International Journal of Orofacial Myology and Myofunctional Therapy
Official Journal of the International Association of Orofacial Myology
50th ANNIVERSARY

Volume 6 | Number 1 | pp. 18-25 1980

Tutorial

Postural Influences on Lingual Activity and Cranio-Facial Form

Justin A. McCarthy *(Northwestern University)*

Suggested Citation
McCarthy, J. A. (1980). Postural Influences on Lingual Activity and Cranio-Facial Form. *International Journal of Oral Myology, 6(1)*, 18-25.
DOI: https://doi.org/10.52010/ijom.1980.6.1.3

Int. J. Oral Myol.
January, 1980

Postural Influences on Lingual Activity and Cranio-Facial Form

by
Justin A. McCarthy, B.D.Sc.,
F.R.A.C.D.S., M.S., Ph.D.,
Associate Professor,
Department of Removable
Prosthodontics,
Northwestrn University Dental School,
Chicago, Illinois

The following paper was presented by the author at a symposium titled "The Application of Myofunctional Therapy in Dentistry and Speech Pathology" and held at Meharry Medical Center, Nashville, Tennessee, April 14-16, 1978. The symposium was funded by the Department of Health, Education, and Welfare.

(*Editor*)

Students in the area of cranio-facial biology, whether researchers or clinicians, accept that the final determination of facial form results from an interaction of genetic coding upon the cellular constituents of the hard and soft tissues and the environmental milieu within which these elements function.

I attended recently the 5th annual symposium co-sponsored by the Center for Human Growth and Development and the University of Michigan. The theme of this particular symposium was "Muscle adaptation in the cranio-facial region." Previous symposia have covered the determinants of mandibular growth, of mid-facial growth and of dental occlusion. The contributors to these symposia are pre-eminent in their respective fields — both research and clinical practice. From the outstanding presentations made at these symposia, together with innumerable other research findings, there is absolutely no doubt that environmental influences play a large part in the final determination of form in the cranio-facial complex.

Dr. Enlow,[1] a participant in this conference, was a previous contributor to this outstanding series of presentations, and it is certainly not my intention, nor is it within my capacity, to enter into a discussion of the state of the art with respect to the growth and development, per se, of this complex region.

The concept of Myofunctional therapy is not new and it is certainly not confined to the New World. As Dr. Hanson[2] has pointed out, it is currently undergoing a renaissance — albeit a turbulent and highly controversial one. This controversy is not surprising, this stormy weather of doubt and attack and ridicule. Indeed it is to be expected because it is no accident that there has occurred a renewed interest, at a purely clinical level, of the form-function controversy. The movement towards this philosophy is but a reflection of the clinician's realization that many of the currently held principles underlying clinical practice do not provide all the answers. It is extremely gratifying to behold that there exists a parallel between current clinical controversy and the now well-recognized major direction of experimental research — a study of form-function interaction. Admittedly it can also be extremely frustrating when one realizes that attempted discussion along these lines mostly results in either a tirade of facetiousness or a conspiracy of silence.

It has become abundantly clear that, in the whole area of cranio-facial biology, previously held concepts are being shown too simplistic and, while this leads to their demise, such concepts are NOT being replaced with alternates. We are now much less sure and much more uncertain as to where truth resides in respect to supplying specific answers to specific questions.

Clinicians are pragmatists — they see a problem, they want a solution. They, too, are products of their educational and practice environments. A major educational objective in their training was the recognition and treatment of health problems, with less importance being attached to an understanding of etiology, prevention or even normal variability. Because their education was at least adequate in respect to recognition and treatment of health problems, their stimulus-response behavior became further entrenched, when, in practice, such behavior continued to reward them with sucess MOST OF THE TIME. The frequency of failure, although low, was persistent. Failure also produced predictable behavior patterns — frustra-

1. Donald H. Enlow, Facial growth and development. **IJOM,** 5 (4): 7-10, 1979.

2. Marvin L. Hanson, An introduction to oral myofunctional disorders. **IJOM,** 5(2): 5-9, 1979.

tion, anxiety or denial. Then along came the protagonists of Oral Myofunctional therapy, and their philosophy appeared to offer the solutions required for a percentage of these failures. Unfortunately, pendula have a habit of not remaining static. In this case the pendulum of acceptance moved too rapidly, and too many and too incredible claims were being made for the efficacy of this treatment regimen. The pendulum moved so rapidly that it outpaced the deliberate, objective and well-documented research data necessary to guide and modify the therapeutic genre being promoted. As a rsult, in many situations, failure was compounded by failure, and that is the last thing a success-oriented clinician needs. Certainly there were successes, and I am not in any way undermining them; I am merely establishing a perspective view. If we want to change the scenario, we have to be brutally objective in analyzing its status quo.

As I interpret the rationale of this conference, it is to analyze the status quo. I think we should be extremely remiss, if, in this analysis, we do not look at the role of the whole lingual complex in the growth and development of the cranio-facial region. As a matter of fact, I should like to envisage that as a future title of the type of symposia that I referred to earlier: "The role of the lingual complex in the growth and development of the craniofacial region." Currently there would be insufficient data to justify such an ambitious undertaking, but if we play our parts there is every reason to be optimistic.

The tongue tip in its resting position and functional gyrations of speech, swallowing, mastication and respiration is but the tip of an enormous muscular iceberg in a cranio-facial ocean. Its influence in the development of both normal and abnormal growth processes is much more far-reaching than any such easily observable phenomenom as anterior open bite in a skeletal class I relationship.

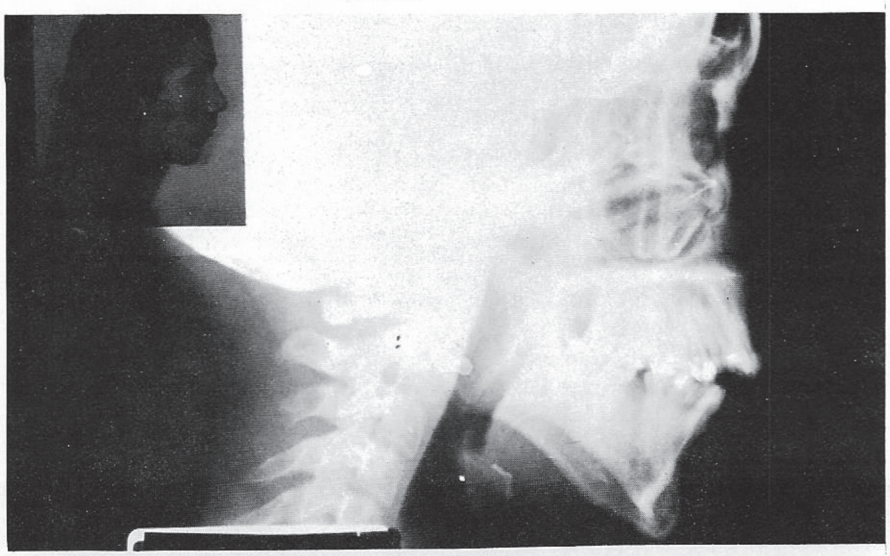
If you will excuse the pun, the major thrust of this peroration has been to establish the fact that the whole concept of oral myofunction, with particular reference to the lingual and peri-oral musculature, must be viewed from the perspective that develops an understanding of:

1. Why its acceptance in dental biology is controversial, and
2. How its development as a clinically efficient therapeutic regimen must be predicated upon a broader knowledge-base than has hitherto been promoted.

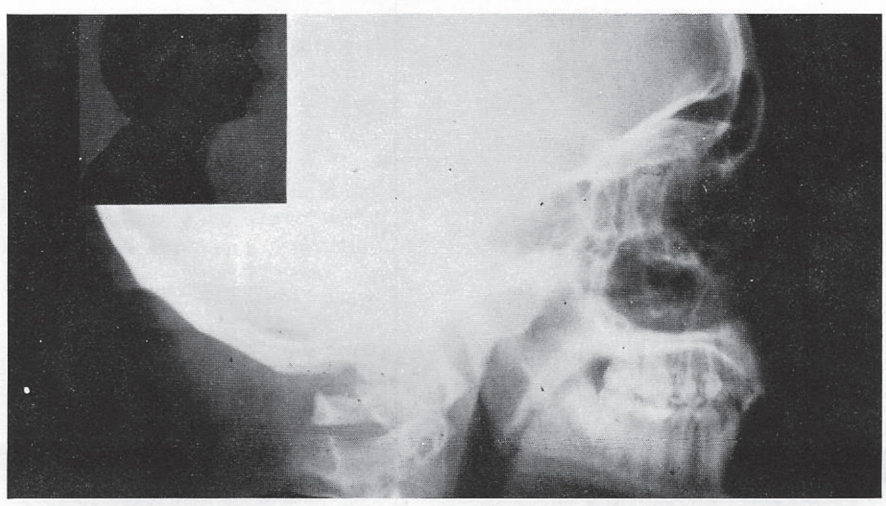
The reasons for the controversy have already been mentioned. There is a changing, but not yet universally accepted concept of form-function interaction. And myofunctional therapy, as practiced, is not yet sufficiently predictable to give the pragmatic clinician the guarantee of success that he has come to demand in other areas of his discipline.

With respect to the acquisition of a broad knowledge-base in the understanding of tongue function, I should like to discuss some of the findings and implications obtained from several research projects. The works which I wish to discuss relate to the postural effects of the tongue mass upon the development of facial form.

In relation to the craniofacial region, it is generally recognized that there are two major Caucasion head and face types, viz., brachycephalic or square-faced and dolicocephalic, long-faced (Enlow and McNamara, 1973) (Figures 1 and 2). However, it has also been shown that, so far as mid-face characteristics are concerned, differences between facial types are not great (Subtelney and Sokuda, 1964; Enlow and McNamara, 1973; Sloan et al., 1967; Ricketts, 1952). It is obvious that there are differences, however, and it is the nature of these differences which is of interest.



1. Dolichocephalic Cranio-facial type.



2. Brachycephalic Cranio-facial type.

Some of the differences which have been recorded between longface and square-face types, or open-bite and closed-bite dentitions, are described below:

1. A more cranio-cervical flexure occurs in the dolicocephalic types (Enlow and McNamara, 1973; Tallgren, 1975).
2. Cervical lordosis tends to be less in the dolicocephalic type (Tallgren, 1975).
3. Shorter posterior cranial base occurs in persistent open-bite cases, i.e. Sella to basion (Subtelney and Sokuda, 1964).
4. The posterior palate rotates downward in the open-bite situation (Sassouni, 1971).
5. There are major alterations in mandibular size (Subtelney and Sokuda, 1964) and shape, especially with respect to gonial angle, antigonial notching (Lindegard, 1953; Bjork, 1960) and in the orientation of the mandibular plane (Di Pietro and Moergeli, 1976).
6. Ricketts (1952) has shown that when comparing Class II cases with normals, the mandible has both a different resting position and movement pattern from rest to occlusion. The free-way space in the Class II patients was on average 3.6 mm at the molars compared to 1.8 mm for the normals, and the movement from rest into occlusion was in a direction of 4° to the vertical in Class II and 22° to the vertical in the normals. Thus, at rest, condylar and mandibular position were more downward and forward in the Class II population (Fig. 3). This correlation between facial morphology and mandibular rest position and freeway space has also been documented by Lindegard (1953) and Sarnas (1959).
7. The position of the hyoid.
   Although the hyoid body appears to assume a fairly constant relationship to the C3-C4 region anatomically, there are many morphological variations. Bench (1963) reports that during growth and development, the hyoid descends more rapidly than do the cervical vertebrae. For tongue-thrust and open-bite cases, its postero-inferior movement was more variable than with normal developers, and this behavior appeared more closely related to cervical activity than to that of the chin. Andersen (1963) on the other hand found no difference in the position of the hyoid relative to C3 when comparing anterior open-bite and non-open-bite cases. Various aspects of Andersen's research methodology, including patient selection and measurement parameters, make it difficult to accept that his results of no difference justify the generalized conclusion that hyoid position does not vary according to other craniofacial cephalometric parameters. Sloan et al (1967), Cuozzo (1973), Manual (1975) and Gobeille and Bowman (1976), all found variations in hyoid resting position when comparing different skeletal and dental populations. To compound the problem, however, several workers have found that while there is a great variation in hyoid position at rest, these variations do not correlate readily with conventional skeletal or dental variations (Gobeille and Bowman, 1976).

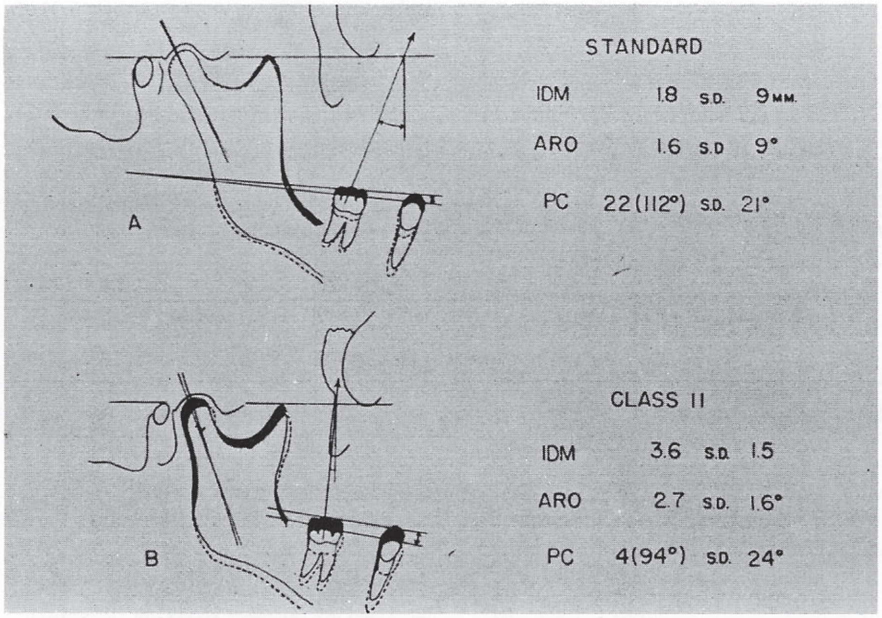
   This is one area which should receive more investigative interest. By establishing parameters other than conventional cephalometric or anthropometric, it is quite probable that a meaningful classification of resting hyoid position could be obtained.
8. Hyoid movement during function.
   Several studies indicate that during function, the hyoid not only starts from a position that varies according to general but unspecified craniofacial characteristics, but that its movement pattern also varies.

   Sloan et al (1967) studied 45 subjects with a mean age of 12 years who were divided into 3 groups, Class I, Class II div. I and Class II div. II. There were no skeletal differences between groups. The class I group showed lower and more posterior hyoid position and a limited functional movement pattern. The class II groups exhibited a higher and more forward hyoid position accompanied by a greater range of functional movements.

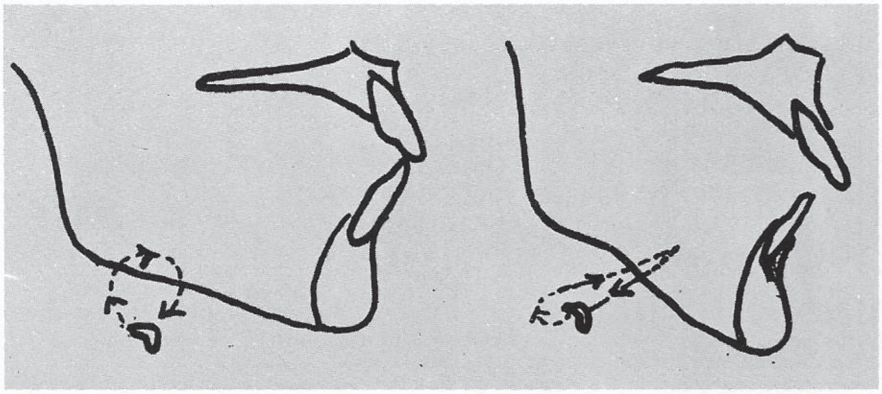
   They found 2 distinct movement patterns (Fig. 4).

   1. Circular: with the hyoid (during swallowing) moving first up and backwards in a smooth and coordinated fashion.
   2. Oblique, elliptical pattern: this pattern was characterized by erratic and unco-ordinated movement and was associated with a tooth-apart swallow.

The adaptability of hyoid position



3. Diagrammatic representation of differences between normal and Class 2 cases. IDM = Freeway space at the molar region. PC = Angle subtended to the vertical plane by the path of closure from rest to centric occlusion position (from Ricketts, 1952).



4. Movement patterns of the hyoid bone during swallowing. Left diagram showing typical circular pattern exhibited by normal occlusion cases. Right diagram showing the oblique, elliptical and erratic movement pattern exhibited by the Class 2 malocclusion groups.

and movement has been studied by Cuozzo and Bowman (1975) and Gobeille and Bowman (1976). These studies involved Class I normals and Anterior open-bite - tongue-thrust patients respectively. Both studies showed that the capacity of the hyoid to adapt during swallowing and following forced distal repositioning via tongue cribs, was related to the resting hyoid position. In those subjects whose hyoid was situated near the mandibular plane, there was a capacity to adapt via a postero-inferior movement of the hyoid at rest. Whereas in those subjects in whom the hyoid was situated distant from the mandibular plane, the hyoid did not effectively reposition (Gobeille and Bowman, 1976).

Reviewing the differences that have been described when comparing normal with open-bite cases and dolicocephalic with brachycephalic types, it appears that the most salient characteristics relate to postural relationships within the cranio-facio-cervical complex.

This complex may be divided into three elements (Fig. 5):

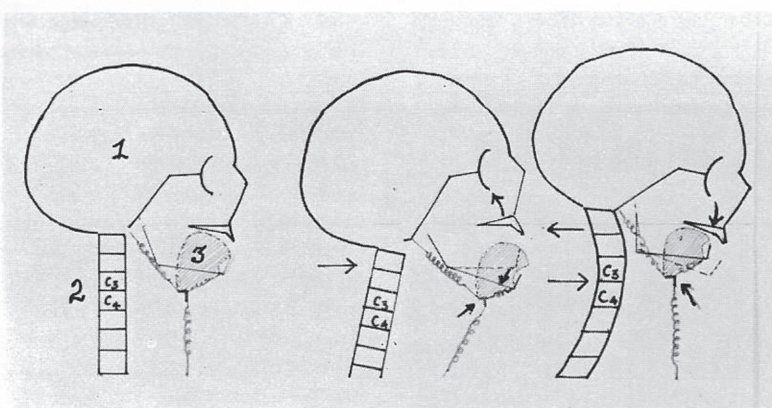
1. The cranium and mid-face,
2. The cervical column,
3. The mandible - tongue - hyoid complex.

The interrelationship of these elements is established and maintained by muscle activity. One functional requirement that is common to all three elements is the patency and adequacy of the air-way. Bosma (1963) states that "... the mechanism of pharyngeal airway maintenance is a principal determinant of the antero-posterior relationship between the tongue tip and the incisors." He is referring here to the infant. As development continues, he says, "... head and neck posture develops in relation to the pharyngeal airway." Moss (1971) has expanded on this concept in his functional matrix theory, and McNamara (1972) and Harvold et al. (1972) have demonstrated how postural modifications can effect morphological changes.

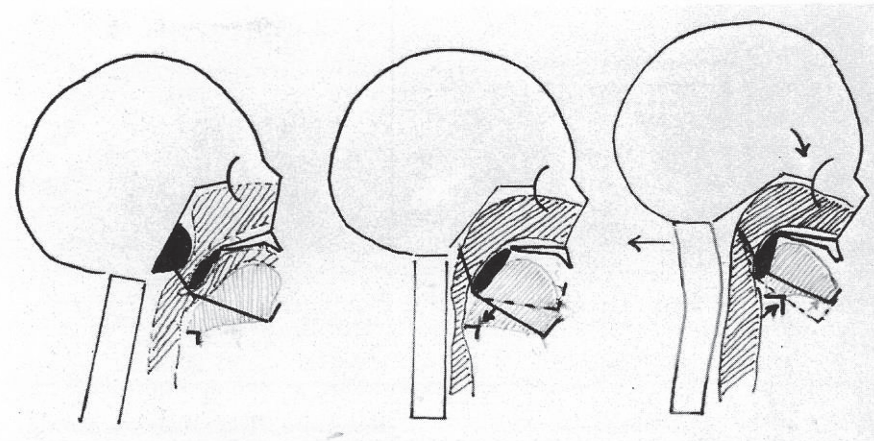
If it is assumed (1) that airway maintenance is of prime importance, and that (2) this important space can be influenced by postural effects, and further that (3) growth and development can be modified by the postural relationships, it becomes reasonable to make the further assumption that the variations in cranio-cervico-facial relationships can, at least in part, be attributable to the functional demands of airway maintenance. These assumptions are given credence from the work of several researchers. Linder-Aronson (1974) showed that following adenoidectomy both dentitional changes (e.g. arch width) and naso-pharyngeal morphological changes occurred and that these changes were significantly different from controls. Koski and Lahdemaki (1975) showed dorsal rotation of the mandible following adenoidectomy.

Ricketts (1968) demonstrated a changed cranio-cervical flexion with resolution of adenoid facies, the head rotated down.

From past research it is apparent that the final answers are not yet available. But it is equally apparent that questions relating to the success of lingual repositioning procedures can only be answered, at least in part, by reference to the postural relationships exhibited between the cranium-midface region and the cervical column and the mandibular-hyoid complex. The ability to re-posture a tongue that is



5. Diagrammatic representation of the 3 major elements of the craniofacial complex. 1. Cranium-midface region. 2. Cervical column. 3. Mandible-tongue-hyoid complex. Left diagram represents Class 1. normal occlusion, normocephalic type. Middle diagram represents change observed in dolichocephalic types, viz., increased cranio-cervical flexure; changed mandibular shape and posture and antero-superior posturing of the tongue-hyoid complex. Right diagram represents typical changes seen in brachycephalics, viz., increased cervical lordosis, cranium-midface rotated downwards, decreased gonial angle and tendency for the tongue-hyoid complex to posture postero-superiorly.



7. Diagrammatic representation of changes occurring with resolution of the limited naso-pharyngeal air passage. Left diagram indicates the relationship of parts with the adenoid mass present. Middle diagram indicates the potential for decreased pharyngeal air space when, after loss of the enlarged adenoids, the head rotates downwards. Right diagram: the decreased craniocervical flexure should be accompanied by increased cervical lordosis to accommodate the developmentally altered mandible and its suspended tongue-hyoid complex.

considered too high or too low or too far forward is interdependent upon the ability to re-posture the head on the neck or to re-orient the cervical column or to change the curvature of the cervical column or to change the resting position of the mandible. The need for these interdependent changes is due to the fact that any inferior or posterior change in hyoid position tends to encroach upon airway space. This problem is magnified when one considers that at the ages in which such therapy is being administered, the body generally is in a state of growth and development, with increasing oxygen requirements — a time in which the pharyngeal airway itself is enlarging. Hence, any attempt to encroach upon existing space is going to be doubly resisted.

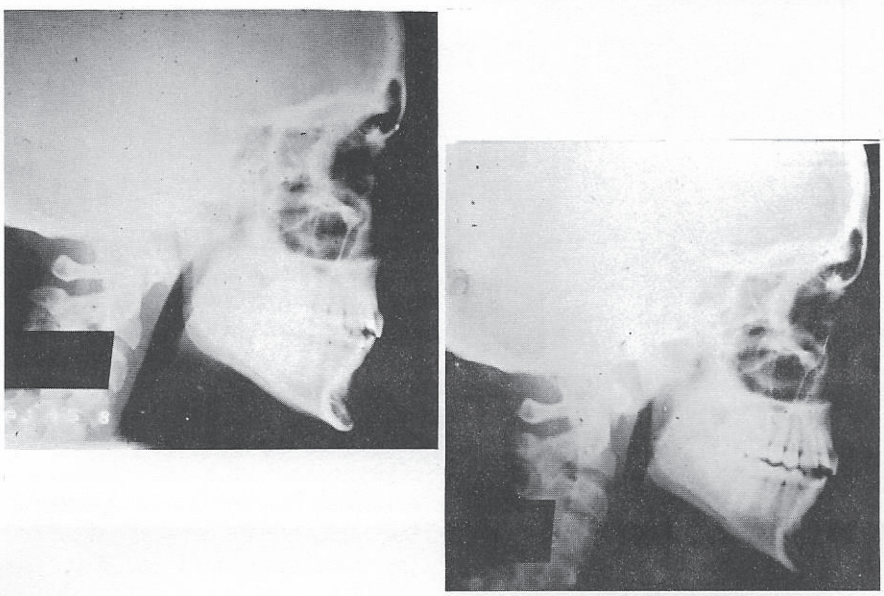
There is, however, another complicating factor in this postural re-orientation process. Consider the patient with the adenoid facies, the anterior open-bite, dolicocephalic individual. As a result of the adenoids (or for other reasons, genetic or otherwise, but not yet identified), he has assumed this typical position (Fig. 6) during early growth and development. This child cannot be considered a Class I type needing only to be re-postured. The development of his mandible has been altered; he will have a larger gonial angle and an increased Frankfort mandibular plane angle. When he re-postures, the mandible-hyoid complex will be carried further postero-inferiorly due to the altered mandibular shape, and this will necessitate greater encroachment upon the oro-pharyngeal region. The ability of the therapist to obtain a new postural position of the tongue-hyoid complex will be severely limited unless the patient can further adapt his cervical curvature to maintain adequacy of airway (Fig. 7).

Form and function have been related scientifically since Darwin's "Origin of the Species." However, it would appear that another dimension must be added that converts this age-old argument from a two-part to a three-part process. The postural effect relates form and function in a meaningful, yet complex, manner. The form of the individual parts can be similar, but their positional relationship determines the functional activity between them; and there is no doubt that functional activity influences form — a veritable menage a trois.

To return to the title of this conference and to restate it as a question: "What is the role of Myofunctional Therapy in Speech and Dentistry?"

Myofunctional therapy can be looked upon as a form of physical behavior modification that is concerned with the unlearning of old, established neuromuscular habits and their replacement with newly learned activities. For these newly learned patterns to be permanently effective, they must be habituated or engrammed. Aside from the psycho-physical skills necessary for successful behavior modification, a subject in itself, it would seem prudent to analyse the anatomical baseline upon which these old patterns were developed and upon which the new patterns must be established.

The prognosis of any treatment regimen is dependent not only upon the competence of the clinician and the co-operation of the patient, but also



6. Cephalometric radiograph of the "adenoid facies" individual.

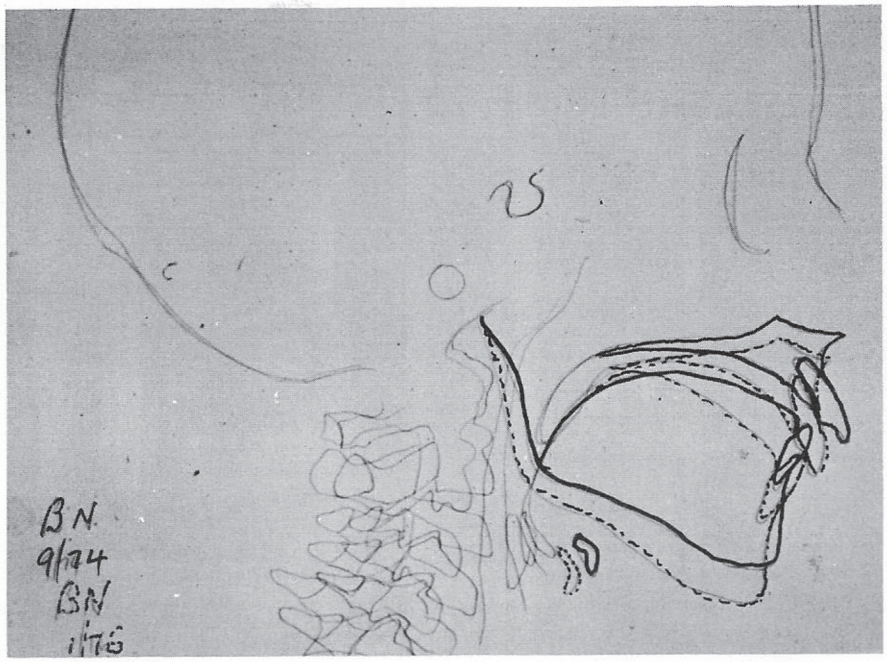
upon the anatomical and physiological bases with which the patient presents. Aside from physiological variables, which to date are largely undocumented, it would seem as if there are a multitude of anatomical variables which all tend to exhibit common behavioral patterns of muscle activity, but may well create variability in prognosis. This paper has been an attempt to establish some of the anatomical variations that can occur and that should be taken into consideration in the further study of craniofacial form and the associated neuromuscular patterns of activity.

We shall now view some cephalometric radiographs and tracings that will indicate postural variations and the changes that occur as a result of, or at least in association with, orthodontic, surgical and myofunctional treatments. These examples have been selected from reviewing old case histories of an orthodontic population in general; due to this ex post facto situation, much of the relevant information is not to hand. However, I feel that with these examples, the point can at least be made that there exists a need for research to focus on this area — although certainly not exclusively!

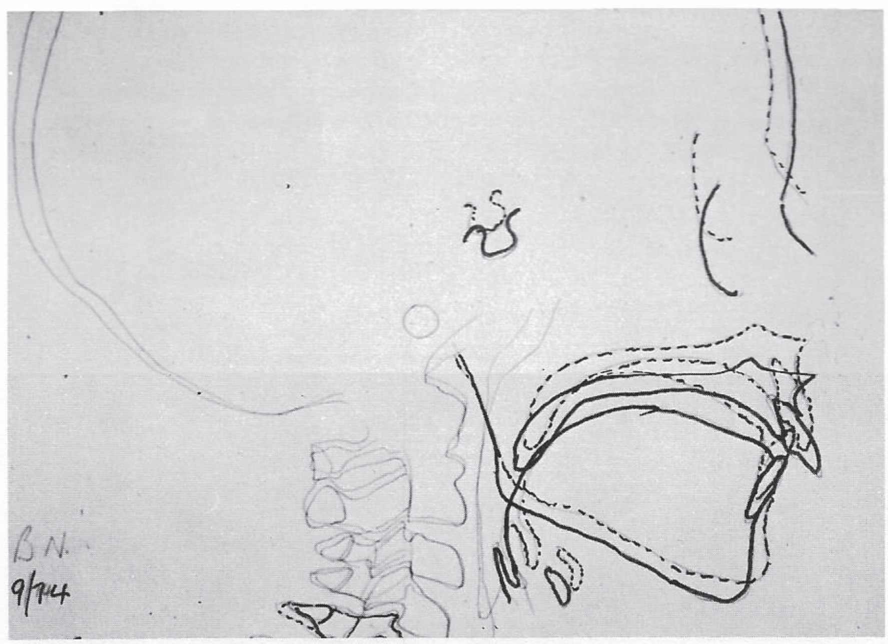
To analyze the differential effects of the repostured and anatomical elements, cephalometric tracings were superimposed in a non-conventional manner. To observe the changes occurring in cranio-cervical flexion, the tracings were superimposed about the upper two cervical vertebrae. Cervical lordotic changes were observed by superimposition about the 5th and 6th cervical vertebrae.

Author's note. In the oral presentation, 10 examples of reposturing were presented. These cases represented a variety of successful and failed cases involving various combinations of orthodontic, myofunctional and orthognathic surgical cases. In the interests of space, only two of these cases are presented here (Figures 8-13).

Figures 8-10 diagram the changes in growth and reposturing between September, 1974, and January, 1976, in a child who had combined orthodontic and myofunctional therapies for correction of an anterior open-bite associated with thumb-sucking and tongue-thrust swallowing.



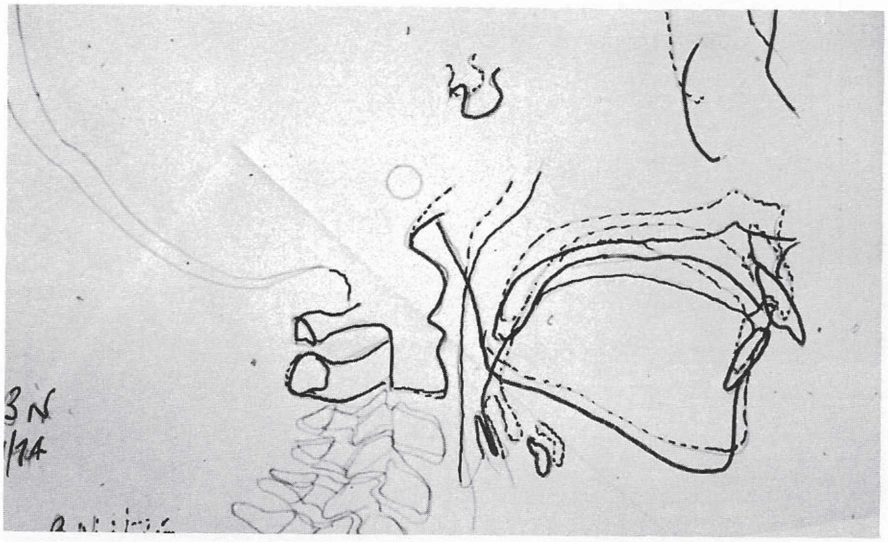
8. Conventional S-N superimposition: mandibular and maxillary growth (from 9/74 to 1/76) is mainly vertical. Hyoid position appeared to move postero-inferiorly which would impinge upon the pharyngeal airway.



9. Superimposition about C5: Decreased lordosis and head extension tending to compensate for the vertical growth changes seen in Figure 8. Hyoid position is anterior and slightly superior to its original position. Note the relative constancy of the outline of the posterior pharyngeal wall.

Figures 11-13 diagram changes following surgical correction of an anterior open-bite. No diagnosis of tongue thrust was reported and, hence, no myofunctional therapy was recommended. Relapse occurred over a $3^1/_2$-year period. The patient was 22 years of age at the commencement of treatment.

After reviewing over 100 records of this type of cases, it appears that postural changes are occurring and that these changes are obvious cepha-



10. Superimposition about C1 - C2: Head extension has occurred showing compensation for the growth changes with respect to the mandibular base. The hyoid has moved slightly forward to permit greater airspace. Note the improved position of the tongue tip and dorsum.

lometrically despite the attempted artificial head orientation through the use of the Nasion positioner. If there were no correlative postural change, then variations of head flexure and extension and in cervical lordosis would tend to be randomly distributed in both amount and direction. However, the records indicate that there is in fact a general tendency towards specific reposturing associated with both successful and relapse or recalcitrant cases. This observation has led to the development of an hypothesis of cranio-cervical reposturing in association with changing morphological characteristics.

HYPOTHESIS

When change is induced in anterior tooth relationships which affect tongue position and/or when mouth breathing is corrected, the change in resting tongue posture will encroach upon pharyngeal air space unless head, neck, and mandible-tongue-hyoid complexes reposture. The repostural changes referred to include changed cranio-cervical flexion, changed cervical lordosis and changed mandible-hyoid orientation.

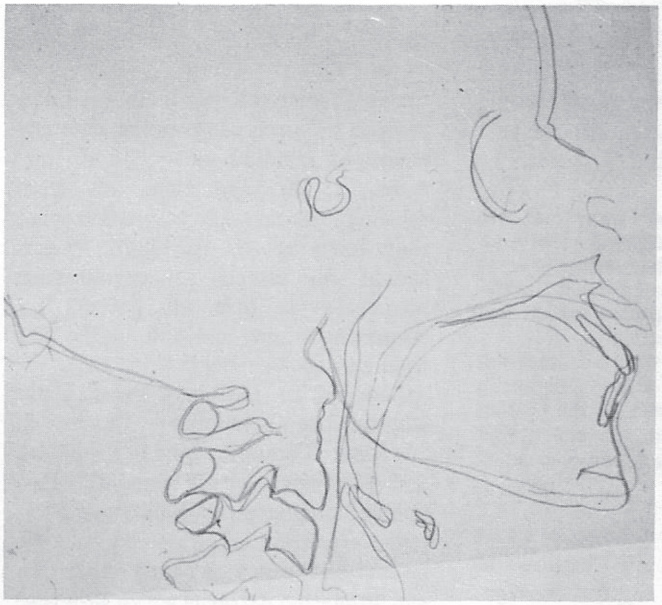
In nearly all successfully treated cases, changes in these postural relationships have resulted in an upward and forward reposturing of the mandible and hyoid which have tended to counteract the downward rotational effects of growth during the period of observation, and the downward and backward positioning of the hyoid that accompanies the decreasing anterior space available for the tongue.

In unsuccessfully treated and relapse cases, cephalometric evidence indicates an inability to develop a postural re.orientation that would permit accommodation to the decreased anterior space available to the tongue.

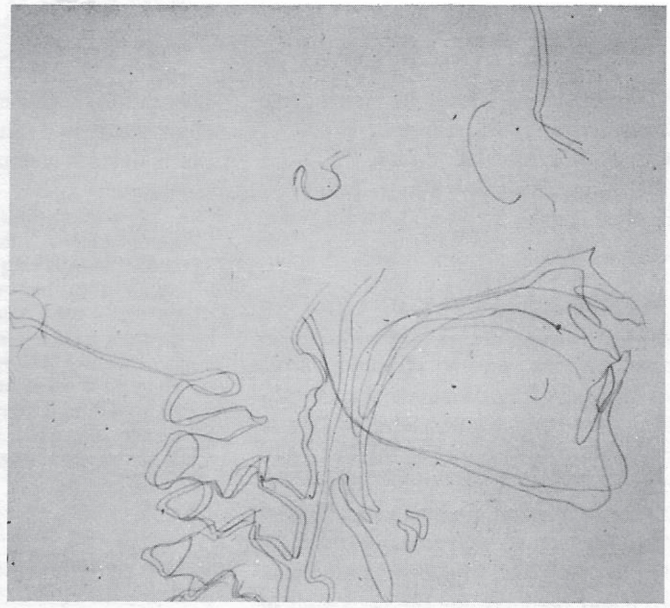
To test the hypothesis, it would be necessary to acquire pre- and post-treatment cephalometric radiographs according to the technic developed by Solow and Tallgren (1971) whereby the cephalometric radiographs are taken with the ear rods in position but with the patient standing (or perhaps sitting?) freely with a natural head position obtained by the patient's own feeling of natural head height. This procedure should not in any way compromise standard orthodontic cephalometric interpretation with respect to growth and developmental changes but would allow adaptive reposturing changes to be recorded.

Until such research information is forthcoming, clinicians should be cautious in their prognostications and should themselves endeavor to obtain this type of information as part of their history and record-taking procedures; and they should monitor, objectively, all postural changes that are occurring as a function of therapy.

11. S - N superimposition: No growth changes are observed or expected. The tracings indicate the surgical repositioning of the anterior segment. Little or no change has occurred in the hyoid position. Note the large External Occipital Protruberance. Subject appears to have marked head extension possibly associated with increased post-cervical muscle activity in an attempt to provide for an adequate airway in compensation for the abnormal anterior growth characteristics.



12. Cervical superimposition indicates little change of note.



13. Cervical superimposition: There have been no postural changes, but a marked, though partial, relapse has occurred.

BIBLIOGRAPHY

Andersen, W.S.: Relationship of the tongue-thrust syndrome to maturation and other factors. *Amer. J. Orthodont.*, 49:264-275, 1963.

Bench, R. Jr.: Growth of the cervical vertebrae as related to tongue, face and denture behavior. *Amer. J. Orthodont.*, 49:183-214, 1963.

Bosma, J.F.: Maturation of function of oral and pharyngeal region. *Amer. J. Orthodont.*, 49:94-104, 1963.

Cuozzo, G.S.: Hyoid repositioning following forced distal positioning of the tongue during swallowing. M.S. Thesis, Loyola University, Chicago, 1973.

Cuozzo, G.S. and Gowman, D.C.: Hyoid positioning during deglutition following forced positioning of the tongue. *Amer. J. Orthod.*, 68:564-570, 1975.

Di Pietro, G.J. and Moergeli, J.R. Jr.: Significance of the Frankfort-mandibular plane angle to prosthodontics, *J. Prosth. Dent.*, 36:624-635, 1976.

Enlow, D.H. and McNamara, J.A.: The neurocranial basis for facial form and pattern, *Angle Orthodont.*, 43: 256-270, 1973.

Gobeille, D.M. and Bowman, D.C.: Hyoid and muscle changes following distal repositioning of the tongue. *Amer. J. Orthod.*, 70:282-289, 1976.

Harvold, E., Chierici, G. and Vergervik, K.: Experiments on the development of dental malocclusions, *Amer. J. Orthod.*, 61:38-44, 1972.

Koski, K. and Landemaki, P.: Adaptation of the mandible in children with Adenoids. *Am. J. Orthod.*, 68:660-665, 1975.

Linder-Aronson, S.: Effects of adenoidectomy on dentition and nasopharynx. *Am J. Orthod.*, 65:1-15, 1974.

Lindergard, B.: Variations in human body-build. A somatometric and X-ray cephalometric investigation on Scandinavian adults. *Acta Psychiat.* (Copenhagen) Suppl.:86, 1953.

Manuel, V.C.: A subjective evaluation of the cranio-cervical angle and hyoid position during swallow and postural changes of the head using rapid sequency roentgenography. M.S. Thesis, The Graduate School, West Virginia University, Morgantown, 1975.

McNamara, J.A. Jr.: Neuromuscular and skeletal adaptations to altered orofacial function. Monograph #1, Center for Human Growth and Development, University of Michigan, Ann Arbor Michigan, 1972.

Moss, M.L.: Functional Cranial Analysis and the Functional Matrix. in Patterns of Orofacial Growth and Development, A.S.H.A. #6, *Am. Sp. and Hear. Assoc.*, Washington, 1971.

Ricketts, R.M.: Study of changes in Temporo-mandibular relations associated with treatment of Class II malocclusion (Angle), *Am. J. Orthod.*, 38:918-933, 1952.

Ricketts, R.M.: Respiratory Obstruction Syndrome, *Am. J. Orthod.*, 54: 495-507, 1968.

Sassouni, V.: *Orthodontics in Dental Practice*, St. Louis, 1971, The C.V. Mosby Co., pp. 127-132.

Sarnas, K.V.: Inter-and Intra-family variations in the facial profile. *Odont. Revy 10* (Suppl.):4, 1959.

Sloan, R.F., Bench, R.W., Mulick, J.F., Ricketts, R.M., Brummett, S.W. and Westover, J.L.: The application of cephalometrics to cineradiography. Comparative analysis of hyoid movement pattern during deglutition in Class I and Class II orthodontic patients. *Angle Orthodont.*, 37:26-35, 1967.

Subtelny, J.D. and Sokuda, M.: Openbite - Diagnosis and Treatment. *Am. J. Orthod.*, 50:337-353, 1964.

Tallgren, A.: Muscle activity relative to changes in occlusal jaw relationship: Cephalometric and Electromyographic correlations. in Occlusion: Research in Form and Function, University of Michigan, School of Dentistry, Ed. Rowe, N.H., pp. 14-37, 1975.