The Relationship Of The Frankfort Horizontal To The His Line

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INTRODUCTION

Much has been written about the use of the Frankfort horizontal plane. It is so indoctrinated into our system of orthodontic diagnosis and evaluation that it will probably always be used by the majority. We know there are certain limitations to its use but this can be true of any base line or plane. The application of the Frankfort horizontal will be discussed in this paper in its relationship to the His line.

REVIEW OF LITERATURE

In a search through the literature it becomes apparent that the Frankfort horizontal is a common and oft-mentioned plane of reference. It had its origin with physical anthropologists as they devised craniometric techniques for the analysis and measurement of skulls. At the Anthropologic Congress held in Frankfort in 1884 it was agreed to accept as standard the horizontal line introduced by Von Ihering in 1872. This line was called the Frankfort horizontal and is known by the same name today. When accepted as a standard in 1884, it was defined as a line drawn through the upper periphery of the two ear holes and the lowest point of the left infraorbital margin.[1]

With the introduction of roentgenographic cephalometry it was natural that the techniques and landmarks used in physical anthropology be carried over. The x-ray technique was worked out by Pacini[2] in 1922 utilizing the measurements, landmarks and indices according to the anthropometric standards as set up by Hrdlicka.[3] In the early days Krogman and Hellman, physical anthropologist and orthodontist with anthropologic interests respectively, were very influential in the use of this plane of reference. In 1951 Krogman published an historical survey of the many planes used in both craniometry and cephalometry. He spoke of the His line, a craniometric plane of reference running from acanthion to opisthion, as having a great weakness, that being the variability of anterior nasal spine which was of very unequal size and often broken off in skulls. He particularly liked the use of the Frankfort horizontal because it made no difference whether craniometry or cephalometry were used because, in their orientation, they were directly comparable.[4]

Downs presented an analysis in 1948 in which he discussed the importance of assessing facial types when proposing treatment. In developing his analysis, he first tested the validity of the Frankfort horizontal as a substitute for the sella nasion plane and the Bolton plane as the plane of reference. The facial angle, which is the facial plane relative to the Frankfort horizontal, was used to describe a facial type.[5]

Johnson, in 1950, showed the importance of the Frankfort-mandibular angle as a valuable diagnostic criterion in the analysis of the facial pattern in orthodontic patients. He described these facial types relative to treatment after classification into four groups according to their Frankfort-mandibular angle.[6] Tweed, in 1946, also had spoken

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of the importance of the Frankfort-mandibular angle in its relationship to the lower incisor.[7] Later he included the Frankfort-mandibular-incisor angle (FMIA) as an important esthetic position of the lower incisor in diagnosis and treatment planning.[8]

Because of an assumed porionic variability many authors favor dropping porion and hence the Frankfort horizontal. Krogman and Sassouni, in their published syllabus of roentgenographic cephalometry in 1957, do not list these authors. And, regardless of the many opinions, Krogman and Sassouni still feel that the Frankfort horizontal, for purposes of orienting the head in a cephalostat, is the best single plane of reference.[9]

> "It is in wide and current use; therefore, it makes possible comparative analysis when several series of data are to be compared; furthermore, it adapts itself to use for purposes of comparison with photography in the living. When lateral and postero-anterior films are used, the plane of orientation becomes more important than when used with just the lateral x-ray. The minimum requirement is to have the lateral and PA films taken under the same plane of orientation if three dimensional views of the face are the aim".

Björk, in 1947, studied the variability of different points and planes before setting up his research standards in his study *The Face in Profile.* The errors obtained in the measurements to the Frankfort horizontal were considerably larger when compared with other horizontal planes. So he believes that porion is an inferior reference point. The Frankfort horizontal, consequently, was not included in his study.[10]

Muzj, in 1956, states that the use of the Frankfort horizontal leads to diagnostic error of facial type because of the upward and downward deflection of the horizontal. The deflections again depend upon the different facial types which the Frankfort horizontal represents, in other words, high ears or low ears in respect to the facial plane. Muzj eliminated this obstacle by finding a correlation which would specifically portray facial type. This correlation was the use of the frontal-facial angle correlating the upper and lower parts of the face. The base line used was Bolton point-anterior nasal spine line.[11]

Koski, in 1956, in an excellent study of the relationships between roentgenologic-cephalometric lines of reference states in his discussion of reference lines:[12]

> "Error was not considered significant except for two linear measurements, nasion - Bolton point and porion-orbitale. . . . Lines of reference which cover the whole length of the skull base, including the His' line . . . bear a more constant relationship to each other than those lines which cover only part of the skull base or the face. . . . 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 Frankfort line and the N-S line, which in our list occupy the 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 Frankfort line and the Bolton line seem to be non-acceptable, 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 Frankfort line. His' line has a low error of measurement, and appears to bear a rather constant relationship to the nasal floor during growth so that it can be considered to be the horizontal growth axis of the facial area . . . the angle between the Frankfort line and the His' line averages 0.8 degrees, i.e., these lines are, on an average, practically parallel to each other."

Seal, in his study of facial growth from ages 8 to 18, found some evidence indicating support of Koski's findings.[13]

We see that some European researchers do not advocate the use of the Frankfort horizontal but at the same time recognize the value of this line when discussing the variability of facial types.

Steiner speaks of the difficulty of locating porion and he offers evidence supporting the variation of this point.[14]

Parker, in 1953, cautions against careless placement of the ear rods because they can displace the Frankfort horizontal. Downs, recognizing that this is a point of error, has suggested that discrepancies in analysis are the result of an operator failing to literally hang his patients on the ear rods.[15]

In 1951 Ricketts eliminated the problem of the variability of the mechanical porion by employing the true ear hole. He located a point at the top of the external auditory canal to be used as the posterior limit of the Frankfort horizontal plane.[16]

At the first roentgenographic cephalometric workshop, sponsored by the American Association of Orthodontics, more information and opinion concerning reference lines became available. The Frankfort horizontal was considered "useful" as a base plane because of its close relation to the cranial base; however, it was not accepted as a possible plane of reference in the cranium.[17] A good summary of the status of porion was discussed by Downs at this workshop.[18]

> "1. Porion is not distinguishable on a film. The assumption, then, is that the integument of the external auditory meati rests upon the earposts; this may not always be true.
> 2. We are using the term "porion" rather loosely in cephalometrics, since it is located on a film or tracing as the superior surface of the earpost. Actually, porion is approximately 3 mm above the ear rod when the head is properly positioned in the cephalometer.
> 3. The tissues of the outer ear canal are extremely sensitive to pressure, making the insertion of the earposts uncertain and at times difficult.
> 4. The external auditory meati are not in a bilateral axis but are pointed forward and upward in varying angles in different persons, thus sometimes increasing the difficulty of inserting the earpost comfortably. There appears to be a necessity for considering a modification of earposts."

It appears that a good substitute for the Frankfort horizontal is necessary not only because of the historical value and impact that the horizontal has had, but also because of its accepted importance in diagnosis and treatment planning. Such a substitute has been suggested by Sassouni in 1960 by introduction of the "optic plane."[19] However, it is the bisectrix of the supraorbital and infraorbital planes and is not specifically based on points. As a substitute to the Frankfort horizontal, the His line appears to be a likely candidate because it is based on midsagittal and widely separated bony points, opisthion and the anterior nasal spine. The anterior nasal spine is defined as the spinous process of the maxilla forming the most anterior projection of the floor of the nasal cavity. The most anterior point is called acanthion. Opisthion is the junction of the internal and external surfaces of the squamous portion of the occipital bone at the posterior portion of the foramen magnum in the midline. By describing an arc along the posterior border of the vertebral canal and extending this line or arc upward until it intersects the squamous portion of the occipital bone, the intersection will give an approximate position of the point opisthion.

The following is a study of the relationship of the His line to the Frankfort horizontal and also a study as to the degree of variability or dependability in positioning the patients in the cephalostat.

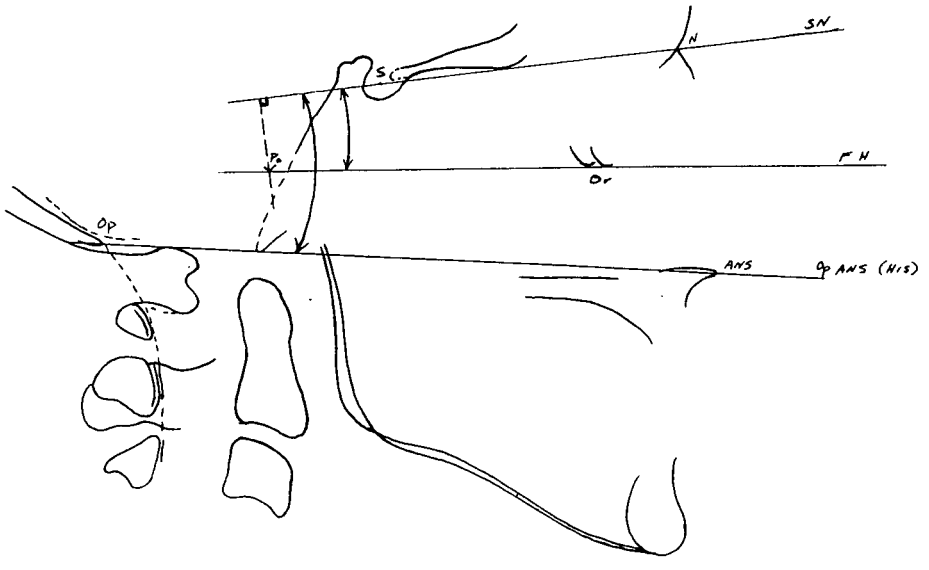

Fig. 1

Method

Two cephalometric roentgenographs were taken of each patient, each by a different operator. Each operator set the patient into the cephalostat independently of the other and each operator was instructed previously of the requisites of good cephalostat positioning. Thus, it was assumed that each could duplicate the roentgenograph of the other by good positioning technique. The operators were particularly cautioned to be sure the patient reached for the ear rods, and that the chair was lowered to obtain the highest possible positioning of the ear rods in the ear.

The group used in the study were 17 children ranging in ages between 10-2 and 16-4. Of the 17 children, 7 were males and 10 were females.

The group, accepted for the study regardless of age and sex, was composed of consecutive patients who needed a headfilm for beginning, progress, or final records. The roentgenographs were taken with a Continental Pacemaker with synchronized timing graded to the 1/10 of a second, The headholder was a Wehmer cephalostat.

A tracing was made on .003 matte acetate tracing paper from the headfilms of each individual. Porion was picked as being 7.0 mm higher than the center point of the ear rod (radius of ear rod plus 3.0 mm) and laid on a perpendicular from the sella-nasion line. The three lines used in the study were the sella-nasion line (SN), the Frankfort horizontal (FH) and the His line (opisthion-anterior nasal spine line). Special care was given to the correctness of the SN line on each individual. As this base line had to be correct, the tracing of the headfilm taken by operator No. 1 was compared with the tracing of the headfilm taken by operator No. 2 to be sure of their duplicity. The remaining points making up the Frankfort horizontal and the His line were picked without any attempt to compare the points. This allowed for the testing of the ability of the individual to pick the same point twice. The angles involved in the study were measured to the nearest 0.5 degree. A sample tracing is shown in Figure 1.

Means, standard deviations, and standard error of the means were computed for each angular measurement. The measurements of the headfilm tracings of operator No. 1 were compared with the measurements of the headfilm tracings of operator No. 2 and the student "t" test was used to test for any differences in the means of the related measurements. This basically tests the operator's positioning technique. A student "t" test was also applied to test for any differences in the two reference lines when related to the sella-nasion line.

The analysis of variance "F" was used to test for any significant amount of variation in the reference lines and for any significant variance resulting from the operator's positioning technique. Finally, the correlation coefficients for the two reference lines were obtained.

Small sample technique was used when computing the statistics in this study.

Findings

Submitted as the findings are Tables I through VI. Table I shows a comparison between operators in positioning the patient in the cephalostat. It was assumed that no sex or age differences in the measurements would show up, therefore sex and age differences were not compared.[13] Table II contains the statistical calculations including the mean, standard deviation and standard error of the means. Tables III and IV contain the student "t" tests testing for any significant differences in the means between the reference lines and between the operator's positioning technique. Tables V and VI contain analysis of variance tests for the above measurements.

Correlations between the two reference lines were .874 and .838 for operators No. 1 and 2 respectively.

Discussion

It is interesting to note that in the positioning of the patients in the ear rods any error would seem to cancel itself (Table I). In spite of the fact that the operators were able to duplicate cephalostat positioning in only 4 out of the 17 patients, the remaining 13 patients were about evenly distributed. (Operator No. 1 had 7 high positions while Operator No. 2 had 6 high positions). This would indicate that both operators were about equal as far as positioning technique was concerned. With this in mind we look into the statistical findings of the measurements to see if this supposition holds true.

By noting the closeness of the means of the angular measurements we would assume that it wouldn't matter whether the Frankfort horizontal or the His line were used as reference lines (Table II). We begin to suspect some individual variation, however, when we see differences in the standard deviations, but we will speak of this variation later. Student "t" tests were applied to the means from which we obtained the following information.

When testing the operators in the positioning of the patients in the cephalostat, we find that there are no significant differences in the means of the angular measurement SN-FH (Table III). We must then assume that, on the average, any amount of error in cephalostat positioning would equalize itself. More important, however, is the fact that a patient is not an average so the Frankfort horizontal, theoretically speaking, as applied to any patient, could possibly be in error. Since we are basically most interested in the static analysis (or diagnosis) and not in a group study, it would be comforting to have other data to substantiate the Frankfort horizontal as a correct reference line.

TABLE I

Position of ear rods by operators during filming

Position	Operator No. 1	Operator No. 2
High	7	6
Low	6	7
No Difference	4	4
Total	17	17

TABLE II

Means, standard deviations, standard error of means for the reference lines

	SN - FH			SN - OpANS		
	$\bar{X}$	σ	$\sigma_{\bar{X}}$	$\bar{X}$	σ	$\sigma_{\bar{X}}$
Operator						
No. 1	7.9	3.1	0.8	7.8	2.7	0.7
No. 2	8.1	3.9	1.0	7.9	2.6	0.7

TABLE III

Student "t" test
Differences in positioning technique means

Degrees	Operator No. 1	Operator No. 2	t value	df = 16 Probability
SN - FH	7.9	8.1	0.625	Over 50
SN - OpANS	7.8	7.9	1.111	.30, not at .20

TABLE IV

Student "t" test
Differences in reference lines

Operator	SN - FH	SN - OpANS	t value	df 16 Probability
No. 1	7.9	7.8	0.102	Over .50
No. 2	8.1	7.9	0.172	Over .50

TABLE V

Variance between reference lines
Standard deviations

Operator	SN - FH	SN - OpANS	t value	df $\frac{17}{17}$ Probability
No. 1	3.1	2.7	1.32	Over .05
No. 2	3.9	2.6	2.31	Over .05

TABLE VI

Variance between the operator's positioning technique
Standard deviations

Degrees	Operator No. 1	Operator No. 2	F Value	df $\frac{17}{17}$ Probability
SN - FH	3.1	3.9	1.67	Over .05
SN - OpANS	2.7	2.6	1.05	Over .05

It would be well to state, at this point, that if more than one headfilm were taken on any patient, we could use the average porion, after all porions have been plotted, provided that the patient had been positioned correctly, i.e., hanging on the ear rods. This average point could then be used in all headfilms for this particular patient with better reliability than when just picking one porion at random.

There are no significant differences in the means of the angular measurement SN-OpANS (Table III). Since both points of the line are bony points, any differences seen would have been due to an error in selecting the points successfully. This is assuming that any point has a certain amount of variability within itself which at this time we choose to ignore.

Because of the trend towards significance in one of the "t" tests ($P = 1.111$), the reason for this should be explained (Table III). The fact is that the measurement had such small amounts of variations that even though there were no real differences apparent when viewing the means, (7.8 and 7.9) the P value resulted in being larger than expected. Actually, the "t" test used was very sensitive, one used to test for very small differences between the means of similar or related measurements. However, it was felt that this trend justified testing the standard deviations by the analysis of variance test.

The four angle variances were not significant at the usual 5% significance level (Tables V and VI). One variance was significant at the 10% level of significance ($P = 2.31$), but this would only suggest that Operator No. 1 had a greater degree of accuracy than Operator No. 2. However, there are still no significant mean differences seen in the positioning technique.

The final question involves the amount of correlation between the Frankfort horizontal and the His line.

Can one be used for the other and with what degree of confidence? After observing the closeness of the two reference lines of the samples without testing and also noting the opinions of the other authors, a good correlation was expected. The results show a correlation coefficient that is significantly greater than zero, and both coefficients reasonably close to 1. A thought occurs when discussing correlation. Correlation must be from independent samples, and both the Frankfort horizontal and the His line are measures that are independent of each other. It is also well to remember that one line would not cause or affect the other line, only that they are correlated.

It would seem that after all of this statistical discussion there should be something practical to offer from the material presented. Basically, what we are interested in doing is to improve our confidence in the position of the Frankfort horizontal when we have only one headfilm. After tracing the Frankfort horizontal and the sella-nasion line, the His line can be noted, to observe its relationship to the other two lines. If the Frankfort horizontal is too divergent in relation to the sella-nasion line, or is even slightly convergent towards the facial profile relative to this line, it is very possible that the His line could substitute for or, at least, influence the position of the Frankfort horizontal that we feel may be in error.

Summary and Conclusions

Seventeen patients were positioned in a cephalostat by two different operators utilizing good positioning techniques. The patients were x-rayed, the headfilms were traced and analyzed with respect to the operator's technique and the relationship of the two reference lines relative to a common cranial base line. The two reference lines were the Frankfort horizontal and the His line. The cranial base line used was sella-nasion line. The following conclusions are presented.

1. There is error in the positioning of a patient in the cephalostat. However, the error averages out, but this average position would not necessarily indicate the patient's true porion.
2. The Frankfort horizontal and the His line are nearly parallel when porion is placed 3 mm above the top of the ear rod.
3. There is less variation in the His line relative to the sella-nasion line than the variation seen in the Frankfort horizontal relative to the sella-nasion line.
4. There is a very high degree of correlation between the two reference lines for both operators. Because of this high correlation, the His line could be used to give confidence or support to the Frankfort horizontal, or to give support to the choice of a new Frankfort horizontal if the original horizontal appeared to be in error.
5. With the above statements in mind, the His line could be used as a substitute for the Frankfort horizontal, particularly in view of the facts that the points are both midsagittal and bony and that they are a considerable distance from each other.

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