The Variability of Roentgenographic Cephalometric Lines of Reference*

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The selection of suitable reference lines in roentgenographic cephalometry remains a problem of fundamental interest even though considerable attention has been devoted to this topic by many investigators[1,2,3]

In the excellent *Syllabus on Roentgenographic Cephalometry,* Krogman and Sassouni[4] outlined the merits of and objections to some of the most commonly used lines such as the Frankfort Horizontal, the nasion-sella line and the Bolton line. Other more recent additions included the spheno-occipital synchondrosis-nasion line and the ethmoidale-nasion line.[5] Koski and Virolainen[6] recommended the His line as the reference line of choice within the facial area. The *Second Research Workshop on Roentgenographic Cephalometry*[5] critically reviewed and discussed the biological validity and the theoretical implications inherent in the use of different reference lines.

Theoretically, the ideal reference line should be one which varied very little in itself biologically so that variations in other craniofacial regions and component parts could be clearly demonstrated. However, as there is no "fixed point" or absolutely stable plane in a growing organism, the line which varied least in comparison with others should become the one of choice.[7]

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This investigation was carried out to compare the variability of five different craniofacial reference lines commonly used in roentgenographic cephalometry in order to identify a reference line which is least variable in comparison with other lines.

METHODS AND MATERIAL

Koski and Virolainen[6] suggested a method of finding the least variable reference line by studying the angular relationships between them. The statistical variances of different angles between the selected lines of reference were chosen as the criteria of variability. In order to assess the rank of variability, each variance was given a rank figure. Each reference line was then given a total rank figure by adding all the rank figures of those angles of which the line was one side. The method of Koski and Virolainen was adopted in this study with one minor change. In addition to the total rank figures, the total sum variances for each reference line were also graded.

The five reference lines selected for study were:

1. Nasion sella line (NSL).
2. Ethmoidale sella line (ESL).
3. Frankfort Horizontal (FH).
4. Cranial base registration point sella line (CRSL).
5. Line of His (OSPL).

The relationships between these five reference lines were measured by the following ten angles formed at the intersection points (Fig. 1):

1. NSL/ESL
2. NSL/CRSL
3. NSL/FH
4. NSL/OSPL

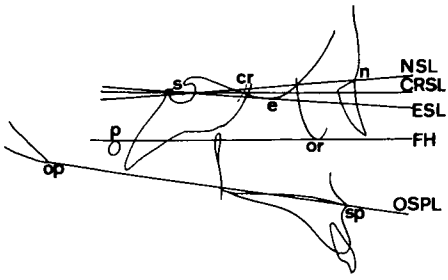

Fig. 1 Reference points and lines used.

5. ESL/CRSL 8. CRSL/FH
6. ESL/FH 9. ERSL/OSPL
7. ESL/OSPL 10. FH/OSPL

The material consisted of 50 lateral head roentgenograms of young adult male Chinese university students residing in Adelaide, South Australia. The roentgenograms were selected at random from a total sample of 84 films.

Measuring Points

In addition to the usual reference points the following were used:

ethmoidale (e): The lowest median point of the contour of the anterior cranial fossa corresponding to the cribriform plate of the ethmoid bone.

cranial base registration point (cr): The intersection of the mid-line point of the two great wings of the sphenoid bone with the sphenoethmoid plane.[9]

opisthion (op): The most posterior point on the foramen magnum.[10]

porion (p): The highest point of the usually ovoid vertical shadow of the porous acousticus externus.[5]

spinal point (sp): (Acanthion) the apex of the anterior nasal spine.

Estimation of the errors of the method

The systematic measurement errors and the total experimental errors were estimated by two series of double determinations after the method of Dahlberg,[12] similar to that reported by Barrett, Brown and MacDonald.[13]

Series 1

Fifteen lateral roentgenograms were selected at random and repeat tracings and measurements obtained from them by one observer two months after the initial records were taken. The differences between the two determinations were statistically analyzed. The results of the double determination tests were expressed as the mean of the differences (M. diff.), the standard error of the mean differences (EM. diff.), and the standard deviation of a single determination (s) for both series. The five and one per cent levels of probability were used in the t-test and designated as probably significant and significant respectively.

Series 2

Fifteen subjects were selected at random and repeat roentgenograms obtained at periods ranging from one day to four weeks after the initial records were taken. From tracings, measurements were compared with the original values. The total experimental errors thus revealed represented the systematic errors plus all tracing and measurement errors, separately derived from the first series.

It was found that only one measurement (OP-SP) differed from zero at the probably significant level ($p = 0.05$), and none was found at the significant level. This small error could have been due to chance and did not necessarily arise from systematic errors. However, a partial explanation may lie in the variability of spinal point.[14,15]

It was concluded that the experimental errors were small and should not influence the sample means and variance to any significant extent.

Results

The relationships between the five reference lines, measured in degrees, are summarized in Table I. The table

TABLE I

Angular relationship between various reference lines expressed in degrees obtained from tracings of lateral roentgenograms of 50 male subjects.

Variable	Mean	s	s_2	Range	Rank
NSL/ESL	2.48	3.6	13.03	−4.5 — 9.0	5
NSL/CRSL	−0.89	3.8	14.12	−8.0 — 6.5	6
NSL/FH	7.15	3.0	9.03	0.5 — 14.0	4
NSL/OSPL	10.00	2.8	8.04	2.5 — 16.5	3
ESL/CRSL	3.64	2.1	4.55	0.0 — 8.5	2
ESL/FH	4.88	4.0	15.85	0.0 — 16.5	7
ESL/OSPL	7.25	4.4	19.40	0.5 — 16.0	8
CRSL/FH	7.92	4.5	21.07	0.0 — 18.5	9
CRSL/OSPL	10.71	4.8	24.39	1.5 — 20.5	10
FH/OSPL	3.21	1.5	2.46	0.5 — 7.0	1

included the means, the standard deviations of the means (s), the variances (s^2), the ranges of variation and the rank figures of the variances.

The angular measurement between the Frankfort Horizontal and the line of His recorded a variance of 2.46 which was the lowest value in this series and was given the rank figure of 1. Similarly, other angular measurements between pairs of reference lines were assigned their corresponding rank figures. A total rank figure for each reference line was obtained by adding the rank figures of angular measurements of which the reference line formed one side. Similarly, the sum variances for each reference line were calculated, and the results are shown in Table II.

The nasion-sella line showed the smallest total sum rank figure as well as the least sum variance. This was followed by FH, ESL, OSPL and CRSL in this order for the sum variances. Based on this method of testing the variability of reference lines, the NSL appeared to be the reference line of choice with the least variability in comparison with the other reference lines used.

Discussion

The results obtained in this study are very interesting. Using an accurate multivariate analysis, Brown[16] found that NSL and FH also showed less variation than several other reference lines including the ESL. Also, Bjerin[17] found that, although the variations of

TABLE II

The total sum rank figures and the total sum variances for each reference line are shown.

	Sum Rank Figures		Sum Variances	
Reference Line	Total	Rank	Total	Rank
NSL	18	1	44.21	1
ESL	22	3	52.83	3
CRSL	27	4	64.13	5
FH	21	2	48.41	2
OSPL	22	3	54.29	4

the mean values and standard deviations of FH and NSL to the true horizontal were fairly great, there was a very small difference in variability between the FH and the NSL.

The stability of the cribriform plate had been suggested by Keith and Campion,[18] Moss and Greenberg,[19] Ford,[20] Elmajian,[21] and Wislander and Tandlakare.[22] The results of this study, however, did not reveal a definite superiority of the ESL and CRSL over NSL or FH, but showed a higher degree of variability.

Most investigators have explained the comparative variability of reference lines on the basis of biological factors, e.g., the stability of certain cranial landmarks during growth. More recently, however, Solow[23] has provided convincing evidence that the variability of angular measurements between different reference lines follows a definite relationship. Furthermore, he established a mathematical formula and confirmed the presence of a negative association between the standard deviations of the angles and the mean of the reference point distances of the angle arms, a reference point distance being defined as the distance between the reference points defining an angle arm. Consequently, no biological factors would be necessary to account for the differences in variability of most reference lines.

Summary and Conclusions

Five commonly used reference lines were investigated for their comparative variability after the method of Koski and Virolainen. The angular measurements between pairs of reference lines and the sum rank figures and total variances were compared.

Although all lines showed considerable variation, the nasion-sella line was least variable. The Frankfort Horizontal was found to be reasonably stable. The ethmoidale-sella line was next in order of variability. The cranial base registration point-sella line and the His line were found to exhibit a large variability.

While it is tempting to explain the differences in variability of different reference lines by biological factors, the interpretation of these data should be viewed in the light of recent findings reported by Solow.

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