The Application Of Cephalometrics To Cinefluorography: Comparative Analysis Of Hyoid Movement Patterns During Deglutition In Class I And Class II Orthodontic Patients*

ROBERT F. SLOAN, B.A.
RUEL W. BENCH, D.D.S.
JAMES F. MULICK, D.D.S., M.S.
ROBERT M. RICKETTS, D.D.S., M.S.
STANLEY W. BRUMMETT, M.D.
JOSEPH L. WESTOVER, M.D.
Los Angeles, California

INTRODUCTION

The problems involved in the study of anatomical parts in function within the oral and pharyngeal region have been greatly facilitated by the use of improved cinefluorographic roentgenograms. By means of this technique the movements of the tongue, hyoid bone, and other related oral structures can be recorded and studied during the process of deglutition and phonation.[23,26]

A more critical evaluation of functional movements can be obtained by the application of static cephalometric analytical procedures to cinefluorographic roentgenograms.[21] By comparing three different classes of children, grouped according to malocclusion types, some insight into functional behavior of the hyoid can be obtained, quantified by the cephalometric-cinefluorographic technique.[18,22]

The purpose of this study is to compare the movements of the hyoid bone during the process of deglutition in three groups of children. Each group represents a different malocclusion (Angle's classification), but all groups have similar craniofacial morphology. Therefore, this study was designed to:

(A) Evaluate the use of cephalometric - cinefluorographic techniques in the assessment of hyoid behavior during deglutition,

(B) Determine if a consistent pattern of hyoid behavior exists during deglutition in patients with the same morphological structures.

In order to properly introduce the data presented in this paper, four phases of initial information are necessary:

(A) Phylogenetic and anatomic considerations of the hyoid,

(B) Functional behavior and growth of the hyoid,

(C) Cephalometric roentgenography, and

(D) Cephalometrics and cinefluorography.

*This work was supported by Grant-in-aid No. DE-01650-04 of the National Institute of Dental Research, Bethesda, Maryland.

From the School of Dentistry, Department of Radiology of the Center for the Health Sciences, University of California at Los Angeles, and Saint John's Hospital Research Foundation, Santa Monica, California.

Based on a thesis submitted for the degree Doctor of Philosophy, Jikeikai University School of Medicine, Tokyo, Japan.

Early descriptions of the hyoid bone were directed toward its phylogenetic and anatomic considerations, as the alleged skeleton of the tongue and support for the larynx. Flowers[6] compared hyoid systems of man and dog from an osteologic viewpoint. Parsons[13] studied 108 specimens, taking age and sex into account in his elaborate morphologic descriptions. Kingsley[8] found variation among the vertebrates in an investigation of the musculoskeletal complex of hyoid and tongue. Neal and Rand[11] proposed that the hyoid is one of several facial structures to have evolved from the skeletal gill supports of primitive fishes. Negus[12] found greater association of hyoid and larynx in lower vertebrates, and a relationship between position of the head and hyoid-larynx posture, as did King[7] in later cephalometric roentgenographic studies of humans. Sprague[19] found that evolution of the hyoid bone was related to changes (developments) in mechanisms of breathing, swallowing, phonation, and tongue function.

In the course of his investigations of movements of the mandible, Thompson[20] noted that movements of the mandible were influential upon the position of the hyoid. As the mandible rotated during opening movements, the hyoid remained at a fixed level exhibiting only a slight movement posteriorly. Mainland[10] felt that fixation of the hyoid by certain muscles would then allow it to be a "platform" from which other sets of muscles could operate. Brodie[4] related actions of the hyoid, suprahyoid musculature, and mandible to the maintenance of an airway during mandibular movements, and called attention to the fact that the hyoid's role as a functional part of the skeletal system has been a recent evolutionary development, associated with man assuming an upright posture.

One of the main tools for studying growth and development of the living human is cephalometric roentgenography. However, a limited number of studies of the hyoid bone have been reported.[20] Both researchers and clinicians have been previously concerned with the more dramatic elements of the craniofacial complex,[16] the mandible and the maxilla. King did the initial growth study of the hyoid bone as part of his pharyngeal growth series. Durzo and Brodie[5] studied five subjects serially, ranging in age from 2 to 17 years. They found the hyoid bone to be suspended by three sets of muscles - from the base of the cranium to the hyoid bilaterally, and from the symphysis of the mandible to the hyoid. It is the relative lengths of these sets of muscles which determine the anteroposterior relation of the hyoid to the vertebral column. In the vertical dimension the hyoid occupies a fairly constant position, opposite the lower portion of the body of the third and the upper portion of the body of the fourth cervical vertebra. As growth occurs in the vertebral column, the cranial base and the mandible, the hyoid seems to maintain its same relative position. Although position of the hyoid may be influenced by mandibular or facial abnormality (growth arrest, or due to trauma), some compensation is made by the suspensory musculature, and the airway is maintained.

Bench[2] also directed his attention to the behavior of the hyoid bone. In evaluating a total sample of 165 subjects, studied both serially and cross-sectionally from ages 2 to 45 years, Bench found that the hyoid bone gradually descends from a position opposite the lower half of the third and the upper half of the fourth cervical vertebra (at age 3) to a position opposite the fourth cervical vertebra (at adulthood). Open-bite malocclusion and dental protrusions have characteristic positions and affect the behavior of the hyoid bone. Bench called for further study of tongue and hyoid behavior by the cinefluorographic technique in order to truly assess functional behavior on an individual basis.

Cephalometric roentgenography, pioneered by Broadbent,[3] was applied to the static study of the hyoid bone by Ricketts[15,24] Bench,[2] and Andersen.[1] These investigators felt the need for further study involving data of functional behavior of the hyoid. Hence a need to be able to analyze a consecutive series of standardized cephalometric roentgenographs during function was seen as the answer. In studies of mandibular function Kydd[9] used a system employing a rapid cassette changer for this purpose. In order to obtain even greater duration of time in the study of functional movements of deglutition, phonation, and respiration, the application of cephalometrics to a standardized system of cinefluorography was proposed.[17,18]

Cinefluorography has been used in the diagnosis and treatment of cardiac and cardiovascular disturbances, as well as renal functional evaluations, and has undergone many technical refinements during the past twenty years.[14] By coupling adequate stabilization of the head and maintaining a standard distance between source, subject, and pickup, standardized cinefluorographic film can be obtained. Complementary cephalometric roentgenographs can then be related to the cine-material and the resultant method of quantification, described by Sloan et al.,[17,25,29] has resulted.

Materials and Methodology

Patients with a variation in age and with similarities of skeletal morphology were chosen in order to control variables. All of the subjects were within the first standard deviation according to standard cephalometric analysis (Ricketts,[24]).

Forty-five subjects, averaging twelve

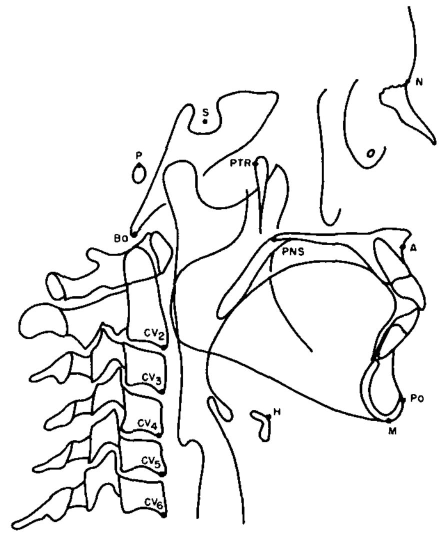

Fig. 1 Cephalometric Points (Normal): N = Nasion; junction of nasal and frontal bones, S = Sella Turcica; center of sella by inspection, P = Porion; top of ear canal by inspection, PTR = Pterygoid Root; anterior border at body of sphenoid A, = Point A; junction of alveolar bone of maxilla with anterior nasal spine, PNS = Posterior nasal spine, PO = Pogonion; anterior border of symphysis, M = Menton; lower border of symphysis, H = Hyoid; antero-superior point of body of hyoid bone, BA = Basion; anterior margin of foramen magnum, CV_2-CV_6 = Cervical Vertebrae; lower anterior border of body.

years of age, were selected. Three groups of equal number representing Class I; Class II, Division 1; and Class II, Division 2 type malocclusions were selected. There were eight males and seven females in each group. The cephalometric-cinefluorographic instrumentation and filming procedures have been reported previously.

A cinefluorographic series during deglutition and a lateral cephalometric roentgenogram were taken of each subject. The lateral cephalometric roentgenogram was traced, and static reference and registration points were identified (Figs. 1 to 3). With the patient positioned in a headholder, 60 cinefluorographic frames were filmed at a speed of 24 frames per second. Sixty

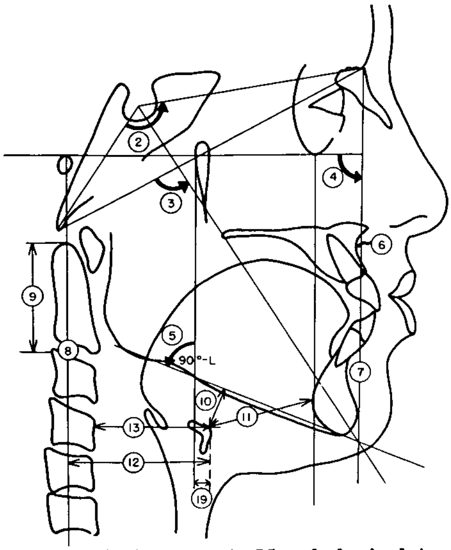

Fig. 2 Cephalometric-Morphological Analysis (Normal): 2. Cranial base, 3. X-Y Axis, 4. Facial Angle, 5. Mandibular Plane, 6. Facial Convexity, 7. Facial Height, 8. CV_5 Height, 9. Dens Height, 10. Hyoid-Mandible, 11. Hyoid-Genial Tubercle, 12. Hyoid-Porion Vertical, 13. Hyoid-Cervical Vertebrae Level, 19. Hyoid Point-Pterygoid Root Vertical.

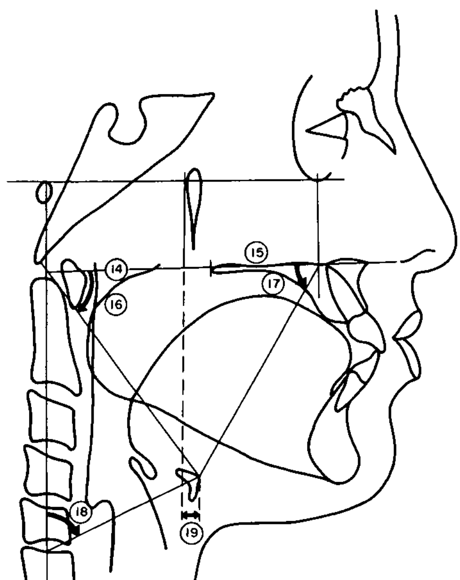

Fig. 3 Cephalometric Hyoid Analysis: 14. PNS - Porion Vertical, 15. PNS - Orbital Vertical, 16. PNS - Porion Vertical-Hyoid, 17. PNS - Orbital Vertical-Hyoid, 18. Porion Vertical-CV_4-Hyoid.

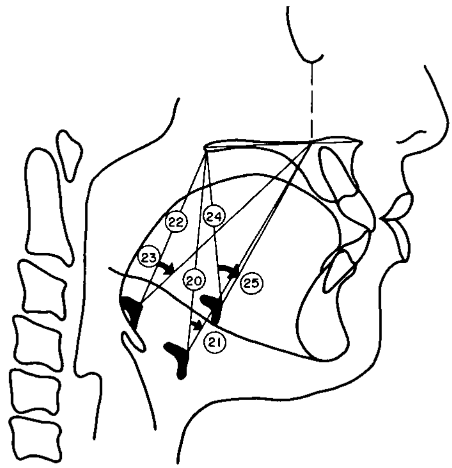

Fig. 4 Cephalometric-Cinefluorographic Hyoid Analysis; 20. Rest: PNS - Hyoid, 21 Rest: PNS - Hyoid-Orbital Vertical, 22. Posterior: PNS - Hyoid, 23. Posterior: PNS - Hyoid-Orbital Vertical, 24. Anterior: PNS - Hyoid, 25. Anterior: PNS - Hyoid-Orbital Vertical.

frames constituted a deglutition cycle. Each frame was traced from the cinefluorographic film, and the static and dynamic measurements were recorded (Fig. 4). Three deglutition cycles, involving 180 frames, were traced and reviewed by three of the investigators, in order to insure the proper magnification ratio between the static cephalometric tracings and the cinefluorographic frames. A small steel calibration rod, 5 inches in length with a 1 mm notch at each centimeter, was placed in the midline of the patient's mouth during the initial cinefluorographic filming. The Cine-analyzer system which enables the viewer to superimpose the cephalometric tracing over the selected cinefluorographic frame was used for analysis.

Functional angles and measurements were thereby corrected for size distribution and recorded from the cinefluorographic film frames using the Cine-analyzer unit. Twenty-five measurements were made for each subject and were grouped into the following categories:

(A) Age,

(B) Cranial base morphology criteria,

(C) Facial morphologic criteria,

(D) Cervical vertebrae criteria,

(E) Static hyoid criteria, and

(F) Dynamic hyoid criteria.

All findings were tabulated and statistically treated by an analysis of variance (Table I).

Results

There was no significant difference in any of the craniofacial skeletal criteria in the sample, irrespective of malocclusion (Columns 2 to 9, 14, 15, 19). However, the static and dynamic position of the hyoid bone was found to be significantly different in the three groups studied (Columns 10, 11, 16 17).

The hyoid was found to be situated more inferior and posterior to the mandible in the group of Class I malocclusions (Columns 10, 11). The greatest range of vertical position of the hyoid (low posture) during functional movements was also found in the group of Class I malocclusions. This same group also showed the most limited functional pattern of the hyoid.

The hyoid was found higher and more forward in the group with Class II malocclusions. This group exhibited

SUMMARY

N=15	1. Age (mos.)	2. Cranial Base (degrees)	3. X-Y Axis (degrees)	4. Facial Angle (degrees)	5. Mandibular Plane (degrees)	6. Facial Convexity (mm.)	7. Facial Height (mm.)	8. CV 5 Height (mm.)	9. Dens Height (mm.)	10. Hyoid-Mandible (mm.)	11. Hyoid-Genial Tubercule (mm.)	12. Hyoid-Porion Vertical (mm.)	13. Hyoid-Cervical Vertebrate Level
Class I													
Mean	144.00	128.20	1.73	86.53	26.87	3.07	115.27	108.13	36.60	16.33	35.27	37.53	3.47
S.D.	26.54	5.37	3.01	3.16	5.53	3.03	8.20	11.21	4.37	5.45	6.04	5.24	0.48
Class II - Div. 1													
Mean	130.60	130.80	1.47	85.27	26.47	4.00	117.53	108.07	36.67	10.13	30.33	40.07	3.27
S.D.	26.00	4.87	3.14	3.15	4.58	2.23	5.42	9.61	3.56	5.58	3.66	6.05	0.37
Class II - Div. 2													
Mean	157.60	129.60	2.27	85.67	23.40	2.07	116.73	113.13	37.73	12.93	32.73	41.40	3.50
S.D.	27.20	4.37	1.87	2.64	4.15	1.62	5.95	5.05	2.40	4.82	4.62	3.76	0.53
F Ratio	3.87	1.06	0.33	0.70	2.35	2.52	0.45	1.56	0.48	5.16	3.85	2.10	1.09

N=15	14. PNS-Porion Vertical (mm.)	15. PNS-Orbital Vertical (mm.)	16. PNS-Porion Vertical-Hyoid (degrees)	17. PNS-Orbital Vertical-Hyoid (degrees)	18. Porion Vertical CV 4-Hyoid (degrees)	19. Hyoid Point-Pterygoid Root Vertical (mm.)	20. REST PNS-Hyoid (mm.)	21. REST PNS-Hyoid Orbital Vertical (degrees)	22. POSTERIOR PNS-Hyoid (mm.)	23. POSTERIOR PNS-Hyoid-Orbital Vertical (degrees)	24. ANTERIOR PNS-Hyoid (mm.)	25. ANTERIOR PNS-Hyoid-Orbital Vertical (degrees)
Class I												
Mean	48.07	31.40	57.80	54.13	77.20	0.00	104.40	27.73	95.60	27.93	84.07	38.33
S.D.	2.69	3.46	4.09	5.68	11.11	5.84	14.20	3.01	18.70	3.22	14.20	5.11
Class II - Div. 1												
Mean	46.93	32.47	54.00	52.53	69.80	-0.67	106.67	28.13	100.73	28.40	88.00	37.47
S.D.	4.13	2.75	4.96	3.62	5.63	5.11	9.42	3.48	9.05	3.80	12.29	6.47
Class II - Div. 2												
Mean	45.43	32.60	54.47	57.73	74.73	0.80	114.87	26.33	109.40	26.13	96.93	34.40
S.D.	2.85	2.61	2.58	5.55	9.51	4.46	11.54	2.94	12.42	3.31	12.41	4.26
F Ratio	2.34	0.74	3.91	4.19	2.60	0.30	3.22	1.35	3.74	1.80	3.86	2.23

S.D. = Standard Deviation
D.F. = Degrees of Freedom
D.F. withing groups = 42
D.F. between groups = 2
5% Level of Significance F = 3.31

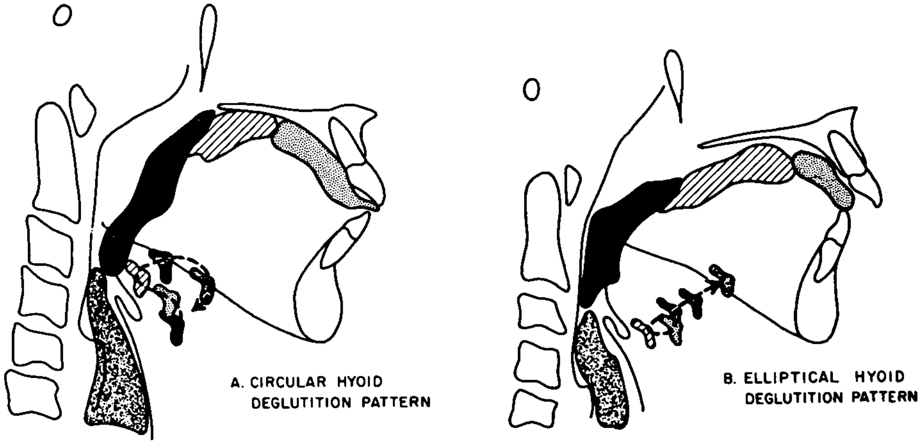

Fig. 5 Variations in Hyoid Deglutition Patterns: A. Circular hyoid deglutition pattern. B. Elliptical hyoid deglutition pattern. Graphic presentation of the two types of hyoid pattern derived from cephalometric - cinefluorographic frame-by-frame analysis of the deglutition cycle.

The black hyoid position indicates the initial or resting position of the hyoid just prior to the deglutition cycle. Each hyoid position during the deglutition cycle is shaded to match the concomitant bolus stage.

the greatest ranges of movement during deglutition (Columns 10, 11).

The hyoid was found to be in a similar anteroposterior position to the pterygoid root vertical in all three groups, as was the hyoid to cervical vertebrae relationship (Columns 19 and 13 respectively).

Two distinct hyoid movement patterns of deglutition were noted:

(A) A circular pattern of hyoid movement typified as smooth and coordinated with repetitious cycling, as visualized by the frame-by-frame analysis of the cinefluorographic films,

(B) An oblique, elliptical pattern of hyoid movement typified by an erratic, discoordinated behavior and associated with tooth-apart swallowing as visualized by the frame-by-frame cinefluorographic film analysis (Fig. 5).

Discussion

The infant must establish the two vital functions of respiration and deglutition in order to survive. Whenever these vital functions are imposed upon, compensations in morphology and physiology must occur.[27]

The infant's central nervous system mediates and integrates morphological and physiological activities. Therefore, variations in these activities require modification of the neurologic pathways. This discussion will deal mainly with variations of function during deglutition.

The short cervical area (neck) of the infant is rapidly lengthened by early normal growth and development. Hyoid function emerges during this growth period. At this stage, during deglutition, hyoid movement patterns are constantly reflecting changes in tongue and associated oral-pharyngeal musculature.

Superimposed upon these developmental changes can be the effects of upper respiratory pathologies. Chronic pharyngitis, pharyngeal and lingual adenitis, allergies, and other otolaryngeal problems modify oral muscle movements. These changes are reflected by variations in hyoid behavior.

The above discussion poses the following questions of interest to the clinician: To what degree do growth and developmental changes modify learned patterns of function? To what degree can an "abnormal" pattern of function be improved by treatment? At the present time, largely because of observational techniques, these questions cannot be answered.

How much is stability of the orthodontic result related to functional imbalances? How often are these functional imbalances themselves related to deeper structural imbalances? Can the pattern change evidenced in early thorough treatment of a severe Class II, Division 1 malocclusion cancel out relapse due to functional imbalances? How much residual functional imbalance exists after full orthodontic treatment?

These are important questions which the clinician would like to answer. We are content today to avoid these questions by saying, "There are too many variables," or "Functional imbalance cannot be measured with sufficient accuracy."

Within our lifetime, however, we will see remarkable improvements in instrumentation that will allow the sophisticated study of these problems.

In this study significant differences in functional behavior of the hyoid (reflecting tongue posture) were seen. This is important because the subjects studied were skeletally similar. This implies that any one, or combination, of the following conditions may have produced these observed functional differences:

(A) Individual modification of the primary neurologic pathways,

(B) Existence of long-standing upper respiratory pathologies,

(C) Residual motor effects related to prior upper respiratory, pathologies e.g., the adolescent mouth-breather with no current airway impingement, but an early, long-standing lymphadenopathy.

Important consideration should be given in future studies to the assessment and correlation of muscle form and function.

Recent developments have been made in electronic measurement and data processing. This should enable future studies to relate electromyographic, cinefluorographic, and other modes of clinical observation in order to provide answers to our present-day questions.

Conclusions

1. Cephalometric-cinefluorography can be used to better study and understand problems of oral physiology during growth and development.

2. Two distinct patterns of hyoid behavior which were hypothesized by the authors have been verified by actual radiologic observations and statistical evaluation.

3. In all three groups in this study the anteroposterior location of the hyoid was found consistently near the anterior root of the pterygoid plates.

4. Class I malocclusions, although exhibiting no skeletal differences from other classes of malocclusion in this study, did show significantly lower and more posterior hyoid locations (relative to the mandible), complemented by limited functional patterns.

5. Class II malocclusions, on the contrary, showed higher and more forward hyoid postures (relative to the mandible) with greater ranges of movement during deglutition.

Summary

This study has evaluated the use of cephalometric-cinefluorographic techniques in the assessment of hyoid behavior

during deglutition. It has presented a brief review of:

(A) Phylogenetic and anatomic considerations of the hyoid,

(B) Functional behavior and growth of the hyoid,

(C) Cephalometric roentgenography, and

(D) Cephalometrics and cinefluorography.

Forty-five subjects averaging twelve years of age were studied. Three groups of equal number representing Class I; Class II, Division 1; and Class II, Division 2 type malocclusions were presented. Two distinct hyoid movement patterns of deglutition were found:

(A) A circular pattern and

(B) An oblique, elliptical pattern.

U. C. L. A. Center for Health Sciences

REFERENCES

1. Andersen, W. S.: The Relationship of the Tongue-Thrust Syndrome to Maturation and Other Factors. *Amer. J. Orthodont.*, 49:264-75, 1963.
2. Bench, R. W.: Growth of the Cervical Vertebrae as Related to Tongue, Face and Denture Behavior. *Amer. J. Orthodont.*, 49:183-214, 1963.
3. Broadbent, B. H.: A New X-ray Technique and its Application to Orthodontia. *Angle Orthodont.*, 1:45-66, 1931.
4. Brodie, A. G.: *Congenital Anomalies of the Face and Associated Structures.* (ed., S. Pruzansky), Springfield, Ill., Chas. C. Thomas, 1961, pp. 251-268.
5. Durzo, C. A., and Brodie, A. G.: Growth Behavior of the Hyoid Bone. *Angle Orthodont.*, 32:193-204, 1962.
6. Flower, W. H.: *Introduction to the Osteology of the Mammalia*, 3rd ed., London, MacMillan and Co., 1885, pp. 143-145 and 158-160.
7. King, E. W.: A Roentgenographic Study of Pharyngeal Growth. *Angle Orthodont.*, 22:23-37, 1952.
8. Kingsley, J. S.: *Comparative Anatomy of Vertebrates*, Philadelphia, Blakiston and Sons, 1912, pp. 53, 73, and 101-220.
9. Kydd, W. L.: Rapid Serial Roentgenographic Cephalometry for Observing Mandibular Movements. *J. Pros. Dent.*, 8:880-886, 1958.
10. Mainland, D.: *Anatomy as a Basis for Medical and Dental Practice*, New York, Paul Hoeber and Co., 1945, p. 580.
11. Neal, H. V., and Rand, H. W.: *Comparative Anatomy*, Philadelphia, Blakiston and Sons, 1936, pp. 228-236.
12. Negus, V. E.: *The Mechanism of the Larynx*, St. Louis, Missouri, C. V. Mosby, 1930, pp. 1-25 and 18-88.
13. Parsons, F. G.: The Topography and Morphology of the Human Hyoid Bone. *J. Anat. and Physiol.* 43:279-90, 1909.
14. Ramsey, G. H. S., Watson, J. S., Jr., Tristan, T. A., Weinberg, S. and Cornwell, W. S.: *Cinefluorography*, Springfield, Ill., Chas. C. Thomas, 1961.
15. Ricketts, R. M.: *Vistas in Orthodontics*, ed., B. Kraus and R. Riedel, Philadelphia, Lea and Febiger, 1962, pp. 122-125.
16. Shelton, R. L., Jr., Bosma, J. F., and Sheets, B. V.: Tongue, Hyoid and Larynx Displacement in Swallow and Phonation. *J. Applied Physiol.*, 15:283-288, 1960.
17. Sloan, R. F., Ricketts, R. M., Bench, R. W., Hahn E., Westover, J. L., and Brummett, S. W.: The Application of Cephalometrics to Cinefluorography. *Angle Orthodont.*, 34:132-141, 1964.
18. Sloan, R. F., Ricketts, R. M., Brummett, S. W., Mulick, J. F., Bench, R. W., Ashley, F. L., and Hahn, E.: Cephalometric-Cinefluorographic Criteria Utilized in Cranio-Facial Problems. *J. So. Calif. Dental Assoc.*, 31: 355-362, 1963.
19. Sprague, J. M.: The Hyoid Region of Placental Mammals with Special Reference to the Bats. *Am. J. Anat.* 72:385-400, 1943.
20. Thompson, J. R.: A Cephalometric Study of the Movements of the Mandible. *J. A. D. A.*, 28:750-761, 1941.
21. Stepovich, M. L.: A Cephalometric Positional Study of the Hyoid Bone. *Amer. J. Orthodont.*, 51:882-900, 1965.
22. Sloan, R. F., Ricketts, R. M., Bench, R. W., Mulick, J. F., and Brummett, S. W.: The Application of Cephalometrics to Cinefluorography. II. Comparative Study of Hyoid Movement Patterns During Deglutition and Phonation in Class II Orthodontic Patients. *Amer. J. Orthodont.* (abstract). 50: 922, 1964.
23. Sloan, R. F., Brummett, S. W., Westover, J. L., Ricketts, R. M., and

Ashley, F. L.: Recent Cinefluorographic Advances in Palatopharyngeal Radiology. *Amer. J. Roentgenol.*, 92: 977-985, 1964.

24. Ricketts, R. M.: A Foundation for Cephalometric Communication. *Amer. J. Orthodont.*, 46:330-357, 1960.

25. Sloan, R. F., Ricketts, R. M., Brummett, S. W., Bench, R. W., and Westover, J. L.: Quantified Cinefluorographic Techniques Used in Oral Roentgenology. *Oral Surg.*, 20:456-463, 1965.

26. Hedges, R. B., McLean, C. D., and Thompson, F. A., Jr.: A Cinefluorographic Study of Tongue Patterns in Function. *Angle Orthodont.*, 35:253-268, 1965.

27. Bosma, J. F., Truby, H. M., and Lind, J.: Upper Respiratory Actions of the Infant. Proc. Conf. Commun. Problems in Cleft Palate. Amer. Speech and Hearing Assoc. Report no. 1 (ASHA, Washington, D. C.), 1965, pp. 35-49.

28. Hahn, E. and Sloan, R. F.: Problems in Tongue Behavior of Children. *J. So. Calif. Dental Assoc.* 34:316-327, 1966.

29. Sloan, R. F., Brummett, S. W., Westover, J. L., and Havel, T.: Diagnostic Techniques in Palatopharyngeal Cinefluorography. Proc. XI Internat. *Congr. of Radiol.*, Rome, 1965 (in press).