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ON THE RELATIONSHIPS BETWEEN ROENTGENOLOGIC-CEPHALOMERTIC LINES OF REFERENCE

by

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In the roentgenological cephalometry investigators have employed several lines of reference, corresponding mostly to the planes of orientation in craniometry and cephalometry (*Krogman* 1951). The most common of these lines is undoubtedly the Frankfurt line, porion-orbitale, which is derived from the Frankfurt plane. This plane was defined at the anthropological congress in Frankfurt am Main, 1882. The definitions for the Frankfurt line as employed in the roentgenological studies vary, however, and do not always correspond to the anthropometrical definition. Other more or less generally used lines of reference include the NS-line, nasion-sella turcica (*Brodie* 1941, *Björk* 1947), the Bolton line, nasion-Bolton point (*Broadbent* 1937), nasion-basion line (*Welcker* 1868, *Lindegård* 1951), nasion-opisthion line (cf. *Beltrami et al.* 1952), and the His' line, acanthion-opisthion (*His* 1864, *Koski* 1953). These lines are clearly and singularly defined.

It is our purpose in this paper to study the angular relationships of the lines of reference mentioned, special emphasis being given to the variability of the relationships.

MATERIAL AND METHODS

The material consists of 100 lateral roentgenograms of the head, taken of adults (dental students) in connection with a comprehensive anthropological study. Both sexes are equally

represented in this sample. There was no selection of the basic material other than that it consisted of dental students. The sample for this study was collected from the files in chronological order according to the date of roentgenographing.

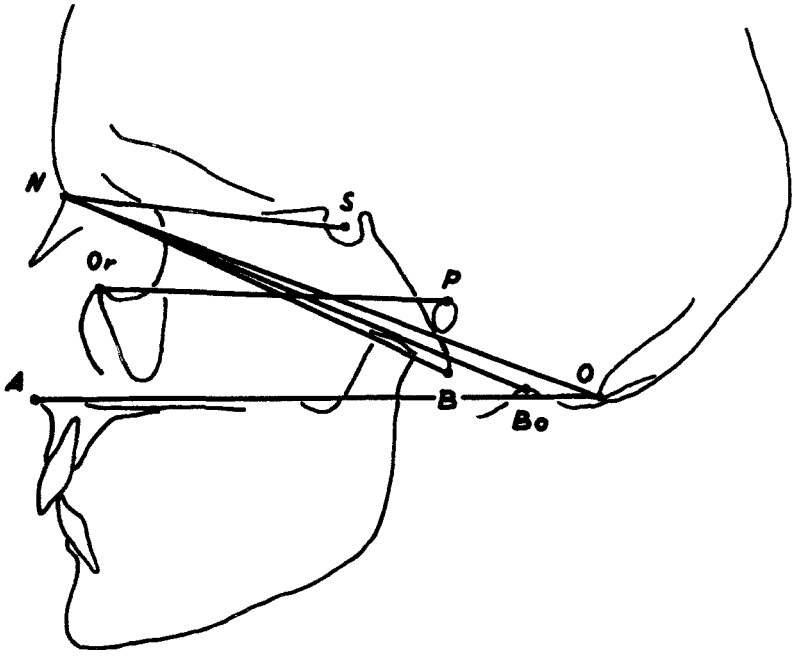

Fig. 1.

The points of measurement were as follows (Fig. 1):

acanthion (A), basion (B), nasion (N), opisthion (O), as defined by the authors (1953);

sella turcica (S), as defined by *Björk* (1947);

Bolton point (Bo), as defined by *Broadbent* (1937);

orbitale (Or), defined for this study as the point at which the shadow line of the floor of the orbit, the ventral shadow line of the zygomatic process of the maxilla, and the shadow line of the ventral wall of the maxilla meet. There is usually a clearly visible triangle-shaped shadow in the roentgenograms at the

ventral end of the floor of the orbit, and the measurement point is the most ventral and cranial point of this shadow;

porion (P), defined for this study as the highest point of the usually ovoid vertical shadow of the porus acusticus externus.

In order to see which point in the roentgenograms coincides most closely with the anthropological orbitale point (the lowest point of the infraorbital bony margin), we took experimental roentgenograms of several persons using a pointed wire to mark the anthropological point. We thus came to the conclusion that the point defined above is the nearest equivalent point to the cranio(cephalo)metric orbitale point.

Porion is generally taken as the highest point of the shadow of the ear plugs of the cephalostat. It is clear, however, that the position of the plugs may vary in the meatus acusticus externus, no matter how carefully the investigator works. Furthermore, this definition of porion does not concern the bony structures, as do all the other definitions of the measurement points. We therefore chose the definition mentioned above. It must be admitted that even then the point porion is not an entirely satisfactory one: the oval shadow visible in the roentgenogram may be a cross-section of some inner part of the meatus, and the exact location of the point is impossible to determine. We feel, however, that the deviations from the real craniometric point are not greater within our method than they are within other methods presented in the literature.

In cases where a double shadow was seen, the measurement point was taken as the midpoint between the two visible points.

The measurements were performed directly on the films. The distances between the measurement points — these measurements were used for checking the reliability of the points only — were measured with an anthropometric sliding caliper having sharply pointed sliding arms, the unit of measurement being 1.0 mm. The angles between the lines of reference were measured with a specially made protractor, the unit of measurement being 0.5 degrees (*Koski* 1953). On the films only the angles between the *His'* line and each one of the other lines were measured. The angles between the other lines were calculated from the figures obtained.

The systematic error of the measurement was studied using double measurements. The results are given in Table 1.

Table 1

Mean differences and standard deviations of the mean differences, in millimeters and degrees, obtained by the two investigators for 20 double determinations of linear and angular measurements (seen in Fig 1).

Measurements Linear	$\bar{x}$	$s_{\bar{x}}$	Measurements Angular	$\bar{x}$	$s_{\bar{x}}$
O–A[1]	– 0.10	0.16	N–O/O–A	+ 0.03	0.03
N–O[1]	– 0.15	0.18	N–Bo/O–A	+ 0.05	0.16
N–Bo	+ 0.75[2]	0.33	N–B/O–A	– 0.08	0.08
N–B[1]	– 0.10	0.20	N–S/O–A	– 0.23	0.11
N–S	0.50	0.31	P–Or/O–A	+ 0.25	0.18
P–Or	– 0.60[2]	0.28			

[1] From *Koski & Virolainen* (1953)

[2] Significant at the level P = 0.05 (t = 2.093)

The systematic error was not considered significant except for two linear measurements, nasion-Bolton point and porion-orbitale. *Björk* (1947) has already noted that porion (his definition of the point differed from ours) and Bolton point are unreliable points for roentgenologic-cephalometric studies, and our results seem to confirm this.

Because both the Frankfurt and Bolton lines are still frequently used in roentgenological cephalometry, we included them in this study, in spite of their inferiority in the said respect. In order to eliminate the systematic error as far as possible we determined all the points in all the films together, and then measured half of the material each.

RESULTS

The numerical results are given in Table 2. In the first column the means are given. Then follow the variance, the standard deviation, the standard deviation of the mean, the range, and the rank figure of the variance.

Table 2

The means, variances, standard deviations, standard deviations of the mean, and the ranges of the angles between the lines of reference, in degrees, and the rank figures of the variances.

Angle	$\bar{x}$	s_x^2	s_x	$s_{\bar{x}}$	Range	Rank
O–A/N–O	21.65	1.598	1.26	0.13	19.0— 25.0	3
O–A/N–Bo	24.45	2.336	1.53	0.15	20.0— 28.0	5
O–A/N–B	26.64	3.018	1.74	0.17	22.5— 32.0	6
O–A/N–S	7.56	4.729	2.18	0.22	2.0— 15.0	10
O–A/P–Or	0.81	4.779	2.19	0.22	– 3.5 – +5.5	11
N–O/N–Bo	2.80	0.737	0.86	0.09	0 — 5.0	1
N–O/N–B	4.99	1.982	1.41	0.14	0.5 – 8.5	4
N–O/N–S	14.12	4.410	2.10	0.21	8.5— 19.5	9
N–O/P–Or	20.88	5.175	2.28	0.23	16.0— 28.0	12
N–Bo/N–B	2.19	1.301	1.14	0.11	– 1.5— +5.0	2
N–Bo/N–S	16.92	3.756	1.94	0.19	12.5— 20.5	8
N–Bo/P–Or	23.64	5.230	2.29	0.23	18.0— 29.5	13
N–B/N–S	19.11	3.026	1.74	0.17	15.0— 23.0	7
N–B/P–Or	25.83	5.943	2.44	0.24	21.0— 31.5	14
N–S/P–Or	6.75	6.604	2.57	0.26	0.5— 12.0	15

All the statistical characteristics were first calculated for both sexes separately, but as the sex differences were found to be insignificant, the figures in Table 2 refer to the total material, 100 cephalograms.

DISCUSSION

When comparing the variability of different angles between the various lines of reference, we have chosen the variance for criterion. It is rather difficult to compare angles like those studied here, and three things may especially affect the accuracy of measurement and, consequently, the results, namely the differences in the magnitude of the angles, the differences in lengths of the lines of reference, i.e., the sides of the angles, and the fact that some of the lines do not intersect each other within practical limits of measuring, that is, on the film area. The last factor can be overcome by employing the geometrical postulate regarding the equivalence of such angles, of which the corresponding sides are parallel to each other, and that was done

here. All the results should, however, be looked upon with some caution.

The range of different angles varies considerably, and it seems only natural, that the variation is smaller in the case of the angles between lines close to each other.

In order to get some idea of the rank of the variability each variance was given its rank figure. Each line of reference was then given a total rank figure, adding together all the rank figures pertaining to those angles of which the line was one side. This gave us the following rank figures for the lines of reference:

N—O	29
N—Bo	29
N—B	33
O—A	35
N—S	49
P—Or	65

This method is admittedly a rather crude one. It gives, however, some indication as to the variability of the lines of reference as compared with each other. According to this ranking, four lines of reference, N—O, N—Bo, N—B, and O—A, are in the same category, whereas the two last lines are clearly more variable, especially the Frankfurt line, which occupies the five last places in the rank list of variances in Table 2.

Since two of the lines, the Bolton line and the Frankfurt line, have been criticized because of their unreliability, it may be of interest to see the list of total rank figures when these lines have been excluded. It is as follows:

N—O	8
N—B	9
O—A	10
N—S	15

According to these evaluations, the lines of reference which cover the whole length of the skull base, including the *His'* line which passes through the posterior part of the skull base and the whole face, bear a more constant relationship to each other than those lines which cover only part of the skull base or the face.

In this connection it may be of interest to cite two historical notes regarding this matter: *Schmidt* (1876) studied the variability of some craniometric horizontal planes employed at that time, ranking the planes according to the ranges of the angles between them. His figures showed that the Göttingen plane and the *His'* plane were equally variable and also the least variable planes. He preferred the Göttingen plane, which is defined as the plane following the upper margin of the zygomatic arch, on the basis of its being the nearest equivalent to the physiological horizontal plane of the head. *His* (1876), discussing the paper by *Schmidt,* states that he came to use the plane acanthion-opisthion because the length of the skull can be projected on it, the height of the skull can be measured from it, and this plane divides the face into the upper part and the lower dental part. Furthermore *His* claims that his plane is practically parallel to the Göttingen plane.

All the lines of reference are arbitrary ones, and their value depends chiefly on the purpose for which they are employed. It is possible, for instance, that the Frankfurt line and the N—S line, which in our list occupy the two last places, would be the lines best suited for differentiating between facial types, just because of their great variability. The only acceptable criteria so far is the reliability of determination of each line of reference. In this respect both the Frankfurt line and the Bolton line seem to be non-acceptable lines, and their employment in scientific roentgenologic-cephalometric studies should therefore be discontinued.

In studies where a line of reference within the facial area is needed, the *His'* line seems suitable and could replace the Frankfurt line. *His'* line, in addition to the "merits" mentioned by *His,* has a low error of measurement (*Koski & Virolainen* 1953), and appears to bear a rather constant relationship to the nasal floor (*Koski & Virolainen* 1955) during the growth so that it can be considered to be the horizontal growth axis of the facial area. It also ties the facial structures to the region of attachment of the skull to the vertebral spine, which is of certain evolutionary significance (*Koski* 1953). Lastly, it can be reported that the angle between the Frankfurt line and the *His'* line averages 0.8 degrees, i.e., these lines are, on an average, practically parallel to

each other. The replacement of the Frankfurt line by the *His'* line would thus not greatly alter the various numerically expressed structural relationships within the face, hitherto arrived at by employing the Frankfurt line.

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SUMMARY

On the basis of a material consisting of 100 lateral cephaloroentgenograms of young adults the angular relationships between the following lines of reference have been studied: opisthion-acanthion or His' line, nasion-opisthion, nasion-Bolton point or Bolton line, nasion-basion, nasion-sella turcica, and porion-orbitale or Frankfurt line.

The systematic error of measurement regarding the Bolton line and the Frankfurt line was found to exceed the acceptable limit, and the employment of these lines in scientific investigations is not recommendable.

The variances of the angles formed by the lines of reference indicate that each one of the lines covering the whole sagittal length of the skull base, including the His' line, has a more constant relationship to other lines of reference than those lines which cover only a part of the skull base or of the face.

For studies in which a line of reference within the facial area is desirable, the His' line is recommended.

RÉSUMÉ

SUR LES RELATIONS ENTRE LES LIGNES DE RÉFÉRENCE RADIO-CÉPHALOMÉTRIQUES

Sur la base d'un matériel de 100 céphaloradiographies latérales de jeunes adultes, les relations angulaires entre les lignes de référence suivantes ont été étudiées: ligne opisthion-acanthion

ou ligne de His, nasion-opisthion, nasion-point de Bolton ou ligne de Bolton, nasion-sella turcica, et ligne porion-orbital ou ligne de Francfort.

Il fut trouvé que l'erreur systématique concernant la ligne de Bolton et la ligne de Francfort dépasse la limite acceptable, et l'emploi de ces lignes pour les recherches scientifiques n'est pas recommandable.

Les variations de l'angle formé par les lignes de référence indiquent que chacune de ces lignes qui couvre la longueur sagittale entière de la base du crâne, y compris la ligne de His, possède une relation plus constante avec les autres lignes de référence que celles qui ne couvrent qu'une partie de la base du crâne ou de la face.

Pour les études ou une ligne de référence à l'intérieur de la région faciale est désirable, on recommande la ligne de His.

ZUSAMMENFASSUNG

ÜBER DIE VERHÄLTNISSE ZWISCHEN DEN RÖNTGENOLOGISCH-CEPHALOMETRISCHEN REFERENZLINIEN

Auf Grund eines aus 100 lateralen Cephaloröntgenogrammen von jungen Erwachsenen bestehenden Materials sind die Verhältnisse zwischen den folgenden Referenzlinien studiert worden: der Opisthion-Acanthion- oder His Linie, der Nasion-Opisthion, der Nasion-Bolton Punkt- oder Bolton Linie, der Nasion-Sella turcica- und der Porion-Orbitale- oder Frankfurter Linie.

Es wurde festgestellt, dass der systematische Messungsfehler hinsichtlich der Bolton Linie und der Frankfurter Linie die erlaubte Grenze überschreitet, und dass die Verwendung dieser Linien in einer wissenschaftlichen Untersuchung nicht zu empfehlen ist.

Die Variationen in den von den Referenzlinien gebildeten Winkeln zeigen, dass jede dieser Linien, welche die ganze Sagittallänge der Schädelbasis einschliesslich der His Linie deckt, ein beständigeres Verhältnis zu den anderen Referenzlinien hat als diejenigen Linien, die nur einen Teil der Schädelbasis oder des Gesichts decken.

Für Untersuchungen, in denen eine Referenzlinie innerhalb des Gesichtsgebietes erwünscht ist, wird die His Linie empfohlen.

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