

Cephalometric reference planes— sella nasion vs Frankfort horizontal

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Abstract

Two anatomical planes, sella-nasion and Frankfort horizontal, are commonly used in cephalometric evaluation. Both reference lines present advantages and disadvantages, and clinicians seem equally divided in their preference for using one over the other. To determine which of the two is more consistently accurate, this study compared measurements made using sella-nasion as the reference line with those made using Frankfort horizontal.

Introduction

A number of reference planes or lines have been used for orientation in routine cephalometric evaluation of orthodontic and/or orthognathic surgery patients. Usually the clinical impression of the clinician is substantiated by the findings of a detailed cephalometric analysis of the patient. However, occasionally there is a major discrepancy between the clinical impression and the conclusions derived from the cephalometric evaluation.

The patient shown in Fig 1 represents such a case. The SNA and SNB values for this patient indicate bimaxillary protrusion, while clinically the face appears well balanced. Similarly, the patient in Fig 2 has SNA and SNB values indicating bimaxillary retrusion, yet again the face appears well balanced.

One major factor leading to such a conflict in findings is the angle of the anterior cranial base and the vertical position of sella turcica. The patient in Fig 1 has a flat anterior cranial base, while the patient in Fig 2 has a steep anterior cranial base. In neither case is the anterior cranial base, particularly sella, in an average position within the skull. Those measurements that use sella-nasion as reference lines will therefore provide erroneous information if established norms are used for comparison. The reason for this is that norms are "average" values of a sample of individuals. That there is an "average" patient indicates that there is also variation about the mean. The two individuals shown in Figs 1 and 2 were at the ends of the spectrum in the angle of their anterior cranial base. Moore¹ also noted this problem and published *corrected norms* for individuals with low or high inclinations to their anterior cranial bases.

An examination of the cephalometric literature reveals that there are two reference planes that have been used most commonly as the basis of cephalometric evaluation, the sella-nasion (S-N) line²⁻⁵ and the Frankfort horizontal (FH) line.⁶⁻¹¹ Other investigators have abandoned cranial reference lines in favor of the "true" horizontal or vertical lines. Such lines are established when the cephalogram is taken with the head in "natural head position."¹²⁻¹⁴ This latter approach has merit, especially because

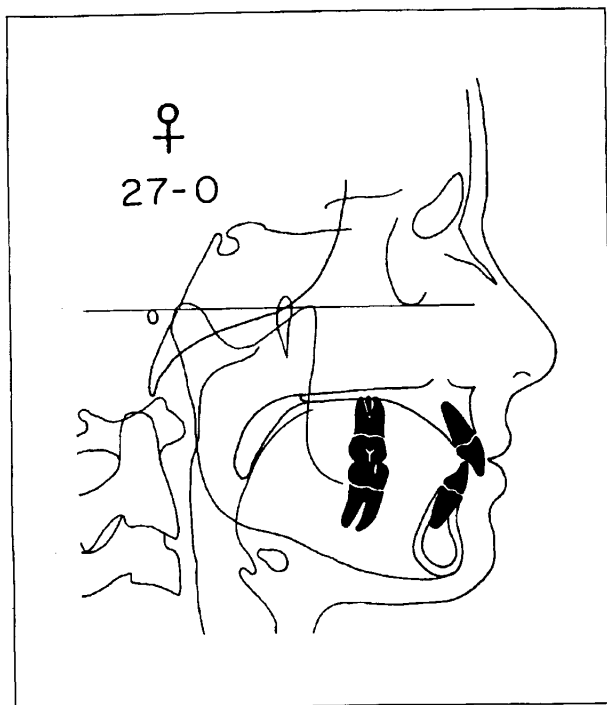


Fig 1 Individual with well-balanced face whose sella-nasion measurements indicate bimaxillary protrusion (SNA = 87°; SNB = 85°). However, when measurements are made using Frankfort horizontal, the position of the jaws is within normal limits (point A-Na \perp = 1.0 mm; Po-Na \perp = 1.1 mm). The reason for the discrepancy between the measures of jaw position is that the angle between the sella-nasion and Frankfort planes in this individual is extremely low—3.9°.

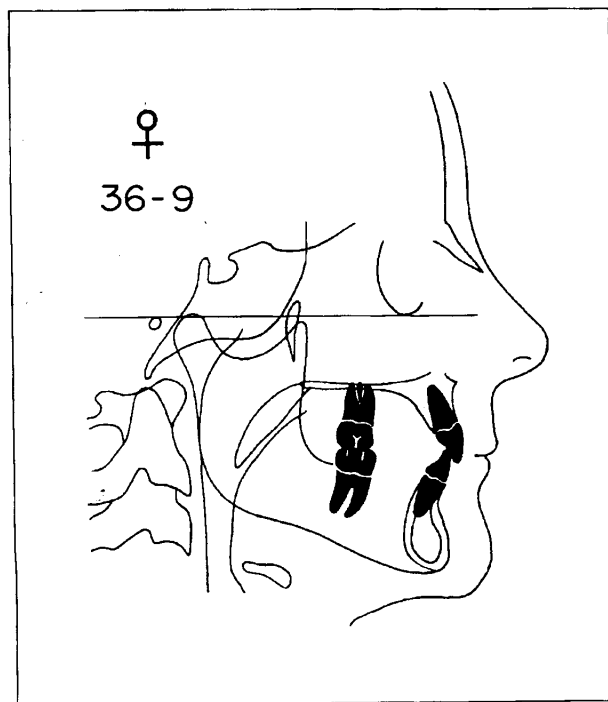


Fig 2 Individual with well-balanced face whose sella-nasion measurements indicate bimaxillary retrusion (SNA = 77°; SNB = 74°). However, when measurements are made using Frankfort horizontal, the position of the jaws is within normal limits (point A-Na \perp = 0.8 mm; Po-Na \perp = 0.7 mm). The reason for the discrepancy between the measures of jaw position is that the angle between the sella-nasion and Frankfort planes in this individual is extremely high—14°.

natural head position is the position in which clinical judgments are made. However, natural head position is technique-dependent and is not useful in large cross-sectional studies of cephalometric radiographs from several sources unless strict adherence to technique is employed.

Most oral and maxillofacial surgeons and orthodontists use a standard cephalostat. We will therefore address the question, Which of the two cranial reference lines (S-N vs FH) is more consistent for use in a static cephalometric analysis? The answer to this question is not as simple as it may seem. One line may be more variable from individual to individual, but more accurately determined. The main strength of the sella-nasion line is the accuracy with which it can be drawn.^{2,4,15} Sella, the center of the ra-

diolucent hypophyseal fossa, is readily visible and reproducibly drawn. Conversely, the main deterrent to the use of the Frankfort horizontal line is the difficulty in locating anatomical porion on the lateral cephalogram. Table 1 lists the advantages claimed for each of these lines.

Frankfort horizontal is defined as the line created when point orbitale (lowest point on the inferior margin of the orbit) and anatomic porion (highest point on the upper margin of the external auditory meatus) are connected. Its use has been condemned by many and eliminated from several analyses because of the difficulty in locating porion, the posterior reference point. Because anatomic porion is so difficult to locate, several investigators have utilized the top of the ear-rod image as a substitute.^{2,6,16-19}

However, the usefulness of the top of the ear-rod has been disputed by many investigators, who suggest that such factors as slight movement of the patient, difficulty in properly seating the ear-rods, and the thickness of the cartilage of the ear canal will all affect the accuracy of ear-rod determination.^{2,6,8-11,20-26} As a result, they recommend anatomic porion as the only reliable posterior landmark for use in determining Frankfort horizontal.^{9-11,26,27} They maintain that with proper cephalometric technique, porion is usually readily visible.

Ricketts¹⁰ has demonstrated that the accuracy of drawing the Frankfort line is not significantly different from the accuracy of drawing the sella-nasion line. However, porion may be obstructed by the ear-rods if the metal centering rings are not removed from the cephalostat. Further, Gormley²⁶ has shown that porion becomes even more visible when a hollow ear-rod is used. Wooden ear-rods provide an excellent alternative because they are more radiolucent than plastic and thus provide less interference with the radiographic image.

Given the fact that clinicians seem equally divided regarding which reference line they use clinically, a study was designed to determine whether the sella-nasion or Frankfort horizontal line is consistently more accurate.

Methods

This study was based on the cephalometric evaluation of a group of individuals who had ideal, untreated Class I occlusions and additionally were judged to have well-balanced faces on the basis of clinical and/or extraoral photographic examination. A total of 81 adults, all women, were included in the study only after three investigators agreed that they met the above criteria.

All cephalograms were traced by one investigator and checked by another to verify accuracy. Anatomic (not ear-rod) porion was used in all tracings.¹ The tracings were digitized at The Center for Human Growth and Development, with landmarks being translated into an x-y

Table 1 Advantages claimed for the sella-nasion and Frankfort horizontal lines

Sella-nasion	Frankfort horizontal
Points more easily located	Useful both radiographically and clinically
Points are midsagittal	More parallel to true horizontal ^{7,12,28,33}
	More relation to the face than the cranium
	Less correlation between measurements of jaw position and FH reference line
	Points are more far-removed from each other
	Also useable on P-A cephalograph

coordinate system. Measurements of craniofacial structure were obtained for each tracing by computer. Measurements of maxillary and mandibular position for which S-N was used as the reference (SNA, SNB, SNPo, SN-MP) were compared with those for which FH was used (point A-nasion perpendicular, facial angle, pogonion-nasion perpendicular, FH-MP).

Analysis was performed on two separate levels. In the first, Pearson's correlation coefficients (parametric) and Spearman's rank correlation coefficients (nonparametric) were calculated comparing the angle between the sella-nasion and Frankfort horizontal lines (SN-FH) with the measurement for maxillary and mandibular position. In the second analysis, the 81 women were divided into three groups based upon their SN-FH angles, and the 10 with the lowest SN-FH angles, the 10 closest to the mean of the entire sample, and the 10 with the high-

The external auditory canals are oval radiolucencies, varying somewhat in shape, approximately 7 mm posterior to the mandibular condyle. Porion, the most superior point of the external auditory canal, is vertically located one half the distance from the depth of the glenoid fossa in most instances. The external auditory canals should not be confused with the internal auditory canals, which are smaller radiolucencies located posterior and superior to the external auditory canals. However, a constant relationship between the two images occurs throughout growth such that, if the location of one is known, the other can be accurately determined.¹⁰ The significance of this finding is that occasionally the internal auditory canal is more visible than the external, and in this case, can be used as a guide to the proper location of porion.

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Table 2 Correlation coefficients for measurements of maxillary and mandibular position with the SN-FH angle in 81 women with well-balanced faces and ideal Class I occlusions

Measurement	r
S-N ref line	
SNA	-.6382
SNB	-.6664
SNPo	-.6305
SN-MP	.4313
FH ref line	
Point A to nasion perpendicular	.2875
Facial angle	.2966
Po to nasion perpendicular	.2958
FH-MP	-.0750

est SN-FH angles were selected and labeled as low, neutral, and high SN-FH angle groups, respectively. A univariate one-way analysis of variance of the measurements of maxillary and mandibular position was performed to assess the difference in these measurements in the three groups.

Results

An underlying assumption of this study was that the faces of the individuals were well balanced and clinically acceptable. Thus, an accurate measurement of maxillary or mandibular position should *not* correlate with the SN-FH angle because this would indicate that as the angle changes, a measurement of jaw position would change accordingly.

Pearson's correlation coefficients for the measurements of maxillary and mandibular position are presented in Table 2. Spearman's rank correlation coefficients for these measurements showed the same results and are not presented. The measurements of maxillary and mandibular position which use the sella-nasion reference line all showed high correlation coefficients with the SN-FH angle. The SNA, SNB, and SNPo correlated with the SN-FH angle significantly, with coefficients ranging from 0.63 to

0.67. The SN-MP angle had a lower coefficient of 0.43. Those measurements which use the Frankfort horizontal plane of reference showed much lower correlations to the SN-FH angle, which ranged from 0.07 to 0.30.

The mean SN-FH angle for the entire sample was 7.97° (SD = 2.42°). The ten individuals in the low SN-FH group had SN-FH angles ranging from 2.83° to 5.09°, with a mean of 4.31°. The ten individuals in the neutral SN-FH group had SN-FH angles ranging from 7.88° to 8.12°, with a mean of 7.99°. The ten individuals in the high SN-FH group had SN-FH angles ranging from 10.96° to 14.51°, with a mean of 12.49°. The results of the analysis of the measurements of maxillary and mandibular position in the three groups are presented in Table 3. Again, the measurements of maxillary and mandibular position in which the sella-nasion line was used showed more significant differences between the three SN-FH groups than did those which used the Frankfort horizontal line.

Discussion

Ever since cephalometric radiography was introduced in 1931 by Broadbent¹⁶ and subsequently used by the orthodontic and oral and maxillofacial surgery specialties, numerous investigators have searched for a craniofacial reference line which would provide the most accurate and reliable information for cephalometric analysis. Most have concluded that there is no "ideal" reference line, but the Frankfort horizontal line has long been accepted as one of the best.^{6-11,21,28,29} The results of this study corroborate this assumption. The variation in the angle between the Frankfort horizontal and sella-nasion lines in well-balanced faces with untreated Class I occlusions was found to be less correlated to the measurements of jaw position which use the Frankfort horizontal reference line than those which use the sella-nasion line. This may indicate that the Frankfort horizontal line is a more accurate reference line to

Table 3 Analysis of measurements of maxillary and mandibular position in low, neutral, and high SN-FH groups

Measurement	Low (A)		Neutral (B)		High (C)		A vs B	A vs C	B vs C
	\bar{x}	SD	\bar{x}	SD	\bar{x}	SD			
S-N ref line									
SNA (°)	85.13	2.12	81.35	2.40	79.06	2.12	†	‡	*
SNB (°)	82.72	2.73	79.71	2.07	76.67	1.99	*	‡	*
SNPo (°)	83.78	2.77	80.76	2.22	78.15	2.26	*	‡	*
SN-MP (°)	26.42	4.35	30.37	2.23	32.98	3.95	ns	†	ns
FH ref line									
Point A-nasion perpend (mm)	-0.60	2.50	-0.70	2.42	1.57	1.59	ns	ns	ns
Facial angle (°)	88.09	2.81	88.76	2.25	90.64	2.11	ns	ns	ns
Po-nasion perpend (mm)	-3.70	5.52	-2.30	4.29	1.21	3.96	ns	ns	ns
FH-MP (°)	22.11	4.21	22.37	2.30	20.48	3.90	ns	ns	ns

(ns) not significant
 *significant at the 0.05 level of confidence (after Bonferroni corrections)
 †significant at the 0.01 level of confidence (after Bonferroni corrections)
 ‡significant at the 0.001 level of confidence (after Bonferroni corrections)

use in a static analysis of jaw position because it is less affected by changes in the angulation between the SN-FH angle.

Some investigators have suggested that the variation in the SN-FH angle is due to variation in the position of sella.³⁰⁻³² The results of this study seem to support this. The mean values of the measurements which use Frankfort horizontal were not found to vary in low, neutral, or high SN-FH angle groups of the same sample of individuals with well-balanced faces, whereas those measurements based on the sella-nasion line did vary. This finding indicates that most of the variation in the SN-FH angle results from a difference in the position of the sella-nasion line. Downs⁶ and Ricketts^{9,11} argue that sella is totally unrelated to the structures of the face and should not be expected to be related to facial development. They feel that Frankfort horizontal is a more useful reference line because it relates the jaws to other structures of the face and therefore facilitates facial typing.

Clinical implications

The function of cephalometric reference lines is their use in describing and classifying the craniofacial complex and the dentition. Perhaps no single reference line will serve this purpose accu-

rately in each instance, and it is not the intent of this study to advocate the use of the Frankfort horizontal line in place of sella-nasion or any other line. However, when compared to measurements using sella-nasion, those in which Frankfort horizontal is used seem to more accurately represent the clinical impression of jaw position in most instances. The reason for this is suggested by the results of this study. When the angle between the sella-nasion and Frankfort horizontal lines differs significantly from the mean, measurements using sella-nasion as a reference line will indicate abnormal jaw positions, even if the positions are normal. Those measurements using the Frankfort horizontal line will still provide accurate information. Thus, one must be cognizant of the angulation between the sella-nasion and Frankfort horizontal lines if the sella-nasion line is used for cephalometric reference. If this angle is abnormal, corrections for cephalometric "norms" must be employed. Moore¹ has published corrected "norms" for SNA and SNB values based on the angle between the sella-nasion and Frankfort horizontal lines. Such corrections are not necessary when the Frankfort horizontal line is used as the reference.

The most significant implication of these results is in the evaluation of large cross-sectional samples of individuals for purposes of research and investigation.

Because the variation in the angulation of the sella-nasion line affects cephalometric measurements using this line as reference, the results of these measurements are difficult to interpret in such studies. This is also the reason why measurements such as SNA and point A-nasion perpendicular, although they both relate the position of the maxilla to the cranium, may not indicate the same anatomical information. This has led us to always publish two sets of measurements in analyzing cephalometric data. One measurement uses the sella-nasion line (for the sake of completeness), and the other uses the Frankfort horizontal line for each anatomical point being evaluated.

Thus, if the SNA and SNB values of a given patient do not verify the clinical impression, the slope of the anterior cranial base should be evaluated. If the anterior cranial base is abnormal in angulation, one should either use corrected "norms" or use measurements which use the Frankfort horizontal line as a reference.

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