The Application Of Cephalometrics To Cinefluorography*

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In 1953 the development of practical x-ray image intensifiers rendered cinefluorography a versatile instrument for roentgen diagnosis, especially in the fields of cardiology, gastroenterology, and orthopedics. More recently, cinefluorographic techniques have been utilized in the fields of otolaryngology, speech pathology,[2] plastic surgery, and dentistry. However, only three per cent of the publications on cinefluorograms have been concerned with diagnostic analysis. Most of these publications were descriptive and did not quantitatively correlate selected anatomic factors and functional kinesiology. Since this paper will deal primarily with various specialties of radiology and dentistry, especially orthodontics and speech pathology, the lack of a reliable system for quantitative analysis, which would provide statistical comparisons for anatomical relationships in the oral and pharyngeal areas, is particularly evident. To date, no analytical system has been developed which would allow a line of communication between the fields of speech pathology and orthodontics when cranial, oral or pharyngeal problems, such as cleft palate and other dental abnormalities associated with speech problems, are examined.

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The application of radiological methods to the study of speech began two years after the discovery of the x-ray. Numerous historical reviews on the application of radiological methods to the speech mechanism have been published.[26]

In the fields of speech pathology and dentistry, radiologic diagnosis during the past half century has been based conventionally upon anatomic alterations revealed by static, lateral head roentgenograms. Roarda traced tongue positions during phonation of various sounds in order to aid aurally-handicapped persons to visualize speech; Barclay and Nelson and Russell demonstrated the vowel positions; and roentgenographic cephalometry has been considered a fundamental tool in orthodontics since 1931.[8] Although head roentgenograms have provided such clear and detailed structural information that measurements of the speech structures may be taken and used for analysis of craniofacial growth, they have only provided illustrations of isolated, sustained physiological acts as the structures were held immobile for the duration of exposure. For an adequate analysis of deglutition and phonation it is necessary to see these processes in motion.[1]

Cinefluorography is the roentgen method for investigating function. This technique has enabled the researcher and clinician to view the previously inaccessible oral cavity and its related pharyngeal complements. The cinefluorographic record provides these basic data: 1) motion of the structures, 2) variation in their radiographic density, and 3) chronology of the changes occurring during the functional cycle.[19]

This paper will present some fundamental requirements for the application of roentgenographic cephalometry to cinefluorography in the study of patients with orthodontic and/or speech problems.

Procedure

Eight basic steps are necessary to the correlation of cephalometric analysis of cinefluorographic craniopharyngeal films.

I. *Cephalogram Evaluation*
- A. Cephalometric head films
  1. Physiological rest
  2. Occlusion
  3. Phonation
  4. Deglutition.
- B. Magnification ratio established between actual cranial size and x-ray film image.
- C. Establishment of basic anatomical landmarks.
- D. Cephalometric tracing analysis of x-ray films (Chart I briefly summarizes the cephalometric system procedure).

II. *Cinefluorographic Evaluation*
- A. Cinefluorographic filming.
  1. Physiological rest
  2. Occlusion
  3. Deglutition
  4. Phonation
- B. Magnification ratio established between actual cranial size and x-ray film image.
- C. Magnification ratio established between cephalometric image x-ray film size and cinefluorographic image x-ray film size.

III. *Cephalometric-cinefluorographic frame-by-frame analysis* (Figs. 6-11 illustrate the present system).

Name of Angle	Mean	S.D.	Range	PLANES	POINTS	Diagnostic Significance
Cranial Base	130°			Basion-Sella: Sella-Nasion	Basion-Sella Sella-Nasion	Obtuse - Deep Nasopharynx Forward Maxilla Acute - Narrow Nasopharynx
Facial	85°	4.0	74°-96°	Frankfort: Facial	Top Porion to Orbital-Nasion to Pogonion	Indicator of Facial Depth: 80°-Retrognathic; 85°-Mesognathic; 90°-Prognathic
X - Y Axis	93°	3.0	78 - 119	X Axis: Y Axis	Basion to Nasion Sella to Chin	Indicator of Facial Height: 90° or less-Dolicocephalic; 93°-Mesocephalic; 96°-Brachycephalic
Frankfort Mandibular Plane	26°	6.0	11°-46°	Frankfort: Mandibular	Top Porion to Orbital-Gonion to Menton	Generalized Interpretation for Width and Depth; Smaller Angle More Depth
Facial Plane-Y Axis Plane	35°			Nasion-Pogonion: Sella-Chin	Same as Planes	Indicator of Anterior Cranial Base Length
Basion-Sella-PNS	61°		52°-69°	Basion-Sella: Sella-PNS	Same as Planes	Indicates Depth of Nasopharynx; Dissect Measurement of PNS to AA has Mean of 42

Chart I. Cephalometric System

I. CEPHALOMETRIC CONSIDERATIONS

The demonstration by Krogman[13] of the similarities between the craniometry of primates and humans and the presentation by Broadbent[8] of the ontogenetic development of occlusion in diagrammatic form of a facial skeleton are considered the fundamental publications which established clinical cephalometry as a tool of dentistry. Prior to 1931, orthodontists were primarily concerned with the description, definition, and classification of malocclusion for etiologic and diagnostic purposes. The relationship of the tooth-bearing organs (maxilla and mandible) to the entire face, concerned primarily with anthropological fields, established the beginnings of dentofacial orthopedics. The numerous diagnostic systems which developed from the two basic works of Krogman and Broadbent are excellently reviewed by Sassouni.[22]

The cephalometric equipment used by the authors was previously described.[20] The following procedure was employed in our initial studies. The patient, seated upright in a chair fitted with rollers, was positioned until the external auditory canals were brought into approximation with the ear-rods. The ear-rods were then inserted, and the patient was lowered until the ear-rods snugly fitted the tops of the canals. No orbital registration or nasion rest was employed since tipping of the head to the anthropometric horizontal position is believed to influence the behavior of the hyoid bone. Roentgenograms were taken during physiological rest, occlusion (lips together, teeth clenched), phonation (of a vowel), and deglutition (swallowing barium when the hyoid complex is in superior aspect). The radiolucent ear-rod assemblies did not obscure the basic cranial structure. Therefore, the external auditory meatus, which was traced directly from the films rather than by employing the ear-rod as a point of registration, was clearly seen.

The magnification ratio between actual cranial size and the image on the films corresponds to Franklin's studies.[10] The following basic anatomical landmarks (Fig. 1) and corresponding lines, planes (Fig. 2), and angles (Fig. 3) were located and plotted.

Points:

N = Nasion
Ba = Basion
S = Sella
P = Porion, superior aspect of ear canal
PTR = Pterygoid root; anterior border of pterygoid plate at body of sphenoid
O = Orbitale, inferior aspect of orbit
PNS = Posterior nasal spine
Point A = Junction of alveolar bone of maxilla with anterior nasal spine
T = Dorsum of tongue at intersection of PTM vertical
MN = Mandibular border at intersection of PTR vertical
Go = Gonion
Po = Pogonion
M = Menton
H = Anterosuperior aspect on body of hyoid bone
CV_2, CV_3, CV_4, CV_5, = Cervical vertebrae

Planes:

P-O = Frankfort horizontal
Porion vertical = Perpendicular to Frankfort through porion
PTR vertical = Perpendicular to Frankfort through PTR
Orbital vertical = Perpendicular to Frankfort through orbitale

Mandibular plane = Border of mandible to lower border of symphysis

Y axis = SGN, X axis = BaN

Our initial angle and measurement patterns are illustrated in Fig. 4. Numerous other sources are available for different systems of analysis.[21]

The main purpose of the tracing analysis is the accurate location of the desired craniopharyngeal landmarks so that they can be superimposed on the identical anatomical landmark on each

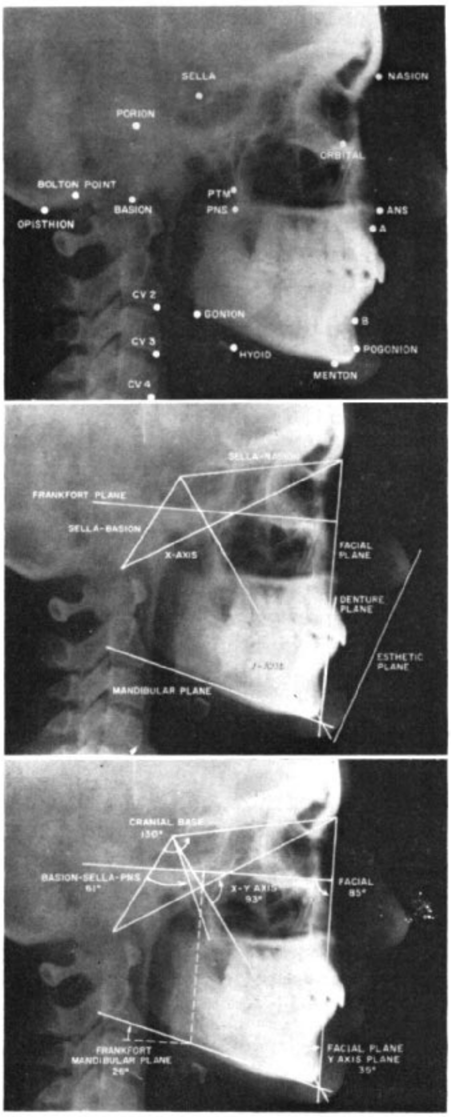


Figure 1. Basic anatomical landmarks
Figure 2. Planes
Figure 3. Angles

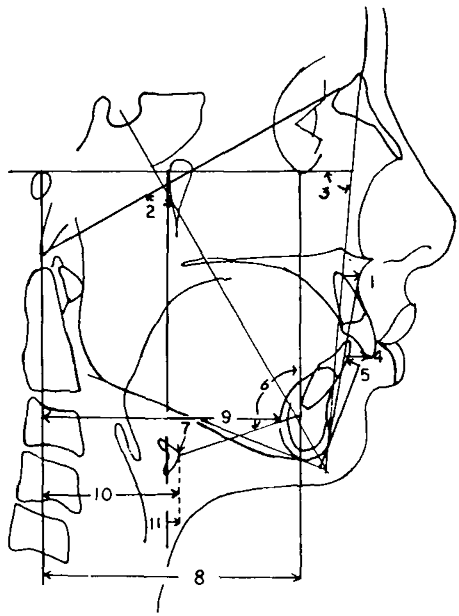


Figure 4. Standard cephalometric analysis and horizontal measurements between the hyoid bone and vertical planes.

Facial and Denture Measurements

1. A to facial plane (convexity)
2. XY axis angle (crossing of Y axis to BaN)
3. Facial angle
4. $\frac{1}{1}$ to APo plane
5. $\overline{1}$ to perpendicular to mandibular plane (distance of tip of lower incisors to perpendicular through pogonion from mandibular plane

Hyoid Measurements

6. HG (line from hyoid to genial point)
7. H to Mpl (perpendicular from mandibular plane to H)

Horizontal Measurements

8. P to O
9. P to G
10. P to H
11. H to O (No. 8 — No. 10)
12. H to PTR

frame of the cinefluorographic film. Cephalometric-cinefluorographic superimposed references are those anatomical references which are considered most stable and immobile during physiological activity such as swallowing; some of these references might be S, PNS, and PTR. In orthodontics, planes of superimposition are used to evaluate 1) changes of facial growth in the same individual, 2) progress in treatment, and 3) comparison with standard tracings. Average tracings of groups of children of the same age and with normal occlusion are available. They are referred to as Cephalometric Standard Tracings (C.S.T.). The tracings of the film of a given child can be superimposed on the C.S.T. of the same age groups.[22]

II. CINEFLUOROGRAPHIC CONSIDERATIONS

The publication by Ramsey, et al.,[19] on the historical background and basic consideration of cinefluorographic methodology serves as an excellent reference source.

Our initial studies were filmed using a 9 inch General Electric Fluoricon image intensifier with a 16 mm cinecamera and a 9 inch Philips intensifier with a 35 mm photosonics camera. Patient positioning, film procedure, deglutition and phonation procedures have been described.[1,2]

To date, accurate magnification ratios between actual cranial size and the cinefluorographic film image have not been completed or published by other investigators. The following factors account for this deficiency: 1) numerous changes in equipment, film type, and processing methods; 2) wide variation in the size and other physical characteristics of the patient; and 3) lack of standardization in patient-to-patient film distances due to a wide range of modification in equipment.

III. CEPHALOMETRIC-CINEFLUOROGRAPHIC ANALYSIS

Our initial impetus for the application of cephalometry to cinefluorography came from a number of disciplines. Pediatrics, radiology,[24] surgery,[6] dentistry, and speech pathology have all used basic anatomical landmarks and systems of linear measurement to study growth and treatment. An examination of these systems when complemented by a number of metric-grid plotting scales suggested the advantages of developing a procedure which would allow these disciplines to compare clinical data using the same system of mensural analysis.

Vastine and Kinney[27] established the normal variations in the position of the pineal body in relation to the margins of the cranium. Using lateral films of several hundred normal persons, they measured the distance from the inner table of the frontal bone to the pineal body and plotted this measurement against the interoposterior dimension of the cranium. They also established the normal zone for the pineal body in relation to the vertex and base by plotting the distance from the inner table of the vault to the pineal body against the dimension of the vertex-base line. Retzius devised a cephalic index to classify the many varied skull shapes.

Shapiro and Janzen[24] reported that the normal basal angle (line from nasion to the center of the sella turcica) was from 121 to 152 degrees with an average of 135 degrees. Chamberlain's line (drawn from the dorsal lip of the foramen magnum to the dorsal margin of the hard palate) developed from an article on platybasia.[9] Prior publications by Shüller[25] and Boogaard[7] were fundamental to Chamberlain's line.

Many other variations and modifications stemmed from Chamberlain's line. Saunders[23] measured from the tip of the odontoid and found a significant, normal variation to Chamberlain's work. McGregor's modification is a line from the dorsal surface of the posterior margin of the hard palate to the most caudal point of the occipital curve.[16] Bull's angle is measured between the plane of the atlas and the hard palate. Boogaard's angle,[7] Klaus' height index,[12] and other specialized systems of cranial mensuration have been developed to document particular aspects of cranial radiology.

Merkel[17] reported that the distance between the posterior border of the vomer and the pharyngeal tubercle of the basioccipital bone remained relatively constant from infancy to adulthood. Piersol[18] and Lederer[14] supported Merkel's findings. McCarthy[15] reported that the nasopharyngeal space is altered by the morphology of the anterior tubercle of the atlas.

The roentgenographic study of pharyngeal growth by King[11] established that the growth of the pharynx is preponderantly vertical, rapid during infancy, but diminishing throughout childhood and late adolescence. King employed a strictly linear system of selected planes.

The systems of analysis used in speech pathology are also primarily linear methods based on soft tissue, e.g., the extent of velopharyngeal contact is measured by the changes in the uvula-soft palate to superior constrictor distances.[5]

The Boscar system,[4] which is used to analyze the movements of the temporomandibular joint, is a sophisticated improvement of the presently available systems. Single cinefluorographic frames appear on a large screen and by digital manipulation, two cross-hairs are positioned on the specific point to be plotted. A reference line is then constructed on the face of the Boscar, tangent to the shadow of the ball-bearing and the superior border of the external auditory canal. This tangent serves as an orienting mark. On all readings of succeeding frames, the tangent line is superimposed on the reference line of the Boscar. The center of the shadow of the ball-bearing is chosen as the center of the coordinate system. When the cross-hairs are positioned over the selected point, a beam of light activates an IBM punch-card machine, and the X and Y coordinates of the point (with reference to the center of the ball) are punched, and their numerical equivalent is typed simultaneously on another paper. X and Y readings are carried out in this manner for light preselected points around the condyle in each frame. At the present time, this system, in conjunction with preselected cephalometric landmarks, is under study in order to develop a more rapid system of frame-by-frame film analysis for all of the disciplines concerned.

The technique employed in the present study consists of four phases: 1) selection of subjects, 2) cephalometric tracing analysis, 3) cinefluorographic filming during deglutition and phonation, and 4) cinefluorographic tracing analysis. Twenty of five hundred orthodontic patients were selected on the basis of the following morphological criteria obtained from cephalometric tracing of each patient: 1) cranial base, 2) X-Y axis, 3) facial angle, 4) facial convexity, 5) mandibular plane, 6) hyoid position, and 7) cervical vertebrae position.

Cinefluorographic films of each subject were taken during deglutition (three swallows of barium microtrast) and phonation (vowels: [i], [a], [u]). In order to insure the proper magnification ratio between the cephalometric tracings of the still x-ray films and the cinefluorographic x-ray frames, a small steel rod, 5 inches in length with a 1 mm notch every centimeter, was placed in the midline of the mouth during the initial cinefluorographic filming. A Ralke Cine-Analyzer projector, Model 710, which enables the viewer to superimpose the cephalometric tracing over the selected cinefluorographic frame, was used for analysis of the films. Magnification ratios were adjusted for each subject by comparing the enlargement size of the previously-mentioned steel rod to its actual size, and tracing accuracy was maintained by head-holder registration, frame counter, and the superimposed 1 mm grid scale. Figs. 6 through 11 illustrate this present system of analysis. A comparative analysis of hyoid movement patterns during deglutition and phonation is now in progress. The analysis is based on one recently presented by Bench.[3]

Conclusions

It is evident that our present-day descriptive analysis of cinefluorographic

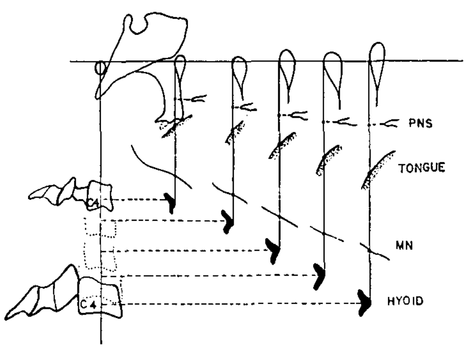
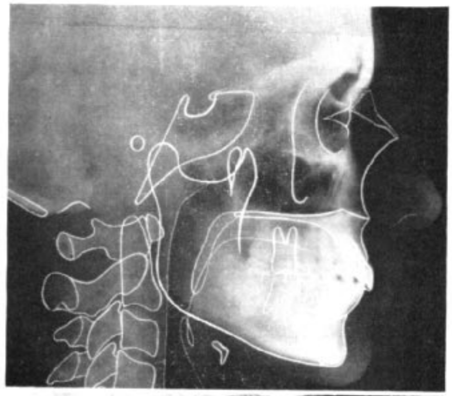
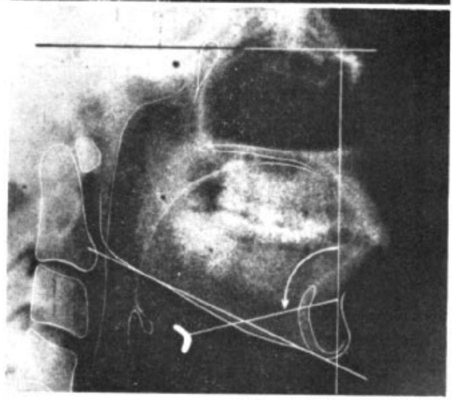


Figure 5. Growth of the cervical vertebrae as related to behavior of hyoid, tongue, and denture. The vertical growth of the fourth cervical vertebrae in various age groups (I. 3-6 years; II. 7-12 years; III. 12-19 years; IV. adults) was compared with the descent of the hyoid bone, mandibular border, tongue, and posterior nasal spine.

The hyoid bone remained relatively stable to the cervical vertebrae but moved away from the border of the mandible; however, all areas displayed a consistent vertical increase.





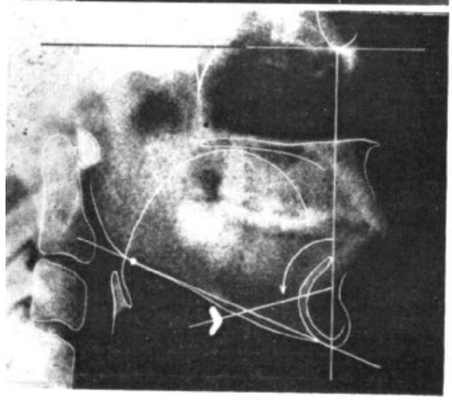
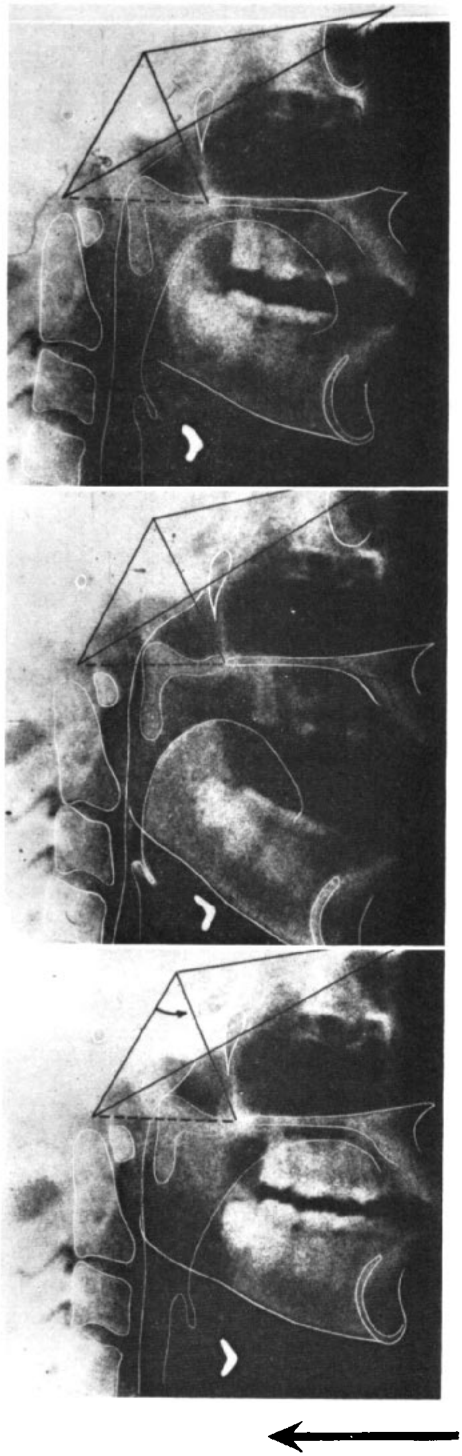


Figure 6. Initial cephalometric tracing

Figure 7. Cephalometric-Cinefluorographic Tracing Analysis (CCTA) of hyoid at rest, and tongue position.

Figure 8. CCTA of the hyoid movement to its most superior-anterior position during the initial stages of deglutition.



films is rapidly becoming outdated and that a quantitative system of analysis is greatly needed. Such a system should take into account the following variables:

1. *Flexibility:* Allowance for constant improvements and changes of equipment and film.

2. *Usage of head-holders:* In our experience, patients with craniofacial anomalies show marked variation in patterns of deglutition and phonation. The use of the head-holder restricts the patient's compensatory behavior.

3. *Standard lateral head films:* At the present time the authors recommend that the cinefluorographic film be complemented by routine cephalometric head roentgenograms.

4. *Establishment of statistical averages:* Volumes of statistical data from each discipline which has utilized a system of analysis are available in the literature. This information, concomitant with the presently collected data, should be correlated to establish a reference baseline.

5. *Improvement:* Above all, the basic system should also be sufficiently flexible to allow for procedural and statistical changes as they occur through refinements of these and other variables.

The fundamental principles of the application of cephalometry to cinefluorography have taken the above variables into consideration. By adapting these principles, an interdisciplinary channel of communication can be

Figure 9. CCTA of soft palate and posterior pharyngeal wall activity during the phonation of the vowel [u] "oo". Dotted lines drawn from PNS to Ba. Solid lines indicated cranial base angular measurements.

Figure 10. CCTA during phonation of the vowel [a] "ah". Other measurements similar to Figure 9.

Figure 11. CCTA during phonation of the vowel [i] "ee".

established, and meaningful quantitative information concerning functional anatomical relationships, as well as localized pathologies, can provide valuable diagnostic data for the analysis of patients with normal and abnormal patterns of craniopharyngeal growth.

SUMMARY

A review of selected publications concerning radiographic analysis of craniopharyngeal relationships is presented.

Eight fundamental steps are outlined in order to apply cephalometry to cinefluorographic studies of the region of the head and neck. The basic principles of the procedure are illustrated and previous systems of analysis are discussed.

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