Patterns Of Deglutition

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The primary concern of this paper is the deglutition pattern often referred to as tongue thrust swallowing. It may be considered axiomatic that any attempt to understand variant function must be based on a knowledge of typically normal function. For that reason we will include a review of normal deglutition preceding our review of tongue thrust deglutition. The data presented in this paper were taken to test some present concepts upon which treatment of tongue thrust swallowers is now based. From the review of the literature and the data we will suggest several working hypotheses which we hope will serve as a basis for the improvement of tongue thrust treatment programs.

Normal Deglutition

The study of deglutition has been hampered by the lack of proper research tools. Direct visual observation in a normal human subject is impossible. The extremely rapid sequential movements in deglutition further complicate analysis. In recent years the use of radiography, fluoroscopy, then cinefluoroscopy, have allowed more detailed examination. Gradually four identifiable general theories have evolved which we have termed: (1) the Theory of Constant Propulsion, (2) the Theory of Oral Expulsion, (3) the Theory of Negative Pressure, and (4) the Theory of Integral Function.

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Theory of Constant Propulsion

Early investigators based their concepts of deglutition on their knowledge of anatomy and upon animal experiments. They assumed that the various structures involved in deglutition acted upon the bolus of food consecutively to propel it from the mouth through the pharynx into the esophagus.[11,24,27,34] The bolus was visualized as being forced through a series of passageways by constant muscular pressure. In the classical work of Magendie[34] three stages of this propulsion were noted. These were identified as the oral, pharyngeal, and esophageal stages. These three stages of deglutition are still recognized in the current literature. With certain important modifications this theory is closely analogous to the modern concept of swallowing.

Theory of Oral Expulsion

In 1880, Kronecker, Meltzer, and Falk[30] suggested that the bolus was ejected from the mouth directly into the stomach by the piston-like action of the tongue and mylohyoid musculature. This we have termed the Theory of Oral Expulsion. Cannon,[14] in 1911, believed that Kronecker's Theory of Oral Expulsion applied to fluids and semifluids. He believed, however, that solids and semisolids were handled by a consecutive peristaltic-type action similar to that described by Magendie. This Theory of Oral Expulsion is not supported by current findings. The actions of the pharynx are so rapid that these observers, using manometric techniques and fluoroscopy, were apparently unable

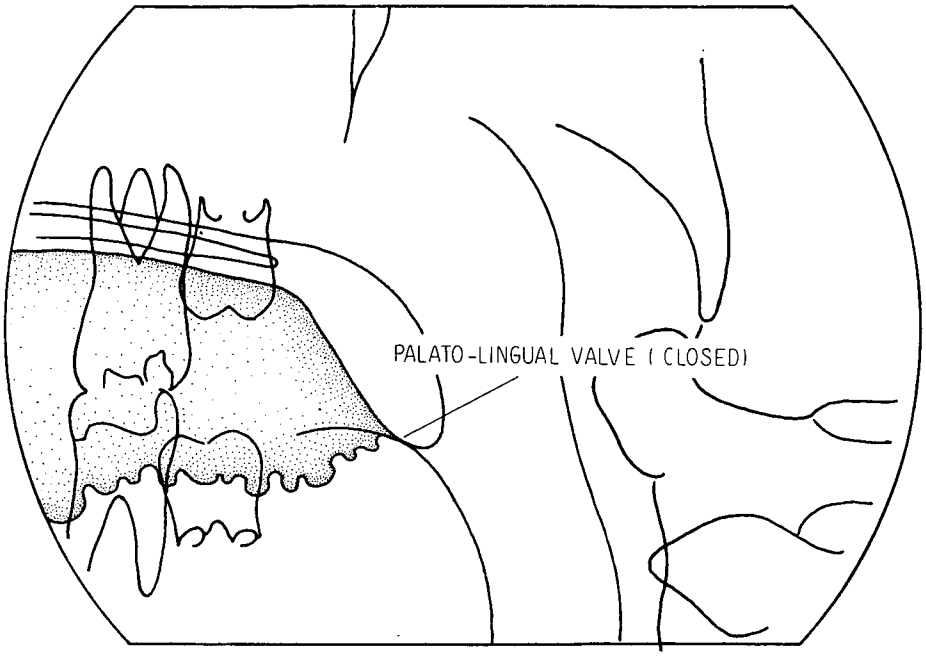

Fig. 1 Initiation of the oral stage of a normal swallow taken from 16 mm cinefluorographic film. Note that the palatolingual valve formed by the soft palate and the tongue controls the entrance of the bolus into the pharynx.

to observe the sequence of events taking place in the pharynx.

Theory of Negative Pressure

Barclay,[8] using fluoroscopic techniques, observed a moment of radiolucency in the hypopharynx immediately preceding the descent of the bolus. He postulated that this radiolucent area, indicating pharyngeal dilation, was evidence of negative pressure, which he felt was the primary propulsive force in deglutition. Barclay believed that this negative pressure was obtained by a simultaneous lowering of the larynx and forward motion of the tongue taking place while the openings of the pharynx were closed. Barclay's Theory of Negative Pressure gained wide acceptance for a number of years and found its way into many of the standard physiology texts.

Barclay's theories bear an important relation to clinical orthodontics because many of our current treatment programs for the correction of tongue thrust swallowing are based upon this theory. Numerous studies[4,12,29,36,39] have indicated that Barclay was probably incorrect. A crucial experiment pertaining to this problem was performed in 1956 by Atkinson.[5] As part of the swallowing phenomenon, he found double peaked, positive air pressure waves in the pharynx. The first peak corresponded to the entrance of the bolus into the pharynx and the second wave corresponded to constrictor action. The presence of these positive pressures effectively refutes the suggestion that suction functions as the pressure source for transmission of the bolus.

Furthermore, cinefluorography shows the palatopharyngeal valve is often open for a moment at the beginning of normal deglutition (Figs. 1 and 2). Negative pressure can not be present to

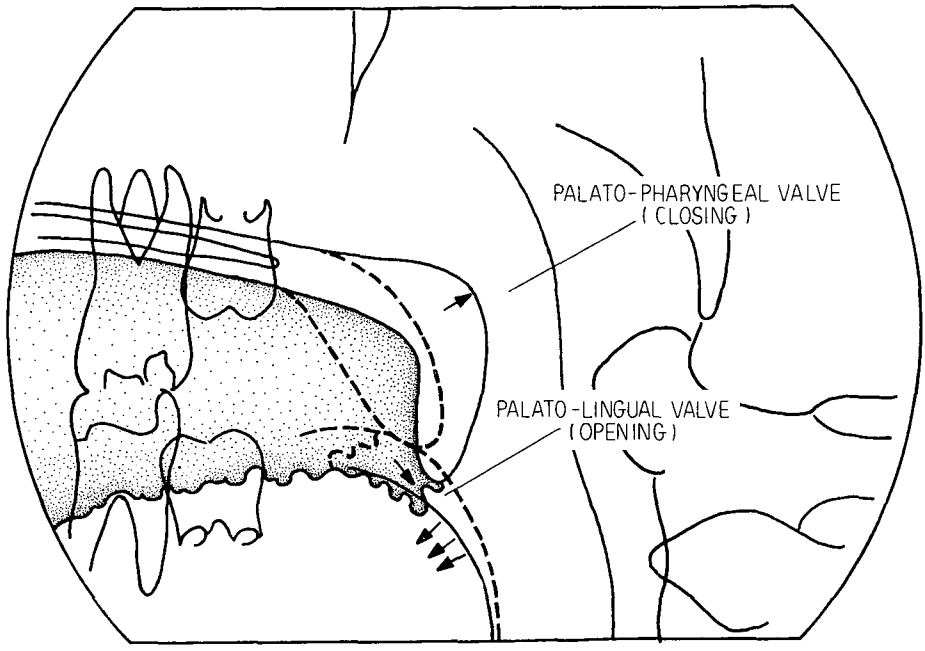

Fig. 2 Tracing of cinefluorographic film during the oral stage of deglutition taken 3/15 second after the frame shown in Fig. 1. The bolus has begun to move distally. Both the palatolingual and the palatopharyngeal valves are open. Since the palatopharyngeal valve is open, suction can not possibly be the initiating force in bolus propulsion.

propel the bolus while the palatopharyngeal valve is open. The rationale for sucking exercises in tongue thrust treatment programs is based on this Theory of Negative Pressure. Since this theory is apparently invalid we feel the use of these sucking exercises should be revaluated.

Theory of Integral Function

Cinefluorography has allowed recent observers visualization of the dynamics of swallowing which was not available to early workers. Studies, using this method of observation, seem to agree generally with the basic concepts of Magendie's Theory of Constant Propulsion. These studies show the bolus to be passed distally by a series of muscular valves, which, by their actions, suggest a highly integrated reflex control. Although Magendie described the basic functions of the swallowing act, his observation techniques were not sufficiently precise to demonstrate this remarkable reflex coordination. The present concept of deglutition which emphasizes this synergistic activity is hereby termed the Theory of Integral Function. The discussion which follows describes the dynamics of deglutition and discusses the contributions of various workers in the development of this theory.

Preparation for Deglutition

Preparation for swallowing begins as the substance to be swallowed is collected by the tongue, formed as a bolus, and moved to a characteristic swallow-preparatory position. Both lateral and anteroposterior cinefluorographs show the bolus to be held momentarily in a cupped or spoon-shaped depression on the dorsal surface of the tongue. The bolus is circumscribed by a peripheral seal. Anteriorly, this seal is maintained

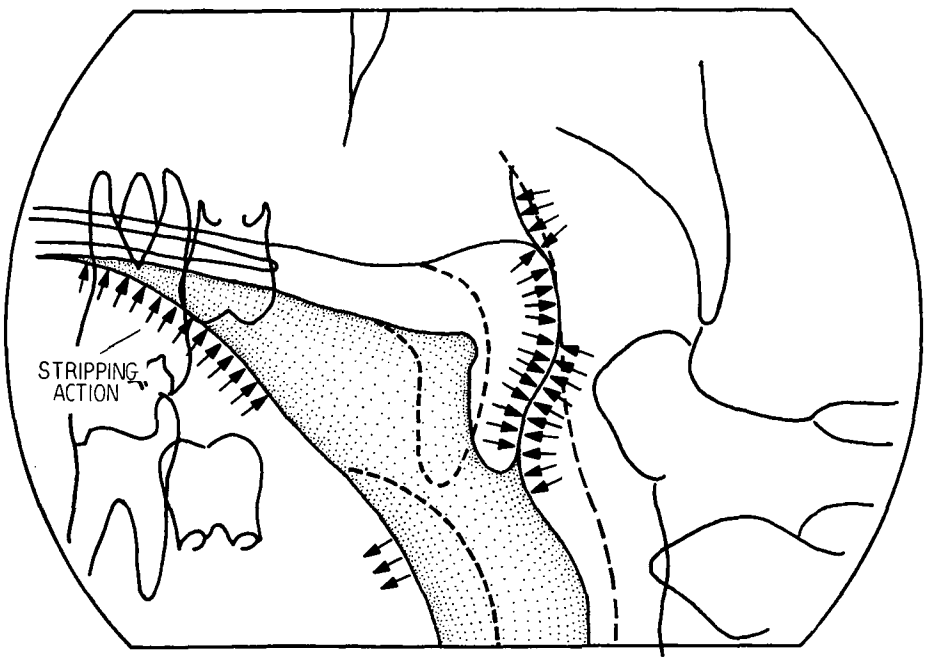

Fig. 3 Tracing of cinefluorographic film taken 1/15 sec. after frame shown in Fig. 2. The soft palate has moved posteriorly and superiorly against the posterior pharyngeal wall which has moved anteriorly to meet it. This action closes the palatopharyngeal valve preventing the entrance of the bolus into the nasopharynx. The elevation of the soft palate together with the final lowering of the posterior aspect of the dorsum of the tongue opens the palatolingual valve allowing the bolus to pass through the isthmus of the fauces. The stripping action of the tongue acting against the hard palate as described by Ramsey is graphically displayed.

by the tip of the tongue positioned against the palatal mucosa adjacent to the anterior teeth. Laterally, the tongue seals against the buccal teeth and the palatal mucosa adjacent to the buccal teeth. Posteriorly, the pharyngeal portion of the tongue arches behind the bolus to meet the posterior pillars, which contract toward the midline, and the tensor-depressed soft palate which moves inferiorly to seal against the tongue. We have termed this posterior seal the palatolingual valve. This valve prevents the bolus from entering the pharynx prematurely. The peripheral seal is important for it provides the necessary control of the bolus as swallowing begins. In orthodontic literature the correct position of the tip of the tongue is stressed but the role of the lateral and posterior seal is often not mentioned.

Oral Stage of Deglutition

Distal movement of the bolus begins with depression of the pharyngeal portion of the tongue and elevation of the palate. This releases the bolus and is followed in rapid sequential action by a progressive distal squeezing of the tongue against the hard palate. Ardran[4] stressed that the bolus is expressed backwards as if it were toothpaste being squeezed from a tube. This analogy is perhaps more accurate for solids than liquids since gravity seems to play an important role in propelling the latter from the oral cavity. Ramsey[39] calls the progressive narrowing and obliteration

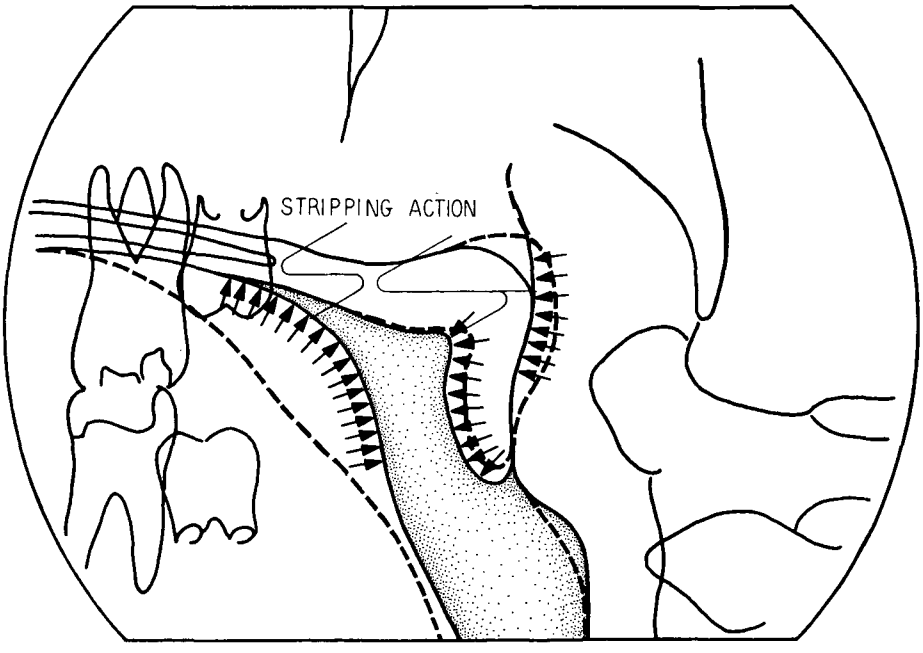

Fig. 4 Tracing of cinefluorographic film taken 1/15 sec. after the frame shown in Fig. 3. The stripping action transporting the bolus distally is shown to be a synergistic action of the tongue moving posterosuperiorly and the soft palate anteroinferiorly. The anterior movement of the posterior pharyngeal wall maintains the palatopharyngeal seal.

of the lumen behind the bolus a "stripping wave." For this stripping or squeezing to be effective, it is apparent that an effective anterior and lateral seal of the tongue against the hard palate is absolutely necessary.

Recent advances in oral myometric research have offered a methodology for the study of the peripheral seal concept.[1,31,55,56] Kydd and Toda[32] found that lingual pressure during deglutition was similar in the anterior and lateral areas of the hard palate but was less in the central areas. This study supports the contention that a peripheral seal is present during swallowing.

Pharyngeal Stage of Deglutition

In the second stage of deglutition the bolus is passed distally in the pharynx by the integrated action of the tongue, soft palate, and pharynx. At the end of the first stage the soft palate elevates to allow the bolus to pass through the isthmus of the fauces. In the second stage the soft palate completes this elevation to contact the opposing posterior pharyngeal wall. This synergistic action of the soft palate and posterior pharyngeal wall prevents nasal leakage of the bolus. The root of the tongue is lowered at the end of the first stage to allow the bolus to pass the isthmus of the fauces (Figs. 2, 3 and 4). In the second stage the bolus is stripped or squeezed distally by the progressive action of the tongue functioning against the contracting constrictor muscles. Jackson and Jackson[28] state that, "the bolus is forced through the faucial isthmus into the grasp of the pharyngeal constrictors which compress the bolus and force it through the first gateway — the mouth of the esopha-

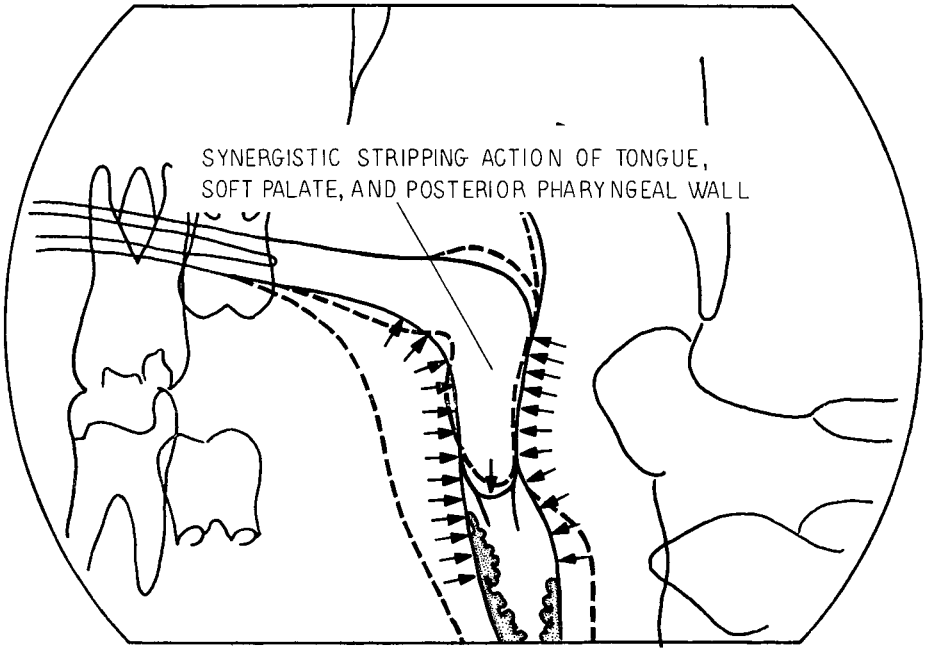

Fig. 5 Single frame of 16 mm cinefluorographic film taken 1/15 second after the frame shown in Fig. 4. The synergistic action of the tongue moving posteriorly, the soft palate inferiorly, and the posterior pharyngeal wall anteriorly, squeeze the remnants of the bolus out of the nasopharynx.

gus." The contraction of the constrictors is seen in lateral films as an anterior movement of the posterior pharyngeal wall moving to meet the progressive posterosuperior movement of the tongue (Fig. 5). Ramsey states that the question as to whether the tongue or the posterior pharyngeal wall is a major propelling force would seem to be irrelevant since the two actions are plainly complementary.

Movements of the epiglottis have, in the past, been the cause of considerable controversy. Barclay claimed that the epiglottis had little to do with protection of the airway, and stood erect during swallowing, "like a rock under a waterfall." With improved cinefluorographic techniques recent observers have refuted Barclay's claims. There is little doubt that the epiglottis does tip down during deglutition. Barclay was probably right in assuming that the epiglottis does not play the major role in the protection of the laryngeal airway. As the bolus descends, the true and false vocal folds are reflexly approximated and the larynx is elevated to approximate the base of the tongue. This sphincteric action efficiently protects the laryngeal additus against bolus penetration. Hence, the tilting of the epiglottis is seen to be a secondary protective mechanism which is not essential when normal laryngeal function exists.

The sequential movements in the hypopharynx have been described by Bosma.[12] He states that as the bolus reaches the hypopharynx, an abrupt final elevation of the larynx occurs, followed in distinguishable succession by an elevation of the floor of the hypopharynx. This final elevation of the larynx in relation to the hyoid bone may

be considered to provide skeletal background for the motions of the hypopharyngeal sphincter. This activity is a culmination of the succession of integrated reflex actions of the pharynx. Bosma points out that these efforts proceed in a constant pattern when they are initiated and are apparently not dependent upon the mechanical action of the bolus.

Movements of the Hyoid Bone

Since the hyoid bone serves as the posterior pedestal upon which the tongue is mounted, and since it is intimately linked with the lingual, pharyngeal, and laryngeal suspensory system, it is a particularly helpful structure to study in relation to the swallowing act.

Displacements of the hyoid bone during the swallowing act demonstrate further the integrated activities of the various participating structures. Shelton et al.[47] describe three phases of hyoid displacement during normal deglutition. Phase I includes simultaneous cephalad displacement of the hyoid, elevation of the larynx, and usually a dorsad movement of the pharyngeal portion of the tongue. This occurs early in the swallowing act prior to descent of the bolus. In Phase 2, hyoid direction of movement has a strong anterior component ranging from "nearly directly ventrad to obliquely cephaloventrad." Deviations from the direct pathway are apparently slight. Phase II occurs as the bolus descends through the pharynx and enters the esophagus. In Phase 3 the structures return to their preswallow positions and, typically, the hyoid descends obliquely posteriorly and inferiorly in conjunction with an anterior movement of the pharyngeal portion of the tongue and the descent and reopening of the larynx. It may be seen that the phases of hyoid movement described by Shelton correspond rather closely with the stages of deglutition classically described by Magendie.

Ramsey[39] notes that movements of the hyoid bone vary with size of the bolus. He indicates that with a large bolus the hyoid bone moves obliquely forward and upward, the forward component being the larger. With a small bolus the movement is first upward, then forward and hence corresponds with the pattern described by Shelton. Ramsey believes that the regularity of these responses indicates that the motor centers are receiving precise information as to bolus size. The observations of Ardran and Kemp[4] concur generally with those of Ramsey and of Shelton. Ardran and Kemp state that the hyoid bone is usually lifted to the level of the lower border of the mandible, then is drawn forward as the main mass of the bolus descends. They note that in some subjects these movements appear to be combined.

It seems logical that the hyoid bone should move upward and forward as Ramsey and Ardran and Kemp stated, to make room for the passage of the bolus through the isthmus. Several authors, however, have not substantiated this contention. Bosma indicates that in the erect swallow of the human adult the initial movement of the hyoid-larynx column is in a combined upward and posterior direction. Saunders and Davis[45] have also described an upward and backward movement of the hyoid, larynx, and tongue. However, the sequence x-rays shown in Saunders and Davis' publication show the hyoid bone to move progressively upward and forward during bolus penetration.

One possible explanation may be advanced for this apparent discrepancy in observations. Writers noting posterior movement of the hyoid may be referring to the tilting of the wings of the hyoid which is associated with the movement of the lateral pharyngeal walls, especially during the preparatory and early phases of swallowing. This rotation of

the hyoid bone may be detected and misinterpreted as posterior movement. The total movement of the mass of the hyoid bone during the swallowing act is upward and forward.

Abnormal Deglutition

In recent years considerable attention has been focused on a variation of normal deglutition performed with teeth apart and the tongue thrust between the teeth. The existence of this tongue thrust swallowing pattern is commonly agreed upon, but the etiology, the clinical significance, and the treatment of this swallowing pattern is a subject of much polemic discussion.

Cinefluorographic Observations

Although extensive cinefluorographic studies of tongue thrust deglutition are not yet available, present preliminary cinefluorographic studies do allow some comparison between tongue thrust and typically normal deglutition patterns. The characteristic low tongue posture and lack of contact between the teeth in the tongue thrust pattern is very apparent in these films. Fletcher[19] has noticed that in normal deglutition with a small bolus, the hyoid bone moves superiorly for a period of time and then anteriorly. In tongue thrust deglutition the hyoid bone moves in a component anterior and superior direction or in an anterior direction followed by a late superior movement. Tongue thrust swallowers performing with a small bolus seem similar to normal swallowers "gulping" a large bolus, as described by Ramsey. This observation confirms the clinical impression that tongue thrust swallowers are "gulping" swallowers. This "gulping" seems to be related to adaptations necessary to substitute gravity for the motions of the tongue in bolus propulsion. This contention is supported by the fact that tongue thrust deglutition is in many ways similar to deglutition of individuals with paralysis of the muscles of the tongue.

This observation bears an important relation to treatment. The tongue thrust swallower must somehow be taught to control a small bolus. Attention to tongue tip position alone is not adequate since the entire dorsal surface of the tongue is involved. If the individual does not seal the bolus against the roof of the mouth using the posterior and lateral aspects of the tongue as well as the anterior portion, the precise control is not possible and the bolus will fall into the pharynx in a large mass. This will result in a gulping swallow. Barrett has stressed the training of the posterior tongue in his treatment programs.

Review of the Literature

Tongue thrust swallowing has been studied extensively in both America and England. Initially the American and English thoughts on the subject were quite divergent. Recently the two groups have begun to reach increasingly broader areas of agreement. The Americans' approach to tongue thrust swallowing has tended to be quite pragmatic. The clinical necessity of finding some way to improve the retention of some types of treated orthodontic cases provided the initial stimulus to our interest in tongue thrust swallowing. Since most of the American work concerning tongue thrust swallowing has been done by clinical orthodontists, their concepts have naturally been influenced by their association with children in the orthodontic treatment age range. This may be the reason Americans have tended until recently to minimize any possible maturation factor. The orthodontist's concern with pernicious habits, such as thumb sucking, encouraged the acceptance of the idea that tongue thrust swallowing is also a pernicious habit. The clinical nature of American interest in this problem led them to concentrate on the retraining of tongue

thrust swallowers. It is easy to understand why the major advances in the treatment of tongue thrust swallowing have been contributed by Americans.

In England consideration of tongue thrust swallowing as a clinical orthodontic problem evolved from a broader academic interest in the orofacial muscular complex. The English investigators were interested in the maturation of the total child and the relation of this broader aspect of maturation to the specific maturation of the orofacial complex. The English interest in comparative anatomy encouraged them to explore more fundamental considerations. Initially the English assumed that tongue thrust swallowing could be corrected with the monoblock appliance which they were accustomed to using. They believed the monoblock would provide a central image of a closed or contained oral cavity stimulating correct reflex patterns. Since experience did not substantiate this hypothesis, the English became quite pessimistic about the possibility of retraining the tongue thrust swallower.

English and American concepts of tongue thrust swallowing have recently shown the results of mutual intellectual interaction. Some of the English authors now seem less pessimistic concerning the possibilities of treatment. American publications indicate an increasing interest in the maturation of deglutition and the relation between deglutition and central nervous system development.

Early Discussions

In 1918, A. P. Rogers[42] presented a "myofunctional concept" of orthodontic treatment which incorporated many principles fundamental to an understanding of orofacial muscle imbalances. He noted particularly that the masticatory and facial muscle systems may be "systematically exercised" to produce modifications in dental alignment and facial contour. Rogers did not consider patterns of lingual activity per se until a later paper.[43] Certain of his early procedures, however, such as resistance exercises for the muscles of mastication and forcing liquids from the lingual to the buccal cavity with the teeth firmly occluded, are currently used by some workers in therapy designed to alter the tongue thrust pattern of swallowing. In his early paper Rogers cited one instance wherein an open bite was corrected solely through muscle training centering on exercises of the muscles of mastication. In 1927 he extended these observations and related them directly to "tongue habits."

The Truesdells[51] were the first observers to describe tongue thrust swallowing. In 1924 they pointed out that persons with severe malocclusions often appear to have great difficulty in swallowing, the act being nearly a gulp. In 1937[52] they published a comprehensive description of normal and tongue thrust swallowing. They felt that the etiology of abnormal swallowing might be related to infected, sore, or tender tonsils or any other factor necessitating forward carriage of the tongue. The importance of upper respiratory infections as an etiological factor in tongue thrust swallowing has subsequently been stressed by many authors.[3,26,37,40,41]

The Truesdells retrained the tongue thrust swallower by encouraging the patient to swallow with the teeth firmly together "letting nature work out the details." This we have termed a "direct approach" since the patient is told what is normal and then learns by direct application of this information in a supervised practice situation. Normal swallowing is learned directly by practicing normal swallowing. Some present-day workers have patterned their treatment after the Truesdells' direct approach.

English Investigations

Little was written concerning abnormal deglutition after the Truesdells' publication until the period immediately following World War II. In England in 1946 and 1947, Rix[40,41] described the "teeth apart swallow" with the tongue thrust between the teeth, acting against the tensed muscles of the lips and cheeks. Rix felt that tongue thrust swallowing was a retention of the infantile swallowing pattern. He believed that the important etiological factors were probably swollen tonsils and upper respiratory infections. He felt that abnormal swallowers were gulping swallowers. Rix also noted the relationship between swallowing and disorders of speech articulation. He stated that, "whenever I have heard a lisp, I have also found an atypical swallow." He noted that these atypical swallowers had less clean mouths because the tongue thrust swallow impairs the self-cleansing action of the mouth.

Ballard[6] first discussed normal and abnormal postural patterns in 1948. His current views are expressed in a paper read in Paris in 1960.[7] According to Ballard, tongue thrust may be endogenous or adaptive. He implies that endogenous tongue thrust is derived genetically. He explains that adaptive tongue thrust is a reflex attempt to maintain an anterior oral seal when incompetent lip posture or skeletal dysplasia make the maintenance of normal anterior seal impossible. These adaptive habits, according to Ballard, do not fall into the category of perverse habits but arise quite subconsciously and reflexly. He feels that openbite, accompanied with endogenous tongue thrust, may slowly disappear during maturation.

Ballard believes that since the adaptive tongue thrust arises subsconsciously and reflexly, re-education of this habit has no useful purpose in orthodontic therapy. He believes that if new patterns are acquired they come about quite reflexly as the result of orthodontic treatment.

Gwynne-Evans, in 1947,[22] stated that abnormal behavior of the musculature was due to persistent infantile characteristics. Unlike Rix, however, he believed that these infantile patterns were a problem of maturation and assumed that this retained infantile pattern would be amenable to treatment with a monoblock. He reasoned that this monoblock would provide a central image of a closed or contained oral cavity stimulating correct reflex patterns. Experience did not substantiate this hypothesis. Since the monoblock did not correct this, Gwynne-Evans[23] reported in 1954 that he believed this pattern was an atypical gradient of development where the orofacial muscles, in swallowing, responded in a manner reminiscent of their visceral origins. He classified swallowing behavior as somatic, which was normal; and visceral, which was the atypical pattern reflecting the visceral origin of the orofacial muscle complex.

Tulley is presently less pessimistic about the possibilities of changing oromusculature behavior patterns than are some of his British colleagues. In 1962[53] he described three categories of oral behavior patterns; endogenous, adaptive, and habit. He agreed with Ballard that adaptive patterns were the response of the orofacial musculature to dental and skeletal patterns which preclude typical normal muscular patterns. He felt that orofacial patterns of behavior listed under habit patterns were a learned reflex response. These adaptive and habit types of oral behavior patterns Tulley believed to be readily amenable to correction. The third type of oral habit pattern he termed endogenous after Ballard. The endogenous patterns, Tulley now believes, may include a wide range of neuromuscular impair-

ment. These cases, according to Tulley, include perhaps only three per cent of the total population. Tulley states that he is not nearly as pessimistic as he has been in the past in the hope of correcting even these disorders.

American Contributions

In America, the work of Walter Straub[49] has actively revived interest in tongue thrust swallowing problems. Straub began studying tongue thrust swallowers in his office in 1943. He came to the conclusion that bottle feeding with the usual over-long nipple with unnecessarily large holes encourages tongue thrust swallowing. He says;

> "Abnormal swallowing habits may develop in bottle-fed babies who are given nursing bottles with the wrong kind of nipple. One villain responsible for many of the abnormal swallowing habits seen today is the long nipple that has several holes. An infant's mouth is very small, and this long nipple, which fits halfway down his throat, will not let him put his tongue against the roof of his mouth, even if he wants to. He cannot suck and swallow properly for, as he sucks, the milk comes so freely that he will either regurgitate and choke or spill the milk out at the sides of his mouth. In self-defense, the child puts his tongue forward and swallows with his tongue in this position. Children who swallow this way from birth may go through life swallowing abnormally."

Straub's theory has gained wide acceptance in this country.[9,54] Rogers,[44] in a recent study, however, has been unable to confirm Straub's findings.

Straub has developed an orderly program using the tools of the speech clinician to retrain tongue thrust swallowers. The details of Straub's treatment program are familiar to most of us and are readily available, so they will not be discussed here. We will discuss underlying concepts. Straub takes advantage of the fact that each speech sound has a characteristic tongue position which is relatively constant for the individual. Sounds which carry the tip of the tongue to the roof of the mouth such as ta, la, sa, and cha are used to position the tip of the tongue in the roof of the mouth. The sounds which carry the tongue high in the back of the mouth against the soft palate such as ka and ga are used to teach the correct position of the back of the tongue during the preparation for swallowing.

The authors feel that this concept of using speech sounds to lead the tongue to a normal position in preparation for swallowing is the key to Straub's success. Clinicians who have adopted and adapted Straub's speech clinician concept have reported encouraging clinical success.

Straub accepts Barclay's theory of negative pressure to explain bolus propulsion. This theory is still expounded by standard physiology texts such as Best and Taylor, which is quoted by Straub. Straub's program includes exercises to develop a sucking action during swallowing. He feels these sucking exercises are a critical part of his program. We have stated above that all recent research has indicated this Theory of Negative Pressure is not valid. If this is so, then the use of Straub's sucking exercises should be re-examined.

Barrett,[9] using Straub's concepts, developed a systematic therapy program for tongue thrust, or as he calls it, reverse swallowing. Barrett feels that there are three major elements of swallowing which the tongue thruster executes precisely backward. The teeth are open instead of closed, the tongue is down rather than up, and the breath thrust forward in the mouth instead of sucked back. Barrett's program is designed to correct these three problems. He stresses strengthening of the muscles of the anterior as well as the posterior portion of the tongue. He feels the muscles used in correct swallowing may be weak and improperly developed.

Harrington[26] has developed an ex-

tensive program for the correction of tongue thrusting which may be considered an adaptation of Straub's basic "speech therapy" approach. Harrington stresses the contention that the musculature associated with tongue thrust swallowing is inherently weak. He believes this weakness also affects the speech of these individuals. Because of this relation between deglutition and speech, Harrington feels that tongue thrust swallowing is a problem for the speech pathologist and not the orthodontist.

Rogers[44] reports that a treatment program similar to the Truesdells' "direct approach" is being used now by the Wichita Institute of Logopedics. The patient is simply asked to swallow carefully with the posterior teeth together and the tongue in the proper position and with the lips sealed without tension. The patient is asked to practice this method of swallowing for progressive periods at home as his skill increases.

Moyers[37] also uses a "direct" treatment approach. He suggests the use of a soldered lingual archwire with short sharp prongs to reinforce the new reflex. Moyer's method varies from others in one aspect. He feels that most people swallow with the tip of the tongue on the junction of the hard and soft palate. This is the way he instructs his abnormal swallowers to carry the tongue.

Hypnotism as a means of aiding muscle retraining in tongue thrust swallowing has been suggested by Dreyer and Viljoen[17] in South Africa, and by Lambert,[33] Cashion,[15] Secter,[46] Stolzenberg,[48] and Palmer[38] in this country. Varying degrees of success have been reported. Palmer reports a mean of one hour and twenty-one minutes treatment time with his patients. The time spent seems rather excessive but Palmer reports excellent success.

We have previously stated that American concepts of treatment have begun to influence some English authors. The influence of English concepts are becoming apparent in recent American publications. The maturation of deglutition, which has interested the English intensely, has largely been ignored in America until recently.

Fletcher, Casteel and Bradley[20] studied the incidence of abnormal swallowing in various age groups of public school children. They found that the incidence of tongue thrust swallowers decreased as the age of the groups increased. The works of Anderson[2] and Bell and Hale[10] report similar findings. These studies definitely support the English contention that tongue thrust swallowing is related, in part at least, to maturation.

Andrews,[3] in 1960, described the maturation of normal deglutition to explain why retained infantile swallowing may result in tongue thrust swallowing. He emphasizes that in a newborn infant the lips take no active part in swallowing but function as an anterior seal around the nipple. With the introduction of strained foods the infant must learn to use his lips to maintain the necessary anterior seal. At this stage the tongue cannot form the anterior seal since it protrudes beyond the alveolar ridges. As the teeth erupt, the swallowing pattern changes. The teeth are occluded during swallowing and the tongue and food are contained within the oral cavity. The lips are not used in this more mature swallowing because they are not necessary to contain the food. When the infant is learning to swallow strained foods, activity of the circumoral musculature is normal, but Andrews states that if this pattern does not progress to a mature level, a retained infantile swallow results.

Subtelny and Subtelny[50] recently urged clinical orthodontists to realize that tongue thrust swallowing may be either primary or adaptive to malocclu-

sion. This supports a basic English concept which has not been generally discussed in America.

We have stated above that English orthodontists use a monoblock to create a central image of a contained oral cavity to encourage the development of normal reflex patterns. In this country Graber uses an adaptation of this approach. Instead of the monoblock, Graber suggests a soldered palatal crib to simulate the contained oral cavity. The English reported little success with their monoblock but Graber has found his soldered palatal arch very successful, after reviewing the results of a large treatment sample.

Study of Tongue Posture and Coordination

The literature reveals a rather constant assumption that a person with the tongue thrust pattern of oral activity may be considered "orally sluggish." This sluggishness is presumed to be a reflection of muscle weakness and a tendency toward discoordination in the more finely integrated movements necessary for these activities. Thus, retraining programs may routinely include activities directed toward increasing muscle strength and precision of motion. One of the purposes of this paper is to present a study which tests the assumption of oral sluggishness in this type of swallower. A second function of the study was to examine the effects of the tongue thrust pattern of deglutition on the static posture of the tongue. The hypothesis examined in this latter instance was that a certain position of the tongue may be used to facilitate the thrusting motion and thus be typical of these individuals.

Methods

Two groups of ten-year old children were selected for the present study from fourth grade classes in the elementary schools of the Oswego School District in Oregon. The swallowing patterns of these children were evaluated by each of the three investigators working independently. The children were placed in one of the three categories: (1) a tongue-thrust pattern wherein the tongue was consistently thrust forward or laterally during the swallowing act, (2) a non-tongue-thrust pattern wherein the swallowing activity was consistently in the pattern traditionally considered to be "normal," and (3) a mixed pattern wherein the subject did not seem to have stabilized his swallow in either of the above patterns or was inconsistent from one swallowing performance to the next. Those subjects placed in category (1) or (2) by each of the three examiners were tentatively selected for further observation. Factors such as scheduling, parent cooperation, etc. were then considered. The final sampling of subjects used in formal data collection was twenty-six children within each of the two groups.

Tongue Posture

To evaluate static posture of the tongue in relation to the hard palate, lateral cephalometric radiographs were taken with the subjects in the standing position. The cephalometer was adjusted to the subject's natural standing position. An attempt was made to distract them from the radiographic procedures by placing a full length mirror in front of them and requesting that they maintain eye contact with their image. Radiographs were taken when the subject seemed to the operator to be in an acquiescent state. After the first film was taken, the subject was removed from the apparatus, asked to relax for a while, replaced in the cephalometer and the procedure repeated. Only the subjects who presented a similar tongue position in the two radiographs were used in the cephalometric data analysis. Five subjects were elimin-

ated from each group for this reason. The distance of the high point of the tongue from the palatal plane in millimeters was used to measure tongue height in the lateral head radiograph.

Values for tongue height for Trial No. 1 and Trial No. 2 were averaged. A mean value for tongue height in millimeters for the subjects using the non-tongue-thrust swallowing pattern (NTT) was 5.42. The mean value for the subjects using the tongue-thrust pattern (TT) was 5.99. The range of NTT was 1.5 to 13.5. The range of TT was 2.0 to 15.0. A *"t"* test of the findings from the two trials of the NTT subjects indicated that the intratest differences were not significant. The variation among the data of the TT sample was less than that of the NTT sample; therefore, a similar conclusion with regard to homogeneity is warranted for them.

The basic hypothesis tested with regard to static tongue posture was that the mean for the NTT sample was different than the mean for the TT sample. The *"t"* test derived from this hypothesis showed no significant difference between the two samples. The data indicate that the tongue thrust pattern of deglutition does not precipitate a unique postural relationship between the tongue and hard palate.

Repetitive Movements of Oral Structures

To permit estimates of coordination in placement of the speech articulators and in performance of maneuvers varying in complexity, the maximum rate of production of repetitive production of the following nine vocalized and two nonvocalized activities were tape recorded and analyzed: pʌ, tʌ, kʌ, fʌ, lʌ, pʌtə, pʌkə, tʌkə, pʌtəkə, "teeth click," and "lip bounce."

The consonants included within the activities were selected to represent different schedules of developmental mastery and to tap different patterns of muscle movement within and among the participating structures. Thus, the /p/ is normally mastered in all positions within a word by age three, the /t/ and /k/ by age four, the /f/ by age five, and the /l/ by age six and one-half. Also, the "pʌ" demands bilabial coordination, the "tʌ" and "fʌ" different types of anterior lingual coordination and the "kʌ" posterior lingual coordination. The "pʌtə" depends upon lip-anterior lingual synchronization; whereas the "pʌkə" necessitates lip-posterior lingual synchronization and the "tʌkə" fine coordination within the tongue. The "lip bounce" reflects the ability to move one structure, the lips, while a contiguous structure, the mandible, is stabilized. Hence, this maneuver requires a fairly mature level of neurological integration. Each activity, therefore, contributes additional meaningful information concerning the possible effects of physical impairment of the mobile structures.

During data collection, two short, approximately three second, unrecorded practices were given each child after the sound had been demonstrated. A third response was then requested and recorded on a tape recorder. The sounds were presented in a random order which varied for each subject. The required number of repetitions for each sound was dependent upon the number of sounds included in the activity. Thus, the number of repetitions in a single sound combination, such as "pʌ," was twenty; in double combination, such as "pʌtə," was fifteen repetitions; and the triple combination "pʌtəkə," was ten repetitions Twenty repetitions were also required of the two nonvocalized combinations.

The tape recordings were fed through an electrophonocardiograph machine from which a printed record was ob-

tained. The rates of response for each subject and each activity were then obtained by direct count from the printed records.

Comparisons between the two groups were made by means of the following "*t*" tests:

TABLE I

Test	*Mean*	*Difference*	*t*	*Significance level*
pʌ				
TT	3.93	.29	2.64	.01
NTT	3.64			
tʌ				
TT	3.86	.25	1.67	NS*
NTT	3.61			
kʌ				
TT	4.16	.03	.02	NS
NTT	4.13			
fʌ				
TT	4.13	.08	.04	NS
NTT	4.05			
lʌ				
TT	4.16	.17	1.13	NS
NTT	3.99			
pʌtə				
TT	5.22	−.10	−.29	NS
NTT	5.32			
pʌkə				
TT	6.43	−.37	−.90	NS
NTT	6.77			
tʌkə				
TT	6.33	−.32	−.74	NS
NTT	6.65			
pʌtəkə				
TT	7.37	.41	.82	NS
NTT	6.96			
lip bounce				
TT	5.03	.30	1.58	NS*
NTT	4.73			
teeth click				
TT	4.33	.13	.76	NS
N = 26				

* Approaching significance

Examination of the above table reveals that in only one instance, repetition of the "pʌ," was a significant difference obtained between two groups. In two other instances, repetition of the "tʌ" and "lip bounce," the difference approached significance.

Discussion

The data above show that the mean value for tongue height of normals during "rest" was not significantly different from the mean value for tongue height of tongue thrust swallowers during "rest". It is generally agreed from both clinical observations and from cinefluorographic studies that tongue thrust swallowers carry their tongues lower during the act of swallowing. It has been assumed that tongue thrust swallowers also carry their tongues low during periods of oral inactivity. The results of this study indicate that this apparently is not so. The range in both samples was large which indicates there may be many interrelated variables involved in the postural adaptations of the individual.

The data do not support a contention that the tongue thrust swallow is accompanied by general oral uncoordination. As a matter of fact, coordination within the tongue, as reflected by "tʌkə", was found to be slightly faster among the group of subjects with tongue thrust swallow, although the difference did not approach significance. The conclusion is that the children with a tongue thrust pattern of oral activity are, in general, no different than children whose oral activity is characteristic of the so-called "normal pattern."

It is interesting to note, however, that the repetitive acts which apparently did discriminate between the two groups were those in which the activities were centered in the peripheral portions of the oral mechanism. Thus the repetition of "pʌ" and lip bounce reflects integration of labial movements while "tʌ" reflects that of anterior lingual movements. In each instance, the differences in rate of repetition favored those subjects who did not use a tongue thrust pattern of swallowing.

These findings could be interpreted exclusively from an anatomical standpoint. Protrusion of the incisors was

present in the tongue thrust sample. This would necessitate a larger excursion of the lips and thus may reduce the rate of repetition for activities dependent upon labial contact.

An alternate and physiological interpretation could be advanced on the basis of studies by Gesell and others[21] at the Yale Child Development Clinic regarding general somatic principles of maturation. They have pointed out that in the process of maturation of any performing organ the center or "nidus" of maximal performance migrates to one margin of the acting organ. For example, Halverson[25] found that the young infant depends entirely upon the palm and massed fingers for gripping. In older infants the thumb and forefingers form the principal support in grasping and holding. Thus he found a "gradual emancipation of the digits from the hand of which no member at birth has specialized functions." Similar findings are reported by Castner.[16]

Gesell and his co-workers[21] have also pointed out that an increased potentiality for rapidity and temporal variety of motions becomes available in the more discretely performing area. Again in analogy to the hand, Gesell notes that "the early approach reveals a crudely functioning hand at the end of a poorly functioning arm while the later approach reveals a well-coordinated arm under the directing influence of a fairly well-developed prehensile organ." Hence, a maturation lag might be expected to be most evident in precise functions involving the peripheral portion of a performing organ. In the present circumstance this would suggest that the most mature functions of lingual coordination would reside in tongue tip activities. The lips may be viewed as the most peripheral portion of the speech mechanism and, if so viewed, would be expected to relate to maturational patterns of anterior lingual control. From this interpretation tongue thrust would be viewed as an immaturity of the anterior or peripheral structures involved in deglutition and speaking, and would be consistent with the earlier speculations of Gwynne-Evans[22] and the later findings of Fletcher et al.,[20] Anderson,[2] and Bell and Hale.[10] It is to be emphasized, however, that since the sample for the present study was small, these interpretations must be considered as no more than tentative and much additional work would be required to validate this hypothesis.

Clinical Applications

It is apparent from the review of the literature as well as from the data presented in this study that some present treatment programs for the tongue thrust swallowing may be based on fallacious concepts. We have compiled a list of specific suggestions for the improvement of tongue thrust treatment programs which we have listed below:

1. Consider the influences of maturation.
2. Recognize the existence of primary and secondary tongue thrust swallowing patterns.
3. Revaluate the use of sucking exercises.
4. Use speech sounds only as postural guides.
5. Recognize the importance of bolus control with a normal peripheral seal.

Influences of Maturation

The authors feel that the ideal treatment time for the correction of the tongue thrust swallowing pattern is not necessarily as soon as it is convenient, or as soon as it is discovered; but rather, depends on a number of interrelated factors. The consideration of maturation is important. We have mentioned that the English have stressed the relation of

tongue thrust swallowing to maturation. The work in America of Fletcher et al., Anderson, and Bell and Hale support this contention that tongue thrust swallowing patterns may be modified as the indivdual matures. We believe that an eight-year-old child with a tongue thrust swallowing pattern may or may not retain this tongue thrust swallowing pattern at the age of twelve. If these maturational modifications do exist, then certainly the clinician should consider delaying treatment to determine the effect of maturation upon the individual. Such factors as severity of malocclusion and associated speech impairment might of course dictate earlier treatment.

Primary and Secondary Tongue Thrust Patterns

Recently Subtelny and Subtelny[50] have urged the orthodontic profession to differentiate between adaptive patterns secondary to the malocclusion and the primary tongue thrust patterns responsible for causing and perpetuating malocclusions. Moore[35] has suggested that orthodontists consider the existence of a "passive" tongue thrust pattern in which the tongue passively adapts to the existing malocclusion. We have discussed the interest of the English in adaptive tongue thrust patterns. The differentiation between these two patterns is important clinically because the adaptive tongue thrust pattern may often adjust with no retraining when the malocclusion is reduced. The authors feel that there are many advantages to beginning tongue thrust training only when the tongue begins to interfere with orthodontic treatment.

Sucking Exercises

The clinician who considers the tongue thrust swallowing pattern from a treatment standpoint is faced with the task of recognizing the normal from the deviant, a task frequently made unnecessarily confusing and burdensome because of failure to recognize that the literature reflects four different theoretical orientations as delineated earlier in this paper.

One of these formulations, Barclay's Theory of Negative Pressure, has been effectively refuted. In normal swallowing there is no evidence of a sucking action. We feel that treatment programs which incorporate sucking exercises should be reconsidered.

Tongue thrust swallowers often do blow air through tense lips. This is said to indicate an abnormal positive pressure derived from a reversal of the swallowing pattern. We would like to present an alternative concept more consistent with accepted theory. In tongue thrust swallowers the anterior seal normally provided by the tongue to the alveolar mucosa is not present. Instead, the anterior seal is provided by the tongue thrust forward to make a contact with the teeth and labial mucosa. It is possible that a strong anterior movement of the tongue during the initial stage of the tongue thrust swallow does indeed create a positive pressure gradient in the anterior segment of the oral cavity. This would be directly analogous to the positive pharyngeal pressure created by the posterior motion of the tongue during the early phase of the pharyngeal stage of swallowing. As swallowing is initiated, this anterior oral pressure gradient may overcome the labial seal causing the blowing of air through the lips. Hence, positive pressure at the labial orifice would reflect a crudeness in tongue activity rather than a "reversal" of the normal pattern.

Use of Speech Sounds

According to the data presented in this discussion tongue thrust swallowers do not seem to exhibit deficiencies in oral coordination. If this is true, the routine use of time-consuming repeti-

tive speech sound therapy to build diadochokinetic abilities is unnecessary.

An exception to this has been stressed by Tulley. Tulley feels that perhaps three per cent of the tongue thrust population might be suffering from central nervous system disfunction. He calls tongue thrust patterns associated with central nervous system disorders "endogenous tongue thrust patterns" after Ballard. In rare cases the orthodontist might possibly be dealing with subclinical cerebral palsy. It seems reasonable that borderline central nervous system disorders might be detected in the function of specialized peripheral structures such as the oral and perioral musculature. If there is an association between central nervous system disorders and tongue thrust swallowing, our data indicate it does exist only in a small percent of the population. Coordination exercises may be necessary in the treatment of the few cases of tongue thrust associated with central nervous system disorders, but the use of repetitive speech sounds in the treatment of typical tongue thrust swallowers serves no purpose.

Use of Bolus Control

Tongue thrust swallowers seem to be gulping swallowers. They are not able to control the bolus size. The bolus appears to tumble down the throat with the aid of gravity with but little assistance from the tongue. The normal swallower may gulp a large liquid bolus by tipping his head back and substituting gravity for the action of the tongue, but he is able, if he wishes, to form and control a small bolus using the tongue to initiate the swallowing act. The bolus is formed in a spoon-like depression on the dorsum of the tongue and sealed against the roof of the mouth in a characteristic position of preparation until the decision is made to swallow. The abnormal swallower cannot form this seal or hold this bolus in the characteristic preparatory position. Teaching the tongue thrust swallower to form and control a small bolus in the manner described above is essential to the correction of the tongue thrust swallowing. Until the tongue thrust swallower can seal a bolus against the roof of the mouth until he wishes to swallow, he will remain a gulping swallower.

Current treatment plans stress the importance of the anterior portion of the peripheral seal. This is the familiar "tongue tip in the roof of the mouth." But treatment cannot be successful until the patient somehow learns to form a complete peripheral seal posteriorly and laterally as well as anteriorly. It is the posterior portion of the seal which prevents the bolus from falling into the pharynx. This portion of the seal is formed by the dorsum of the tongue arching superiorly against the depressed soft palate and the posterior pillars which are contracted toward the midline. We have called this posterior seal the palatolingual valve.

Barrett has stressed the importance of the posterior part of the tongue. He includes an open mouth phase of treatment using speech sounds such as /k/ and /g/ as positional guides to teach a central image of a closed palatolingual valve. The authors find that the correct central image of the entire peripheral seal may be imparted with the use of the continuous phonation of the speech sound /n/.

Treatment Program

The authors would like to describe the basic essentials of their treatment program. Some of our techniques are borrowed from Straub and Barrett. We also feel indebted to the Truesdells who urged the tongue thrust swallowers to "clinch the teeth and swallow, letting nature work out the details."

In any treatment program the im-

portance of a firm occlusion should be stressed. Complex physiological performances are dependent upon postural stabilization to serve as a platform underlying integrated activities of the mobile organs. In the oral cavity this stabilization during the normal swallow is typically provided by firm occlusion of the teeth, thus releasing the tongue for precise manipulation of the bolus. During the tongue thrust swallow, postural stability is apparently achieved by thrusting the tongue firmly against the teeth as the food is expelled from the oral cavity.

In the following treatment program we use speech sounds only as positional guides. We do not use repetitive speech sound exercises. For convenience we have broken our treatment program into several steps, as follows:

Step I.
The patient is instructed to open his mouth and to cup the tongue so that a small amount of water may be dropped and held on the dorsum of the tongue. This is reasonably difficult for some tongue thrust swallowers.

Step II.
The patient is asked to raise the cupped water to the roof of the mouth, clenching the teeth tightly together. To test if the water is enclosed in the peripheral seal, the patient is asked to tip the head forward and then backwards and then to open the mouth demonstrating the presence of the water on the dorsum of the tongue. When this exercise is first begun it is interesting to notice that most tongue thrust swallowers will at first swallow the bolus when they tip their head back. This is due to an open palatolingual valve. If the patient does have difficulty maintaining the peripheral seal, he is asked to phonate continuously the speech sound /n/ as he raises the water to the roof of the mouth.

Step III.
When the patient can control a fluid bolus in the peripheral seal in preparation for swallowing, he is asked to swallow this bolus with the teeth clenched tightly together. If the preparation for swallowing position is correct, then Step III should be reasonably easy.

Step IV.
The patient is asked to masticate and form a small bolus of peanut butter on the dorsum of the tongue. The patient is asked to raise the bolus to the roof of the mouth forming a peripheral seal as he did with water. In some patients the seal tends to break down at first with a solid bolus and the peanut butter sticks to the roof of the mouth. After a period of practice a patient should be able to swallow an entire peanut butter bolus.

Step V.
When the patient has mastered an isolated swallow with a peanut butter bolus, he is asked to place a mirror by his plate at mealtime for a month or so to encourage the development of peripheral seal swallowing as an automatic reflex.

We find that when a tongue thrust treatment program is stripped of many nonessential activities, the correction of tongue thrust swallowing patterns is reasonably simple and not particularly time-consuming.

Summary

In an attempt to formulate a workable and efficient program for the treatment of tongue thrust swallowing, the authors have reviewed the concepts and literature of both normal and abnormal deglutition. Tests of tongue position and repetitive abilities of normal patients and patients with tongue thrust swallowing patterns were compared. No significant difference was found between the two groups in either tongue carriage or repetitive ability. The authors have suggested several hypotheses for consideration and have tried to show how these ideas may be used to simplify tongue thrust treatment programs. The authors have described their own basic plan of treatment which incorporates these concepts.

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