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The reliability of the Frankfort Horizontal in roentgenographic cephalometry

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SUMMARY This longitudinal investigation was undertaken to assess the reliability of the Frankfort Horizontal line (FH) when using either anatomical Porion (Po–a) or machine Porion (Po–m) as reference landmarks. Lateral head films (22 pairs) from subjects at the ages of 11 and 14 years were analysed twice. The results revealed that: (i) the registration error of Po–a was larger than of Po–m; (ii) for Po–a the registration error from the 11 year head films was approximately twice as large as from the 14 year head films; (iii) Po–m was, on average, located ~9 mm below and 2 mm anterior to Po–a; (iv) during the 3 years of observation, Po–m changed its position downward markedly more than Po–a; (v) due to the diverging location of machine Porion (Po–m) in relation to true Porion (Po–a) and the large change of Po–m with time, the FH was affected considerably. It was concluded that machine Porion was unsuitable for the construction of the FH. A misjudgement of the reference line may result in diagnostic misinterpretations and lead to false conclusions in longitudinal studies, e.g. when the outcome of a particular treatment procedure is evaluated.

Introduction

The Frankfort Horizontal (FH) was originally introduced at an anthropological conference in Frankfurt, Germany in 1884. It was defined as a plane extending from the left Orbitale to both Porion points. The plane was initially used as a craniometric reference plane for classification purposes.

With the development of radiographic cephalometry, the FH was adopted almost in its entirety. Orbitale remained defined as the lowest point of the infraorbital margin and Porion as the outer, upper margin of the porus acousticus externus. But due to the lack of visibility of 'anatomic porion' many authors have been using 'machine porion' instead (Broadbent, 1931; Tweed, 1946; Downs, 1948). This landmark is a radiographic marker on the ear rod which is placed into the external auditory meatus as part of the cephalometric head positioning device.

Defining Porion by cephalometric instrumentation may, however, introduce a clinically significant source of error when constructing the FH (Krogman and Sassouni, 1957; Ricketts, 1961, 1981; Ricketts *et al.*, 1974). Since ear rod positioning and the size of the external auditory meatus are extremely variable, machine Porion may be located distant from the true Porion (Ricketts, 1981).

To our knowledge, no longitudinal data have been published with respect to the difference in the location of anatomical and machine Porion and the resulting effect on the position of the FH.

The purpose of this longitudinal study, which covered a time period of 3 years, was to analyse the reliability of the FH when using either the anatomical Porion or the machine Porion as reference points. In particular the following questions were of interest:

i. What is the difference in the location of anatomical Porion and machine Porion?
ii. Is there any change in landmark location with time?
iii. How will the differences in landmark location affect the FH?

Materials and methods

Lateral cephalometric roentgenograms from 22 subjects (11 boys and 11 girls) treated successfully with activator appliances during an aver-

age time period of 3 years (range 2–4 years) were analysed. The pre-treatment head films were taken at an average age of 11 years and the post-treatment head films at an average age of 14 years.

All roentgenograms were taken with the same machine and with a standardized technique using a fixed focus to midsagittal plane distance of 155 cm and a constant midsagittal plane to film distance of 10 cm. The central ray was perpendicular to the film passing through the ear rods. The cephalostat used has been described elsewere (Iikubo *et al.*, 1975). The values measured were not corrected for linear enlargement (approximately 7 per cent in the median plane). All roentgenograms were of good quality.

In constructing the FH, two definitions were used (Fig. 1):

1. The line running through the landmarks Orbitale (Or) and anatomical Porion (Po–a).
2. The line running through the landmarks Orbitale (Or) and machine Porion (Po–m).

The different landmarks were defined as follows:

Orbitale (Or): The lowest point on the average of the right and left borders of the bony orbit.

Anatomical Porion (Po–a): The highest point on the average of the right and left ovoid bony shadow of the external auditory meatus.

Machine Porion (Po–m): The midpoint of the line connecting the centre points of the radiopacity generated by each of the two ear rods of the cephalostat.

Registration and measuring procedure

On all the head films at 11 and 14 years of age the landmarks Sella (S) and Nasion (N) were marked by means of a fine pen with Indian ink, thus forming fixed landmarks. The registration of the landmarks (Or, Po–a, and Po–m) and the FH were performed by means of an acetate tracing paper attached to the head films. On the tracing paper a horizontal and a vertical line were printed so as to form a right-angled cross. This cross was used as a reference coordinate system for the orientation of the tracing paper and for the measurements. The tracing paper was orientated so that the horizontal line of the reference cross went through N and S, with the centre of the cross at S. Thus, the line represented the NSL. The vertical line was called NSPL (Fig. 2).

After orientation of the tracing paper on the head films, the landmarks Or, Po–a and Po–m were located and marked on the tracing paper. The horizontal (x) and vertical (y) coordinates

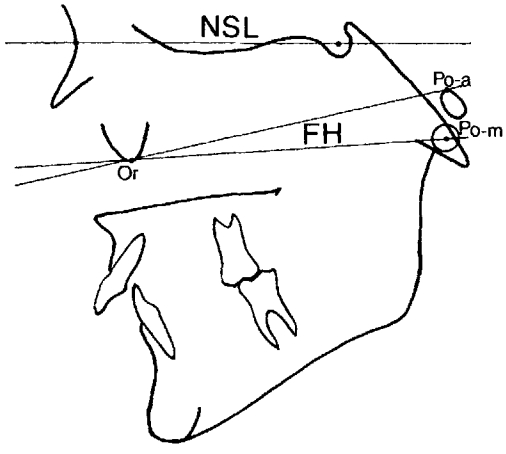

Figure 1 Diagram showing the Nasion–Sella line (NSL) and the Frankfort Horizontal (FH) defined according to Orbitale (Or), anatomical Porion (Po–a) and machine Porion (Po–m).

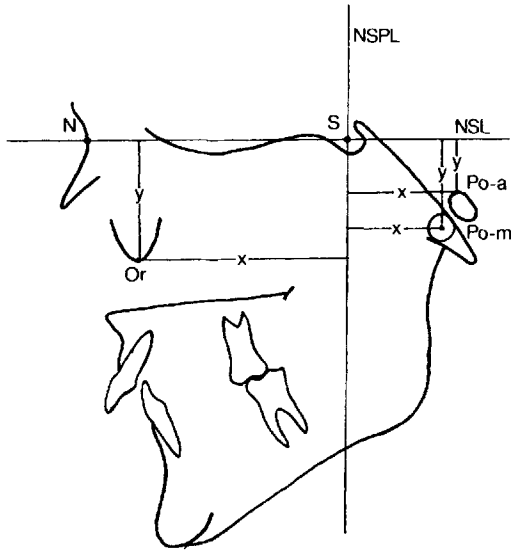

Figure 2 Diagram showing the horizontal (x) and the vertical (y) measurements that define the position of Orbitale (Or), anatomical Porion (Po–a) and machine Porion (Po–m) in relation to the reference cross NSL/NSPL.

Table 1 Error of the method (ME) for double registration (Reg. 1 and Reg. 2) from 22 lateral head films at 11 and 14 years of age. The registration errors in the horizontal (x) and vertical (y) planes for the three landmarks (Or, Po–a, Po–m), defining the Frankfort Horizontal (FH), as well as for the FH angle when using Po–a or Po–m, are given.

Variable		11 years					14 years				
		Reg. 1		Reg. 2			Reg. 1		Reg. 2		
(mm)		X	SD	X	SD	ME	X	D	X	SD	ME
Orbitale	x	51.6	4.03	51.8	4.26	0.37	53.7	4.25	53.6	4.33	0.34
(Or)	y	25.6	2.38	25.6	2.44	0.24	26.8	3.07	26.8	3.13	0.24
Anatomical	x	26.0	2.17	26.1	2.71	0.70	26.8	2.91	26.9	2.99	0.30
Porion (Po-a)	y	12.6	3.56	12.9	3.44	0.58	13.4	3.61	13.6	3.51	0.31
Machine	x	24.0	4.34	24.0	4.41	0.25	24.8	5.04	24.8	5.01	0.19
Porion (Po–m)	y	21.8	5.11	21.8	5.12	0.12	24.6	4.46	24.7	4.44	0.18
FH angle	Po–a	9.5	3.23	9.3	3.26	0.41	9.0	3.19	8.9	3.18	0.31
	Po–m	2.7	4.45	2.8	4.46	0.21	0.9	3.40	1.1	3.33	0.35

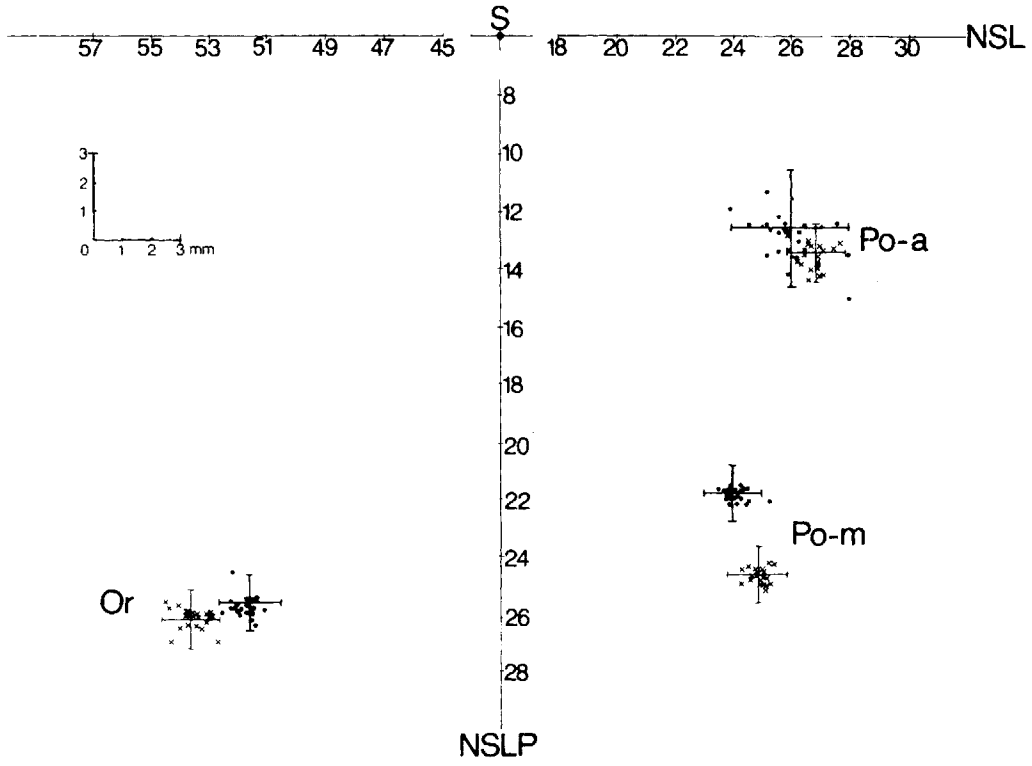

Figure 3 Diagram demonstrating the variability in double registrations of the cephalometric landmarks Orbitale (Or), anatomical Porion (Po–a) and machine Porion (Po–m). Individual recordings from 22 lateral head films at 11 years (●) and 14 years (×) of age. Landmark deviation of the second registration in relation to the first registration is shown. The NSL/NSLP reference cross is given.

for each landmark were assessed (Table 1). The FH according to the two definitions was constructed by interconnecting Or with Po–a and Po–m respectively. The inclination of the FH to the NSL was measured. All registrations and measurements were performed twice (Reg. 1

and Reg. 2) with an interval of approximately one week.

The linear measurements were performed with a ruler to the nearest 0.5 mm and the angular measurements were performed with a protractor to the nearest 0.5 degrees. All registrations and measurements were undertaken by the same operator.

Method error analysis

The combined method error (ME) in locating the landmarks on the radiographs, orientating the tracing paper on the head films and performing the tracing and measuring procedures was calculated by the formula

$$ME = \sqrt{\frac{\Sigma d^2}{2n}}$$

where d is the difference between two registrations of a pair and n is the number of double registrations. All the 22 head films at 11 and 14 years of age were analysed twice.

Results

Registration error of landmarks and reference line

The registration error of Po–a was larger than of Po–m and Or. This was especially true for the 11 year head films (Table 1, Fig. 3).

The registration error of Po-a for the 11 year head films was about twice as large as that for the 14 year films (Table 1, Fig. 3).

The registration error of FH (FH angle) for the 11 year head films was about twice as large when using Po–a instead of Po–m as the registration landmark for Porion (Table 1, Fig. 4). For the 14 year head films, the registration error of FH was about the same when using Po–a and Po–m (Table 1, Fig. 5).

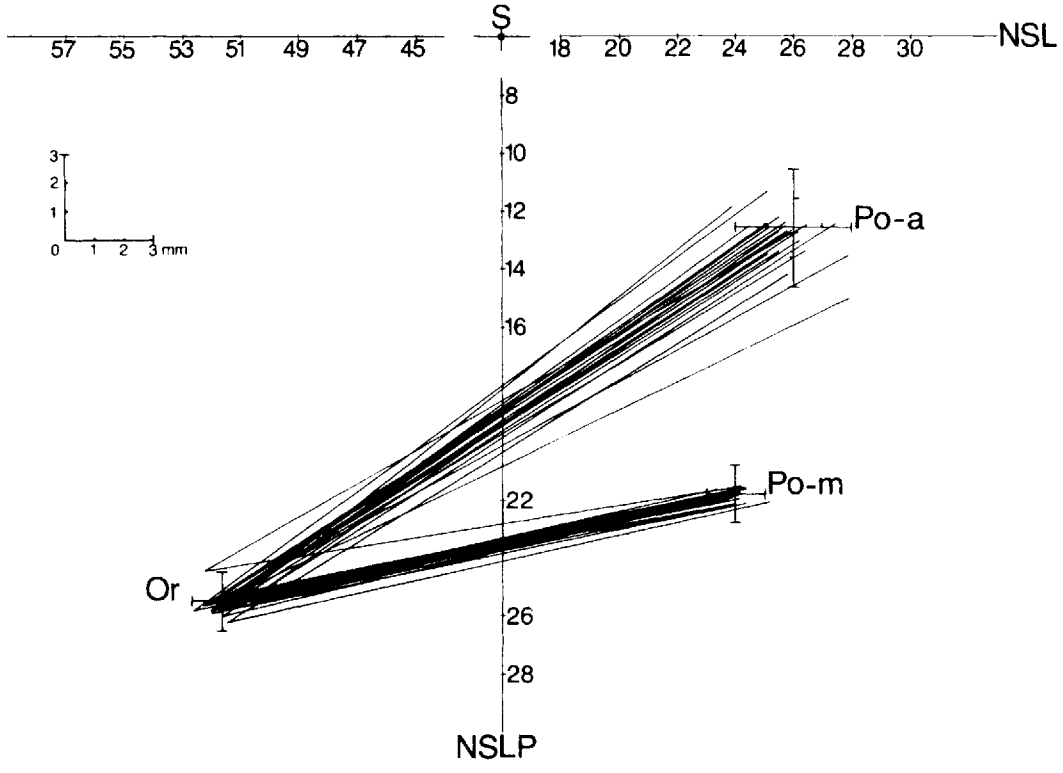

Figure 4 Diagram demonstrating the variability in double registrations of the Frankfort Horizontal line (FH) defined according to anatomical Porion (Po–a) and machine Porion (Po–m). Individual recordings from lateral head films of 22 subjects at 11 years of age. FH deviation of the second registration in relation to the first registration is shown. The NSL/NSLP reference cross is given.

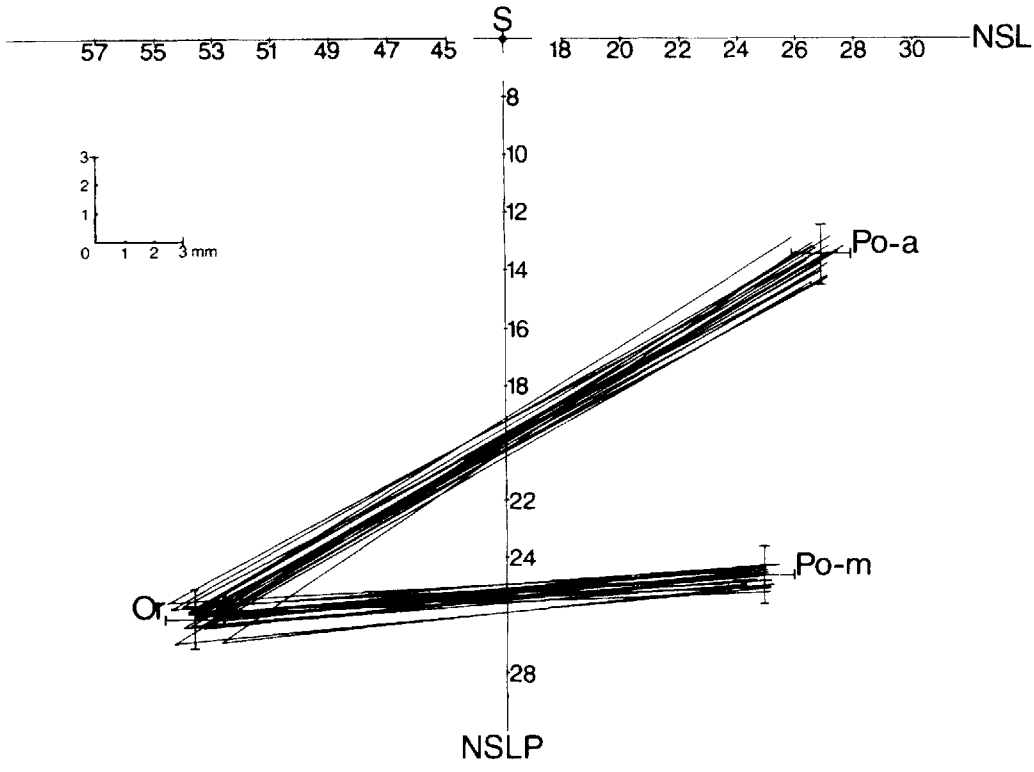

Figure 5 Diagram demonstrating the variability in double registrations of the Frankfort Horizontal line (FH) defined according to the anatomical Porion (Po-a) and machine Porion (Po-m). Individual recordings from lateral head films of 22 subjects at 14 years of age. FH deviation of the second registration in relation to the first registration is shown. The NSL/SNLP reference cross is given.

Location of landmarks and reference line

On the head films at 11 and 14 years of age Po–m was, on average, located more than 9 mm below and ~2 mm anterior to Po–a (Table 1, Fig. 3).

During the 3 years of examination, the landmark position was changed to a great extent. Po–a and especially Po–m moved downward and somewhat backward, or was moved forward and somewhat downward (Table 1, Fig. 3).

Due to the difference in the location of the landmarks Po–a and Po–m and their changes with time, the inclination of the FH varied accordingly. Thus, the FH angle was considerably larger (~6.5 degrees at 11 years of age and 8.0 degrees at 14 years of age) when using Po–a instead of Po–m as registration landmark (Table 1, Figs. 4 and 5).

Discussion

The results of this investigation revealed that the registration errors of the landmarks Or, Po–a and Po–m used for defining the FH were larger in the horizontal than in the vertical plane. This observation is in accordance with that from other investigations, (Richardson, 1966; Baumrind and Frantz, 1971; Broch *et al.*, 1981; Stabrun and Danielsen, 1982; Baumrind *et al.*, 1976) demonstrating that the distribution of the landmarks were parallel to their relevant anatomical structures.

When comparing the reproducibility of Po–a at 11 years of age with that at 14 years of age the registration error was about twice as large in the former group. Although all the cephalometric films were of high quality, the radiolucent area around Porion was more frequently blurred in the 11 than in the 14 year films. Thus the

possibility exists that radiographic visibility of Po–a is age (maturity) related.

Although the registration error of Po–m was smaller than for Po–a the machine ear rod is untrustworthy (Krogman and Sassouni, 1957; Ricketts 1961, 1962, 1981). It was found that Po–m was located >9 mm below Po–a. Thus, the radiographic ear rod marker, which basically is a soft tissue landmark, is unsuitable as a representation of the anatomical Porion (Po–a). The different locations of the two Porions will affect the angulation of the FH and therefore also the measurements related to this reference line. Gross errors in the diagnosis and the treatment planning of orthodontic and surgical cases may thus result.

It was further shown that Po–m exhibited large instability when comparing the head films at 11 and 14 years of age (Fig. 3). This change in landmark location with time is a serious disadvantage as landmark consistency is the main requirement for a stable reference line (Proffit, 1993). A misjudgement of the FH in longitudinal studies may lead to false conclusions, e.g. when the outcome of a particular treatment procedure is evaluated.

In conclusion it can be said that the radiographic marker of the ear rod (Po–m) is unsuitable as a substitute for the true Porion (Po–a) and should not be used in the construction of the FH.

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