Malocclusions, Orthodontic Corrections and Orofacial Muscle Adaptation

J. DANIEL SUBTELNY, D.D.S., M.S.

INTRODUCTION

It is generally acknowledged that abnormal patterns of orofacial muscle function, as well as abnormal postures of the tongue and lips, may create orthodontic problems. As of late, however, it has not been as generally conceded that the "so-called" abnormal patterns of orofacial muscle function may actually be an adaptation to an already-existent orthodontic problem. Furthermore, considerable doubt seems to have evolved as to whether changes in the patterns of orofacial muscle function might be anticipated with changes in the contiguous environment incident to orthodontic correction.

Muscle adaptation or the lack of adaptation to orthodontic problems and their correction is a relatively unexplored area: a veritable "no man's land" in treatment, retention, and potential stability or relapse. There are many questions which need to be answered. If there is an abnormal oral or dental environment and a concomitant abnormal pattern of muscle activity, did the muscular structures create the abnormal environment or are the muscular structures adapting to the environment? If the muscular structures are adapting to the contiguous orofacial environment, what is the pattern of function relative to that particular oral environment? Can patterns of muscular activity in the orofacial region be consciously and subconsciously altered by intensive and regimented training procedures? If the environment is altered correctly, subsequent to a proper diagnosis, how and when is there an adaptation of muscle activity? Finally, under what circumstances can an inadequate adaptation be anticipated?

PROCEDURAL MECHANISMS IN STUDYING RELATIONSHIPS OF FORM AND FUNCTION

Obviously answers to the aforementioned questions are contingent on a recognition of environmental differences and their possible influence on patterns of function. What may be a factor within one specific type of "form" may not be a significant factor within another type of "form". It is important to recognize variation in patterns of muscle activity and modifications in function incident to environmental differences. Abnormalities in tongue and lip function during speech and deglutition are reputed to be able to affect arch form and tooth position.[1,2] However, despite claims to this effect, the basic relationship between patterns of orofacial muscle activity and malocclusion is still not clearly understood. Therefore, as part of a large, on-going study concerned with deglutition and adaptive behavior of the tongue and lips, it was decided to evaluate characteristics of swallowing behavior in different types of oral environments.

A study was designed to determine the movement patterns of orofacial structures from cineradiographic records taken on a group of subjects with nor-

From the Department of Orthodontics, Eastman Dental Center, Rochester, New York. Research reported in this study was supported by Grant DE 01837 from the National Institute of Dental Research, National Institute of Health, United States Public Health Service.

Read at the Eighteenth Biennial meeting of the Angle Society, Denver, Colorado, November, 1969.

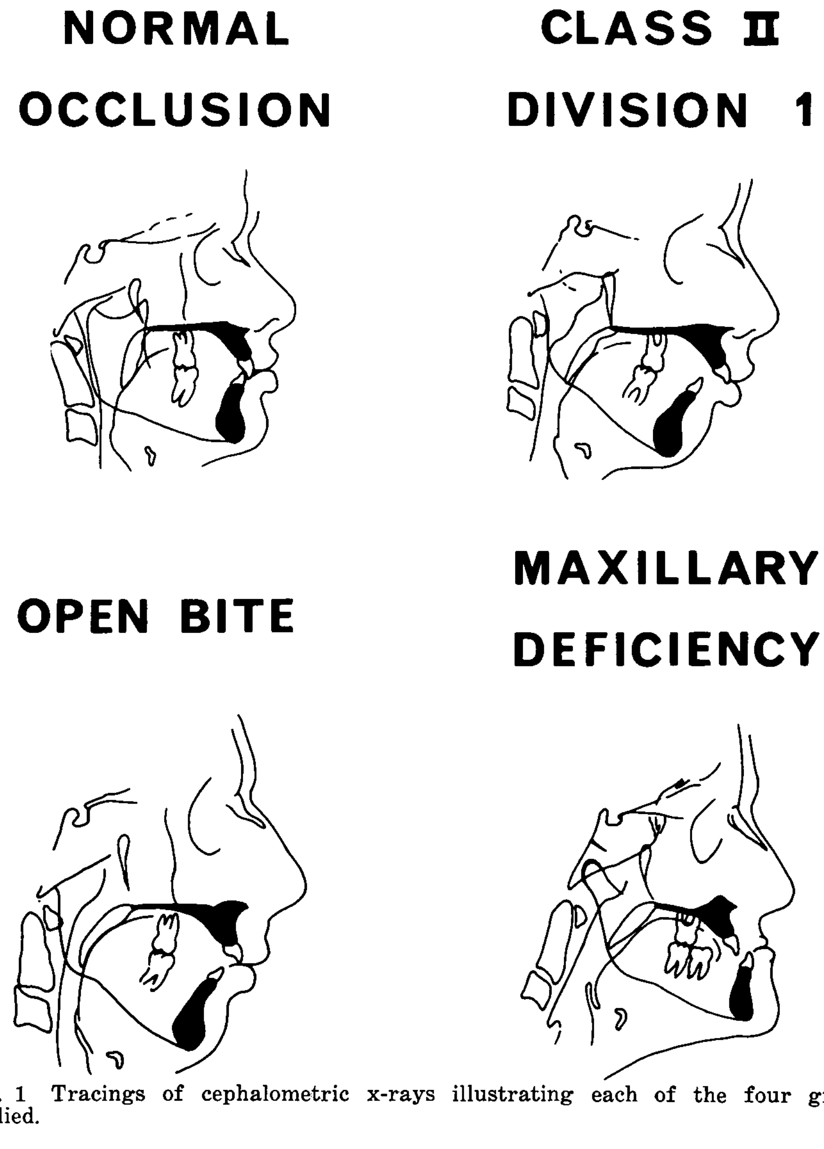

Fig. 1 Tracings of cephalometric x-rays illustrating each of the four groups studied.

mal occlusions and three groups of subjects with basically different types of deviant occlusions. Two groups in the malocclusion category had problems in an anteroposterior or horizontal relationship. These were represented by severe maxillary protrusions with considerable dental overjet and by severe maxillary retrusions with an accompanying lingual positioning of the maxillary anterior dentition. The latter cases were not judged to be mandibular prognathisms, but rather subjects with proportionately reduced maxillary jaw structures; this group included cleft-palate patients as well as cases with marked maxillary deficiency. The third malocclusion group consisted of subjects with problems in vertical relationships as evidenced by cephalometric evaluations and obvious dental open bites. Each of the four groups consisted of ten subjects so that a total of forty subjects was examined and evaluated (Fig. 1).

High speed cineradiographs, recorded at the rate of 240 frames per second, were made for each subject. These records were obtained during several sequences of swallowing and during the production of selected speech sounds within the context of sentence structure. A modified cephalostat was used to orient and stabilize each of the subjects. Subsequent to proper positioning, the ear rods were removed and four adjustable rubber cups were used to maintain head position (Fig. 2). Removal of the ear rods seemed desirable to eliminate any possible interference with the natural movements of the lower jaw. It seems important to state that, since pulses generated by the cine camera were used to drive the x-ray tube at 240 frames per second, the x-ray beam was on for only twenty-four per cent of the time, thus reducing radiation dosage. During an average recording sequence of fifteen seconds, the subjects received approximately 0.67 roentgens of radiation dosage.

The resultant x-ray motion pictures were first analyzed on a preliminary basis using a special movie projector with a frame counter to select frames for measurement purposes and to visually study the swallowing sequence. Cineradiographic frames representing five stages of deglutition were selected. These included: 1) the momentary posture from which the different functional movements related to swallowing are initiated; 2) frames representing progressive elevation of the tongue tip towards palato-dento-alveolar contact; 3) first point of palato-dento-alveolar contact; 4) progression of tongue movement until the tongue dorsum reaches the point of junction of the hard and soft palate; and 5) maximal swallowing effort coincidental with maximum anterior and superior movement of the

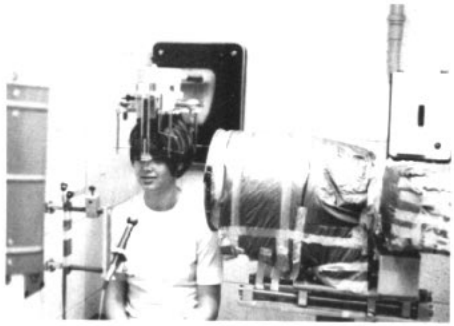

Fig. 2 Subject positioned in the modified cephalostat prior to cineradiographic registration. The intensifying screen and high speed camera are to the right.

body of the hyoid bone. After recording relevant frame numbers, a Benson-Lehner Oscar Model F with decimal converter was used for measurement of selected frames. This instrument permits control of the write-out scale so that all measurements may be recorded directly in the desired units. This was accomplished by presetting the instrument to the correct scale for each subject using an anatomic structure of known dimension, such as a molar tooth, to establish a conversion factor. The distances between selected landmarks (Fig. 3) were automatically recorded on a typewriter and computer cards for analytic purposes. Once the desired data were recorded on computer cards, then information could be retrieved on each subject establishing the relative position of the different anatomical landmarks to each other at varying stages of deglutition. Each group of subjects was then considered as a unit for statistical analysis to compare the four different groups and to establish the similarities and differences to be found in the varying oral environments.[3] For purposes of brevity and clarity, general descriptions of patterns of movement during swallowing, as ascertained by the analysis of the many measurements (Tables I, II), will be presented for each of the four groups.

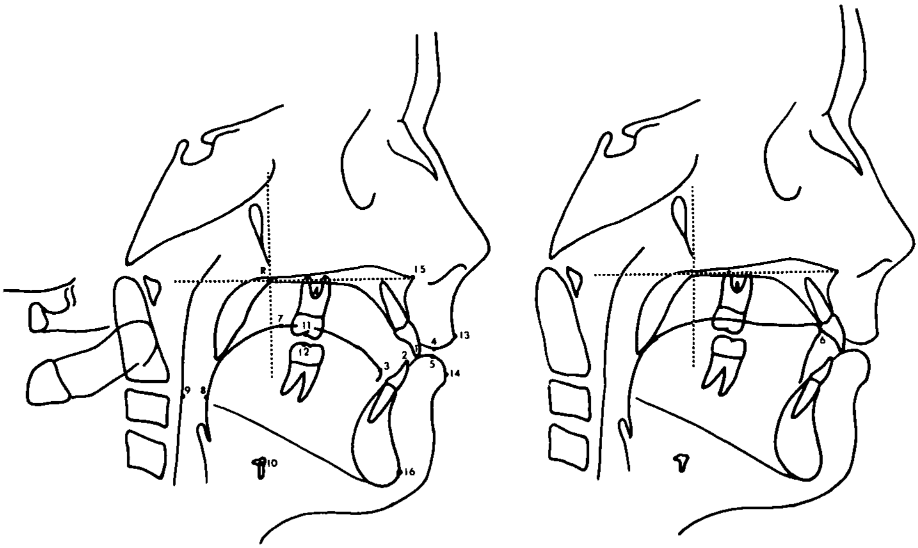

Fig. 3 Tracings of cineradiographs illustrating the selected landmarks used for measurement: 1. Incisal edge of the maxillary left central incisor; 2. Incisal edge of the mandibular left central incisor; 3. Tip of the tongue; 4. Most inferior point of the upper lip; 5. Most superior point of the lower lip; 6. Point of first contact of the tip of tongue with the palate (alveolar portion or lingual surface of upper incisor); 7. Dorsum of the tongue; 8. Root of the tongue; 9. Posterior pharyngeal wall, that point on the posterior pharyngeal wall horizontally opposite to the point selected as the root of the tongue; 10. Hyoid bone. The midpoint in the body of the hyoid bone; 11. Maxillary left first molar. The mesiodistal midpoint on the occlusal surface; 12. Mandibular left first molar. The mediodistal midpoint on the occlusal surface; 13. Most anterior point on the upper lip; 14. Most anterior point on the lower lip; 15. Anterior nasal spine; 16. Pogonion.

Patterns of Function Relative to Form

The attainment of definitive information observing functional swallowing movements at high rates of film speed in subjects with normal occlusions seems desirable; it is here that a baseline can be established for comparative purposes. As visualized on the high-speed cineradiographs, taken on the normal occlusion group (Fig. 4), the tip of the tongue was observed to be positioned slightly lingual to the lower incisors in preparation for swallowing. Subsequently, the tip of the tongue was observed to progress toward the lingual aspect of the maxillary incisors in the region of the cingulum and the closely situated palatal tissue while the mandible and the lower lip were elevating with the lower incisors approaching the maxillary incisors. Shortly thereafter, the upper and lower lips were observed to make contact during the process of tongue tip elevation, but prior to tongue tip contact. In the normal occlusion group, it appeared that at this point an anterior oral seal was established during deglutition. No strain was observable in the region of the lips. After initial tongue tip-dento-alveolar contact, the dorsum of the tongue was observed to touch the roof of the mouth and to progress posteriorly in contact with the hard palate until the area of junction of the hard and soft palates was reached. At this point elevation of the soft palate was initiated; the dorsum of the tongue was observed to touch the oral surface of the soft palate. During this phase of the swallowing procedure, actual contact between the nasal

Table I

Means and standard deviations of the Various Measurements in four stages of Swallowing in Normal Occlusions and Maxillary protrusions.

	Normal Occlusion								Class II, Div. 1							
	Stage 1		Stage 3		Stage 4		Stage 5		Stage 1		Stage 3		Stage 4		Stage 5	
Measure	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
TT-UI	9.05	2.60	4.42	1.07	3.83	1.56	3.69	1.65	15.49	6.19	10.92	3.08	10.58	3.01	10.58	3.29
TT-LI	5.62	1.95	3.53	1.93	1.96	1.22	1.93	1.25	5.59	3.70	3.39	2.68	3.39	2.51	3.53	3.27
TT-AUL	23.52	2.43	16.21	1.96	15.97	1.94	16.04	2.66	25.96	7.02	16.89	3.97	16.53	3.33	16.35	3.60
TT-ALL	19.65	1.59	15.65	1.74	15.00	1.99	14.83	2.86	18.06	5.24	15.38	3.10	14.12	2.34	14.10	2.67
TT-RT	61.36	3.60	69.45	4.35	71.02	3.51	75.89	4.94	57.73	13.07	66.04	14.59	66.27	4.86	69.57	16.29
SLL-UI	4.99	1.01	4.53	1.28	4.70	1.31	4.64	1.33	5.20	2.16	5.63	2.37	5.81	2.72	6.05	3.06
SLL-LI	7.73	1.10	7.54	1.56	7.18	1.25	7.27	1.08	6.68	1.91	7.11	3.01	6.79	2.88	6.96	2.80
IUL-UI	6.06	1.45	4.63	1.39	4.71	1.31	6.64	1.33	6.83	2.46	5.95	2.71	6.03	3.23	6.24	3.10
IUL-SLL	3.95	2.82	0.15	0.41	0.02	0.04	0.00	0.00	11.00	3.20	8.93	4.40	8.42	4.19	8.68	4.37
LAA-UI			4.58	1.36							10.96	3.09				
DT-PP	−8.99	3.25	7.91	3.79					−8.60	2.35	−7.12	2.53				
PW-RT	9.24	1.92	7.49	2.33	5.78	2.83			4.58	2.37	4.33	2.82	3.90	1.95		
UM-LM	3.91	1.71	1.79	1.44	0.83	1.33	0.82	1.13	3.96	2.40	1.82	2.11	1.37	2.04	1.42	1.85

(TT-UI) The tip of the tongue to the incisal edge of the upper central incisor; (TT-LI) The tip of the tongue to the incisal edge of the lower central incisor; (TT-AUL) Tip of the tongue to the most anterior point of the upper lip; (TT-ALL) Tip of the tongue to the most anterior point of the lower lip; (TT-RT) Tip of the tongue to the root of the tongue; (SLL-UI) The most superior point of the lower lip to the incisal edge of the upper central incisor; (SLL-LI) The most superior point of the lower lip to the incisal edge of the lower central incisor; (IUL-UI) The most inferior point of the upper lip to the incisal edge of the upper central incisor; (IUL-SLL) The most inferior point of the upper lip to the most superior point of the lower lip; (LAA-UI) The point of first contact of the tip of the tongue with the upper jaw to the incisal edge of the upper central incisor; (DT-PP) The dorsum of the tongue to the horizontal plane of reference (palatal plane); (PW-RT) The posterior pharyngeal wall to the root of the tongue; (UM-LM) The upper first molar to the lower first molar.

Table II

Means and standard deviations of the Various Measurements in four stages of Swallowing in Maxillary deficiency and Open bite Malocclusions.

	Maxillary Deficiency								Open Bite							
	Stage 1		Stage 3		Stage 4		Stage 5		Stage 1		Stage 3		Stage 4		Stage 5	
Measure	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
TT-UI	7.21	2.07	3.43	3.54	4.20	4.53	4.47	3.82	12.19	3.51	5.75	2.66	5.46	2.29	5.45	3.18
TT-LI	5.74	2.23	7.13	3.71	4.71	3.17	3.93	3.19	4.78	2.54	6.23	3.25	4.94	3.04	5.14	3.46
TT-AUL	21.35	4.17	15.53	3.21	17.62	5.69	15.90	6.50	24.96	3.53	15.24	2.48	15.71	2.00	16.28	3.43
TT-ALL	19.40	4.37	17.00	4.75	16.98	5.58	15.63	5.76	18.76	3.28	14.24	2.34	13.86	2.19	14.25	2.26
TT-RT	54.07	7.94	60.54	8.74	60.12	10.46	62.56	6.32	65.37	7.08	73.59	6.90	73.76	7.25	78.98	8.68
SLL-UI	7.71	1.70	6.67	1.78	7.48	2.13	7.44	2.09	4.86	2.45	2.56	1.15	2.63	1.34	3.25	2.10
SLL-LI	8.36	1.59	8.29	1.67	8.05	2.34	7.88	2.42	7.87	2.03	8.96	2.42	9.14	2.59	9.25	2.61
IUL-UI	7.84	1.52	6.89	1.80	7.52	2.17	7.44	2.09	5.63	2.66	3.64	2.16	3.47	2.35	3.76	2.30
IUL-SLL	3.38	3.18	0.61	1.52	0.38	1.20	0.42	1.27	7.57	5.88	2.78	3.97	1.87	3.57	2.79	5.39
LAA-UI			3.52	3.46							6.49	2.42				
DT-PP	−11.47	2.46	−10.12	3.92					−8.57	3.02	−7.62	4.31				
PW-RT	7.91	2.08	4.98	3.11	4.59	2.47			8.18	1.49	6.66	2.74	5.69	1.67		
UM-LM	3.52	1.76	2.78	1.15	1.63	1.42	1.62	1.59	2.69	2.27	0.75	1.20	0.54	0.92	0.68	1.12

(TT-UI) The tip of the tongue to the incisal edge of the upper central incisor; (TT-LI) The tip of the tongue to the incisal edge of the lower central incisor; (TT-AUL) Tip of the tongue to the most anterior point of the upper lip; (TT-ALL) Tip of the tongue to the most anterior point of the lower lip; (TT-RT) Tip of the tongue to the root of the tongue; (SLL-UI) The most superior point of the lower lip to the incisal edge of the upper central incisor; (SLL-LI) The most superior point of the lower lip to the incisal edge of the lower central incisor; (IUL-UI) The most inferior point of the upper lip to the incisal edge of the upper central incisor; (IUL-SLL) The most inferior point of the upper lip to the most superior point of the lower lip; (LAA-UI) The point of first contact of the tip of the tongue with the upper jaw to the incisal edge of the upper central incisor; (DT-PP) The dorsum of the tongue to the horizontal plane of reference (palatal plane); (PW-RT) The posterior pharyngeal wall to the root of the tongue; (UM-LM) The upper first molar to the lower first molar.

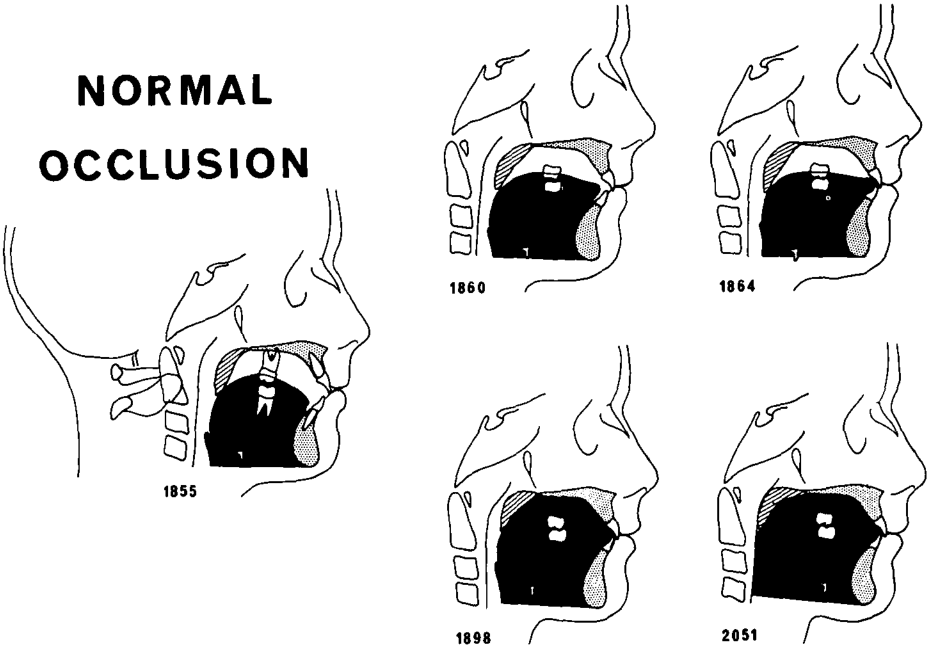

Fig. 4 Tracings of cineradiographic frames of a subject with normal occlusion depicting the five stages of deglutition selected for study. Frame numbers are noted under the tracings.

surface of the soft palate and the posterior pharyngeal wall has not yet been established. Seemingly, it was during this time that the molar teeth did or did not come into occlusion. Only two of the ten normal occlusion subjects were observed to have their molar teeth together during the major portion of deglutition. The remaining eight subjects gave evidence of no molar contact or of contact only during a limited part of the swallowing procedure. During the remainder of the swallowing process, the tip of the tongue was observed to stay in the same approximate area as observed in the first lingual-dento-alveolar contact. The lips established firmer contact and the soft palate was observed to elevate into union with the posterior pharyngeal wall, effectively separating the nasopharynx from the oropharynx. Subsequently, the root of the tongue made firm contact with the posterior pharyngeal wall; this union progressed inferiorly to complete the clearance of saliva and terminate the swallowing process.

Differences were noted in the movement patterns of muscular orofacial structures in the subjects with various types of malocclusions. In the maxillary protrusion group (Fig. 5) as in the normal occlusion group, preparatory to swallowing, the tip of the tongue was postured lingual to the lower incisors. However, in most instances the lower lip was concomitantly observed to be positioned behind the maxillary incisors and in minimal contact with these teeth. Interestingly, the Class II, Division 1 group presented the smallest mean distance between the root of the tongue and the posterior pharyngeal wall prior to the initiation of swallowing. The fact that several cases exhibited retrognathic lower jaws possibly caused the tongue to be postured in a retruded position while occupying a smaller mandibular

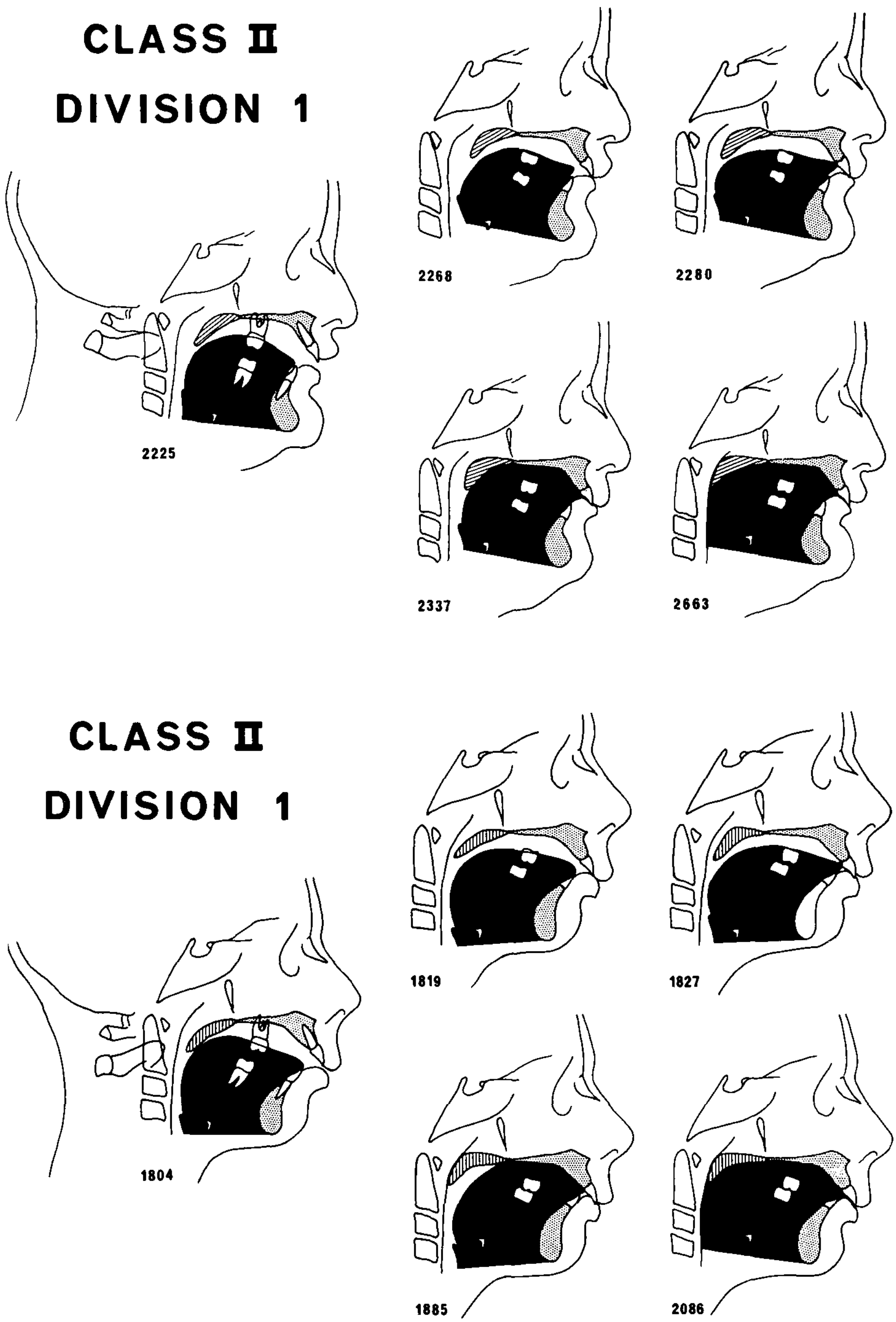

Fig. 5 Tracings of selected cineradiographic frames of two different subjects with maxillary protrusions represented by Class II, Division 1 malocclusions. Positioning of the lower lip lingual to the maxillary incisors during swallowing is noted.

environment. As in the normal occlusion group with the progression in the initiation of swallowing, the tip of the tongue was observed to elevate toward the cingulum area of the upper incisors and the adjacent alveolar tissue. Concomitantly, the lower jaw, the mandibular incisors and the lower lip were observed to move superiorly. After the first lingual-dento-alveolar contact was established, the dorsum of the tongue was observed to roll posteriorly against the hard palate progressing toward the soft palate. During the subsequent swallowing sequences, before the soft palate had fully elevated to meet the posterior pharyngeal wall, several variables were noted in comparison to the normal occlusions. During this time the lower lip had usually moved upward behind the upper incisors. The lower lip was placed lingual to the upper incisors in all of the maxillary protrusion subjects, the only variable being the degree of upward movement. In the majority of the subjects the tip of the tongue was observed to slip forward from the position of the first lingual-dento-alveolar contact, resulting in a demonstrable tongue tip protrusion, simultaneously with the forceful upward movement of the lower lip. Sometimes tongue-lower lip junction was evident. In the normal occlusion group the lips made contact to provide the seal in the anterior region of the mouth. In the maxillary protrusion subjects this physiologic seal was sometimes provided by union between the lower lip and the lingual surfaces of the upper incisors or by a tongue-lower lip-maxillary incisor contact. Molar occlusion was observed during swallowing at the approximate time that the dorsum of the tongue reached the junction of the hard and soft palates. However, only four of the ten subjects made contact with the molar teeth during the major portion of deglutition. Following this, the soft palate actively elevated to firmly meet the posterior pharyngeal wall. The tongue maintained contact with the oral surface of the soft palate and generally occupied the entire oral cavity. Finally, the root of the tongue touched the posterior pharyngeal wall with this contact progressing caudally to complete the swallow.

For purposes of comparison the maxillary deficiency group presented an opposite type of abnormal oral environment, a retruded rather than a protruded maxillary structure. These patients also postured the tip of the tongue lingual to the lower incisors preparatory to swallowing. During the tongue tip elevation phase of swallowing, the subjects with a severe maxillary deficiency brought the tip of the tongue upward and sometimes backward attempting to achieve the first lingual-dento-alveolar contact in the maxillary region (Fig. 6). Sometimes this initial junction was achieved with the most anterior portion of the hard palate and sometimes with some aspect of the lingual surfaces of the upper incisors. It appeared that some of the subjects curled the anterior portion of the tongue back on itself to facilitate bringing the tip of the tongue to a position to achieve first lingual-dento-alveolar contact lingual to the retropositioned maxillary incisors. After initial contact was achieved, the dorsum of the tongue coursed progressively posteriorly approaching the posterior border of the hard palate. Concurrently, the tip of the tongue was observed to move anteriorly from the location of the first lingual-dento-alveolar contact. Thereafter, some degree of tongue protrusion was evident in numerous subjects; however, in contradistinction to the maxillary protrusion group, it was manifested by the forepart of the tongue moving forward under the maxillary incisors, contacting the lower

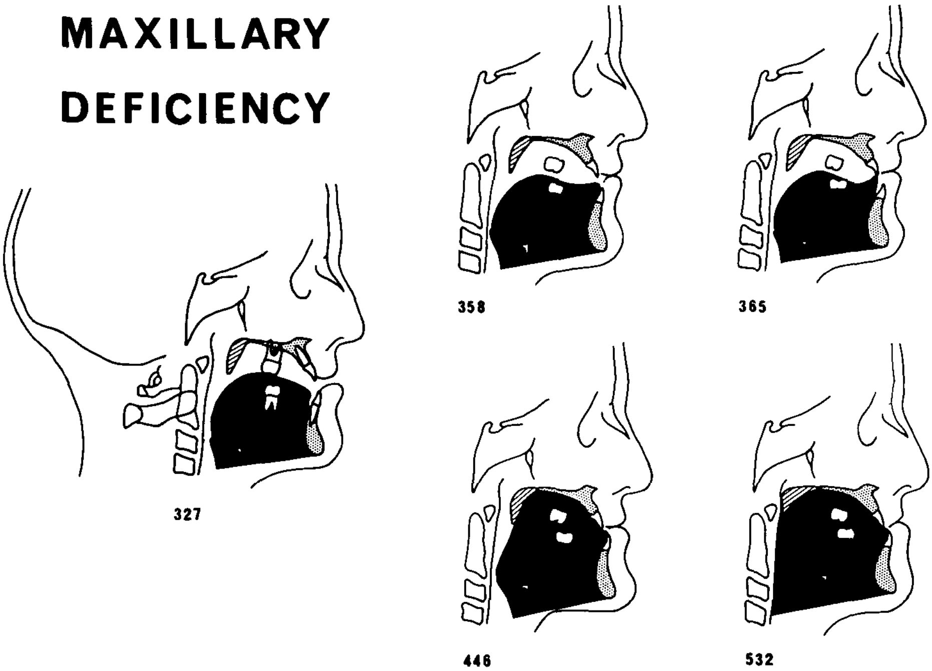

Fig. 6 Tracings of cineradiographic frames representing five stages of deglutition in an individual with a maxillary deficiency.

incisors and/or the lower lip. The degree of tongue tip protrusion seemed limited by the amount of negative overjet present in individual subjects. Very few of the subjects in this group brought their molar teeth into occlusion during any aspect of the swallowing procedure, which to a degree might be coincidental with inadequate vertical maxillary development as well as anteroposterior maxillary deficiency. This might also explain why in a few of the cases some aspects of the dorsum of the tongue were observed to move away from the palate to a lower posture within the oral cavity during the swallowing process. Toward the terminal aspects of the swallowing process, the usual sequences were evident except for a few times when tongue protrusion persisted although lips were kept in firm apposition.

Recently there has been great interest in the swallowing patterns in a malocclusion which represents a problem in vertical relationships, the open bite. With this malocclusion it may be especially difficult to attain an anterior seal because of the abnormal vertical opening between the anterior teeth. In the open-bite group (Fig. 7) the tip of the tongue was also observed to move from a posture behind the lower incisors to the most anterior aspect of the maxillary palatodental area to establish first tongue tip contact within the oral cavity. Similarly, the mandible, lower incisors and lower lip elevated during the time of tongue tip elevation, but in contradistinction to the other groups, the upper lip was observed to simultaneously move inferiorly to a considerable extent in an apparent effort to contact the lower lip. Succeeding movements, following the attainment of initial lingual-dento-alveolar contact, similarly involved the dorsum of the tongue pressing against the hard palate and

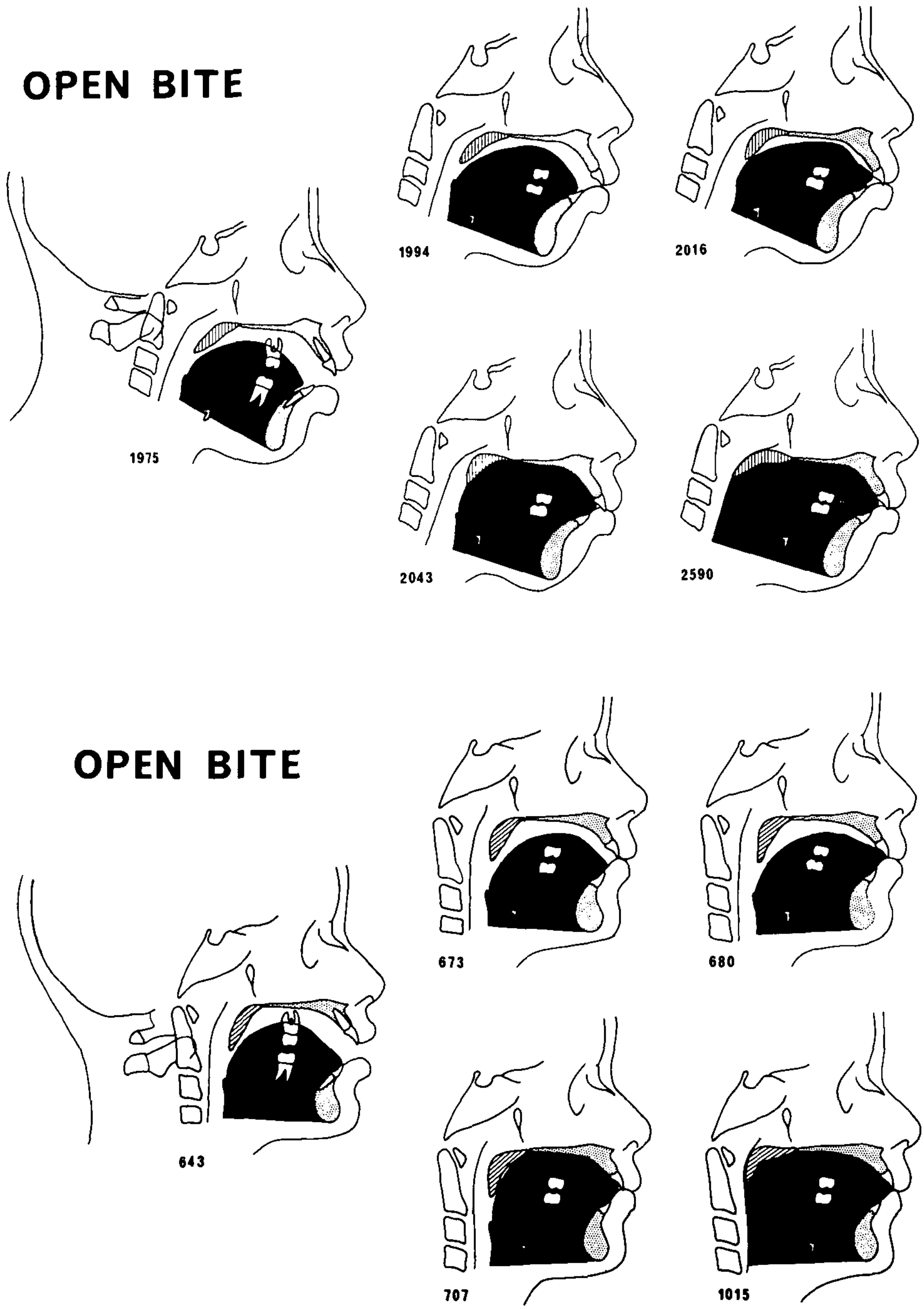

Fig. 7 Tracings of selected cineradiographic frames obtained during the act of swallowing on two different subjects with open-bite malocclusions.

progressing posteriorly to reach the posterior aspects of the oral cavity. Up to this point, contact between the soft palate and posterior pharyngeal wall had not been achieved; however, by this time, as well as during the ensuing stages of deglutition, definite molar occlusion was observed in seventy per cent of the subjects. The open-bite group showed the greatest percentage of "teeth together" swallows when compared with the other groups. With progression in the swallowing process the soft palate was subsequently observed to elevate to obturate any opening into the nasopharynx. Concurrently, the tip of the tongue moved forward from the position of initial lingual-dento-alveolar contact to protrude between the anterior teeth. As this time in the swallowing process the lips were also observed to close and in a few of the cases tongue tip contact was clearly evident. Protrusion of the tongue tip was observed to maintain itself while the root of the tongue made contact with the posterior wall and this apposition progressed inferiorly to complete the swallow.

Adaptation of Function to Form

It might be stated that the fundamental aspects of the process of deglutition are basically the same in different individuals and in different oropharyngeal environments. The patterns of movement in the initial and terminal aspects of the swallow were comparable in all of the different oral environments. For example, in preparation for swallowing, the tongue tip was found to be positioned lingual to the lower incisors in all cases. During the early stages of swallowing all of the subjects, regardless of the configuration of their oral environment, seemed to be directing the tip of the tongue toward the lingual aspect of the maxillary incisors and their contiguous alveolar tissue. It can be hypothesized that the anterior portion of the tongue needed some proprioceptive cue or sensory contact with the palatodental tissue for stabilization to permit proper progression of tongue movements. Additionally, once the dorsum of the tongue reached the posterior regions of the oral cavity, the swallowing process seemed similar and consistent in all of the subjects studied.

When variation in the swallowing procedure was to be seen in the different types of oral environment, it was observed in the area of particular interest to the orthodontist, the anterior region of the oral cavity. Here the patterns of movement seemed to adapt or vary in function according to the configuration of the anterior malocclusion. The tongue tip protruded over the lower incisors in an attempt to contact the upper incisors in the maxillary protrusion cases. It passed under the upper incisors and touched the lower incisors in the maxillary deficiency cases, and protruded between the incisors in the open-bite cases. An impression is gained that the tongue tip may be adapting to a specific anterior oral environment to achieve a seal during swallowing. Furthermore, the tongue tip seemed to maintain a close functional relationship to the lips during most of the swallow. In the normal occlusion cases it was consistently close; in the malocclusion cases the tongue tip protruded in various fashions and to various degrees to maintain a close relationship with the lips. It seems possible that a sensory relationship between these muscular structures must be achieved, regardless of the oral environments, to attain and maintain a proper anterior oral seal.

Function also seemed to adapt to differences in "form" in other ways. In the maxillary deficiency cases, a "molar apart" swallow seemed prevalent, possibly in an effort to compensate for a lack of development in the vertical aspect of the maxilla. A mandibular posture, considerably away from the maxilla, may have been assumed to maintain proper vertical relationships for tongue function during the swallowing process. Overclosure may have caused increased difficulty in swallowing. In the openbite cases molar contact during swallowing seemed prevalent. Once again this may reflect an attempt to attain proper vertical relationships by permitting the greatest possible decrease in anterior vertical relationships. It is also possible that the molar contact might represent an attempt to attain some dental stabilization during swallowing in adapting to the lack of dental approximation anteriorly. In answer to the first two of the original questions, the indications are that functional movements of orofacial muscular structures adapt to the variables of the form of the oral environment. This observation seems pertinent since most of the variables in tongue and lip activity seem to be correlated with, and can be explained on the basis of, the observable abnormalities within the surrounding environment.

Orofacial Muscle Activity: To Train or Not To Train?

Within the context of "Form, Function and Adaptive Changes", the question arises as to whether, in the presence of abnormal form, "so-called" adverse patterns of function can be corrected by training without changing that "form". In other words, it seems pertinent to question a prevailing concept that abnormal function, if observed during swallowing, must be corrected prior to correcting form. Furthermore, will corrective training of functional patterns result in concurrent alterations in form? To this end, a study was conducted to see if abnormal function could indeed be corrected without first correcting form. Five children with various combinations of the characteristic features of abnormal orofacial muscular activity, such as tongue tip protrusive activity and/or facial muscle activity during swallowing function, were selected for study. It should be emphasized that not all of the five subjects exhibited tongue protrusion, commonly called "tongue thrust". However, by clinical examination they showed different features, and combinations thereof, of abnormal swallows. The clinical evaluations were made five times on each subject to determine the activity of the muscles of facial expression, mentalis muscle activity and tongue function. Four of the subjects had pronounced malocclusion and poor arch form; one subject had a minor malocclusion and good arch form, but did exhibit slight tongue protrusive activity.

It was decided that these children would be placed in an intensive habit therapy program in an effort to alter patterns of activity during swallowing. Prior to the initiation of therapy, in addition to clinical appraisals of swallowing, cephalometric radiographs, dental study models, and high-speed cineradiographs of swallowing were obtained for each child. A trained speech specialist conducted the muscle education program as has been described in the literature.[4] This program recommended a series of lessons which were conducted exactly as outlined with two exceptions. Lessons were given on an individual basis, not once a week, but twice a week, with each period lasting thirty minutes, and eight of the lessons were repeated.The purpose of these exceptions was two-fold: first, to double the actual therapy doses in repetitive efforts to train the abnormal muscle patterns of activity during swallowing; secondly, to prolong the education program over a three month period so that the subjects could again be exposed to radiation with safety and security. The objectives of muscle-training lessons to correct abnormal swallowing procedures were as follows: 1) To eliminate activity of the muscles of facial expression during swallowing; 2) to correct mentalis habits; 3) to teach each subject to swallow with the tip of the tongue against the roof of the mouth and not between the anterior dentition; and 4) to swallow with molar teeth in contact. Within ten days following the *completion* of the intensive therapy sessions, new clinical appraisals were made and new records including the high speed cineradiographs of swallowing were obtained. The before and after therapy records were then comparatively analyzed.[5] Only the general findings and major interpretations will be discussed.

First of all, did the muscle education have any effect on form; did it cause any change in the configuration of the dental arches and in the positions of the teeth? Measurements of intercanine and intermolar widths, as well as overjet and overbite, were made. The before and after therapy dental models revealed no significant changes. Only slight changes in overjet were noted. Two of the subjects indicated a slight increase in overjet while two of the other subjects indicated a comparable decrease in overjet. The appraisal of relationships of parts as ascertained from the cephalometric x-rays also revealed no significant changes. There were no differences in the relationship of skeletal structures, and minimal differences in the relationship of dental and soft tissue structures. In one case the lower incisor seemed slightly more lingually positioned. Form did not seem to be appreciably altered by the habit therapy.

Cineradiographs were used to determine whether different patterns of function could be trained into something as basic as the swallowing procedure and be maintained on a consistent and permanent basis. Answers were sought for in the clinical evaluations as well as in the analysis of the cineradiographs. Upon clinical re-evaluation it was ascertained that the subjects exhibiting tongue protrusion prior to therapy continued to protrude their tongues during swallowing after therapy; subjects with activity of the muscles of facial expression continued to exhibit this activity; the subject with a mentalis habit retained the habit. One subject who had slight facial muscle activity and slight tongue protrusive activity showed some correction, but this was the one subject who exhibited good arch form prior to therapy. Comparable findings were interpreted from the analysis of the cineradiographs. Frames of the cineradiographic films were traced at critical points during swallowing. From these it is possible to readily study tongue as well as lip activity without the artifact of mechanically parting the lips to make observations. The four subjects with abnormal arch forms and severe malocclusions retained their habits after the training program. Where tongue tip protrusive activity and abnormal lip activity were manifest prior to habit therapy, the same were observable after therapy. There was some change in the timing sequence within individual swallowing patterns. After therapy one received the impression that the subjects were consciously attempting to prevent tongue-protrusive activity. Prior to the education program, such activity was clearly evident during the early or oral phases of swallowing when most activity was still centered within the oral cavity (Fig. 8). This was not observed subsequent to the training sessions; the protrusive activity became more evident during the later stages of swallowing when the activity became more pharyngeal in nature. It not only occurred at a later time in the swallowing sequence, but also

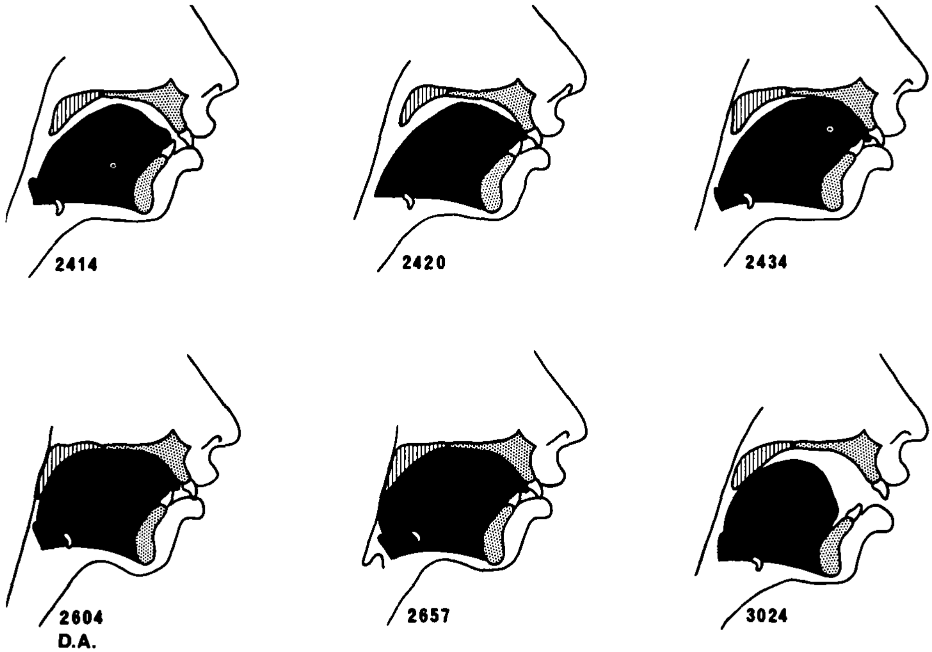

Fig. 8 Tracings of selected cineradiographic frames taken during the swallowing process on one of the subjects studied prior to the initiation of the muscle education program.

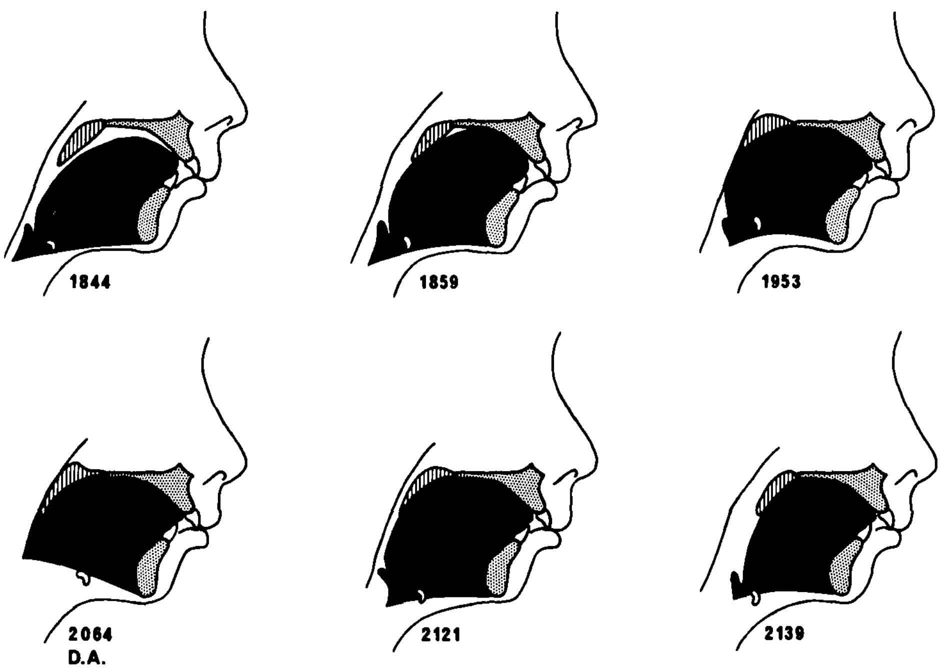

Fig. 9 Tracings of the swallowing cineradiographs of the same subject as in Figure 8 after the training program. Tongue protrusive activity is still present, but manifests itself at a later stage during the swallowing process.

persisted during the more terminal aspects of the swallowing procedure (Fig. 9). In other words, the "so-called" abnormal activity appeared somewhat later during the process of swallowing; it became visually evident and was found to maintain itself during the later stages of swallowing. In this way it differed from what was observed prior to the habit therapy.

From the interpretation of the cineradiographs it could be concluded that where form was not conducive for proper function to take place, as in the severe malocclusion cases, the function remained unchanged after habit therapy. In trying to change the functional patterns of the oropharyngeal musculature, the evidence from the five subjects indicated that these attempts failed in all but one case to accomplish the desired change in function. The one in which some habit correction was achieved, good upper and lower arch form were evident before therapy. This was not true of the other four subjects. It is concluded that abnormal function should not be corrected *prior* to the correction of form. If functional patterns cannot be readily changed within an abnormal environment, then it is necessary to see if the correction of form will result in a change of functional patterns.

Change in Function Incident to Change in Form

Can we hope for a modification in the functional patterns of the oral and perioral soft tissues if we change the dental-skeletal environment? In seeking an answer to this question high-speed cineradiographs have been obtained on many subjects with severe malocclusions undergoing orthodontic treatment. This represents an accumulation of cases with the initiation of orthodontic treatment spaced over a period of several years. Many of these subjects have had follow-up cineradiographs obtained after orthodontic correction and the placement of retention, and some have had records taken subsequent to the removal of retentive appliances. It should be pointed out that it is planned to continue this aspect of the study on a long-term basis in an attempt to reach some insight into the presently prevailing question as to whether function adapts to form or whether function produces that specific form. Of course, once a malocclusion is evident, it is difficult to ascertain whether function created it unless a multitude of records are available or secured prior to the formation of the malocclusion. However, it is possible to determine whether orthodontic alteration of form will produce a change in functional patterns. It was decided to initially study Class II, Division 1 malocclusion since in the past this type has been most commonly associated with abnormal swallowing activity.[6,7] Ten of the present sample of Class II, Division 1 malocclusion cases have been studied. Six of these have been carefully measured and statistically analyzed to achieve some degree of objectivity to the analysis of changes.[8] The remaining four have been subjectively evaluated by visual comparison of before and after treatment records and by an appraisal of tracings of selected and functionally comparable cineradiographic frames.[9] In the objective analysis, recordings of chosen points were made on the Oscar F Film Analyzer for one swallow before and one after orthodontic therapy and during selected speech sequences. Statistical analyses of pertinent data were then conducted to establish statistical significance to changes between pre- and posttreatment function (Table III). All of the subjects studied initially presented severe Class II, Division 1 malocclusions and associated tongue tip protrusive activity and/or aberrant lip

Table III

Measurements in Millimeters	Before Treatment		After Treatment	
	$\bar{x}$	SD	$\bar{x}$	SD
Tongue tip to tip max. incisor	9.38	0.65	4.66	0.86
Tongue tip to tip mand. incisor	1.57	0.55	1.67	0.83
Tongue tip to ant. point max. lip	19.31	1.10	18.47	1.19
Tongue tip to ant. point mand. lip	12.08	0.68	15.06	1.29
Sup. point mand. lip - tip max. incisor	5.32	0.40	6.21	1.74
Sup. point mand. lip - tip mand. incisor	4.03	0.51	8.66	1.88
Inf. point max. lip - tip max. incisor	9.22	0.57	7.44	1.40
Inf. point max. lip - tip mand. incisor	13.14	0.70	10.04	1.44
Inf. point max. lip - sup. mand. lip	10.64	0.76	1.96	3.35
Abscissa-tip max. incisor	55.00	0.67	53.43	0.72
Ordinate-tip max. incisor	24.47	0.59	31.65	0.67
Abscissa-tip mand. incisor	45.49	0.48	49.84	0.95
Abscissa-tip of tongue	45.82	1.07	49.52	1.06
Ordinate-inf. point max. lip	15.50	0.44	26.80	1.37
Abscissa-sup. point mand. lip	49.31	0.38	57.82	1.34
Abscissa-ant. point mand. lip	55.08	0.61	63.27	0.87

Measurements attained from analysis of cineradiographs of subject depicted in Figures 10 and 11. Recordings of points on the Oscar F were made for one swallow before and after orthodontic treatment; relationships of selected landmarks were analyzed for the entire swallow.

habits during the swallowing procedure. None of the subjects had received speech or swallowing training.

It had been previously determined that the area of primary adaptation appears to be the anterior region of the oral cavity. Therefore, it was decided to determine what functional changes are seen in the positions of the anterior part of the tongue and the lips, in relation to each other and to the anterior dentition, incident to orthodontic correction of the malocclusion. Rather than presenting specific measurements the following will be an interpretation of the measurements and a presentation of the general as well as pertinent findings. The analysis of the cineradiographs of the six subjects that were objectively evaluated, as well as the four subjects that were subjectively evaluated, provided a dramatic and fairly consistent demonstration of the adaptation of function to change in form. In every instance either aberrant tongue tip activity and/or aberrant lip activity were evident during swallowing and speech production prior to orthodontic treatment. In the majority of the cases the posttreatment cineradiographs showed complete correction of the aberrant soft tissue function. In those cases where complete correction of soft tissue function could not be categorically said to have been achieved, marked improvement in soft tissue function was clearly evident. Before treatment, the lower lip in the Class II, Division 1 malocclusion cases assumed an abnormal posture lingual to the maxillary incisors at some time during the swallowing process. The labial musculature appeared quite active with the lower lip frequently rolling under and pressing against the lingual aspect of the upper incisors, especially during the later

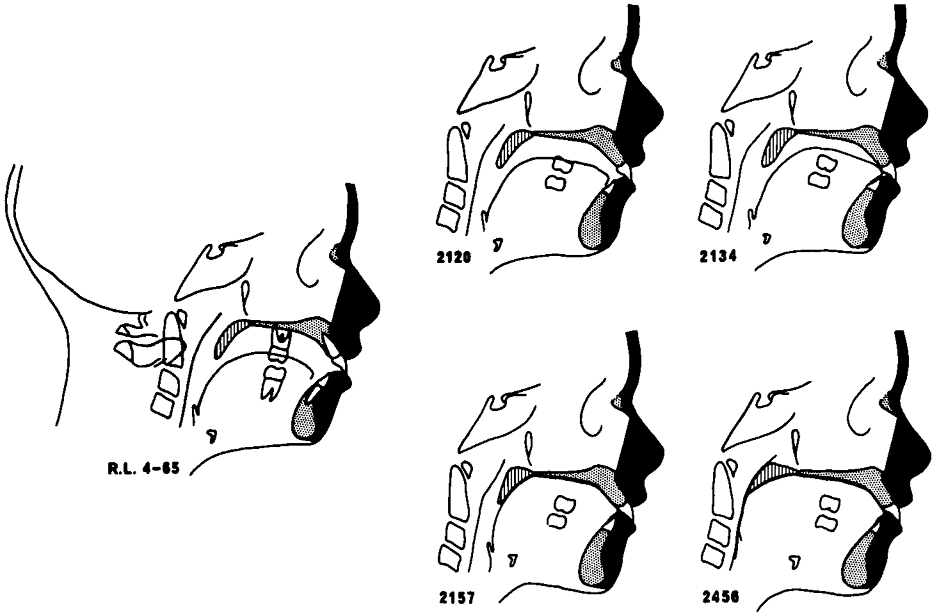

Fig. 10 Tracings of selected frames of cineradiographs taken during swallowing on one of the subjects with a Class II, Division 1 malocclusion. Lower lip activity lingual to the maxillary incisors is evident.

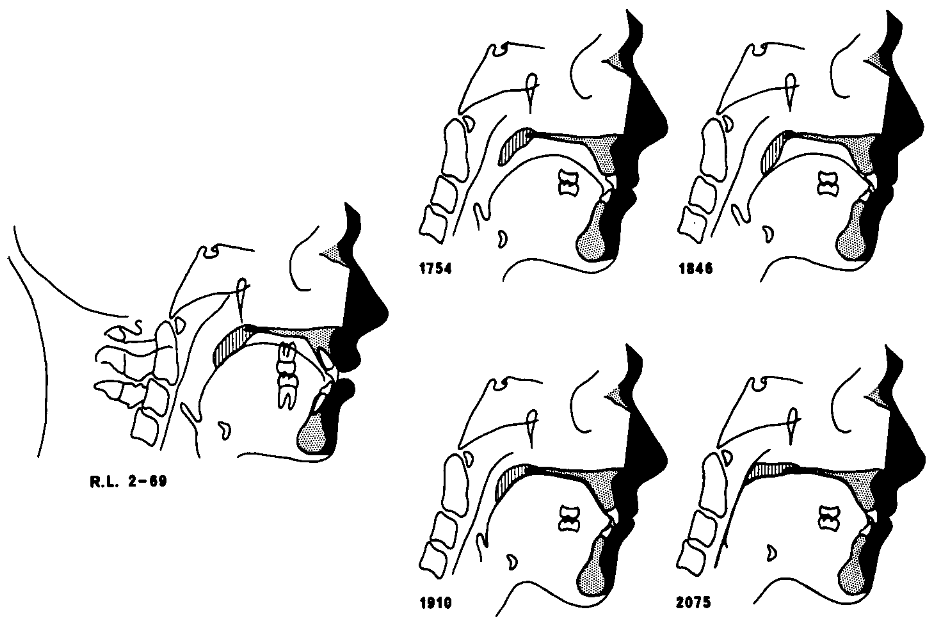

Fig. 11 The same subject as depicted in Figure 10. Cineradiographs reveal that the lower lip functions labial to the maxillary incisor after orthodontic correction.

stages of swallowing (Fig. 10). During the production of speech sounds which involved lip movement, the lower lip musculature frequently contacted the lingual surface of the upper incisors, but the movement did not seem as extensive nor as forceful as seen during swallowing. Subsequent to orthodontic correction of the malocclusion, the lower lip was never observed to retrude lingually to the maxillary incisors during functional sequences (Fig. 11). With the reduction of the overjet and some retraction of the maxillary anterior teeth, lip function seemed within normal limits. The lower lip was observed to function labial to the upper incisors during swallowing and speech, covering part of the incisal area of the labial surface. Lip hyperactivity, which had been seen in pretreatment films, was observed to have been eliminated.

Although, in the Class II cases, the greatest functional abnormality was manifested by a lingual positioning of the lower lip relative to the maxillary incisors, a few of the cases presented elements of tongue-protrusive activity prior to orthodontic treatment (Fig. 12). During the swallowing process three of the ten cases exhibited pronounced activity, while two cases presented marginal protrusive activity Where pronounced activity was noted in the pretreatment films, the tongue tip was observed to posture forward over the lower incisors during some stage of swallowing. In the after-treatment films the tongue tip was most frequently observed to elevate to contact the lingual surfaces of the maxillary incisors during the initial stage of swallowing and not to protrude between the incisors which indicated an absolute response to the changed environment (Fig. 13). In only one case was the pretreatment tongue-protrusive activity not observed to modify completely in response to the orthodontic correction. In this instance during one of the four swallows, some protrusive activity was still evident with the tip of the tongue progressing beyond the incisal edges of the lower incisors while making contact with the upper incisors. However, it must be stressed again that in most instances where the pretreatment tongue tip activity was noticed to have an abnormal pattern of function by protruding between the anterior teeth, this was observed not to occur subsequent to the change in the environment.

One consistent finding in all of the Class II cases, which may have significance in the consideration of form and function, is that there appeared to be no significant change in the relative positions of the tip of the tongue and the incisal edges of the mandibular incisors while at rest and preparatory to the swallowing procedure. Analysis of measurements revealed that the tip of the tongue maintained the same relative position to the incisal edge of the lower incisor both before and after treatment. This was observed in cases where the lower incisors were orthodontically moved to a considerable extent as well as in those cases where there was little or no change in the position of these teeth incident to orthodontic treatment. It could be assumed that the locus of initiation of tongue tip function may in some way, either through proprioceptive influence or otherwise, be closely associated with the mandibular incisors. Thus, the positioning of these teeth could be an important aspect of treatment when function is considered.

It should be stated that a significant number of years have not passed since the end of active treatment in these cases to permit the conclusion that the lips and the tongue have permanently adapted to the new dental form established by orthodontic treatment and that the newly-established patterns would not return to the original, ab-

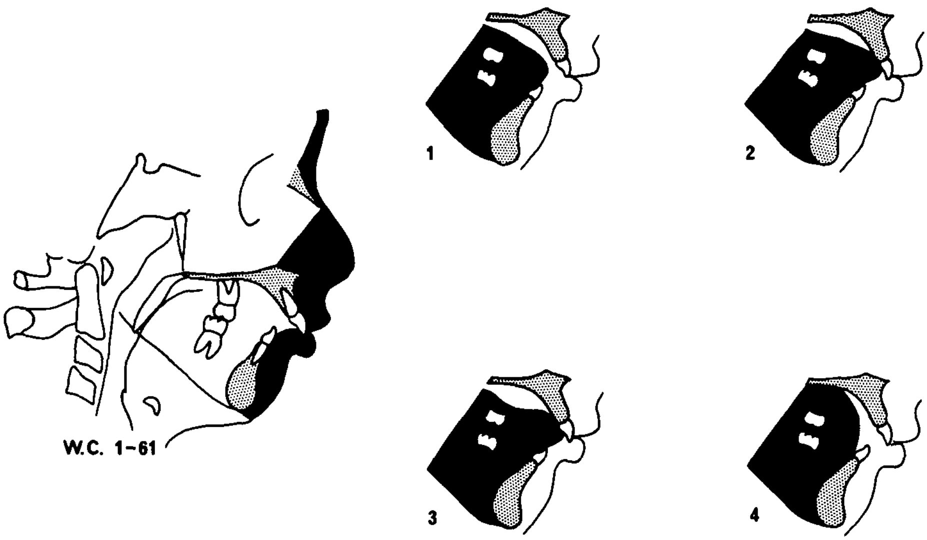

Fig. 12 Cineradiographs of a maxillary protrusion subject, taken during swallowing, reveal tongue protrusive activity prior to orthodontic treatment.

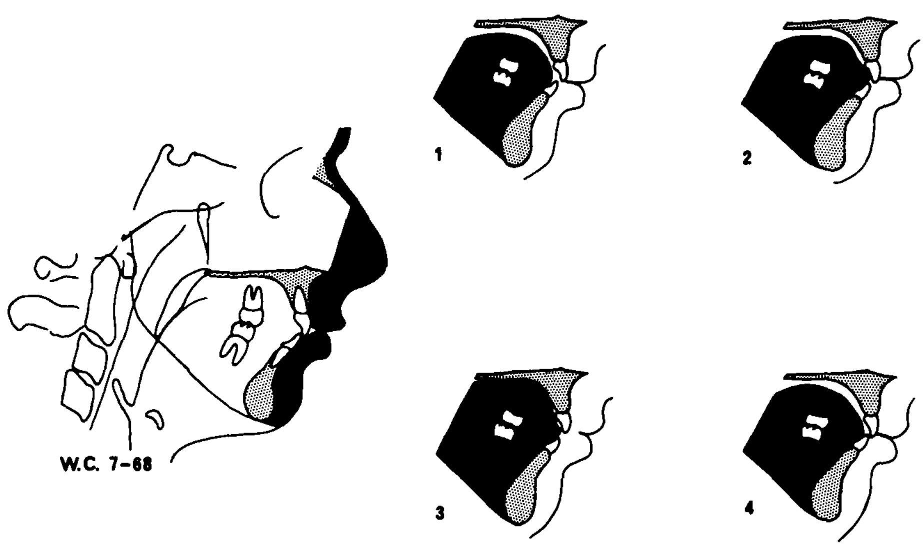

Fig. 13 The same subject as illustrated in Figure 12. Years subsequent to the removal of retention, the cineradiographs reveal a change in tongue tip activity. The tip of the tongue does not protrude over the lower incisors after orthodontic correction.

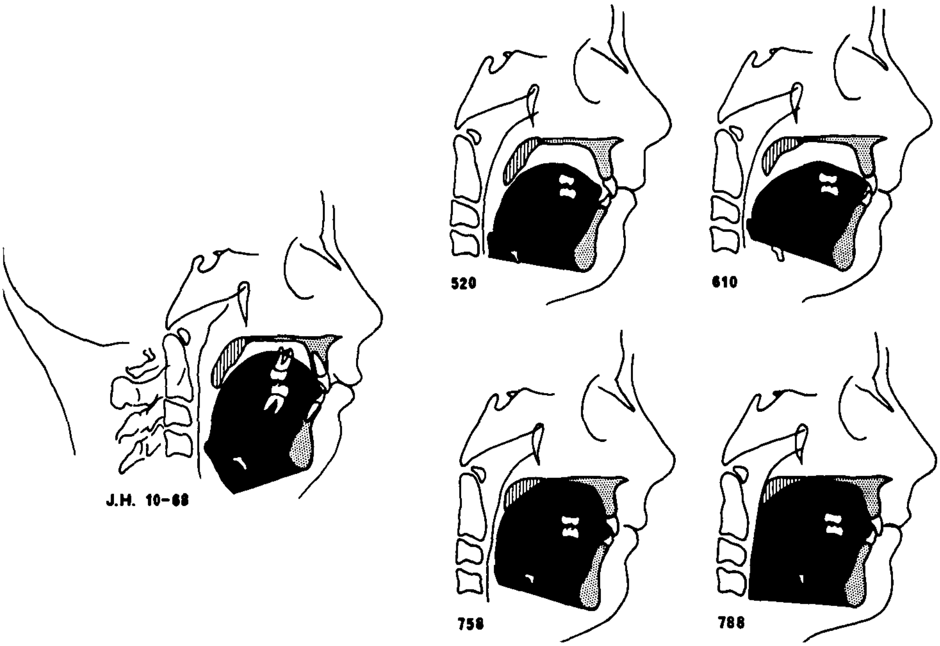

Fig. 14 Tracings of cineradiographic frames, taken during swallowing, of a subject with an open-bite malocclusion. Prior to treatment the tongue is observed to protrude into the anterior open-bite area.

normal functional patterns. It is clear, however, that abnormal function does not persist in its original pattern of activity after there has been a change in form; a definite adaptation of functional patterns to newly established form can be hoped for and anticipated.

The maxillary deficiency cases are being studied, but many are undergoing long-term orthodontic care and/ or maxillary surgical correction. Follow-up records will be a long time in becoming available. However, adaptation also seemed to be the outcome of orthodontic correction of cases with anterior dental open-bite malocclusions. To date, seven cases have been subjectively evaluated and some are presently being objectively analyzed to attain the numerical figures to talk with confidence. It must be emphasized that a much larger number of cases will soon have follow-up records for objective analysis. Initially, cases with anterior dental open bites and without severe skeletal abnormalities or severe soft-tissue deformities have been chosen for evaluation. Prior to orthodontic treatment, the tip of the tongue was observed to come forward and to protrude into the open-bite area between the anterior teeth at some time during the swallowing procedure (Fig. 14). In many instances excessive activity of the lips, especially that of the upper, was noted, and many times tongue tip-lip contact was observed during the more forceful stages of swallowing. With the correction of the anterior dental relationships and with the achievement of an adequate overbite the tongue tip was observed to be contained within the dental arches and not to protrude between the incisor teeth but to function in a more normal relationship (Fig. 15). Lip activity did not seem as forceful as was previously observed and greater activity was noted in the lower

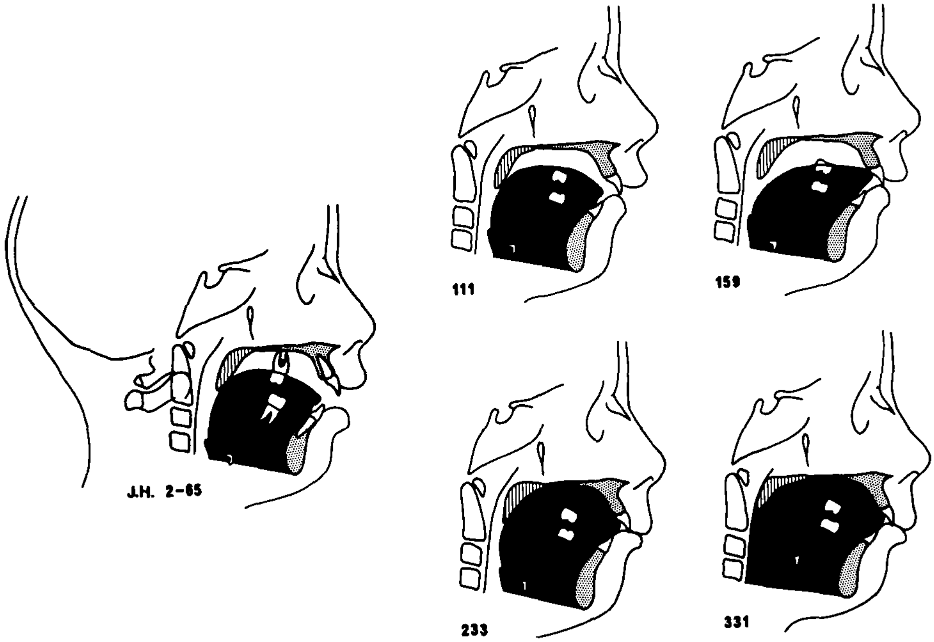

Fig. 15 The same subject as seen in Figure 14 with records taken after correction of the open-bite malocclusion. Adaptation of tongue tip activity is noted with a cessation of protrusive tongue tip posturing.

lip rather than the maxillary lip. Where adequate correction had been achieved, the lower lip was observed to function labial to the incisal area of the maxillary incisors.

Of particular interest was one open-bite patient who came to our clinic after she had trained herself into a swallowing pattern which was considerably unlike her natural swallowing procedure. Through a period of muscle education she had learned to consciously swallow differently than she was accustomed to, in an effort to overcome an open-bite malocclusion where contact was evident only on the molar teeth. The patient expressed the thought that for over a year she consciously swallowed in the educated position but was not secure about her swallowing patterns when "she was not really thinking about it". Cineradiographic records were used to evaluate both swallowing procedures, by asking her to swallow according to the muscle-trained education pattern and by attempting to record a "so-called" natural swallow. Differences were noted. As part of a natural swallow, strong protrusive activity was clearly noted with the tip of the tongue passing well beyond the lower incisors to contact lip structure (Fig. 16). In the educated swallow the tongue tip was observed to initially posture in the midpalatal area and did not protrude between the anterior teeth at any time (Fig. 17). Despite this learned procedure the malocclusion maintained itself for a period that exceeded one year as evidenced by earlier models and cephalometric x-rays. After evaluation it was decided that occlusal equilibration might adequately reduce the open bite and this was attempted on an experimental basis. Following equilibration, there was a major reduction in the open bite but not a full correction of the malocclusion, since some maxillary overjet was evident and

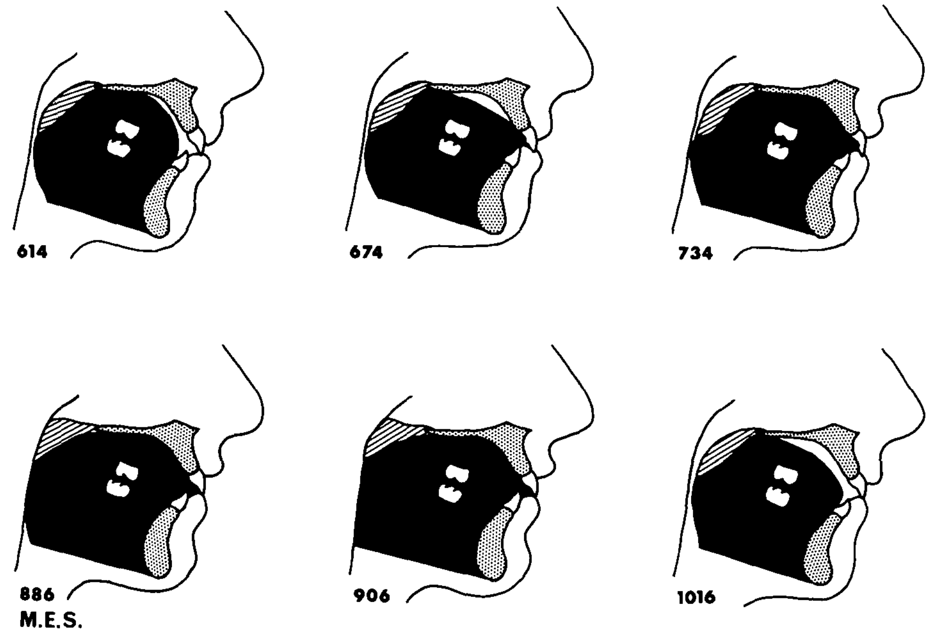

Fig. 16 Cineradiographic records reveal strong protrusive activity of the tip of the tongue during swallowing when the subject was requested to attempt a natural or nontrained swallow.

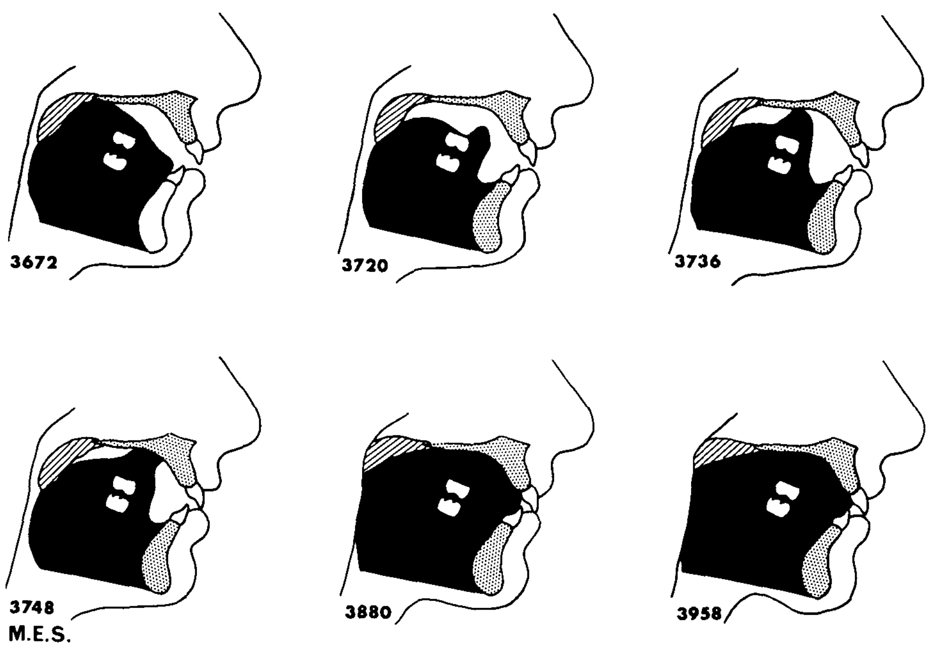

Fig. 17 Records of the same subject as in Figure 16 showing differences in tongue tip positioning when she attempted the educated procedure during swallowing.

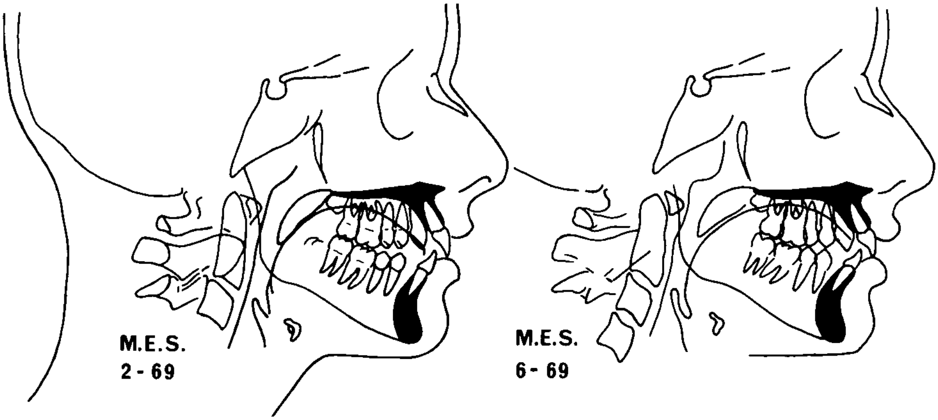

Fig. 18 Cephalometric tracings with teeth in occlusion of the aforementioned subject, before (left) and after (right) treatment with occlusal equilibration. A period of four months had lapsed between cephalometric records.

openness occurred to a slight extent in some localized areas (Fig. 18). New cineradiographic records were secured which followed the initial records by a six-month period and the pattern of swallowing was evaluated. Subsequent to the measurable reduction in the open bite it was observed that the swallowing procedure differed from the original swallowing patterns (Fig. 19). The tongue tip was observed not to go as far back within the oral cavity as in the learned or educated procedure, but initial contact was achieved in the region of the alveolar process and rugae lingual to the maxillary incisor teeth. Slight protrusive activity was still observed but to a considerably reduced degree. It could be interpreted that the tongue adapted to a new environment, which was achieved by results other than orthodontic therapy, since a change in the functional patterns of the tongue during swallowing was evident. The initiation of her orthodontic therapy will probably be considered at a future date.

These preliminary studies show that, barring severe anatomic and physiologic complications, if the environment is favorably altered, then the muscular patterns of function will probably alter favorably. This is significant to orthodontic treatment. Functional muscular patterns can adapt to a new and correct relationship. The secret lies in evaluating the cause and effect relationship, in determining which factors cause a problem and which are adaptive. If there is nothing seriously abnormal in form, that is, in size or position, and there is nothing seriously wrong relative to function, that is, in neurological control, etc., then a change in the contiguous environment should allow an adaptive change in function. The classical examples were the severe Class II malocclusions with extensive overjets. Since most frequently there was nothing anatomically or neurologically abnormal in the muscular patterns, modifications of the environment resulted in a change in the function of the musculature contiguous to the environment.

Inadequate Adaptation: When and Why.

It is important to know and recognize the inevitable range of variation to the "so-called" abnormal as well as the normal patterns of muscular function. Variation is the rule, and what may seem to be an abnormal pattern that should change with an altered environ-

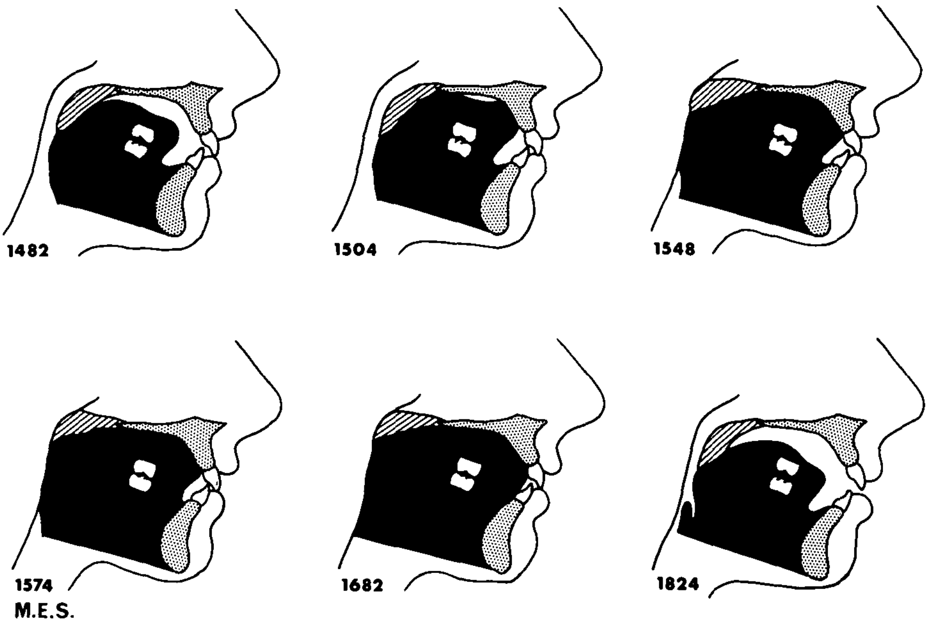

Fig. 19 Tracings of the films of the same subject recording the swallowing procedure after some closure of the bite. A difference in tongue-protrusive activity can be noted when compared to her original cineradiographic records as depicted in Figures 16 and 17.

ment may actually be a manifestation of a problem that can never permit adaptation. Circumstances involved with certain anatomic and concomitant physiologic features may dictate that spontaneous adaptation could never occur. Problems will arise in two regards: in abnormal muscle size or in abnormal skeletal relationships.

Tongue size may be disproportionately large and result in undesirable tongue postures as well as tongue movements. It is true that macroglossia per se is rare and not frequently seen in clinical situations.[7] However, one cannot lightly dismiss this possibility since it is really a matter of proportionality; it is the proportionate size of a tongue within its own environment that makes the muscular structure large or small. An averaged size tongue mass within an obviously small environment morphologically creates a proportionately large tongue, which can demonstrate abnormal postures and abnormal patterns of activity. A morphologically oversized tongue within an exceptionally large dentoskeletal environment may not demonstrate abnormal tongue posture and function. In actuality, this tongue cannot be considered anatomically large, but rather proportionately adequate or even small. Proportionate sizes are clearly individual, differing from person to person, making it virtually impossible to develop a universal concept of tongue size that will fit all individuals. Proportional tongue size must be considered, but problems will arise in recognizing a disproportionately large tongue. Anterior dental open bites, spacing between teeth, and protrusive tongue postures and function are some of the telltale signs. Obviously, clinical experience will be a strong factor in estimating how much of the oral cavity is filled by the tongue; sometimes this determination

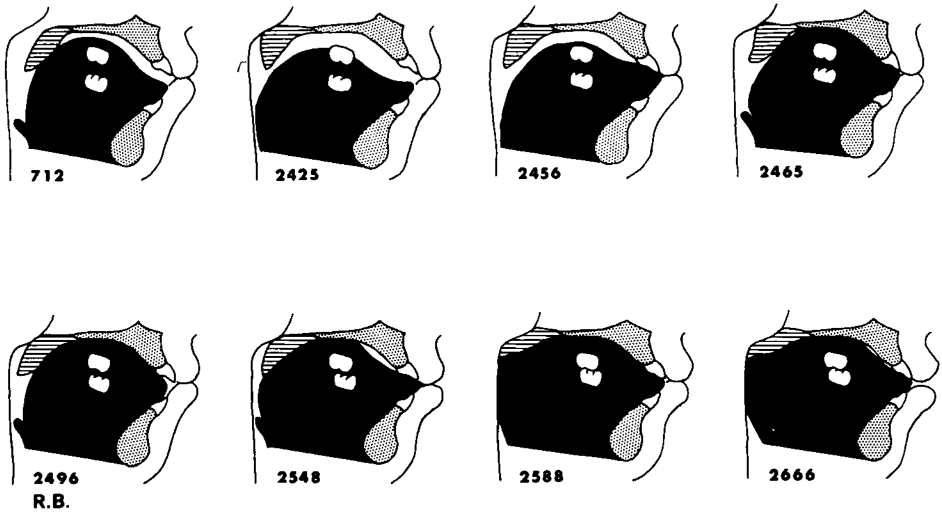

Fig. 20 Tracings of the cineradiographic records obtained during swallowing in an individual with a disproportionately large tongue. Protrusive activity between the anterior teeth is clearly evident through most of the swallowing process, especially as the tongue begins to occupy the major area of the oral cavity.

can best be aided by the use of cephalometric radiographs. One may observe that the tongue mass, at rest, occupies most of the oral cavity leaving little space between the dorsum of the tongue and the palate and between the root of the tongue and the posterior pharyngeal wall with the tip of the tongue approximating the anterior teeth and/or the lips. In this relationship a tongue is disproportionately large occupying most of the environment and functioning abnormally within it (Fig. 20). In this situation, adequate increase in the size of the environment must occur incident to time and growth in order to overcome the disproportionate tongue dimension and permit better posture and functional relationships.

If further growth cannot be hoped for or if adequate increase in oral cavity dimensions cannot be anticipated, then it may be pertinent to consider reduction in tongue mass. This, of course, is clearly contingent on a decision that the disproportionality in size will not and cannot change with time and growth to be adequately confined within its environment. At times, it may be feasible to consider corrective measures which may permit an increase in the dimensions of the confining oral cavity. In certain instances maxillary orthopedics, by rupturing the midpalatal suture, may permit adequate increase in width and sufficient change in oral cavity dimensions to properly house a tongue. This may be especially true in cases where the tongue was observed to be somewhat low in posture and inhibited in function as a consequence of a constricted maxilla. In other instances it may be possible to obtain more vertical dimension to the oral cavity to increase space for the tongue. This is especially true in cases of overclosure. In these cases it may be feasible to orthopedically move a mandible in a downward and backward direction permitting the eruption of posterior teeth. The eruption of posterior teeth,[10] in causing the mandible to be postured farther away from the palate, can cause an increment in oral cavity space by increasing vertical dimensions (Figs. 21, 22).

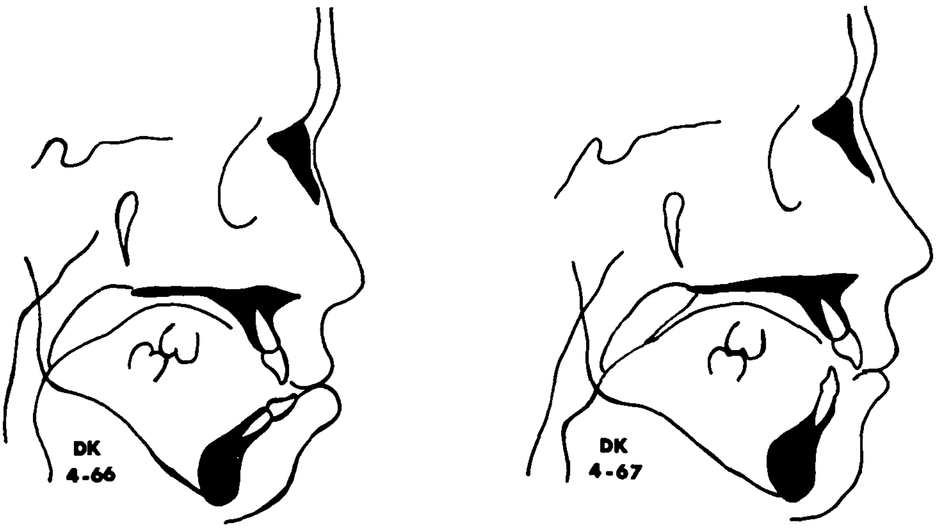

Fig. 21 Cephalometric tracings of the same individual with a disproportionately large tongue. An increase in vertical dimension seemed desirable as a part of orthodontic treatment to create more room (vertically) within the oral cavity. A change in anterior dental relationships can be noted.

Inadequate adaptations may also arise in certain cases where skeletal relationships are poor and possibly beyond the limitations of correction. Today we are cognizant of so-called "skeletal open bites" with steep mandibular planes, short posterior vertical ramal heights, divergent gonial angles, tipped-up maxillary palates and open-bite malocclusions which may not be readily amenable to conventional orthodontic correction. However, there may be aberrant skeletal relationships that approach, but do not quite demonstrate, the extreme of these undesirable features. Tendencies may be noted whereby skeletal relationships may be proportionately although not fully involved. Abnormal tongue posture and activity may be associated with undesirable skeletal relationships such as steep mandibular planes coupled with retrognathic facial patterns. In these instances, in addition to a reduction in horizontal oral cavity space, there may not be adequate vertical space, especially in the posterior regions, to properly contain the tongue mass. This impression was recently strengthened by a study investigating the relationships of the palatomandibular plane in various types of malocclusion.[11] As has been reported,[12,13] most studies concerned with

Fig. 22 The two cephalometric tracings of Figure 21, superimpositioned on the palatal plane, registered on the posterior nasal spine. Changes are noted by the black areas. An increase in vertical dimension seemed to be achieved by permitting the eruption of posterior teeth.

growth have indicated a general trend toward increase in height in the ramal region or in the more posterior aspects of the oral cavity. In normal subjects increase in posterior facial height was found to be more the rule than the exception. It can be hypothesized that, by posterior vertical increment, the attainment of greater oral cavity space to house a tongue mass can be achieved. It was surmised that the tongue is housed within the oral cavity and is bounded superiorly by the palate and limited inferiorly by the lower border of the mandible, thus the evaluation of the palatomandibular plane.

The question arose as to whether there are deviations in the posterior vertical relationships in different types of malocclusions and skeletal types which might indicate inadequate space in the oropharyngeal region, as well as the oral region, to completely contain tongue mass. The palatomandibular plane relationship was evaluated and compared in a large number of subjects: 24 normal occlusions, 30 Class I malocclusions, 29 Class II malocclusions related to skeletal malrelationships, 26 Class II malocclusions associated with dento-alveolar malrelationships but with good skeletal relationships, 28 cases judged to be skeletal open bites, and 10 cases judged to be muscular and/or dental open bites. The mean age in all groups was 12.5 years. Of interest is the fact that severity in deviation was more pronounced in poor skeletal patterns than in those malocclusions that seemed basically dental abnormalities (Table IV). When compared with normal occlusions, all of the malocclusion groups had more divergent palatomandibular planes indicating some degree of deviation in this direction. However, the Class I, the Class II dental, and the dental or muscular open bites more closely approximated the normal occlusions. Those judged to be true skeletal

Table IV

Means and Standard Deviations For The Angular Relationship of The Mandibular Plane to The Palatal Plane

Occlusion	N	Mean	S.D.
Normal Occlusions	24	21.35	5.31
Class I Crowding	30	26.86	4.77
Class II (Dental)	26	24.84	4.99
Muscular Open Bite	10	26.90	5.65
Class II Skeletal	29	30.20	2.17
Open Bite Skeletal	28	32.03	6.24

problems, such as skeletal open bites and Class II malocclusions with skeletal malrelationships, were clearly more extreme in deviation. In the latter cases with severe divergence of these two planes and apparent lack of posterior vertical height, the tongue may be forced to occupy an excessive proportion of the oral cavity within that specific skeletal environment. Thus, tongue-protrusive activity might be more evident in these cases. This might be the reason why such activity is frequently reported and somewhat predominantly observed in Class II malocclusions.[6,7] Many of these individuals may have underlying skeletal malrelationships which may contribute to this pattern of function. Thus, in actuality, the tongue may still be adapting to that specific and unfavorable skeletal environment. In situations such as this, the tongue may continue to be the victim of an unfavorable environment (Fig. 23).

In conclusion one might state that an intimate relationship must logically exist between "form and function". However, from all observations it seems that aberrant "form" must be changed if the orthodontist hopes to change functional patterns. It is first necessary to identify

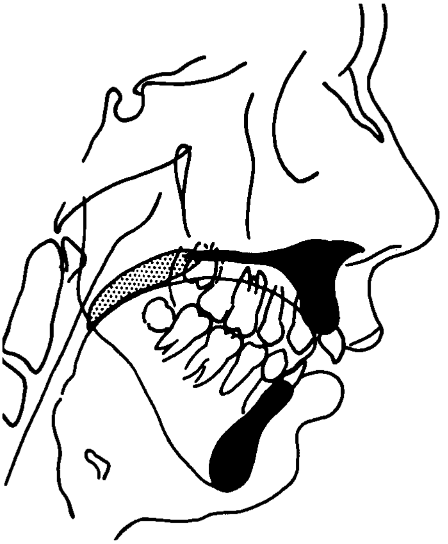

Fig. 23 Cephalometric tracing of an individual with undesirable skeletal relationships. A lack of posterior vertical height is noted. Four premolars had been extracted in this subject and a resultant disproportionately large tongue did not permit adequate correction of the orthodontic problem. The tongue seems to be a victim of the oropharyngeal environment.

patterns of activity and then to search for the basis for that particular functional pattern. The basis might be skeletal or morphologic rather than physiologic in nature. As previously observed, changing function will not necessarily result in a change in form. It is mandatory for the orthodontist to make a judicious decision as to whether abnormality exists in the environment, where it exists, and whether it can or cannot be adequately modified. If it can be modified, then changes in patterns of muscular function can be anticipated and hoped for. If change in function does not occur, then, and only then, is it time to seek other avenues of possible correction with concerted efforts to modify or change the functional patterns. The orthodontist must remember that factors other than muscle forces can determine the alignment of teeth. Muscle forces are undoubtedly a strong factor but they do not stand alone, in isolation, as causative mechanisms.

Eastman Dental Center
Rochester, N.Y.

BIBLIOGRAPHY

1. Straub, W. J.: Malfunction of the Tongue. Part I. *Am. J. Orthodont.*, 46:404-424, 1960.
2. ——— Malfunction of the Tongue. Part II. *Am. J. Orthodont.*, 47:596-619, 1961.
3. Lopez, O.: Cineradiographic Study of Orofacial Muscle Function During Deglutition in Subjects With Different Types of Occlusions. Unpublished research study; Department of Orthodontics, *Eastman Dental Center*, 1969.
4. Straub, W. J.: Malfunction of the Tongue, Part III. *Am. J. Orthodont.*, 48:486-503, 1962.
5. Orthodontic Class of 1968 (Gugino, G. A.; Hull, J. R.; Johnson, W. L.; Kho, G. H.; Musgrave, K. S.; Ryder, R. R.): Adaptive Tongue Patterns; Evaluation of Swallow Reeducation Therapy. Unpublished research study; Department of Orthodontics, *Eastman Dental Center*, 1968.
6. Blyth, P.: The Relationship Between Speech, Tongue Behavior and Occlusal Abnormalities. *Dental Practitioner*, 10:11-22, 1959.
7. Tulley, W. J.: A Critical Appraisal of Tongue Thrusting. *Am. J. Orthodont.*, 55:640-650, 1969.
8. Connor, S. S., and Wells, R. L.: Cineradiographic Study of Orofacial Muscle Function in Class II, Division I Subjects, Before and After Orthodontic Treatment. Unpublished research study; Department of Orthodontics, *Eastman Dental Center*, 1969.
9. Lieberman, K., and Hawrylzak, J.: Cineradiographic Study of Orofacial Muscle Function in Class II, Division I Subjects, Before and After Orthodontic Treatment. Unpublished research study; Department of Orthodontics, *Eastman Dental Center*, 1967.
10. Woodside, D. A.: The Vertical Dimension in Orthodontic Treatment Planning. Presentation: 16th Biennial Meeting of the Edward H. Angle Society of Orthodontia. Boston, Mass., Oct. 10-14, 1965.

11. Fowler, H.: A Study of the Angular Relationships of the Mandibular Plane to the Palatal Plane in Various Types of Malocclusion. Unpublished research study; Department of Orthodontics, *Eastman Dental Center,* 1969.

12. Brodie, A. G.: Late Growth Changes in the Human Face. *Angle Ortho.,* 23:146-157, 1953.

13. Björk, A.: Variations in the Growth Pattern of the Human Mandible: Longitudional Radiographic Study by the Implant Method. *J. Dent. Res.,* 42:400-411, 1963.

Discussion

Nicholas A. Di Salvo, D.D.S., Ph.D.

Dr. Subtelny's paper contains so much "meat" that it is difficult to adequately discuss all of its facets in ten minutes. In an attempt to resolve this difficulty I have resorted to the following analysis.

This paper reports the results of experiments designed to answer three fundamental questions regarding the relationship of dental arch form to tongue function during speech and deglutition:

(1) Are form and function related?
Subtelny concludes: *Yes.* I believe most would accept this.

(2) If form is changed, does function change?
Subtelny concludes: *Yes.* I believe many would accept this. (Although some may cite relapse tendencies as evidence that it does not always do so).

(3) Can form and/or function be changed by "myotherapy" or "habit therapy" alone?
Subtelny concludes: *No.* I believe many would challenge this conclusion.

The following slides show intraoral photographs of ten patients with anterior open bite, before and after receiving myotherapy alone. None of these patients received any type of mechanotherapy prior to or during the interval between photographs (which interval varied from six to twelve months). One of these patients is from my private file, five received treatment in "habit therapy" in the Columbia University Orthodontic Clinic from a dental hygienist under the supervision of Professor Clifford L. Whitman who has long had an interest in myotherapy, and four patients are from Dr. Whitman's private file. (Slides shown)

These cases show definite improvement and appear to refute the conclusion of Dr. Subtelny to question No. 3.

To what can this difference in result be attributed?

It may be due to differences in 1) application of the experimental technique, or 2) recording or assessment of the result.

Experimental technique.

Myotherapy is not easy to standardize. It requires a close rapport between therapist and patient. Varying results may be expected due to:

(1) Differences in the ability of different therapists to motivate patients. One would expect differences in results of myotherapy just as there are differences in results in the use of extraoral appliances. One should ask, "Was this therapist 'gung-ho' for this procedure?"

(2) Differences in patients' abilities to learn the procedures taught. These differences may be:
   (a) Psychological (lack of motivation)
   (b) Physiological (proprioceptive)
   (c) Anatomical. One would expect greater difficulty in learning in cases having gross dis-

crepancies. (Dr. Subtelny states that four out of the five cases studied had "pronounced malocclusion".)

(3) The time interval. Three months may not be enough time to show significant changes in form. Nevertheless, Dr. Subtelny did find that function did not change; one would therefore not expect form to change as a result of function. Moreover, with longer time intervals, it becomes difficult to rule out the effects of other variables such as growth and development.

Assessment of results

(1) Changes in function. Dr. Subtelny's method is certainly a most objective one. Proponents of myotherapy have only reported clinical observations which are too subjective and therefore inadequate.

(2) Changes in form. Again, Dr. Subtelny's method is more objective, even though I am sure he would admit its limitations. Proponents of myotherapy have presented casts and photographs as evidence of changes in form. These too have inherent errors.

One cannot conclude from this limited study that myotherapy does not produce favorable changes in form or function. However, in all fairness the burden of proof of success of the method must lay with its proponents. I have found it difficult to become convinced on the basis of some of the so-called evidence presented to support the success of myotherapeutic procedures. The most serious deficiency has been the lack of adequate controls to clearly delineate those changes produced by myotherapy alone.

Some comments on reflex activity

Speech and swallowing are reflexly coordinated activities. Reflexes are nature's way of freeing the "executive" parts of the nervous system (i.e., the cortical or voluntary areas) from important but routine activities necessary for life. This is analogous to the busy practitioner who delegates important but routine matters to his assistant. *Reflexes are continually monitored and modified by a change in sensory input. Some* reflexes may be modified by voluntary control. Generally speaking, the more fundamental (i.e., linked to survival) is the reflex, the less easily modified by volition. *Individuals vary in their ability to voluntarily modify fundamental reflexes,* e.g., most of us cannot modify heart rate at will, yet cases have been reported of certain individuals who can do so.

Speech is not one of the fundamental functions needed for survival. It can be modified by training; this is the basis of "speech therapy". However, in addition to the usual type of proprioceptive and general sensory monitoring found in other types of motor activity, speech is constantly monitored by hearing. This is a very important adjunct in helping to modify this activity.

Swallowing, on the other hand, is a fundamental and important function. The only voluntary control is in initiating the act. Once initiated it cannot be stopped. It is possible to voluntarily control certain muscular movements even in the later, involuntary parts of the act. This is most difficult and requires constant attention. I am sure that individuals vary in their ability to do this. When this is realized, it is most remarkable that any clinical results at all can be achieved by volitional control of this reflex act. Yet I am sure that in certain, select situations this is possible. However, *from a physiological standpoint, it makes much more sense to alter the reflex by altering the sensory input* (i.e., correcting the malocclusion) because this is how reflexes are normally and constantly monitored and modified. My own conclusions about this are:

(1) Form and function are related.

(2) Change in form can probably be accomplished by "habit therapy" in certain cases but it is a difficult and chancy procedure.

(3) Correction in form produced by mechanotherapy is most often followed by a change in function to a more "normal" or more "desirable" type.

(4) There are some cases, a small percentage, in which the adaptation to more desirable function does not follow. This may be due to any number of reasons such as proprioceptive deficiencies, anatomical abnormalities, etc. In such cases one should supplement mechanotherapy with myotherapy for whatever additional benefits may be gained.

In conclusion, I am pleased to have had the occasion to discuss this fine paper. Dr. Subtelny is to be congratulated on an excellent piece of research and on a most lucid presentation. I hope he will be able to continue to study this most important area.