

Cephalometric Evaluation of Incisor Position

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An evaluation of seventeen measurements of incisor angulation and position for their applicability in describing the incisor relationship to maxilla and mandible. Most are better descriptors of other relationships that could confound interpretation of relationships to the supporting bones.

KEY WORDS: • CEPHALOMETRICS • INCISOR • MANDIBLE •

The rise in the level of sophistication and precision of orthognathic surgical procedures during the last decade has increased the need for more accurate preoperative prediction of their outcome. Coordination of the dental arches prior to surgery is particularly important, so that the optimum anteroposterior, transverse and vertical changes in jaw position can be achieved.

One important consideration is the positions of upper and lower incisors relative to each other and to their supporting bones. Incisor interferences can prevent the desired surgical repositioning of osseous components, as when retro-positioned upper incisors inhibit forward repositioning of the mandible.

Two general approaches to evaluating upper and lower incisor positions prior to surgery are commonly used. One is the hand articulation of original or progress casts. Although the relative positioning of the teeth in each arch can be readily determined in this way, the relationship of the teeth to their underlying bony bases is less obvious, and may be impossible to determine from dental casts alone.

The lateral cephalograph provides a second source of information on the positions of the maxillary incisors, maxilla, mandibular incisors and mandible.

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Therefore a need has arisen for cephalometric measures which are sensitive not only to the position of the teeth within a given bone, but which are sensitive to the relationship of the jaw elements and cranial base structures to one another. This study considers only the relation of the teeth to their respective supporting bones.

The determination of incisor position is a part of most cephalometric analyses. DOWNS (1948, 1952 AND 1956), STEINER (1953, 1959 AND 1960), TWEED (1953 AND 1954), RICKETTS (1960, 1972 AND 1981) and RIEDEL (1952) all present specific measures of incisor position.

Most of the popular analyses were conceived prior to the use of orthognathic surgical procedures for the three-dimensional repositioning of almost every bony structure in the face, so little consideration has been given to their appropriateness in those applications. Many of the measures of incisor position are based on osseous structures of the face that may be surgically repositioned. In addition, descriptive measures of relationships to specific bony landmarks are independent of measures that may indicate whether those landmarks are in a normal relationship to the remainder of the face.

Maxillary Incisors

A theoretical discussion of the following eight cephalometric measures of maxillary incisor (U1) position demonstrates their broad variation.

1. U1/S-N † (Fig. 1)

The angle between the axis of the maxillary incisor and the S-N plane (RIEDEL 1952, DRUMMOND 1968, WAITE ET AL. 1971 AND BISHARA 1981) relates maxillary incisor position to the anterior cranial base,

independent of maxillary and mandibular positions. However, tilting of the maxilla causes a comparable change in the U1/S-N angles.

2. U1/FH (Fig. 1)

The angle between the maxillary incisor axis and the Frankfort plane (RIEDEL 1952 AND 1957) is also based on a superior skeletal reference plane, similar in application to the U1/S-N measure (Fig. 1).

3. U1/PP (Fig. 2)

The angle between the upper incisor axis and the palatal plane (Anterior Nasal Spine to Posterior nasal Spine) (BURSTONE ET AL. 1978) is an excellent indicator of orientation within the maxilla. Although the palatal plane may vary in angulation, many of the maxillary deformities corrected by orthognathic surgery are denotolveolar in nature. In these patients, the U1/PP measure is very useful.

4. U1/N-A (angular) and U1↔N-A (linear) (Fig. 3)

The nasion-A line (STEINER 1953, RIEDEL 1957, MACINTOSH 1970, AND KHOUW ET AL. 1970) is used as both an angular and linear reference. The angular measure shows the axial procumbency of the inci-

† Cephalometric Notations

Lines and planes are indicated by a short dash between terminal points, as A-B.

Angles where two lines intersect at an identified landmark are indicated by the two lines that form the angle, as A-N-B.

Angles where the intersection is not a named point, and angles between lines that do not intersect, are indicated by a slash between the two lines, as FH/N-B or FH/MP.

Linear measurements are indicated by a double arrow between the landmarks that define the measurement, as A↔N-Po.

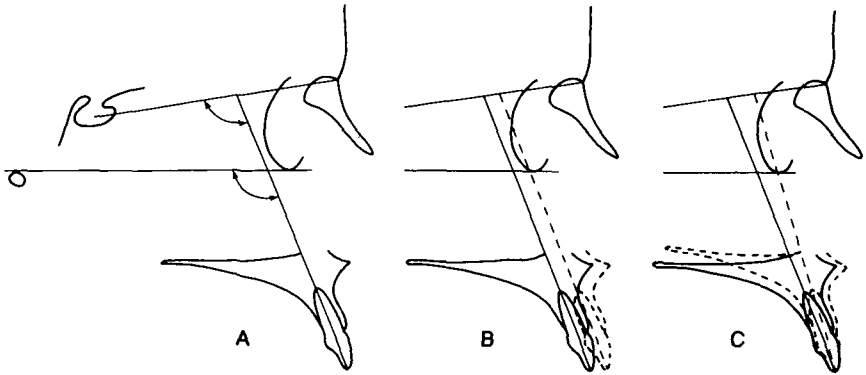
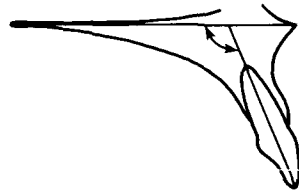


Fig. 1
A — a cephalometric tracing showing the upper incisor to sella-nasion (U1/S-N) and upper incisor to Frankfort horizontal (U1/FH:) measures.
B — altering the maxillary skeletal position in the horizontal plane (dashed lines) has no effect on these measures because the lines are parallel.
C — the effect of tilting the maxilla (dashed lines). Both measures change in direct relationship to the amount of maxillary tilt.

Fig. 2
 The upper incisor to palatal plane measure (U1/PP). Note that this measure is based on maxillary points; altering the position of the maxilla will not affect this measure.



isor, and the linear measure shows the horizontal distance between the facial surface of the maxillary incisor and the N-A line, independent of the axial inclination.

Although these have become two of the most accepted measures of maxillary incisor position, an examination of the N-A line shows a need for careful interpretation. When the maxillary skeleton (and therefore point A) is positioned posteriorly without changing the position of the incisor within the maxilla, the change in the angulation of N-A causes the U1 ↔ N-A measures to become larger.

5. U1 to Point A Vertical (U1 ↔ A^{VERT}) (Fig. 4)

The U1 ↔ A^{VERT} measure, as defined by McNAMARA (1983) is another way to relate the maxillary incisor to the maxilla. The U1 ↔ A^{VERT} measure is the horizontal distance between the facial surface of the maxillary incisor and a perpendicular erected from point A to the Frankfort horizontal plane. Because its angulation is unaffected by the position of the maxilla or the mandible, this is a sensitive measure even in patients with maxillo-mandibular disharmonies. Although it

Fig. 3
 The upper incisor to nasion-A measures (U1/N-A and U1↔N-A). Altering the horizontal position of the maxillary skeleton changes these measures. As the maxilla is brought forward, they are decreased (and vice-versa). These changes in the U1 to N-A measures occur even though the position of the upper incisor within the maxilla may remain unaltered.

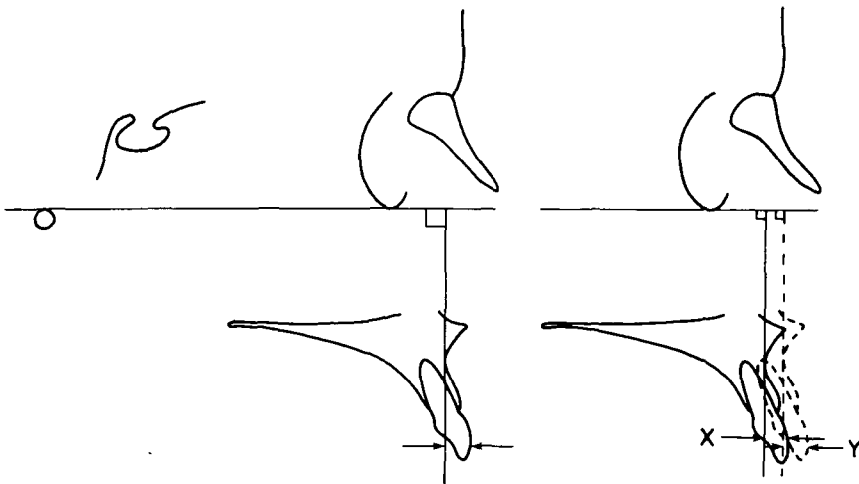
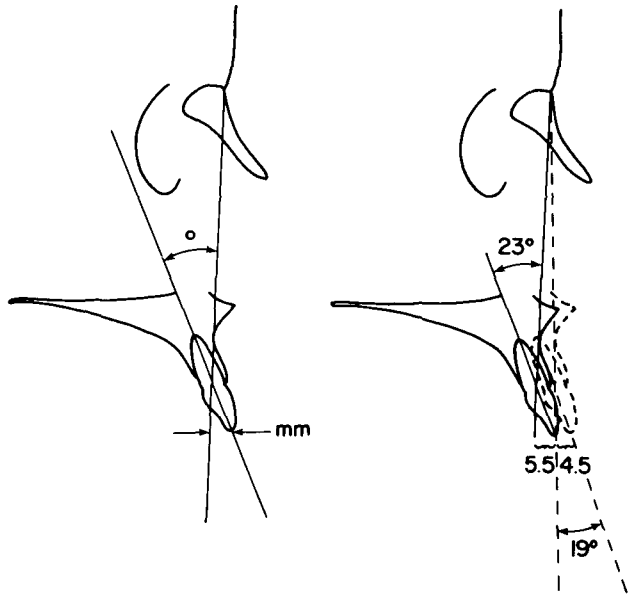


Fig. 4
 The upper incisor to point A vertical (U1↔A^{VERT}) measure. This measure is the horizontal distance between the facial aspect of the upper incisor and a perpendicular erected to the Frankfort horizontal plane through point A. Note that this measure is unaffected by horizontal movements of the maxillary skeleton.

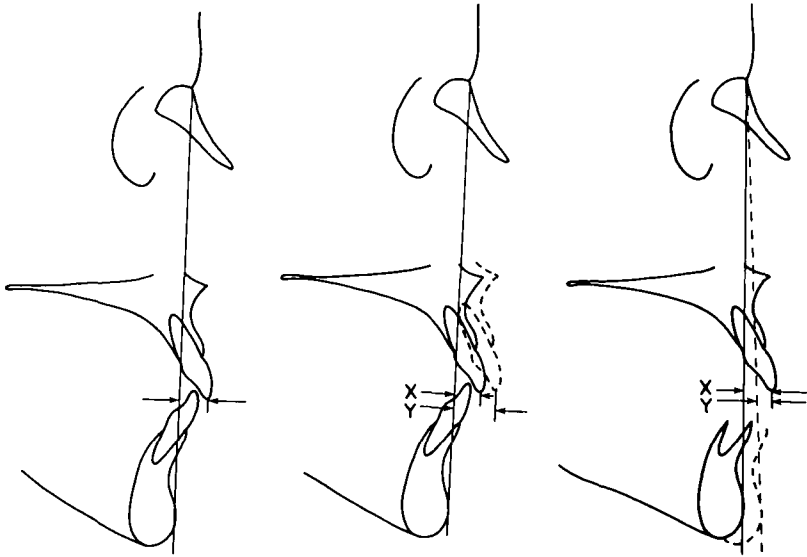


Fig. 5
 The upper incisor to facial plane measure (U1↔N-Pog), and the effects of altering the horizontal position of the maxillary or mandibular skeleton. The U1↔N-Pog measure is increased by anterior movement of the maxilla, and decreased by anterior movement of the mandible.

utilizes cranial landmarks for reference (porion and orbitale), it relates the maxillary incisor to the bony maxilla.

6. U1↔N-Pog (Fig. 5)

This reference line for maxillary incisor position, popularized by RIEDEL (1952 AND 1957), is similar to the U1↔A-Pog line measure described below. It is the distance between the incisal edge of the upper incisor and the nasion-pogonion line (facial plane). However unlike the A-Pog measure, it eliminates one of the highly variable points (point A) from the analysis. Although nasion may also be abnormal in position, it is certainly more constant than the maxilla, which is frequently affected in malocclusions (ELLIS ET AL. IN PRESS, LAWRENCE ET AL. IN PRESS). However, the mandible is one terminus

of the N-Pog line, and is also affected in many malocclusions.

7. U1↔A-Pog (Fig. 6)

The distance from the incisal edge of the maxillary incisor to the A-Pog line (DOWNS 1948, 1952 AND 1956; RICKETTS 1960, 1972 AND 1981; RIEDEL 1952, 1957; SCHEIDEMAN ET AL. 1980; BISHARA 1981) obviously demarcates jaw structures which may themselves be in abnormal relationships to each other. A retruded mandible with a retruded maxillary incisor may result in a normal U1↔A-Pog measure. Conversely, a protruded mandible with a protruded maxillary incisor may also produce a normal value. Endless combinations of U1↔A-Pog values are possible when various maxillary (Point A) and mandibular (Pogonion) positions are combined.

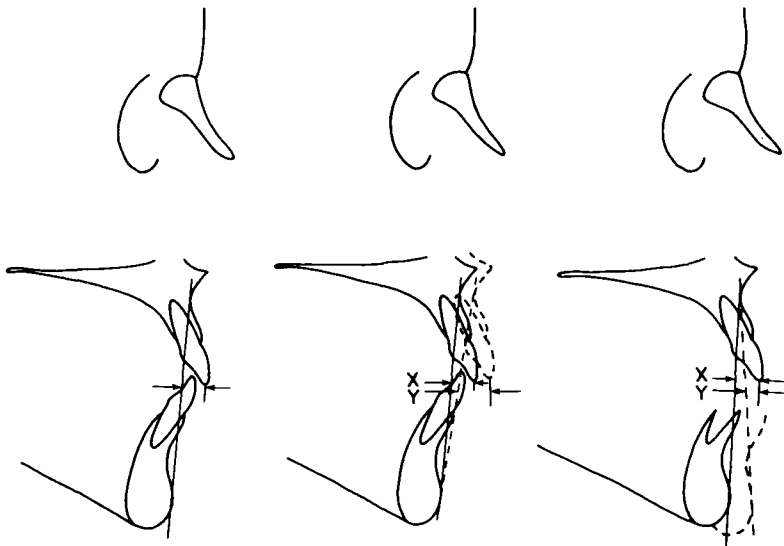
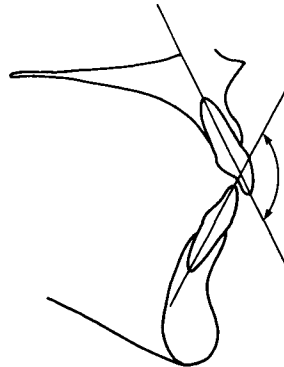


Fig. 6
 The upper incisor to A-pogonion (U1 to A-Pog) measure, and the effects of altering the horizontal position of the maxillary or mandibular skeleton. It is increased when the maxilla is brought forward, and decreased by forward movement of the mandible.

Fig. 7
 The interincisal angle (U1-L1). Note that this angle can be changed by angular change of either tooth or either supporting bone.



8. U1/L1 (Fig. 7)

The interincisal angle has been used ubiquitously in the literature as an indicator of relative maxillary and mandibular incisor orientation. The U1/L1 angle

can be affected by the position of the maxillary incisor, the mandibular incisor, and the relative positions of the mandible and the maxilla, so that a given angle can result from many combinations of maxillary and mandibular relationships.

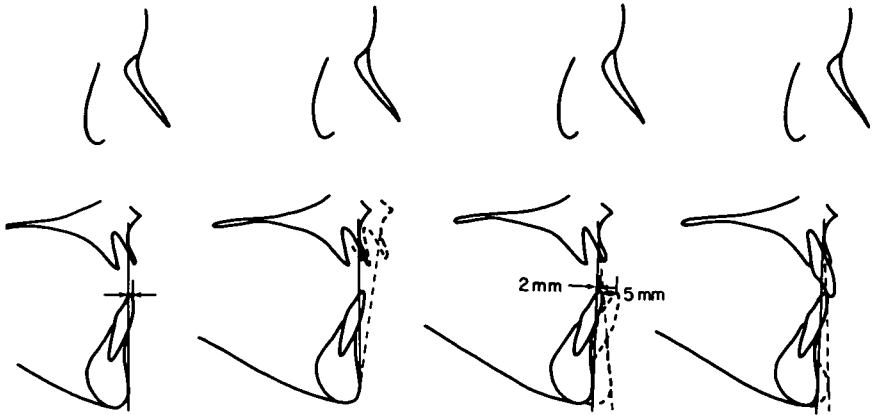


Fig. 8
 The lower incisor to A-Pogonion (L1 to A-Pog) measure. This measure is very sensitive to maxillary and mandibular skeletal relationships; moving the maxilla forward results in a lower value, and moving the mandible forward results in a higher value.

Mandibular Incisors

The most generally used measures of lower incisor position are —

1. L1 to A-pog (Fig. 8)

The distance from the incisal edge of the mandibular incisor to the A-Pog line (DOWNS 1948, 1952, 1956; RICKETTS 1960, 1972; McNAMARA 1983)) is a measure of mandibular dental protrusion. This is another measure in which both of the points determining the line are located on skeletal structures which may be in abnormal positions and often involved in malocclusions. Maxillary protrusion may cause retrusive L1 to A-Pog measures for a normally-positioned lower incisor, and mandibular protrusion will cause more

protrusive L1 to A-Pog values. This measure is therefore appropriate only for describing lower face profile relationships, not the relationship of incisor to mandibular symphysis.

2. U1/L1 (Fig. 7)

The interincisal angle previously described as a measure of the upper incisor also describes lower incisor orientation, and the same considerations apply. It is a descriptor of the relationship of incisors to each other, and nothing more.

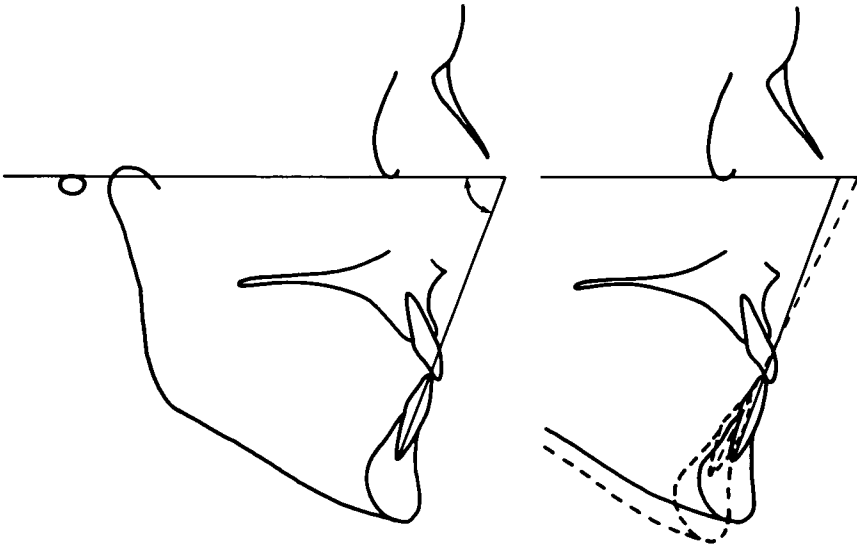


Fig. 9
The Frankfort mandibular incisor angle (L1/FH or FMIA). Altering the mandibular vertical position (and mandibular plane angle) can affect this measurement.

3. *L1/FH, or FMIA (Fig. 9)*

The Frankfort-mandibular incisor angle (FMIA, or L1/FH) proposed by TWEED (1954) has been a popular indicator of mandibular incisor orientation. This angle is strongly influenced by the vertical dimensions of the mandible, and it has little utility in cases which may require surgical therapy.

4. *L1/MP, or IMPA (Fig. 10)*

The angle between the lower incisor axis and the mandibular plane (gonion to menton) (RIEDEL 1952 AND 1957, DOWNS 1956, TWEED 1954, WAITE ET AL. 1971 AND BURSTONE ET AL. 1978) provide an excellent indication of mandibular incisor position that is unrelated to the position of the mandible. This is a distinct advantage in cases which vary considerably in the ver-

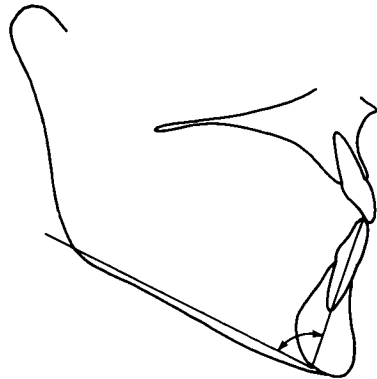


Fig. 10
The lower incisor-mandibular plane angle (L1/MP or IMPA). This measure is entirely confined to the mandible, so it is unaffected by changes in skeletal positions.

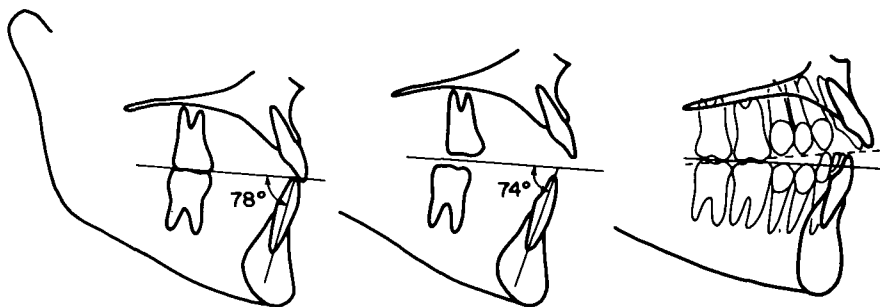


Fig. 11
The lower incisor to occlusal plane angle (L1/OP). Identification of the occlusal plane can be an important variable, as in open or deep bites where the interface between upper and lower teeth is not a plane.

tical dimension, since the angulation of the mandible is usually affected in these cases. L1/MP is very useful in surgical cases because it directly relates the mandibular incisor to the bony mandible without the involvement of any cranial landmarks.

5. L1/OP (Fig. 11)

The angle between the mandibular incisor axis and the occlusal plane (DOWNS 1948, RIEDEL 1952 AND ALTEMUS 1960) directly relates the incisor to the other teeth. It is not affected by the anteroposterior position of the mandible. However, vertical discrepancies in tooth positions can present problems in selecting an occlusal plane. An averaged occlusal plane may not accurately reflect the position of either the maxillary or mandibular dentition, and reproducibility is especially difficult in patients who have excessive curves of Spee. This problem is compounded in serial studies where the occlusal plane has been altered by treatment.

6. L1/N-B and L1↔N-B (Fig. 12)

The N-B line (STEINER 1953, RIEDEL 1957, DRUMMOND 1968, KHOUW ET AL. 1970, MACINTOSH 1970, BISHARA 1981) is used as a reference to measure both angular orientation and horizontal position of the mandibular incisor. The angular measure gives the axial procumbency, and the linear measure is the horizontal distance between the facial surface of the incisor and the N-B line, independent of the axial inclination.

Although these measures of mandibular incisor position are widely accepted, an examination of the N-B line shows that they can also be misleading because the relationship of the incisor to the line is affected by the anteroposterior position of the mandible.

7. L1-B^{PERP} (Fig. 13)

This measure has been used as an indicator of mandibular incisor position by one of the Authors (E.E.). The L1-B^{PERP} measure is the distance between the facial

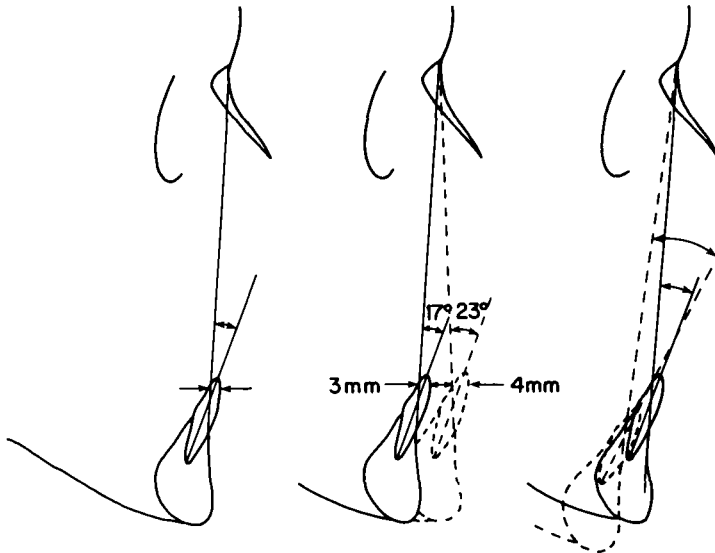


Fig. 12
The angular and linear measures based on the N-B line (L1/N-B and L1↔N-B). These measures are increased by forward horizontal and vertical opening movements of the mandible.

aspect of the mandibular incisor and a perpendicular erected from point B to the mandibular plane. Like L1/MP, it relates the incisor to the mandible; however, unlike L1/MP, it also relates the tooth to the alveolar bone. In a balanced face with ideal occlusion, this measure should be -1.7mm (s.d. = 1.97mm) (ELLIS UNPUBLISHED DATA), indicating that the facial aspect of the incisor is 1.7mm behind the constructed line.

Overview —

The foregoing brief review of the cephalometric measures that might be applied to evaluate incisor positions demonstrates their specificity and the need for careful selection for appropriate application. Intuitively, one can readily see how some of these measures can be misleading if used inappropriately. To

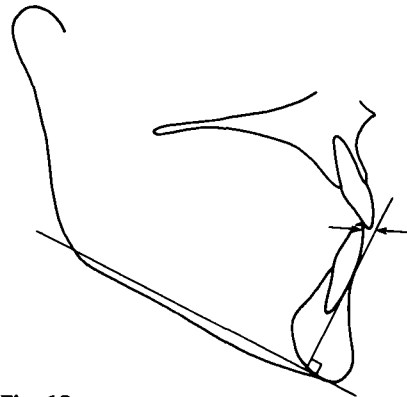


Fig. 13
The lower incisor to Point A perpendicular (L1-B^{PERP}) measure. This line is a perpendicular constructed from point A to the mandibular plane. As a wholly mandibular measure, it is unaffected by mandibular position will have no affect on this measure.

more thoroughly evaluate the usefulness of these analyses and to quantify the inherent pitfalls of misapplication, the following study was undertaken.

— Methods —

Lateral cephalometric radiographs of 242 male and 424 female patients (666 total) from The Center for Human Growth and Development and The Department of Oral and Maxillofacial Surgery at the University of Michigan were evaluated. All were over 16 years of age. There were no other criteria for selection. All classes of malocclusion were represented, including 125 individuals with Class I untreated occlusions and well-balanced faces. No cases of cleft palate or identifiable craniofacial syndromes were included.

All of the cephalographs were traced by one investigator and checked by another to verify accuracy. Tracings were digitized at The Center for Human Growth and Development, and as the cephalographs were obtained from several sources, enlargement was standardized to 8% by computer.

Several measures of craniofacial structure were recorded for each cephalograph, including those for maxillary and mandibular incisor position presented above. Analysis of those measures that may be used to indicate incisor position was performed as described below.

Maxillary Measures

A "neutral" position for the relationship of the maxillary incisor to the palatal plane of the maxilla was chosen as a U1/PP angle between 108° and 112° (BURSTONE ET AL. 1978; SCHEIDEMAN ET AL. 1980). Those cephalographs with maxillary

incisors within this range were then plotted against S-N-A, a measure of maxillary skeletal position, and against FH/N-Pog, a measure of mandibular skeletal position, to determine how an incisor "normally" related to the maxilla may be related to maxillary and mandibular positions.

Spearman's rank correlation coefficients (r) were computed for all of the measures in these cephalographs, both dental and skeletal, to determine how they relate to one another.

Secondly, this sample was further divided by determining the median values for S-N-A and FH/N-Pog and then subdividing the groups into low and high groups for each parameter. The Mann-Whitney U-test was then used to determine differences in the maxillary incisor variables between the low and high groups.

Mandibular Incisors

A "neutral" relationship of the mandibular incisor to the mandible was chosen as an L1/MP (IMPA) angle between 89° and 93.5° (RIEDEL 1952 AND 1957, DOWNS 1956, TWEED 1954, WAITE 1971, BURSTONE ET AL. 1978 AND SCHEIDEMAN ET AL. 1980). All of those cephalographs with mandibular incisors in this range were then plotted against FH/N-Pog, a measure of horizontal mandibular skeletal position, and against FH/MP, a measure of vertical mandibular skeletal angulation. The objective of these comparisons is to determine how measurements of an incisor that is positioned normally on the mandible may be affected by various mandibular positions.

In addition, the L1↔A-Pog measure was plotted against S-N-A, a measure of maxillary skeletal position, to determine

how the maxillary position might affect the L1 ↔ A-Pog values.

Spearman's Rank Correlation Coefficients (r) were computed for all of the measures in these cephalographs, both dental and skeletal, to determine how they relate to one another.

The sample was further divided by selecting the median values for facial plane angle (FH/N-Pog) and mandibular plane angle (FH/MP), and using these to subdivide the sample into low and high groups for each measure. The Mann-Whitney U-test was then used to determine differences in the mandibular incisor variables between the low and high groups. This same test was performed on the L1 ↔ A-Pog measure to determine how maxillary skeletal positions (S-N-A) affect the measures.

— Results —

Maxillary Teeth

The first step was to determine the number of individuals who had a "normal" relationship of the maxillary incisor to the maxilla. Out of 666 cephalographs, 120 had U1/PP angles within the 108°–112° range. These 120 cases were used for the remainder of the calculations.

The best measures of maxillary incisor position in the maxilla should not be correlated with changes in maxillary or mandibular position. Such correlation could indicate the effect of outside influences on the measurements. The S-N-A angle was used as an indicator of maxillary position.

The Spearman's rank correlation coefficient (Table 1) for the measures of maxillary incisor position versus S-N-A revealed the following:

Correlation Not Significant $p \geq 0.05$	Correlation Significant $p \leq 0.05$
U1/FH	U1/S-N
U1/PP	U1/N-A
U1 ↔ A ^{VERT}	U1 ↔ N-A
U1 ↔ N-Pog	
U1 ↔ A-Pog	
U1/L1	

Scatter plots for the U1 ↔ A^{VERT} and U1/N-A angular measures versus S-N-A for the 120 individuals in the sample are shown in Figure 14. The lack of any discernible relationship of the points in the scatter plot for U1 ↔ A^{VERT} was typical of those measures of maxillary incisor position which did not correlate with maxillary skeletal position, whereas the linear pattern in the plot for U1/N-A[°] was typical of those measures which did.

The U1 to N-A measures were both inversely related to maxillary skeletal position, meaning that in protrusive maxillae, the U1 to N-A measures were lower, while in retrusive maxillae, the U1 to N-A measures are larger.

A direct correlation was found for the U1/S-N measure and maxillary skeletal position. This measure also was highly correlated with the angle PP/S-N ($r = -.94$). The U1 ↔ A-Pog and U1 ↔ A^{VERT} measures, although constructed with maxillary skeletal landmarks, showed no correlation with maxillary skeletal position.

The results of the Mann-Whitney U-test, where the sample was subdivided into two equal groups ($n = 60$ /group) above and below the median S-N-A value (80.16°), demonstrated very similar findings (Table 1).

The Spearman's rank correlation coefficient (Table 1) for the measures of maxillary incisor position versus mandibular

skeletal position (FH/N-Pog) revealed the following:

<p>Correlation Not Significant $p \geq 0.05$ U1/S-N U1/FH U1/PP U1/N-A U1↔N-A U1↔A^{VERT}</p>	<p>Correlation Significant $p \leq 0.05$ U1/N-Pog U1↔A-Pog U1/L1</p>
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Scatter plots for the angular measure U1/N-A and the linear measure U1↔A-Pog versus FH/N-Pog are shown in Figure 15. The lack of any discernible relationship of the points in the scatter plot for U1/N-A is typical of those measures

of maxillary incisor position which did not correlate with mandibular skeletal position, whereas the linear pattern in the plot for U1↔A-Pog is typical of those measures which did.

All of those measures based on a mandibular skeletal point of reference (U1↔A-Pog, U1/N-Pog and U1/L1) show significant correlations with the FH/N-Pog angle values ($p < 0.01$). These same maxillary incisor measures were also correlated highly with other skeletal measures that are dependent on mandibular skeletal position (mandibular length, S-N-B, pogonion to N^{VERT}, S-N-Pog, A-N-B, Wits analysis, and dental overjet) ($r > .65$). The U1/L1 measure also correlated ($p < 0.01$) with mandibular plane angle measures (S-N/MP, FH/MP).

Table 1
Relationship of Maxillary Incisor Measures to Horizontal Maxillary and Mandibular Positions in 120 Individuals with a Neutral Relation of the Upper Incisor to the Maxilla (U1/PP 108°-112°)

	Maxillary Position (S-N-A)		Mandibular Position (FH/N-Pog)	
	r	U	r	U
U1/S-N	<u>+ .355</u>	<u>1143</u>	+ .151	1663
U1/FH	-.060	1781	+ .148	1701
U1/PP	-.040	1644	-.005	1672
U1/N-A(°)	<u>-.576</u>	<u>861</u>	-.124	1546
U1↔N-A (mm)	<u>-.367</u>	<u>1319</u>	-.027	1606
U1↔A vertical	+ .032	1543	+ .173	1715
U1↔N-Pog	+ .112	1547	<u>-.824</u>	<u>360</u>
U1↔A-Pog	+ .0130	1672	<u>-.817</u>	<u>326</u>
U1/L1	-.050	1653	<u>+ .701</u>	<u>548</u>

r — Spearman's Rank Correlation Coefficient
U — Mann-Whitney U-test

Significant at 0.01 level

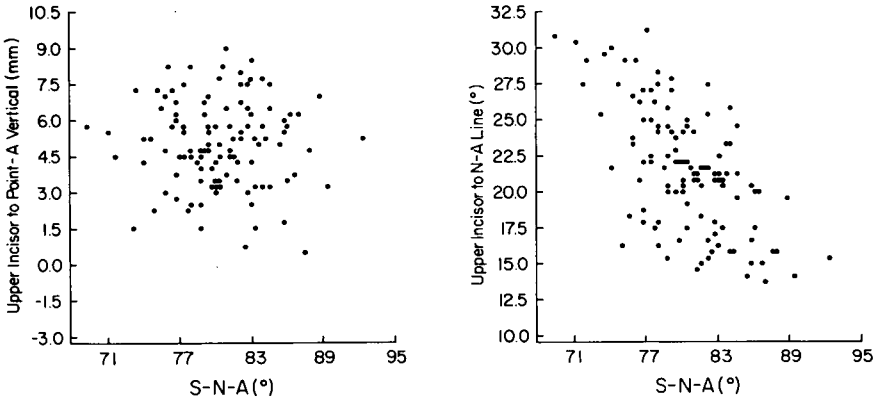


Fig. 14
 Scatter plots of the measures $U1-A^{VERT}$ and $U1/N-A$ versus $S-N-A$. The distribution for $U1-A^{VERT}$ appears to be random, while an inverse linear relationship is seen in the $U1/N-A$ plot (a more protrusive maxillary skeleton gives smaller $U1/N-A$ angular values).

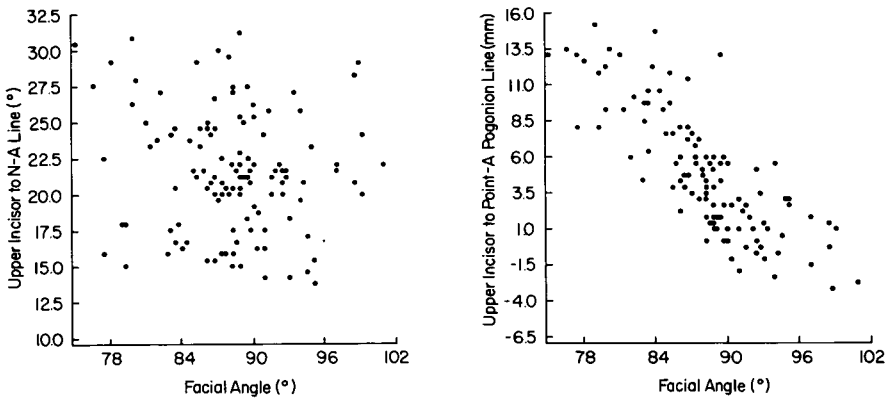


Fig. 15
 Scatter plots of the measures $U1/N-A$ and $U1 \leftrightarrow A-Pog$ versus $FH/N-Pog$. No linear relationship is seen in the $U1/N-A$ plots, whereas an inverse linear relationship is seen for $U1 \leftrightarrow A-Pog$. This indicates that the $U1/N-A$ angular measure is not affected by mandibular skeletal position, and the $U1 \leftrightarrow A-Pog$ measure is inversely related to mandibular skeletal position (a more protrusive mandible gives smaller $U1 \leftrightarrow A-Pog$ values).

Those measures of maxillary incisor position not involving a mandibular reference point did not show any correlation with mandibular skeletal position. The results of the Mann-Whitney U-test where the sample was subdivided by the median FH/N-Pog angle value (88.3°) were the same as found in the rank correlations.

Mandibular Incisors

The number of individuals who had a "normal" relationship of the mandibular incisor to the mandible, with L1/MP angle within the 89°-93.5° range, was 102, and these were used for the remainder of the calculations.

A measure of mandibular incisor position on the mandible that correlated with changes in mandibular position would be

suspect. The facial plane angle (FH/N-Pog) was used as a measure of horizontal mandibular skeletal position, and the mandibular plane angle was used as an indicator of vertical mandibular skeletal position.

The Spearman's rank correlation coefficient for the measures of mandibular incisor position versus horizontal mandibular skeletal position are listed in Table 2. The results reveal the following:

Correlation Not Significant	Correlation Significant (p ≤ 0.05)
U1/L1	L1 ↔ A-Pog
L1/MP	L1/FH
L1/N-B	L1/OP
L1-B ^{PERP}	L1 ↔ N-B

Table 2 Relationship of Mandibular Incisor Measures to Facial Angle FH/N-Pog and to FH/MP in 102 Subjects with a Neutral Relation of the Lower Incisor to the Mandible (89° < L1/MP < 93.5°)

	Facial Angle (FH/N-Pog)		Mand Plane Angle (FH/MP)	
	r	U	r	U
L1 ↔ A-Pog	<u>+ .373</u>	<u>978</u>	<u>+ .238</u>	<u>1044</u>
L1/FH (FMIA)	<u>+ .696</u>	<u>316</u>	<u>- .981</u>	<u>36</u>
L1/MP (IMPA)	<u>- .036</u>	<u>1277</u>	<u>- .027</u>	<u>1152</u>
L1/OP	<u>+ .466</u>	<u>591</u>	<u>- .728</u>	<u>434</u>
L1/N-B°	<u>- .053</u>	<u>1097</u>	<u>+ .700</u>	<u>476</u>
L1 ↔ N-B (mm)	<u>- .242</u>	<u>948</u>	<u>+ .524</u>	<u>580</u>
L1 ↔ B ^{PERP}	<u>- .139</u>	<u>1156</u>	<u>+ .173</u>	<u>1112</u>
U1/L1	<u>+ .192</u>	<u>913</u>	<u>- .431</u>	<u>896</u>

r Spearman's Rank Correlation Coefficient
 U Mann-Whitney U-test

Significant at 0.05 level
Significant at 0.01 level

Scatter plots for the L1-B^{PERP} and L1/FH measures versus FH/N-Pog are shown in Fig. 16. The lack of any discernible relationship of the points in the scatter plot for L1-B^{PERP} was typical of those measures which did not correlate to horizontal mandibular position, whereas the linear pattern of the points in the plot for L1/FH was typical of those measures which did.

The results of the Mann-Whitney U-test, where the sample was subdivided into two equal groups (n=51/group) above and below the median FH/N-Pog angle value (88.2°), demonstrated very similar findings for most measures. (Table 2). However, in contrast to the Spearman's rank correlations, the U1/L1 and the L1↔A-Pog measures showed significant differences between the low and high FH/N-Pog angle group.

The Spearman's rank correlation coefficient for the measures of mandibular incisor position versus FH/MP are also found in Table 2. The results revealed the following:

Correlation Not Significant p ≥ 0.05	Correlation Significant (p ≤ 0.05)
L1/MP	L1↔A-Pog
L1-B ^{PERP}	U1/L1
	L1/FH
	L1/OP
	L1/N-B
	L1↔N-B

Scatter plots for the L1-B^{PERP} and L1/FH measures versus FH/MP are shown in Figure 17. The lack of any pattern of relationship in the scatter plot for L1-B^{PERP} was typical of those measures of mandibular incisor position which did not correlate with vertical mandibular skeletal position, whereas the linear rela-

tionship of the points in the plot for L1/FH was typical of those measures which did.

The results of the Mann-Whitney U-test comparisons of the subdivisions of the sample by the median mandibular plane angle value (27°) were similar to those of the rank correlations.

The correlation between the L1↔A-Pog measure and S-N-A was not significant (r=.08). Similarly, the Mann-Whitney U-test found no significant correlation (U=1290; p=.9440) between these measures.

— Discussion —

Results of this study make it apparent that many of the cephalometric measures which are frequently utilized to determine maxillary and mandibular incisor position must be used only with a full understanding of the other variables that may affect the measurements. Reference lines based on points which are far removed from the incisor can be affected by remote variables, so are inappropriate for local descriptive applications.

It is important to note that correlations neither prove nor disprove cause-effect relationships. While correlations with remote structures suggest the possibility of corrupting influences, these findings are not definitive evidence of such effects. Conversely, the absence of correlation could be due to a lack of effect or the presence of a canceling countereffect.

On an individual basis, these references may still be used to provide useful information, provided that the various confounding factors are taken into account. For example, if one uses the U1↔N-A measures to evaluate maxillary incisor position, the position of the maxilla must also be considered. Simi-

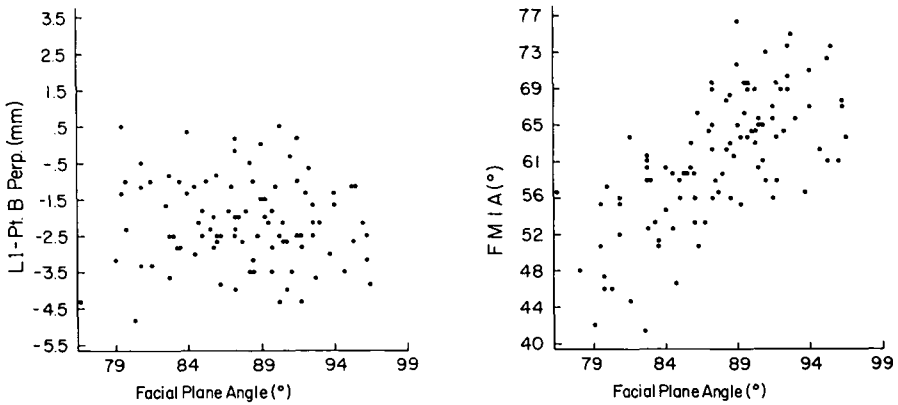


Fig. 16
 Scatter plots of the measures $L1-B^{PERP}$ and $L1/FH$ (FMIA) versus the FH/MP angle. $L1-B^{PERP}$ shows a nearly random distribution, whereas $L1/FH$ shows a linear tendency indicating a tendency for a larger $L1/FH$ angle with a more protrusive mandible.

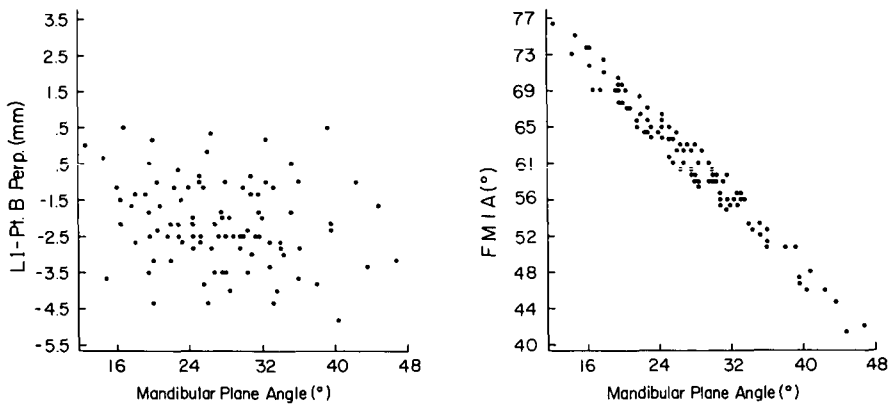


Fig. 17
 Scatter plots of the $L1-B^{PERP}$ and $L1/FH$ (FMIA) measures versus the mandibular plane angle. $L1-B^{PERP}$ shows no discernible linear relationship, indicating that it is unrelated to the mandibular plane angle. That would require a change in the $L1/FH$ angle with a change in mandibular plane angle, and the remarkably linear distribution seen in the plot for the $L1/FH$ angle shows this relationship. The $L1/FH$ angle tends to be larger with a more horizontal mandibular plane.

larly, if one uses the $U1 \leftrightarrow A$ -Pog measure, the maxillary and mandibular positions must also be taken into account.

Problems can come into play especially when such measures are used in studies where large samples are analyzed. In such instance, it behooves us to employ those measures which are least affected by skeletal factors which could make interpretation of the results difficult or questionable.

The advent of new orthognathic surgical procedures brings a need for cephalometric analyses which adequately represent the structures being altered. These should relate the jaws to the cranium and the teeth to the jaws.

As shown above, most of the measures of maxillary incisor position relate it to structures other than the maxilla. Only the $U1/PP$ angle and $U1 \leftrightarrow A^{VERT}$ reliably present the relationship of the upper incisor to the maxilla. Similarly, only the $L1/MP$ angle and $L1 \leftrightarrow B^{PERP}$ dimension reliably indicate the position of the mandibular incisor in the mandible.

The $U1/L1$ measure indicates the relation of upper to lower incisor. It is one of the least reliable indicators of incisor position within the respective supporting bones, because it is strongly affected by the position of the opposing incisors and by the relative horizontal and vertical positions of the maxilla and mandible.

The $U1 \leftrightarrow A$ -Pog and $L1 \leftrightarrow A$ -Pog measures, also prominent in our literature, relate the incisors to both jaws, making them very sensitive to the horizontal position of the mandible and the anatomy of the chin. The maxillary and mandibular positions must be taken into account in any evaluation.

A genioplasty can change these values dramatically.

Useful though such information may be for some applications, the variables

obviously make these measures unreliable as indicators of incisor position within the maxilla and mandible, even though maxillary and mandibular points serve as termini of the reference line.

Contrary to our expectations, no significant correlation was found between the position of the maxilla and the $U1 \leftrightarrow A$ -Pog values. This could be a result of a canceling effect from the various mandibular positions that were also highly correlated with the $U1$ -APog measures.

$L1 \leftrightarrow A$ -Pog is comparable with the upper measure. Although no significant correlation between the position of the maxilla and the $L1 \leftrightarrow A$ -Pog values was found in this study, this could be a result of a canceling effect from the various mandibular positions that were significantly correlated with the $L1 \leftrightarrow A$ -Pog measures.

A further problem with these measures stems from the fact that even if the mandible is in its proper location, horizontal macrogenia may bring pogonion farther forward.

Reduction genioplasties are performed frequently with or without other maxillofacial surgical procedures, and this operation will dramatically change the $L1 \leftrightarrow A$ -Pog value. Thus, while this measure has no utility as a measure of incisor position in the mandible, it can serve as a guide in such surgical procedures.

The $U1 \leftrightarrow N$ -Pog measure also relies on pogonion for one of its points of reference, so it is not a reliable indicator of the position of the maxillary incisor in the maxilla for the same reasons.

The $U1$ to N -A measures are among the most frequently used maxillary incisor measures. They are consistently reliable with a normally-positioned maxilla, but there is a significant correlation between these measures and the position of the maxilla. This means that the posi-

tion of the maxilla must also be taken into consideration. Of the two measures, the linear $U1 \leftrightarrow N-A$ measure seems to be the more reliable on the basis of its lower correlations with other structural variations.

The $U1/S-N$ measure theoretically relates the maxillary incisor to the cranium independent of the position of the maxilla. However, the results of this study show a significant correlation between this measure and maxillary skeletal position ($S-N-A$). This indicates that influences other than the horizontal position of the maxilla must be responsible for this correlation, since horizontal movements of the maxilla will not affect the $U1/S-N$ measure on a purely geometric basis. Changes in the angulation of the maxilla, however, do cause changes in the $U1/S-N$ measure (Fig. 1).

The interesting question is, why does the $U1/FH$ measure not show a similar correlation with maxillary skeletal position? It is similar to the $U1/S-N$ measure in most respects, other than its plane of reference. The reason may be indicated by the variation in the angle between $S-N$ and FH . The mean angle between $S-N$ and FH was 8.4° (s.d. = 2.7°), and the mean angle between $S-N$ and the palatal plane was 8.1° (s.d. = 3.4°). The mean angle between the palatal plane and the Frankfort horizontal plane was -3.1° (s.d. = 3.2°), indicating a different pattern of variation.

The $U1 \leftrightarrow A^{VERT}$ measure, although utilizing the cranial landmarks porion and orbitale, relates the maxillary incisor to the maxillary skeleton via point A. This measure was found to bear no relationship to the positions of the maxillary or the mandibular skeletons, and only slightly affected by the tilt of the maxilla, making it a very reliable indicator of incisor position in the maxilla.

The $U1/PP$ angle, which was chosen as the measure by which those with "neutral" maxillary incisor positions were selected from the total sample of 666 cephalographs, is the only measure which directly relates the maxillary incisor to the bony maxilla. It is suitable for this purpose, but an angular measure is often not as helpful in clinical practice as a linear measure.

Most clinicians deal with linear measures more than angular ones, and their measurement is more direct and less subject to error in constructing lines prior to measurement. In a patient with maxillary incisor retrusion, it is often more helpful to know how many millimeters of protrusion is desirable rather than how many degrees.

For linear measurement of the maxillary incisor position, the $U1 \leftrightarrow A^{VERT}$ measure is very useful. Nevertheless, either can effectively serve the purpose of relating the maxillary incisor to the maxillary skeleton, and can be used in data from large samples without the confounding problems inherent in the other measures of maxillary incisor position.

The $L1/FH$ (FMIA) measure theoretically relates the mandibular incisor to the cranium independent of the position of the mandible. However, the results of this study show a significant correlation between this measure and mandibular skeletal position, both horizontal and vertical. Autorotation of the mandible around its hinge axis changes the FMIA values, even though the position of the incisor within the mandible may remain unaltered. The $L1/FH$ (FMIA) measure is useful if one takes into account the position of the mandible, but this makes it unsuitable for use with large samples.

The $L1/OP$ angle, which has the theoretical advantage of relating the lower incisor to its plane of function, was

shown in this study to be a very insensitive measure of mandibular incisor position in the mandible. It correlated with both the horizontal and vertical positions of the mandible, and as such, would make interpretation of its measures very difficult without taking mandibular position into account.

One problem with the L1/OP is the difficulty in accurately drawing the occlusal plane. It is difficult to reproduce this plane from one cephalograph to the next, even within the same individual. Further, when a vertical dysplasia such as an anterior overbite or openbite is present, the occlusal plane is frequently drawn midway between the incisors to the molar contacts. Future changes and the inaccuracies of this halving procedure make serial studies especially questionable.

The L1:N-B measures are among the most frequently used measures of mandibular incisor position. In a normally positioned mandible, they are consistent indicators of incisor position on the mandible. However, significant correlations between the L1↔N-B measure and the horizontal position of the mandible, and between both of the L1:N-B measures

and the vertical position of the mandible were found in this study. This indicates that for these measures to be useful, one must also take into consideration the horizontal and vertical position of the mandible.

As noted earlier, most measures of mandibular incisor position do not relate the incisor to the mandible. The only measures which accurately do this are L1/FH (IMPA), which was chosen as the measure by which those with "neutral" mandibular incisor positions were selected, and the L1-B^{PERP}. Both reliably relate the mandibular incisor to the mandibular skeleton, and can be used in data analysis of large samples without the confounding problems inherent with in the other measures of mandibular incisor position. For clinical convenience, the linear measure L1-B^{PERP} may be preferred.

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