EIGHTEEN YEARS OF RESEARCH AT ILLINOIS (Cont.)

After this work had been undertaken and the first curves had been drawn our interest in the third plane, the frontal, was awakened once more. We had long sought a method that would permit a quantitative examination of the frontal film and several students had struggled with the problem to no avail. A member of last year's class, Dr. Brader, decided to attempt it again and accordingly sought permission to use the laminagraph in the Department of Roentgenology. This was readily granted and the study that resulted was entitled:

The Applciation of the Principles of Cephalometric Laminagraphy to Studies of the Frontal Planes of the Human Head

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The fundamental objectives of this investigation were threefold: (1) to demonstrate the practicality of the recently developed laminagraphic method of roentgenography in projecting on x-ray film certain cranial and facial planes of interest to the student of human growth; (2) to demonstrate the accuracy of this technique by comparing measurements of certain dental structures in laminagraphic projection with identical measurements taken directly upon dental casts; (3) to so standardize exposure technique and head positioning as to permit the direct super-positioning of subsequent film (or their tracings) as an essential to future longitudinal investigations on growth in the frontal planes.

Cephalometric roentgenography was introduced in 1922 by Pacini in a thesis entitled, "Roentgen Ray Anthropometry of the Skull", for which work he was awarded the Leonard Research Prize by the American Roentgen Ray Society. His was the initial impetus to an adaptation of, and modification upon, then existing anthropometric techniques. Pacini recorded a technique for producing and accurately measuring the anatomical structures of both the dried skull and the living human head in roentgenographic projection on lateral headplates. It was he who first observed the limitations of the cephalometric roentgenogram in anteroposterior projection (frontal headplate).

It remained for Broadbent ('31) to apply similar techniques to growth investigations. Broadbent devised the Broadbent-Bolton cephalometer, which instrument first permitted standardization of fixation and orientation and made possible the superpositioning of consecutive headplates (or their tracings). In this manner it was possible to conduct longitudinal roentgenographic investigations on growth and development of the heads of living individuals.

Adams tested and published ('40) a method whereby projected scales permitted direct absolute measurements on cephalometric x-rays. Wylie and Elsasser ('47) designed and constructed an instrument termed a "compensator" which also permitted direct absolute measurements upon cephalometric x-rays. The utilization of such measuring devices vastly facilitates the mensuration chore involved in cephalometric investigations.

Significant longitudinal investigations upon human growth and development and upon changes incident to orthodontic treatment have been conducted upon cephalometric roentgenograms in lateral projection as prepared with the Broadbent-Bolton cephalometer and according to standardized techniques. Significant is the paucity of investigation utilizing frontal headplates, attesting to the inadequacy of these films for such purposes.

In an effort to make the frontal view available for cephalometric studies it was decided to examine the possibilities of laminagraphic projection. Laminagraphy permits projection, on x-ray film, of any selected plane of a body to the exclusion of all other planes. "The fundamental principle (of the laminagraph) is that the tube (target or anode) and film move during exposure in such a manner that the roentgenographic shadow of a selected plane remains stationary on the moving film (building up an image) while the shadows of all other planes have a relative displacement upon the film, and are therefore blurred in varying amounts depending on the distance of such planes from the one selected". Hence, the laminagram makes possible the visualization of certain anatomical structures or pathological lesions which are not susceptible to clear projection by any other method. The laminagraph is, in effect, a mechanical focusing device which allows the operator to reproduce radiographically and to visualize the various strata of a body much in the manner of the microscope.

Bocage ('22) first published information relative to body-section roentgenography. Vallebona ('30) devised and was the first to utilize a successful apparatus. Ziedes des Plantes ('30) independently devised apparatus embodying one principle set forth by Bocage. Bartelink ('32) improved Vallebona's method. Grossman ('35) introduced tomography.

Laminagraphy, applied in combination with the techniques of cephalometric roentgenography, comprised the basic method of this investigation. Standardization of exposures necessitated requirements of methodology which may be summarized as follows:

(1) Constancy of source of x-rays in the size and nature of target.
(2) Constancy of position of the head in relation to the source of x-rays, which implies:
    (a) Employment of a headholding device which must maintain constancy of position in relation to the source of x-rays, and,
    b. Constancy of position of the head in relation to the headholding device.
(3) Constancy of distance of target to film
(4) Constancy of distance between target, film and plane of focus (focal plane). This particular requisite is unique to laminagraphy.
(5) Utilization of a projected metric scale.

The laminagraph employed herein is a device which was designed by Jean Kieffer and was constructed by the Kelley-Koett Manufacturing Company, Inc., of Covington, Kentucky. It is equipped with a Machlett, AC-Type, shockproof tube which is energized by standard equipment. This double-focus tube permits use of either small (1.5mm) or the larger (3.5mm) focal spot. In this work emphasis on detail in the finished laminagram necessitated employment of the small (1.5mm) focal spot.

FIG. 1. Conventional frontal cephalometric roentgenogram taken on Broadbent-Bolton apparatus.

FIG. 2. Frontal laminagram through first molar area of same individual.

A headholding device was utilized to permit the localization of a projected plane in such manner that repetition of exposure yielded headplates which were strictly comparable in orientation and magnification. The device employed in this work is an instrument similar to the Broadbent-Bolton cephalometer, without x-ray equipment; it was constructed to be used with the patient in a horizontal position on the table of the laminagraph. The self-centering earpost portion was designed and constructed by Drs. Tirk and Thurow and was modified by the author for adaptation to the available laminagraph.

A metal, metric projection scale, adjustable to a vertical, plastic metric scale was designed and constructed by the author; in use, it was set at the level of the selected plane of focus as measured in millimeters above the surface of the laminagraph table. The image of this metal scale was projected on each film and served a double purpose: (1) to permit direct absolute mensuration of the images of the anatomical structures *in focus,* and, (2) to check upon the accuracy of the lamingraph setting which determined the level of the plane in focus. Thus, if the projected scale image was not sharply rendered on the film it was assumed that the projected anatomical plane was not the one selected, and conversely.

Similar types of films and screens were employed throughout this investigation. The patient material comprisd the following: (1) one congenitally malformed infant (7 months); (2) ten normal adults; (3) one adult cleft palate patient.

A soft (2H) pencil was used to mark the position of the left orbitale directly on the face of the patient. The patient was then oriented in prone position on the laminagraph table surface in such manner that all pro-

jected planes were oriented perpendicular to the Frankfort Horizontal Plane.

The patient was requested to arrest breathing during the time required for each exposure. Infants required sedation; Seconal was the sedative of choice employed in this investigation.

The first planes exposed were selected at random levels in order to ascertain those which could be most efficiently projected and would, at the same time, reveal the greatest number of anatomical structures deemed interesting for this and subsequent investigations. Subsequently, arbitrary exposures were made consecutively at one centimeter intervals above the surface of the laminagraph table top. Adequate adjustment was provided by the machine to permit the projection of the plane of any selected level.

Figures 1 and 2 illustrate the comparison between a conventional frontal headplate and a frontal laminagram of the same individual projected at the level of the maxillary first permanent molars.

It was decided to determine the accuracy with which images in laminagraphic projection might be measured. By projecting the image of the metal scale on each film from the level of the focal plane the labor of individual calculation for each measurement was saved. Certain measurements were made upon the teeth on a series of laminagrams of an individual utilizing the projected scale. Similar measurements were then taken directly upon the dental casts of the same individual. A comparison of these recorded measurements revealed that discrepancies were of the order of 1.0 mm and resided within practical limitations.

The following conclusions appear justifiable as a result of this investigation.

1. The production of cephalometric laminagrams is a practical method of visualization of the anatomical structures of the skull in frontal projections. The method permits accurate determination of the configuration and dimensions of structures which are obscure by conventional methods. See figures 1 and 2.
2. The preliminary tests to determine the accuracy with which images in laminagraphic projection may be measured indicate that such measurements lie within the limitations of scientific accuracy; i. e., within 1.0 millimeters of direct measurements.
3. In application with the accepted principles of standardized exposure techniques employed in cephalometric roentgenography, laminagraphy, by inference, may be utilized to meet the specifications of exposure technique requisite to the undertaking of longitudinal investigations.
4. Cephalometric laminagraphy may well provide the student of human growth with a new tool with which to approach his problems of growth and development.

Initial inspection of laminagraph exposures imparts a feeling of distrust of the accuracy of the projected images because many structures on the overall film appear blurred. It must constantly be borne in mind while viewing laminagrams that only those structures lying in the projected plane are sharply rendered while structures in approximating planes are *deliberately blurred* images. The blurred images on the remainder of the film are purposely out of focus; they may be visualized only by alterations of the focal plane and exposure made at the levels of the skull at which these structures are located.

It would appear that the techniques of cephalometric laminagraphy meet the requirements for longitudinal investigations on changes in skull anatomy; such studies demand that images in roentgenographic projection be susceptible to measurement within the limitations of scientific accuracy and that exposure technique be standardized to permit the superpositioning of subsequent films or their tracings. The critical tests herein conducted to determine the accuracy of measurements made upon images in laminagraphic projection revealed that the discrepancies existing between film and actual measurements were of the order of 1.0 millimeters. They were random in nature; film measurements sometimes exceeded actual measurements and sometimes were less than actual measurements. Furthermore, the same measurements repeated at subsequent intervals were found to vary within the same extremes suggesting that the error inherent in the operator exceeded that in methodology.

Subsequent films showing the same focal plane of the same individual indicate that superpositioning is permissible within the tolerance inherent to conventional cephalometric roentgenography.

The major problem involved in longitudinal studies on frontal planes is posed by the anteroposterior growth of the head forward of the meati of the ears. This growth would result in a gradual increase in the distance between the films and the earpost level. Growth studies would be possible only if the successive films represented the same anatomical plane.

I am indebted to Allan G. Brodie for the suggestion that the original focal plane be used throughout the entire range of investigation on any individual and that the frontal plane of choice would be that which passes through the pterygomaxillary fissure and the coronal suture. Both of these are readily discernible on a correctly oriented lateral headplate and the distance of the plane anterior to that of the auditory meati (porion) can be measured. Thus it would be necessary only to allow for complete growth when establishing the original focal plane. Longitudinal studies will be necessary to substantiate this procedure.

Although present laminagraphic apparatus is relatively recent in design, it would appear that the possibilities of application are extensive for the advancement of scientific knowledge.

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