuozzo, in his work studied subjects with class I "normal" occlusions as compared with this study, which was comprised of open bite, tongue thrust subjects.

Cuozzo indicated that the hyoid bone could not reposition beyond the limits of the stylohyoid ligament which suspends the hyoid bone from the skull. Therefore, he concluded that the bone had to reposition to a new position on an arc formed by this ligament. Another possible means for positional change could result from rotation of the hyoid bone. In his study, as in this one, the only reproducible part of the hyoid bone was the body of the hyoid, due to the quality of the cine-flourographic films.

Cuozzo reported that the group of his subjects who held the hyoid bone close to the lower border of the mandible, showed the ability to move the hyoid bone inferiorly and posteriorly. Those subjects whose hyoid bone was further from the mandibular plane were unable to reposition the hyoid bone in this fashion.

He concluded that a possible reason for the poor accommodating ability of some of his subjects may have been due to the fact that the hyoid bone could not move down and back without infringing on the airway. The initial rest position distance of the hyoid bone from the lower border of the mandible may well be correlated with the tongue musculature and the subjects ability to avoid respiratory embarrassment.
The important discovery in Cuozzo's work was that there is physiological variation in the capacity of the hyoid bone to adapt to a new position when the tongue is forced distally, some individuals have the potential to accommodate, while others do not.

The subjects in this study were considerably different anatomically as well as physiologically in terms of normal deglutition. They consisted of anterior open bite malocclusions with pronounced tongue thrust during deglutition. Tongue function was markedly different from the so-called "normal" swallowers, and, initially this author felt that they would show far less potential for adaptation to distal tongue positioning. The important clinical question here deals with a cause and affect relationship. Does the abnormal tongue function cause the anterior open bite to develop, or does the anterior open bite result from other etiology and merely allow the tongue the freedom to move between the anterior teeth during deglutition?

In general, the results of this study support the hypothesis developed by Cuozzo. The subjects reacted in the same manner as did the class I "normal" occlusions. Those subjects whose initial hyoid rest position was 20 mm or less from the mandibular plane evidenced good potential for accommodation of hyoid position. The only exception to this was K.B., who showed good tongue pressure adaptation, but whose hyoid bone did not reposition inferiorly and posteriorly. Upon questioning this subject, it was found that she had been involved in a severe electrical wiring accident as an infant, leaving a good deal of scar tissue intraorally in the lips and in the surrounding molarial
musculature. It is believed that this apparent exception can be explained by altered anatomical structure and more significantly an alteration in the mechanisms.

It can be observed in Table IV that T.F. showed favorable hyoid positional change after 24 hours and once again the initial hyoid position was 20 mm or less from the mandibular plane. However, this subject showed an increase in tongue pressure after evaluating the myometric results. This may be explained by an increased dominance of the other extrinsic and intrinsic muscles of the tongue. At the same time there may possibly have been an increase in tonus of the infra-hyoid musculature. It would seem likely that this reaction would be due to the specific response to the proprioceptive feedback of the tongue in accordance with the appliance shape and position.

One other subject, P.C., displayed good hyoid positional accommodation but at the same time appeared to have had an increase in average maximum tongue thrust from the time before the appliance was placed until 24 hours after placing the appliance. However, on more careful examination of Table I, it should be observed that this subject did actually show significant tongue thrust accommodation in the 24 hour period the appliance was worn. The average maximum tongue thrust for this subject was 237 grams at the time the appliance was inserted and only 113 grams after the 24 hour period that the appliance was in place. The four subjects whose initial hyoid rest position was more than 20 mm from the mandibular plane showed no accommodation to the new distal positioning of the tongue. After 24 hours, they showed increased tongue
thrust on swallowing and no significant hyoid repositioning. Once again this would support the hypothesis that since the hyoid bone was already well back and down away from the mandibular plane that any further repositioning inferiorly and posteriorly could cause a decrease in the patency of the airway.

This author found the hyoid position and cycle quite reproducible for each subject with the cinefluoroographic technique. This is contrary to Cleall (1965), who found the hyoid cycle of tongue thrusters jerky and inconsistent. Each subject in this study displayed a characteristic hyoid cycle which was in the form of a triangle when outlined. Stepovich (1965) felt that accurately measuring hyoid position was extremely difficult if not impossible with the cinefluoroographic technique. This author, however, agrees with Ingervall (1969) who claimed that Stepovich exaggerated the lack of precision with this technique.

Cleall (1965) found that the hyoid bone is more posterior in the tongue thrust group of his sample as compared to "normal" swallowers. The subjects in this study show a range of hyoid positions similar to those reported as swallowers.

Durzo and Brodie (1962) claimed that the hyoid bone was quite stable through the periods of growth and development of the individual but also indicated that since the bone is essentially suspended by musculature that it may show great variability in functional positions at any one time. This is certainly supported by the results of the study by Cuozzo, as well as those reported herein.
In this study, as with any study with a significant number of variables, there are many unanswered questions which it is hoped will stimulate further investigation. Some of the variance in results may possibly be answered on an individual basis. Tulley (1962), as stated earlier, divided tongue thrusters into a number of categories and felt that tongue thrust as an adaptive behavior was the only category that the clinician should concern himself with. He felt that tongue thrust as a habit could be corrected simply by wearing a "tongue crib" or by closing down the open bite. This author feels that there is much more that must be considered. The patients neurological patterns and proprioceptive feedback mechanism are of ultimate importance and, thus far, very poorly investigated in the area of deglutition. The anatomical limitations of the patient are also critical and even if the tongue thrust appears to be habit, it may not be correctible if the hyoid and associated muscles can not be repositioned due to problems with embarrassment of the airway. In these cases, it might be better not to treat the anterior open bite malocclusion orthodontically or hope to achieve tongue adjustment through retraining the intrinsic muscles of the tongue.

The hypothesis developed in Guzzo's study that subjects with the hyoid bone close to the mandibular plane seem to have greater potential for accommodation than those subjects with the hyoid further from the mandibular plane certainly has been supported in this study of anterior open bite, tongue thrust subjects. A further investigation to support this hypothesis could be performed by selecting two groups of subjects;
those with the hyoid near the mandibular plane, and those with the hyoid further away from the mandibular plane, and then testing their ability to accommodate by using the same techniques as presented in this thesis. If this hypothesis bears out and technical problems with head positioning can be overcome, the clinician may someday be able to determine which tongue thrust patients are good candidates for successful orthodontic therapy, prosthetic appliances, or orthognathic surgery.
SUMMARY AND CONCLUSIONS

This study was performed to determine to what extent the hyoid bone and thus the tongue re-adapts its position during the swallowing pattern in anterior open bite, tongue thrust subjects, when the tongue is forced to a new distal position. This would, to some degree, determine the ability of the individual subject to accommodate to new tongue positioning.

Ten subjects were selected, all of whom had anterior open bite malocclusions with pronounced tongue thrust upon deglutition. An appliance was constructed to reposition the tongue approximately 15 mm posteriorly in the oral cavity. The following procedures were followed to test the hypothesis:

1. Before the appliance was placed:
   a. The subjects were asked to swallow water while recording tongue thrust using the myometric method.
   b. A series of films were taken with the cinefluorograph while the subject was instructed to swallow barium sulfate to record "normal" hyoid position and cycle.
   c. A lateral cephalometric X-ray was taken to record roentgenographic anatomy.

2. The appliance was then placed and cemented to the cuspid teeth.

3. Immediately after the appliance was placed:
   a. Once again tongue thrust was recorded using the myometric method.
   b. Hyoid position and cycle were again recorded on film using
the cinefluourograph.

c. Another lateral cephalometric X-ray was taken.

4. Twenty four hours after the appliance was placed, the same techniques and procedures were once again repeated.

5. The results were analyzed and then organized for the sake of the reporting.

Originally this author felt that the open bite, tongue thrust subjects would have far less potential for hyoid repositioning and accommodation than the class I subjects with "normal" occlusions and swallowing patterns. This did not prove to be true. These subjects showed the same type of response as the class I "normal" occlusion subjects in a previous study. The hypothesis of hyoid-mandibular plane distance was once again born out. The subjects with the hyoid bone close to the mandibular plane showed good potential for accommodation while those with the hyoid position further from the mandibular plane were unable to reposition the hyoid bone.

Some questions remain unanswered and it is hoped that further study will be done in this area. Tongue-thrust and anterior open bite will continue to plague the clinician in orthodontics, prosthetics, and orthognathic surgery until some more definitive answers can be found.
BIBLIOGRAPHY


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

5/15/74
Date

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