A Cinefluorographic Study Of Tongue Patterns In Function

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The relationship of tongue function and tooth position has been of considerable concern for many years. Angle[1] noted this when he wrote, "We are just beginning to realize how common and varied are the vicious habits of the lip and tongue, how powerful and persistent they are in causing and maintaining malocclusion, how difficult they are to overcome." More recently Brodie[7] has stated, "The teeth and alveolar processes should be looked upon as passive though responsive victims of a continuous interplay of muscular forces, their positions dictated by the resultants of these forces." Gwynne-Evans[15] has referred to the fact that the general alignment of the teeth and the form of the dental arches can be greatly influenced by the forces exerted by the perioral musculature and the tongue during swallowing, facial expression, and speech.

Interest has been aroused by the practicing orthodontist during the past decade concerning the influence of abnormal swallowing habits upon the developing dentition. Publications by Ballard,[4] Rix,[26,27] Rogers,[28] Straub,[34,35] and others have contributed to the knowledge on this subject. Further inquiry, utilizing electromyographic methods, into the frequency,[18] duration,[11] and force[14,39,40] exerted by the tongue in the oral stage of deglutition has contributed more to the knowledge of this function. Doubt persists, however, concerning the normal pattern of the tongue and occlusal relationships during the oral stage of deglutition. Physiology textbooks indicate varying opinions, and separate investigations[17,20] have been inconclusive or have contained too many variables for complete accuracy.

If it is true that abnormal swallowing habits play an important role in the development of these factors, then any abnormal use or function of the perioral and lingual musculature, such as in speech, also would be an important etiologic factor in the development of a malocclusion.

In 1813 Magendie[22] described the act of swallowing and divided it into three stages. Although others have disagreed as to the function of the epiglottis, his description remains essentially accurate with the first or oral stage being the only voluntary portion. Several investigators[3,20,30] utilized the cinefluorographic technique to describe the process of deglutition. Evidence concerning the frequency of teeth-together and teeth-apart swallows is not well documented and simultaneous lip movement during deglutition is rather vague. Tulley[37] attributes this to the difficulty in obtaining a true lateral view of a subject without a headpositioner.

The cause and effect relationships between speech defects and malocclu-

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sion have been debated for many years. Although this has been pointed out by Angle,[1] Green,[13] Strang,[32] Wray,[41] and others, there does not appear to be any absolute correlation between defective speech and malocclusion from the subjective point of view. Objective studies with reasonably large sampling have been presented by Fymbo,[12] Fairbanks and Litner,[10] Bernstein,[5] Blythe,[6] and Rathbone and Snidecor,[25] but the general disagreement still persists. There appears to be some relationship between abnormal swallowing, tongue thrusting, and speech defects. According to Tulley[36] many cases that have a vigorous thrusting behavior also have interdental sigmatism. Although the speech therapist may overcome the lisp, the basic pattern of tongue behavior is usually not changed and this is a poor diagnostic sign in cases where an attempt is being made to treat an open bite. Winders,[38,39] and Hopkins and McEwen[16] have investigated lingual and buccal musculature pressures and agree that there is considerable tongue pressure both in swallowing and in the production of certain sounds. The general opinion of most investigators is that, while some patients with malocclusion have speech defects, other patients with severe malocclusion may have perfectly normal articulatory speech. Also, individuals have been observed who have normal occlusion and defective speech. It would appear that the tongue is the most important organ in compensating for oral deficiencies and it can take up the function of the other abnormal parts of the mouth. At the same time, the inconsistency of this compensation in the presence of malocclusion is not clear. Some investigators believe that intelligence, emotional state, and social conditions play an important role in determining whether a patient with a malocclusion can compensate automatically for his mechanical oral disability.

Before the effect of abnormal function in speech or deglutition can be determined, or before the degree of aberrancy necessary to produce an abnormal relationship of teeth and associated structures can be determined, a definitive knowledge of the normal function is necessary. The basis of this study is the hypothesis that children with *normal* occlusion, acceptable speech, normal skeletal morphology, no history of oral habits, and good medical histories will possess normal tongue function during speech and deglutition.

The objectives of this study were:

1. To observe in the oriented subject the oral stage of deglutition.
2. To attempt to establish a base line for tongue function during the production of certain sounds.

Since the development of the electronic image intensification tubes,[8] cinefluorography has become an important and practical procedure in many fields of research. Its capacity to capture rapid movements on film, yet maintain clarity of stationary structures, renders it a suitable instrument for the study of speech and deglutition in function. *Recent* investigators[3,19,20,23,24,30,31,37] have demonstrated its proficiency for this purpose. Cinefluorography with image intensification was used in the present investigation to explore the swallowing patterns and occlusal relationships during deglutition, and the tongue positions in the production of certain sounds. Orientation of the head by means of a headpositioner made serial comparisons possible.

The dentitions of 250 school children from the 6th, 7th, and 8th grades were evaluated clinically. From this group 40 were selected who possessed excellent occlusions. The final selection of 30 children was based on parental approval and the willingness of the children to participate in this investigation. Cinefluorographic films with simultaneous sound tracks were obtained on this group of 30 children. Additional records, including past and present medical history, tape recordings of specified sentences, and lateral cephalometric headplates were obtained for each child for further analytical evaluation.

The case history included information on infant feeding methods, childhood diseases, habits, and present medical status. It was deemed necessary to eliminate one child from this investigation as speech therapy had been instituted at an early age. No other findings in the histories precluded acceptance of the remaining children.

The tape recordings of the remaining individuals were evaluated by the speech departments of two universities. Attention was directed toward the assessment of correct articulation, and a "normal" classification was received for 27 of the children. The remaining two subjects had various articulatory disorders; therefore, they were considered unsatisfactory as further subjects in this investigation.

Skeletal and denture morphology were evaluated from the lateral cephalometric headplates. This procedure was considered necessary in order to maintain the most harmonious relationship possible in the sample. Although the entire group of children had excellent occlusions clinically, an additional reduction of the sample was necessary. Four of the children had unacceptable skeletal patterns in relation to the accepted ranges of variation.[9]

Because of a defective cinefluorographic film, one other child had to be eliminated. This left 22 Caucasian subjects characterized by clinically excellent occlusion, acceptable skeletal and denture morphology, normal speech function, and no past or present history that would be incompatible with or affect the aforementioned factors. The

Fig. 1 Cinefluorographic unit: a. rotating anode x-ray tube, b. Videx cone adaptor, c. image intensifier, d. binocular mirror system, e. auricon camera, f. headpositioner.

mean age of the eleven boys and eleven girls of the study series was 12.4 years.

Standard cinefluorographic equipment (Fig. 1) at St. Christopher's Hospital for Children was used and was supervised by John A. Kirkpatrick, Jr., M.D. The Dynamax "50" grid-controlled rotating anode with a .5 mm fine focal spot allowed only 1/500 of a second exposure per frame of film. The 9 inch Keleket Image Intensifier afforded 3000x amplification producing a bright, clear, and sharp diagnostic image with minimal radiation exposure. The films were made by a Deluxe Auricon 16 mm cine camera motor driven at a synchronized speed of 30 frames per second. An optical sound track recorded the speech of each subject as the subject read from a prompting card prepared by the Department of Speech and Hearing, Temple University. It was read by the subject while being exposed from the lateral view. Following this, the subject was rotated in the headpositioner and exposed in the anteroposterior view while reading the last half of the prompting card. Each child was exposed to approximately 90 feet of film which amounted to 1.8 r as measured in air. This is well under the accepted range for conventional fluoroscopy[21,29] and compares quite favorably to the amount of radiation received during a complete oral roentgenographic examination.

The means of evaluating the films consisted of repeated projection at 30 frames per second, repeated slow motion projection, and frame by frame viewing on a special screen from which master tracings were made. The Bell and Howell Filmosound Specialist projector was equipped with a fire shutter gate which automatically dropped into position during frame by frame viewing. A specially designed and constructed tracing table was utilized so that the magnification of the image could be adjusted by sliding the projector along rails. This was considered necessary to standardize the image and subsequent master tracings to the approximate size of the lateral cephalometric radiogram.

In studying the pattern of tongue function during the process of deglutition only those portions of the films that represented the swallowing mechanism were analyzed. For each subject this included the lateral view of the swallowing of barium and of saliva. In the portion of this study which considered the pattern of the tongue in the function of producing certain sounds, only those parts of the prompting card which contained the sentence "That Tall Tree Sits On The Pretty Street" were used. This sentence was constructed in order that the tongue function during the production of various "T" and "Th" sounds could be studied during normal conversational speech. Since these two sounds are respectively a lingual alveolar plosive and a labial dental fricative, their use was thought to have the most effect on the position of the maxillary and mandibular incisors.

In the portion of this study which pertains to the process of swallowing, the maxillary and mandibular incisors were recorded in centric relation as seen on the lateral cephalometric headplate. This position of the central incisors and the amount of overbite were accurately observed during the frame by frame viewing of the films. If at any time in the course of the oral or pharyngeal stages of the swallowing act the maxillary and mandibular incisors assumed this related position, it was considered to be a teeth-together swallow. Ninety-four master tracings were made representing 382 individually traced frames.

For that portion which pertains to the production of the certain sounds, the hard palate and the positions of the maxillary incisors were traced from the lateral cephalometric radiograms. The projector image was adjusted so that a corresponding image size was projected on the tracing glass. All positions of the tongue that were used in the phonation of the entire test sentence were recorded, but only those used during the production of the "T" and "Th" sounds were evaluated. A total of 154 master tracings were accumulated representing 616 individually traced frames.

Swallowing

During the cinefluorographic filming of the 22 subjects 252 swallows were performed and recorded. Of this total, 45 were barium swallows and 207 were saliva swallows. Six barium swallows (13%) were teeth-together swallows, while 39 barium swallows (87%) were of the teeth-apart type. Ninety-seven saliva swallows (47%) were teeth-together swallows, while 110 saliva swallows (53%) were of the teeth-apart category. During the teeth-together swallows, the patterns of tongue movement for the saliva swallows were essentially the same as the patterns of tongue movement for the barium swallows. Accordingly, the tongue movement was illustrated when swallowing barium, since this movement was more distinct and thus contributed to the accuracy of the illustrations. This same

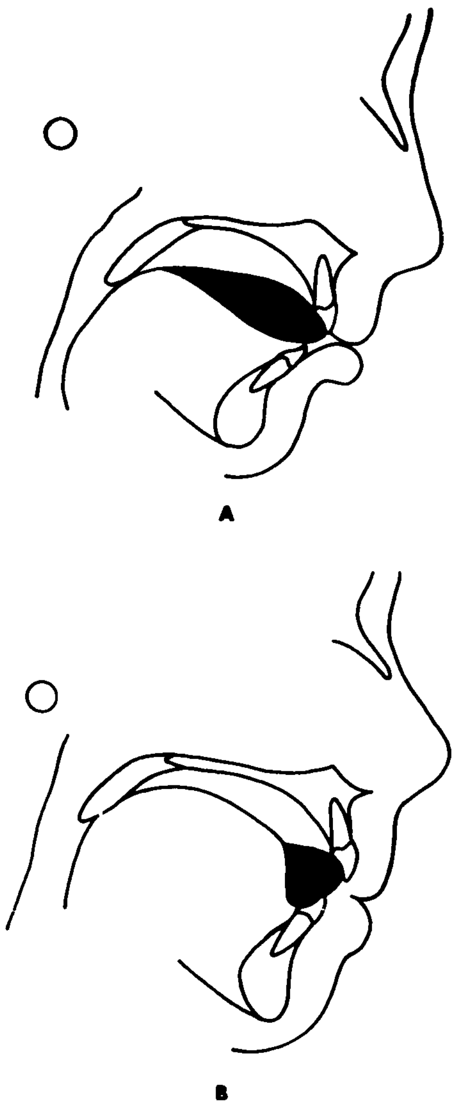

Fig. 2 Collection phase of teeth-together swallow: A. Liquid bolus on the dorsum of the tongue. B. Liquid bolus lingual to the mandibular incisors.

procedure was valid for the patterns of tongue movement during the teeth-apart swallows.

The oral and pharyngeal stages of swallowing were divided into four phases in an effort to combine simplicity and accuracy when depicting the patterns of tongue movement. This method, it was considered, would reflect more accurately the tongue in relation to the positions of the teeth and alveolus, yet remain sufficiently simple for descriptive purposes. During the act of swallowing, the tongue, however, is in constant movement, and at no time do these four phases portray stopped motion. The following is a description of the typical teeth-together swallow during the ingestion of a mixture of barium and water flavored with chocolate:

1. *Collection Phase.* (Fig. 2A) Since the mixture to be swallowed was conducted to the oral cavity through a straw, it usually collected on the midline portion of the anterior part of the dorsum of the tongue. In this phase the posterior portion of the tongue is arched to contact, or nearly contact, the soft palate. At this time the lips are apart and the maxillary and mandibular incisors are not in contact. Another manner of collecting the liquid bolus was observed (Fig. 2B) in which the liquid bolus was situated lingual to the mandibular incisors and anterior to the tip of the tongue. This created a more vertical, convex inclination of the dorsum of the tongue. The tongue tip then "scooped up" the bolus and placed it on the dorsum of the tongue.

2. *Anterior Alveolar Phase.* (Fig. 3A) After the bolus was formed on the tongue, the initial action of the swallowing act began. The tip of the tongue was placed on the anterior alveolar ridge just lingual to the maxillary central incisors. This action lowered the posterior part of the tongue and broke its contact with the soft palate. The bolus then moved more posteriorly on the dorsum of the tongue. Concurrently, the lips closed and the maxillary and mandibular central incisors came closer together. The time for the movement to take place between phases

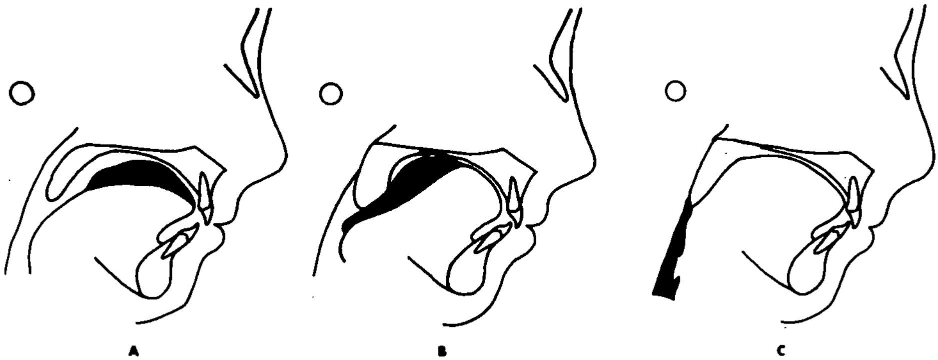

Fig. 3 **A. Anterior alveolar phase of teeth-together swallow. B. Midpalatal phase. C. Posterior compression phase.**

was approximately 1/5 of a second.

3. *Midpalatal Phase.* (Fig. 3B) The anterior one half of the tongue is now pressed against the maxillary alveolar ridge and the anterior one half of the hard palate; simultaneously the teeth are placed together in centric relation. This compression forces the bolus more posteriorly on the dorsum and root of the tongue which now slopes downward from the middle of the palate toward the epiglottis. While this is occurring, the soft palate is elevated, becomes triangular in shape, and contacts the posterior pharyngeal wall. Synchronously, Passavant's pad, produced by a forward movement of the posterior pharyngeal surface, contributes to formation of the seal initiated by elevation of the soft palate. It takes approximately 1/6 of a second to reach this phase.

4. *Posterior Compression Phase.* (Fig. 3C) This phase begins with the strong contraction of the mylohyoid muscle, evidenced by the swift upward and forward movement of the hyoid bone, and ends with the placement of the base of the tongue back against the posterior pharyngeal wall. The bolus is propelled through the entire pharynx and into the esophagus by this contraction and compression in about 1/10 of a second. The posterior pharyngeal wall continues its wave-like movement from above downward. By this constriction it aids in the movement of the bolus through the pharynx. Simultaneously, by the synergistic action of the infra and suprahyoid musculature, the larynx rises and is pulled forward under the root of the tongue, and the epiglottis folds down over the laryngeal opening (Fig. 4). This change of position, plus the adduction of the vocal folds and the arytenoid cartilages,[2,24] protects the laryngeal airway and opens the esophageal orifice. The teeth remained constantly in centric occlusion and no lip movement was discernible up to and including this phase.

The swallow was considered complete when the soft palate returned to its original position. This recovery period varied considerably from one individual to another, but on the average it was approximately ½ of a second. During this recovery period the reinflation of the pharynx could be observed. This occurred primarily from the nasal cavity as the soft palate returned to its original position, and then secondarily from the larynx.

Except for the anterior alveolar phase, the pattern of tongue movement for the teeth-apart swallow was similar

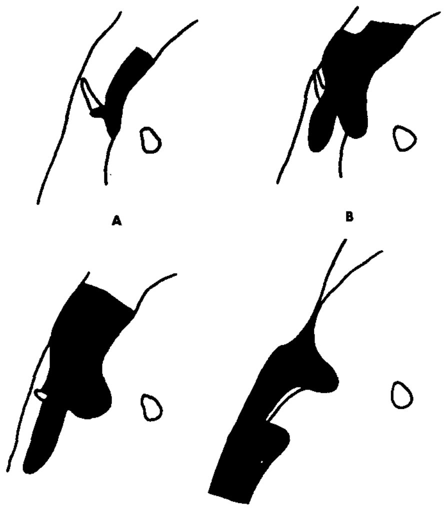

Fig. 4 Action of the epiglottis. Series A to D showing the epiglottis folding backward to cover the larynx as the hyoid bone moves anteriorly.

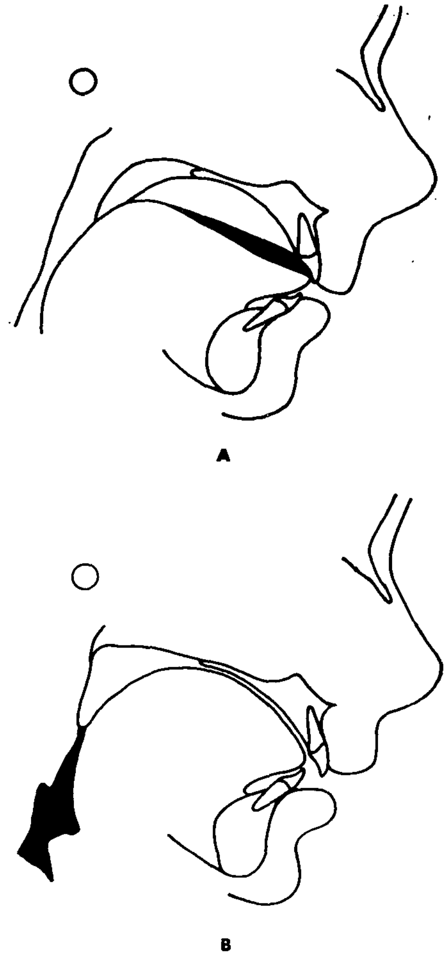

Fig. 5 A. Anterior alveolar phase of the teeth-apart and lips-apart swallow. B. Posterior compression phase.

to the teeth-together swallow. Even the variations of collecting the bolus were identical. In the teeth-apart swallow the tongue tip placement in the anterior alveolar phase was more inferiorly placed on the gingiva of the alveolar ridge; in the majority of the cases, the tongue contacted the lingual surface of the maxillary incisors. The lips were separated or closed, but in either case movement was discernible. If the lips remained apart, a comparison of phase two with phase four shows a perioral muscle contraction occurred with a resultant indention between the vermilion border of the lower lip and the chin (Fig. 5). The upper lip moved superiorly, thereby exposing the maxillary incisors to view. When the lips were placed together, the comparison of these two phases disclosed the same type of perioral muscular contraction. In addition, both lips were slightly protruded (Fig. 6). The typical tongue pattern for the teeth-apart swallow, therefore, has the tongue tip placed more inferiorly during the anterior alveolar phase, after which the tongue proceeds in a similar manner to the teeth-together swallow. Accompanying lip movement, with the lips either separated or together, was one of the distinguishing features of this type of swallow.

Five variations of tongue pattern were observed for the typical teeth-apart swallow seen in these children. Two of these variations had a high degree of constancy within the individuals that exhibited these differences,

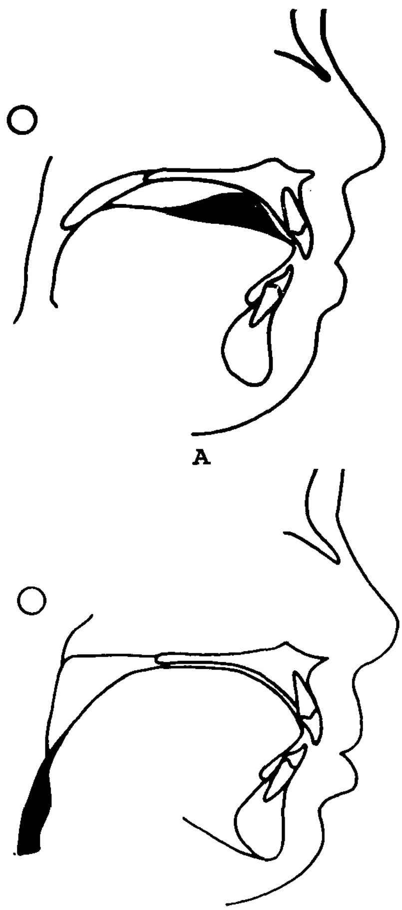

Fig. 6 A. Anterior alveolar phase of the teeth-apart and lips- together swallow. B. Posterior compression phase.

while the other three variations were merely adaptations, either to the type and size of the bolus or to the written command to swallow. One of the variations always apparent in the individual so characterized was a tongue thrust pattern with the lips together (Fig. 7). This subject had a total of 11 swallows, and only two of these swallows were with the teeth together. The bolus was collected on the dorsum of the tongue, but when the tongue reached the anterior alveolar phase, the tip was protruded between the teeth and the lips. It was withdrawn somewhat in the succeeding midpalatal phase, but it completely occupied the space between the maxillary and mandibular incisors. The lips parted for the latter part of the posterior compression phase, and once again the tongue protruded between the maxillary and mandibular incisors. The other variation constantly produced by the subject so distinguished was a "double swallow" pattern. For this the subject followed every teeth-apart swallow immediately with a teeth-together swallow. Both swallows conformed to the conventional pattern for the sample and both were with the lips together.

The projection of the anteroposterior view demonstrated a typical middorsal grooving of the tongue. This grooving varied in degree but was observed in all

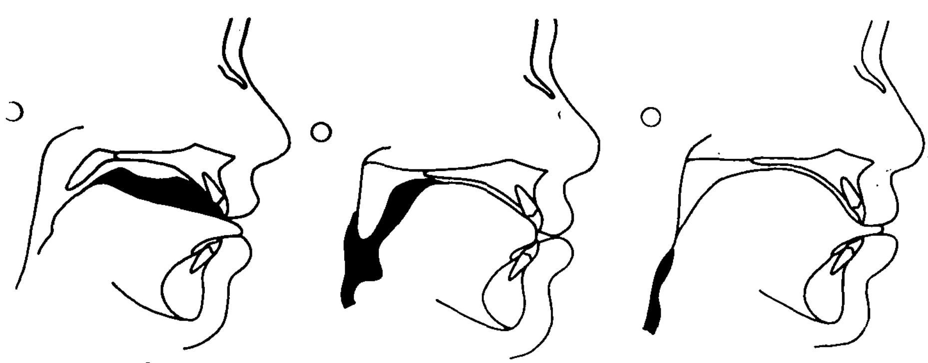

Fig. 7 Tongue thrust pattern with the lips together. A. Anterior alveolar phase B. Midpalatal phase. C. Posterior compression phase.

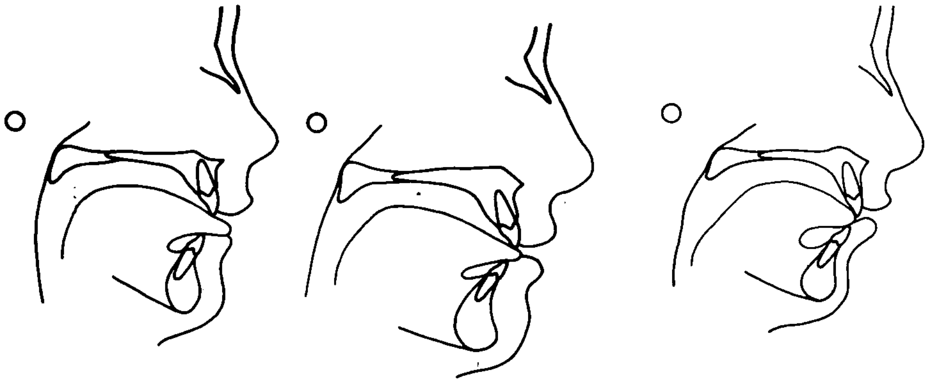

Fig. 8 Variations of tongue position during phonation of the "Th" sound in the word "THAT".

but two of the films. Of these two films, one was underexposed and the other film had too few swallows for an accurate observation. It was impossible to tell, by projection only, whether or not the teeth were in occlusion or precisely at what phase this grooving occurred. By comparing the timing with that of the lateral projection, however, the grooving usually began just after the anterior alveolar phase. The grooving would continue to deepen and then become more shallow as the tongue was raised toward the hard palate. At the start of the posterior compression phase the groove was obliterated as the tongue completely occupied the hard palate. As the groove was being eliminated, the lateral margins of the tongue spread so as to maintain contact with the maxillary posterior teeth. The entire action for the groove to appear and disappear was approximately 1/6 of a second.

Sound Production

Subjective appraisal of the tracings used in this investigation showed a high degree of variation in tongue positions. In the production of the nine "T" and "Th" sounds used in the test sentence there was a variation among the children as well as a variation in the production of each sound within the individual child. There were no sex differences noted which made possible the evaluation of the group as a whole.

The most significant variation in tongue position was found during the phonation of the "Th" sound in the word "That". Three distinct positions of the tongue existed during the phonation of this first sound (Fig. 8). Ten of the children showed extreme protrusion (8-10 mm) of the tongue between the maxillary and mandibular incisors. Five of the sample showed only mild protrusion (3-4 mm) of the tongue. The remaining seven showed no protrusion, the apex of the tongue being positioned against the lingual surfaces of the maxillary and mandibular incisors.

In the phonation of the word "The" a similar variation existed. Only two tongue positions, however, were observed for this second "The" sound. Eight of the cases exhibited a slight protrusion (2-3 mm) of the tongue between the maxillary and mandibular incisors while the remaining fourteen children placed their tongues against the lingual surfaces of the maxillary incisors and just touched the incisal edges of the mandibular incisors. In a comparison of the two "Th" sounds it was noted that only four of the subjects revealed similar tongue positions for both words.

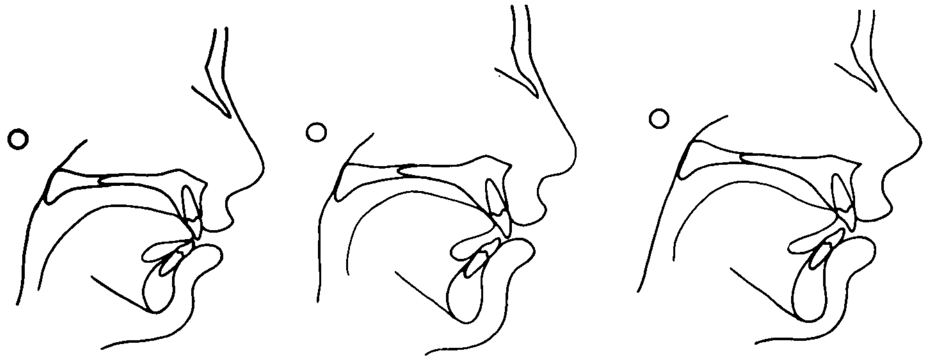

Fig. 9 Variations of tongue position during phonation of the "T" sound in the word "TALL".

For the words "Tall" and "Tree" the tongue was usually placed against a portion of the lingual surfaces of the maxillary incisors and the alveolar process. A variation existed, however, in the amount of contact the tongue made with these two structures (Fig. 9). During the phonation of the "T" sound in the word "Tall", eleven of the children placed the dorsum of the tongue against the upper half of the lingual surfaces of the maxillary incisors. There was slight contact with the lingual alveolar tissue while the apex of the tongue was against the incisal edges of the mandibular incisors. Eight other children held their tongues in a more superior position and made contact with a larger portion of the lingual alveolar tissue but only touched the cingulums of the maxillary incisors. The remaining three children placed only the apex of the tongue at the junction of the lingual surfaces of the maxillary incisors and the alveolar tissue. In these last two categories the tongue did not touch any portion of the mandibular incisors.

During the phonation of the "T" sound in the word "Tree", fourteen children positioned the apex of the tongue at the junction of the lingual alveolar tissue and the maxillary incisors (Fig. 10). The three children having this same tongue position for the word "Tall" were also included in this group. Eight of the children used the dorsum of the tongue instead of the apex in the production of this sound and they were divided into three groups.

1. (Fig. 10 upper right) Five of these children placed their tongues against most of the lingual surfaces of the maxillary incisors while the apex of the

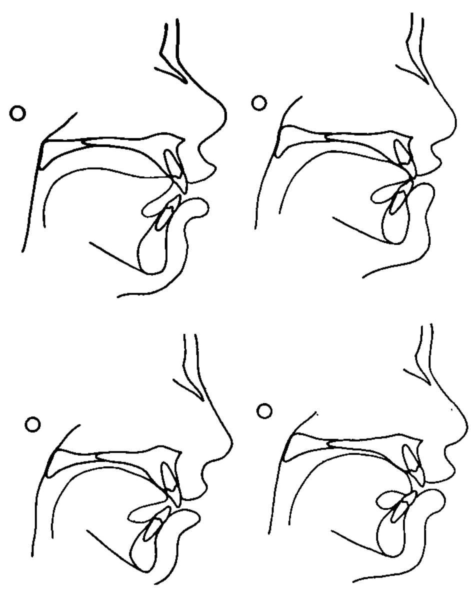

Fig. 10 Variations of tongue position during phonation of the "T" sound in the word "TREE".

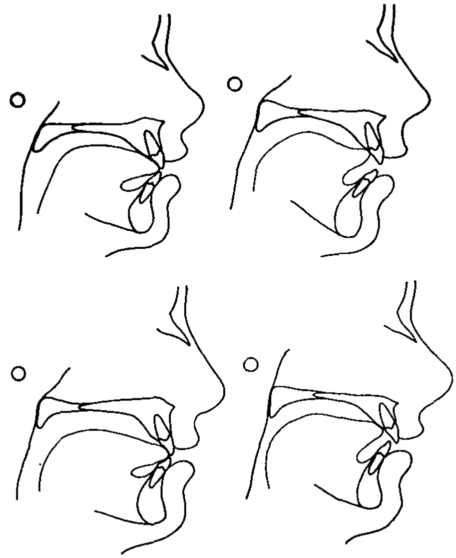

Fig. 11 Variations of tongue position during phonation of the "T" sound in the word "SITS".

tongue touched the mandibular incisors.

2. (Fig. 10 lower left) Two of the children held their tongues close to the palate and contacted more of the lingual alveolar tissue while only the tip of the tongue was against the maxillary incisors.

3. (Fig. 10 lower right) The last child contacted a large portion of the palate with the dorsum of his tongue while the apex was against the lingual surfaces of the mandibular incisors. In a comparison of the two words "Tall" and "Tree", only six children used the same tongue position during the phonation of both "T" sounds.

Four different tongue positions existed for the "T" sound in the word "Sits" (Fig. 11). In eleven of the children the dorsum of the tongue was placed against most of the lingual surfaces of the maxillary incisors and just touched the lingual alveolar tissue. The apex of the tongue rested against the lingual surfaces of the mandibular incisors. Six other children placed the apex of their tongue at the junction of the lingual alveolar tissue and the maxillary incisors. Four contacted just the maxillary and mandibular incisors while in the remaining child the tongue was positioned against the lingual alveolar tissue only.

In a comparison of the "T" sounds in the words "Tall", "Tree", and "Sits", it was noted that only two children utilized the same tongue position during the phonation of all three of these "T" sounds.

The least variation in tongue position existed for the "T" sound in the word "Pretty" (Fig. 12). Eighteen of the twenty-two subjects positioned the apex of the tongue at the junction of the lingual alveolar tissue and the maxillary incisors. This pattern is similar to some of the other patterns already described where only the apex of the tongue was used; however, for this particular "T" sound the posterior half of the tongue was positioned much higher and was almost in contact with the hard palate. The remaining four children made contact with the lingual alveolar tissue with the dorsum of the tongue while the apex was against the lingual surfaces of the mandibular incisors. No contact was made with the maxillary incisors in these four children.

During the phonation of the first "T" sound in the word "Street" (Fig. 13), nine of the subjects positioned the dorsum of the tongue against the lingual alveolar tissue and half of the lingual surfaces of the maxillary incisors. No contact was made with the mandibular incisors. Eight of the children placed the apex of the tongue at the junction of the lingual alveolar tissue and the maxillary incisors. The remaining four children positioned their tongues against the alveolar tissue while no contact was made with either the maxillary or mandibular incisors. Seven of those children using the apex of the tongue exhibited the same tongue position for

Fig. 12 Variations of tongue position during phonation of the "T" sound in the word "PRETTY".

the word "Pretty", although in this sound the tongue was generally flatter and the middorsum of the tongue was lower in relation to the hard palate.

These same three tongue positions were also observed for the final "T" sound in the word "That". Only ten, however, of the twenty-two subjects utilized the same tongue position in both phonations and these ten children were divided among all three different categories as described for the first "T" sound in the word "Street".

Similar tongue positions were also observed for the final "T" sound in the word "Street". When producing this sound, all of the subjects positioned the tongue higher while the middorsum was in close approximation to the hard palate (Fig. 14).

Discussion

If the action of the intestinal musculature which propels the bolus through the alimentary canal is kept in mind, an analogy to the tongue action can be made. Instead of being surrounded by musculature, the food bolus in the oral cavity is bounded above by the hard palate and below by the tongue, making circular constriction impossible. This requires the tongue to secure an anterior position of mechanical advantage at the beginning of the swallow. This prevents the bolus from being displaced anteriorly and allows the tongue to press

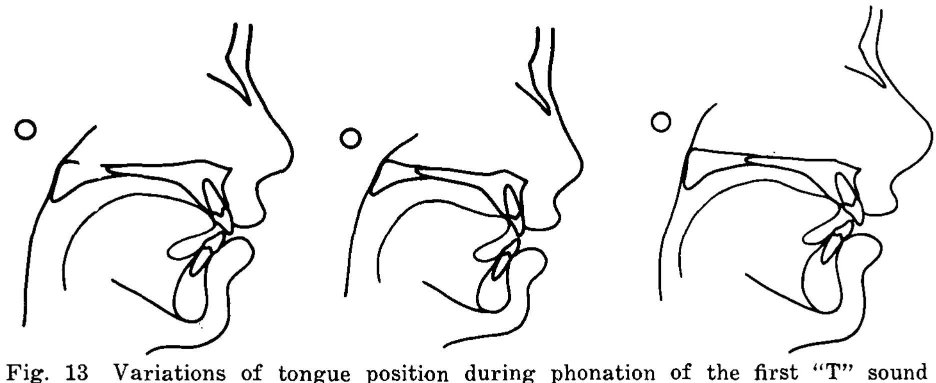

Fig. 13 Variations of tongue position during phonation of the first "T" sound in the word "STREET".

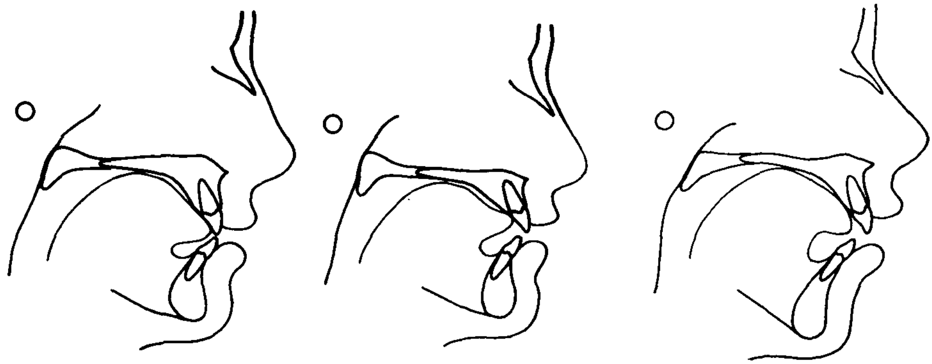

Fig. 14 Variations of tongue position during Phonation of the last "T" sound in the word "STREET".

against the anterior one half of the hard palate, thus eliminating the space which the food bolus occupies. The action of the muscles of mastication, the supra and infrahyoid muscles, and the superior and middle pharyngeal constrictors aid the extrinsic and intrinsic muscles of the tongue in their action to propel the food bolus from the oral cavity through the pharynx. These children with excellent occlusions demonstrated two distinct swallowing patterns, one with teeth-together and one with teeth-apart. The major difference of tongue movement in these two patterns existed in the anterior alveolar phase, the tongue tip being placed more inferiorly on the maxillary incisors when the swallow occurred with the teeth-apart. This can be explained by the fact that in the teeth-together swallow the normal amount of overbite would prevent the tongue tip from touching the lingual surface of the maxillary incisors. Furthermore, the tongue tip, in the collection phase, travels up the lingual slope of the mandibular incisors so that it is directed more to the lingual of the maxillary incisors when the teeth are together than when they are apart.

Accessory perioral musculature movement, with the lips either closed or apart, was observed. Whether or not this movement was excessive or minimal would be a subjective conclusion. Its presence, however, was distinctly recognized and therefore recorded as an integral part of the teeth-apart swallowing pattern. The occurrence of deglutition approximately once a minute[18] emphasizes the importance of the swallowing pattern. The accepted concept of normal swallowing[26,33,34,35,39] is the teeth-together swallow without any movement of the perioral musculature. Strang,[32] in his description of normal swallowing, mentions movement of the perioral musculature as an aid to the swallowing act. Differences of opinions make the standardization of normal difficult. Variation appears to be the theme and there is no question that variation does exist. To state that in the normal swallow the teeth must be together and that there is no movement of the perioral musculature seems unwarranted. Upon viewing the patterns of tongue movement in these children with excellent occlusions, it is suggested that the term "acceptable" be substituted for "normal" as a more practical and a more inclusive designation. To ignore the fact that the majority of swallows were teeth-apart is not possible. The pattern of teeth-apart swallowing must be an acceptable pattern since all other associated factors were considered acceptable.

The presence of tongue thrust pattern in this group was rather startling. Investigations[4,26,28,33,34,35] have shown this type of pattern to be the most undesirable of all and to be one which is conducive to an open-bite condition. Apparently, the amount of tongue pressure exerted, the resistance of the alveolar bone, the degree of separation between maxillary and mandibular incisors, the consistency and amount of the bolus, and the force exerted by perioral musculature are other factors to be considered. It may be possible that a tongue thrust pattern, in order to produce an anterior open bite, must be accompanied by other factors such as muscular tension or emotional stress. This, then, may have a perpetuating influence on the dentition.

The concept of variation was further substantiated in the production of the various sounds. These variations must be considered as acceptable since the subjects were selected on the basis that all other related factors were acceptable. The fact that different tongue positions were utilized by the same child for the various "T" and "Th" sounds used in the test sentence is not surprising as no two sounds are alike. Each of these sounds was preceded or followed by different consonants and vowels. Most authorities are in agreement that the tongue position for any one particular sound will be influenced by the sound that precedes or follows the particular sound in question. The lack of intersubject consistency in tongue position during the phonation of any one of the different sounds was surprising. Many factors that were not originally considered in the selection of the sample could possibly account for some of these variations. The most probable appears to be that of tongue morphology. Currently there are no available standards to evaluate the difference in size, shape, and mobility of the tongue. This may be a definite factor and bears consideration for future investigation. Other factors that could partially account for some of the differences are: variation in body type, slight changes in postural positioning of the subject in the head-positioner, the effort expended by the different subjects in the phonation of the test sentence, slight apprehension of some of the individuals, and the speed at which the sentence was repeated. It was thought that angulation and position of the maxillary and mandibular incisors might have some bearing on the particular tongue position used by some of the subjects. No correlation existed, however, in a subjective comparison of the different categories of tongue positions and the figures obtained from the cephalometric denture analysis. Although various tongue positions were observed for all the sounds used in this investigation, some of the words exhibited fewer variations than others and might prove to be more valid for use in future diagnostic comparisons. These include the "T" sound in the word "Pretty", the "Th" sound in the word "The", and the final "T" in the word "That".

Cinefluorography with image intensification was found to be an excellent method for evaluating tongue function during deglutition and speech. Certain limitations of the procedure, however, should be mentioned. A thorough analysis of the film is quite difficult and time-consuming; therefore, cinefluorographic studies are not practical from a routine clinical standpoint. The danger of excess radiation places further limitations on any long-range cinefluorographic procedures and all precautions must be taken for the protection of the patient and the operator. Although the amount of radiation exposure to the children in this particular study was considered to be well within acceptable limits, long filming procedures or serial studies are not recommended. Some of the variations incorporated in this investigation could be due to the fact that, at thirty frames per second, all the tongue movements were not seen. Therefore, different tongue positions in different individuals could have been observed when, in actuality, similar tongue positions were used by all subjects. In previewing all the films before actual tracings were made this did not seem to be the case. This problem was considered thoroughly before the present investigation commenced and sixty frames per second was thought to be the ideal speed. At this speed, however, there is no available method to record and play back a synchronized sound track. Since the sound track was an integral part of this investigation, the films had to be exposed at thirty frames per second.

This investigation is a beginning of understanding of tongue function during deglutition and speech in cases of normal occlusion. The remaining material obtained on the original films dealing with speech can be utilized in future studies. An understanding of both the swallowing and speech patterns in these normal individuals is essential before it is possible to assess adequately the abnormal. This study has attempted to set up a base line for this understanding and opens up the possibility of continuing similar studies in the fields of malocclusion, speech pathology, and congenital abnormalities.

Broad above Allegheny

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