Reliability and Reproducibility of Natural Head Position: A Cephalometric Study

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ABSTRACT

Aims: (1) To determine the variability of S-N and Frankfort planes, (2) to establish the reproducibility of natural head position, (3) to establish norms for five cephalometric parameters in natural head position.

Materials and methods: A sample of 31 young adults from dental student population was selected under certain criteria. Two lateral cephalograms in natural head position (NHP) for each subject were taken within a span of 5 to 10 minutes following standardized procedure. All cephalograms were developed and traced by the same clinician under standard conditions. A true horizontal line drawn on film was transferred to tracing paper.

The conventional cephalometric planes were drawn. Subsequently, five angles were measured between true horizontal (HOR) and these conventional cephalometric planes.

Results: The above observations were subjected to statistical analysis to establish the variability of conventional intracranial reference planes and consistency of NHP. Statistical norms for five cephalometric parameters with respect to NHP were also established.

Conclusion: Since there is considerable variation in the inclination of conventional S-N and FH planes, a true horizontal extracranial reference line in NHP should substitute, or at least supplement, the use of intracranial reference planes for efficient orthodontic diagnosis and treatment planning. The new norms established for the five cephalometric parameters provide data that more closely describes morphology as it appears in real life. Hence, this data is more meaningful in clinical practice.

Keywords: SN, FH plane variability, Reliability and reproducibility of NHP, HOR.

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INTRODUCTION

The introduction of radiographic cephalometrics in 1934 by Hofrath of Germany and Broadbent of United States to orthodontics provided a research as well as a clinical tool to study malocclusion and underlying skeletal disproportions. Initially cephalometrics was used as a research tool to study growth of craniofacial complex. However, it soon became evident that the cephalometric films could be used to evaluate dentofacial proportions and understand the anatomic basis of a malocclusion.

A malocclusion detected clinically is the result of an interaction of the relation of the jaws to the cranium, the position of the teeth in jaws as they erupt, which in turn is determined by the relation of the upper and lower jaws. Hence, two apparently similar malocclusions as evidenced from the dental casts may turn out to be quite different when evaluated more completely using cephalometric films.

In any technique of cephalometric analysis, it is necessary to establish a reference plane. This problem was first encountered in the anthropometric and craniometric studies of the early nineteenth century. The Frankfort plane (adopted in 1882), employed for orientation of the head of the patient remains the commonly used reference plane even now. An alternative horizontal line, easily and reliably detected on cephalometric films, is the line from sella turcica (S) to the junction between the nasal and frontal bones (N) designated as S-N plane.

For the long dead skulls, the anatomists had no choice but to use the anatomic landmarks for the true horizontal. However, in living beings, it is possible to use a ‘true horizontal line’ established physiologically rather than anatomically. This means that this line is determined by the internal physiologic mechanisms that balance the head of the patient in space which may be termed as natural head position (NHP). NHP can be defined as a standardized orientation of the head which is readily assumed by the subject when focusing the eye to a point at a distance. This position can also be obtained when a relaxed subject looks into the image of his own eyes in a mirror placed in front of him.

A broad range of biologic variation is observed in facial configuration, maxillomandibular relationship, shape and size of the dental arches and teeth. This biologic variation is also evident in the anatomic location of skeletal landmarks that define intracranial reference planes. This variation usually gives rise to inconsistent cephalometric results, which in turn result in erroneous diagnosis and treatment planning.
The clinical significance of the variability of the three reference planes, viz, sella-nasion (S-N) plane, basion-nasion (Ba-N) plane and Frankfort plane used in the common cephalometric analyses has been investigated by various authors. The greater stability and reproducibility of NHP have also been demonstrated. Natural head position describes dentofacial and profile features of the patient as they appear in real life. Thus NHP in cephalometrics, as a standardized orientation of head in space, obviates reliance on inconsistent intracranial reference planes.

AIMS AND OBJECTIVES

The aims of this present study are as follows:
1. Determining the variability of two intracranial reference planes viz, S-N plane, Frankfort plane.
2. Establishing the reproducibility of a true horizontal line in NHP.
3. Establishing norms for five cephalometric parameters related to NHP.

MATERIALS AND METHODS

Total sample for the present study consisted of 31 young adults (16 males, 15 females) selected from the student population of MR. Ambedkar Dental College, Bengaluru. Subjects were selected to be included in the study only if they fulfilled the following criteria:
1. Age between 18 and 28 years.
2. Acceptable profile with good facial balance and normal lip seal.
3. Full complement of teeth except third molars.
4. Good occlusion with Class I molar relation.
6. No history or existent oral habits, cervical or spinal problems.
7. No ophthalmological problems and not wearing glasses or contact lenses.
8. No history or existent postural or hearing problems.
9. No history of nasorespiratory problems or surgery.

Two lateral cephalograms with a time interval of 5 to 10 minutes of each subject were taken in natural head position. To determine the natural head position of each subject, the following procedure was employed.

Subject was asked to stand relaxed; hands at his/her side and look through the window at a distant object. The posture of the subject was carefully observed by the operator. Subsequently, the subject was asked to walk slowly and sit in the vertically adjustable chair of the cephalostat (Trophy radiologie). The subject was subsequently asked to sit upright and relaxed and look into the image of his/her own eyes in a vertical mirror fixed on the wall perpendicular to the midplane of the cephalostat at a distance of 5 meters.

In consideration of the subject’s height, the chair was raised or lowered so that the ear rods of the cephalostat were in level with the external auditory meatus. The nasion rest of the machine was placed in position. The subject was moved gently forward or backward with the operator’s hand on the subject’s shoulder, taking care that the operator’s hand should not touch the subject’s head, to adjust the anteroposterior position of the external auditory meatus to the ear rod. Care was also taken that the subject did not tilt the head when so adjusted. The operator confirmed whether the subject so seated oriented his/her head in the same manner as when standing and looking at a distant object. The ear rods were inserted gently into the external auditory meatus and nasion rest is placed gently touching the soft tissue nasion and fixed firmly. This stabilized the head in both anteroposterior and transverse planes. The subject was then asked to keep the teeth in contact. Lateral cephalogram was exposed at 15 mA, 85 kVp for 1.25 seconds. This cephalogram was designated as mirror position I (MP I).

The subject was released from the cephalostat and instructed to walk around. Within an interval of 5 to 10 minutes, a second cephalogram was taken, duplicating the procedure observed while exposing the first film. This was designated as mirror position II (MP II). All cephalograms were developed by the same operator under standard conditions.

A true horizontal line (HOR) was drawn on each film using indelible ink parallel to the lower edge of the film. This line was drawn above the frontal sinus through the calvarium so as not to obscure any diagnostically important landmarks. This line represented an extracranial horizontal line.

Each cephalogram was traced by the same operator, under same illumination and magnification on acetate matte tracing paper. The registration crosses and true horizontal (HOR) were transferred to the tracing paper.

Each cephalogram was traced in the following order to outline
1. Soft tissue profile, external cranium.
2. Cranial base, internal border of cranium, frontal sinus and ear rods.
3. Maxilla and related structures including nasal bone, pterygomaxillary fissures, lateral orbital margins, infraorbital ridges, key ridges, first molars and incisors.
4. Mandible including first molars and incisors.

On the MP I tracings, the following points were located. 

_Sella (S):_ Geometric center of the pituitary fossa located by visual inspection.

_Nasion (N):_ The most anterior point on the frontonasal suture in the midsagittal plane.

_Orbitale (Or):_ The lowest point on the inferior rim of the orbit.

_Portion (Po):_ The most superiorly positioned point of the external auditory meatus.

_Pogonion (Pog):_ The most anterior point on the bony chin.

_Menton (Me):_ The lowest point on the symphyseal shadow of the mandible.

_Gnathion (Gn):_ A point located by taking the midpoint between the anterior (pogonion) and inferior (menton) points of the bony chin.
Point A: The most posterior midline point in the concavity between the anterior nasal spine and the prosthion (the most inferior point on the alveolar bone overlying the maxillary incisors).

Point B: The most posterior midline point in the concavity of the mandible between the most superior point on the alveolar bone overlying the lower incisors (infradentale) and pogonion.

The following planes were drawn as defined below.

- **Frankfort horizontal plane (FH):** A line joining porion and orbitale.
- **Sella-nasion plane (SN plane):** A line joining sella and nasion
- **Y-axis:** A line joining sella and gnathion, extended to HOR.
- **Long axis of the upper incisor (UL):** A line passing through the incisal edge and root apex of the maxillary incisors extended to HOR.

**Facial plane:** A line joining nasion and pogonion extended to HOR.

**AB plane:** A line joining points A and B extended to HOR.

**Long axis of lower incisor (LI):** A line passing through the incisal edge and root apex of the mandibular incisor extended to HOR.

On the MP II tracings, only S-N plane was drawn.

Subsequently, the following angles were measured on MP I tracings.

1. **SN/HOR:** The anteriosuperior angle between SN line and a line parallel to HOR passing through sella.
2. **FH/HOR:** The anteriosuperior angle between Frankfort plane and a line parallel to HOR passing through porion.
3. **Y-axis/HOR (Angle 1):** The anterioinferior angle between the Y axis and HOR.
4. **UL/HOR (Angle 2):** The posteroinferior angle between the long axis of maxillary incisor and HOR.
5. **Facial plane/HOR (Angle 3):** The posteroinferior angle between the facial plane and HOR.
6. **AB/HOR (Angle 4):** The anterioinferior angle between the AB plane and HOR minus 90°.
7. **LI/HOR (Angle 5):** The anterioinferior angle between the long axis of mandibular incisor and HOR.

Only SN/HOR was measured on MP II tracings.

These angles were measured to the nearest 0.5°. All measured values were tabulated and statistically tested.

**RESULTS**

From the measurements mentioned above, the following distributions of data with statistical tests were done and Tables 1 to 7 complied with graphic representation on bar diagrams (Graphs 1 to 3).

1. Distribution of the age of the subjects.
2. Distribution of angle FH/HOR in MP I.
3. Distribution of angle SN/HOR in MP I.
4. Comparison of angle SN/HOR in MP I to MP II.
5. Distribution of difference of angle SN/HOR observed between MP I and MP II.
6. Distribution of the angles of five cephalometric lines to HOR.
7. Estimated 95% confidence intervals of the above five lines to HOR.
Table 1: Age distribution of male and female respondents

<table>
<thead>
<tr>
<th>Sex</th>
<th>Mean Age ± Standard Deviation ± Standard Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>23 years 10 months ±2 years 5 months ±0.6</td>
</tr>
<tr>
<td>Female</td>
<td>22 years 01 months ±2 years ±0.5144</td>
</tr>
<tr>
<td>Combined</td>
<td>22 years 11 months ±2 years ±0.3741</td>
</tr>
</tbody>
</table>

Table 2: Distribution of FH/HOR angle in MP I

<table>
<thead>
<tr>
<th>Sex</th>
<th>Mean ± Standard Deviation ± Standard Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>3.75 ±3.33 ±0.8342</td>
</tr>
<tr>
<td>Female</td>
<td>5.07 ±5.06 ±1.3072</td>
</tr>
<tr>
<td>Combined</td>
<td>4.38 ±4.24 ±0.7615</td>
</tr>
</tbody>
</table>

Table 3: Distribution of SN/HOR angle in MP I

<table>
<thead>
<tr>
<th>Sex</th>
<th>Mean ± Standard Deviation ± Standard Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>7.625 ±3.96 ±0.9911</td>
</tr>
<tr>
<td>Female</td>
<td>9.330 ±4.80 ±1.2431</td>
</tr>
<tr>
<td>Combined</td>
<td>8.452 ±4.40 ±0.7908</td>
</tr>
</tbody>
</table>

Table 4: Distribution of SN/HOR angle in MP I and MP II

<table>
<thead>
<tr>
<th>Sex</th>
<th>Mean ± Standard Deviation ± Standard Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>7.625 ±3.96 ±0.9911</td>
</tr>
<tr>
<td>Female</td>
<td>5.07 ±4.80 ±1.2431</td>
</tr>
<tr>
<td>Combined</td>
<td>4.38 ±4.40 ±0.7908</td>
</tr>
</tbody>
</table>

Table 5: Distribution of difference between SN/HOR angle of MP I and MP II

<table>
<thead>
<tr>
<th>Sex</th>
<th>Mean ± Standard Deviation ± Standard Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>1.5625 ±1.36 ±0.341</td>
</tr>
<tr>
<td>Female</td>
<td>2.0000 ±1.60 ±1.1342</td>
</tr>
<tr>
<td>Combined</td>
<td>1.7743 ±1.46 ±0.2620</td>
</tr>
</tbody>
</table>

Table 6: Distribution of five factors to HOR

<table>
<thead>
<tr>
<th>Sex</th>
<th>Angle 1 Y-axis/HOR Mean ± SD ± SE</th>
<th>Angle 2 UI/HOR Mean ± SD ± SE</th>
<th>Angle 3 Facial plane/HOR Mean ± SD ± SE</th>
<th>Angle 4 AB/HOR Mean ± SD ± SE</th>
<th>Angle 5 LI/HOR Mean ± SD ± SE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>55.75 ±3.02 ±0.755</td>
<td>116.68 ±5.78 ±7.446</td>
<td>90.81 ±3.14 ±0.787</td>
<td>4.87 ±4.57 ±1.145</td>
<td>119.94 ±7.90 ±1.976</td>
</tr>
<tr>
<td>Female</td>
<td>54.47 ±4.14 ±1.068</td>
<td>119.27 ±7.23 ±1.868</td>
<td>91.13 ±5.14 ±1.327</td>
<td>4.00 ±6.92 ±1.787</td>
<td>120.33 ±7.41 ±1.914</td>
</tr>
<tr>
<td>Combined</td>
<td>55.13 ±3.60 ±0.647</td>
<td>117.93 ±6.55 ±1.177</td>
<td>90.97 ±4.10 ±0.738</td>
<td>4.45 ±5.24 ±0.941</td>
<td>120.12 ±7.54 ±1.355</td>
</tr>
</tbody>
</table>

To test the statistical significance of difference between means in all the above comparisons, Student’s t-test was applied. The t-value was calculated by the following formula:

\[
t_{\text{cal}} = \frac{X_1 - X_2}{\sqrt{\frac{SD_1^2}{n_1} + \frac{SD_2^2}{n_2}}}
\]

where,

- \(X_1\) = Mean of parameter 1
- \(X_2\) = Mean of parameter 2
- \(n_1\) = No. of determinations of parameter 1
- \(n_2\) = No. of determinations of parameter 2

The t table value for \(n_1 + n_2 - 2\) degrees of freedom was obtained from standard statistical textbooks. The difference is considered to be significant if calculated t-value was greater than the t-value from the Table.
DISCUSSION

Selection of an anatomically stable and technically reproducible plane has been a point of much debate since the inception of radiographic cephalometrics into orthodontics. Two most widely used reference planes, viz., Frankfort plane (FH plane) and S-N plane have been found to vary considerably in their inclination, which prompted second thinking among orthodontists regarding their very use in cephalometric diagnosis and treatment planning.\(^2\)\(^-\)\(^6\) These conventional intracranial reference planes were found to vary to a considerable degree, within individuals, depending on various factors.\(^7\) The search for an alternative lead to NHP, which showed better stability and reproducibility.\(^1\)\(^-\)\(^3\),\(^8\)\(^-\)\(^10\) Moreover, NHP was seen to describe dentofacial and profile features of the subject in the head plate as they appear in real life.

Natural head position is the result of the interaction and interrelation of a number of physiologic mechanisms. Hence, it is necessarily affected by a number of factors like craniofacial morphology,\(^11\)\(^-\)\(^13\) future growth trends,\(^14\),\(^15\) spinal posture,\(^8\),\(^16\) malocclusion of teeth,\(^13\) abnormal oral habits, orthognathic surgery,\(^17\) respiratory need,\(^18\)\(^-\)\(^23\) ophthalmological problems, hearing and balancing problems involving VIII cranial nerve.

This paper aimed to study the reproducibility of NHP as compared to variability of S-N and Frankfort planes. Further, an attempt was also made to establish norms for five important cephalometric parameters, often used in orthodontic diagnosis, as now related to NHP.

The pilot study on 10 subjects statistically decided the sample to be of 31 subjects. All subjects fulfilled all the criteria of selection to be included in the study. The sample was selected from the student population of MR Ambedkar Dental College, Bengaluru, comprising of subjects from different parts of India. No bias of any nature was exercised other than the selection criteria mentioned in the selection of the sample. Hence, the entire population had equal opportunity to be included in the sample. Hence, the sample studied can be considered as a mixed Indian population in a professional college and may be a very miniaturized true representation of Indian population. However, it is clearly stated here that a study on a larger and better chosen sample is necessary for scientific rationalization of the norms given as findings of this study.

As previously stated, NHP is affected by craniofacial morphology and dental malocclusion. Solow and Tallgren\(^13\) found positive correlations between head posture, dentoalveolar heights and inclination in occlusal plane. The correlations reflected dentoalveolar compensatory adaptation to the variation in vertical jaw relationship. This was found to be associated with craniocervical angulation, alveolar prognathism and incisor inclination. Hence, in selection of subjects, acceptable profile with good facial balance and normal

Table 7 shows the upper and lower limits of the angles between five cephalometric lines and HOR in a 95% probability chart.

### Table 7: Estimated 95% confidence limits of five factors to HOR

<table>
<thead>
<tr>
<th>Sex</th>
<th>Angle 1 Y-axis/HOR</th>
<th>Angle 2 UI/HOR</th>
<th>Angle 3 facial plane/HOR</th>
<th>Angle 4 AB/HOR</th>
<th>Angle 5 LI/HOR</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Lower limit</td>
<td>Upper limit</td>
<td>Lower limit</td>
<td>Upper limit</td>
<td>Lower limit</td>
</tr>
<tr>
<td>Male</td>
<td>49.70</td>
<td>61.79</td>
<td>105.12</td>
<td>128.25</td>
<td>84.52</td>
</tr>
<tr>
<td>Female</td>
<td>46.19</td>
<td>62.19</td>
<td>104.80</td>
<td>133.74</td>
<td>80.85</td>
</tr>
<tr>
<td>Combined</td>
<td>47.92</td>
<td>62.33</td>
<td>104.82</td>
<td>131.04</td>
<td>82.75</td>
</tr>
</tbody>
</table>
lip seal was a major consideration. With the same consideration, subjects with good Class I occlusion, full complement of teeth excepting third molars and no history of previous orthodontic treatment only were included in the sample.

NHP is also influenced by pernicious oral habits, cervical or spinal problems. Hence, subjects giving a history of any of these were not included in the sample.

NHP is the orientation of the head in space related to the visual axis being horizontal. In subjects with ophthalmological problems, orientation of the head will vary and hence subjects with ophthalmological problems were excluded from the sample.

Earlier studies by Solow and Siersbaek-Nielsen,15 Soow and Tallgren13 and Mew20 indicated the presence of some biologic mechanism coordinating changes in posture and lower facial development but did not indicate the direction of the cause and effect relationship, that is, whether posture influenced structure or vice versa. They felt that posture or factors determining posture do seem to influence the direction of growth of the face. According to soft tissue stretching hypothesis of Solow and Kreiborg,15 obstruction of the upper airways can lead to an increase in craniocervical angulation to facilitate respiration. This leads to a stretching of the soft tissue layer covering the face and throat. The backward and downward components of the strain in this soft tissue layer restricts or redirects the forward component of facial development in a more caudal direction. Since, these studies have shown that various types of airway obstruction do lead to extension of the head, subjects with history of nasorespiratory problems, orientation of the head will vary and hence subjects with history of nasorespiratory problems or surgery were excluded from the sample.

The method of orienting the head of the subject in NHP in this study is considered simple and the procedure is easy to learn and master for both the orthodontist and the auxiliary. Presently, the three methods of obtaining the NHP in vogue are:

1. By using a fluid bubble taped on the subject’s head.
2. Use of an external eye reference point.
3. Use of a comfortable ‘self-balance’ position or orthoposition without any external eye reference.

The fluid bubble device works on the following principle of hydrostatics. In a non-accelerating fluid system, the surface of the liquid is horizontal. The fluid surface tends to align in level with the two points where the fluid, glass and air meet, and will automatically seek the same level of gravity. These two points determine a line that is parallel, to the wire perpendicular to the gravity thus defined as true vertical. The use of fluid bubble device to orient NHP eliminates the need for double exposure which is unavoidable in reproducing NHP using external eye reference point or orthoposition.

External eye reference point can be the image of the subject’s eyes in a vertical mirror placed in front of the cephalostat or a paper dot pasted on the wall in front of the cephalostat 2 cm above the level of ear posts.

Molhave8 defined orthoposition as the intention position for walking. Solow and Tallgren8 advised forward and backward head oscillations before allowing the head to settle into a ‘self-balance’ position. Cooke and Wei8 suggested tilting of the head backward or forward with decreasing amplitude until a comfortable position of natural balance was achieved. It was demonstrated that this self-balance position differed significantly in male subjects from the NHP adopted when an external eye reference point was used. The boys tended to look up more in changing from the self-balance position to the mirror position, whereas no differences were found for the girls. A possible explanation is that girls are encouraged socially to adopt a good upright posture and to look straight ahead. They continue to adopt this posture even in the absence of an external eye reference point. But, the boys seem to adopt a lazier head posture in the self-balance position.

Two methods are used to represent true vertical in NHP radiographs. One is by a suspended metallic chain. The other method is using vertical edge of the film to represent true vertical, provided the cassette holder is aligned exactly perpendicular to the floor.

The fluid bubble device and suspended metal chain to represent true vertical were not used in this study since both were considered to be operator sensitive. Moreover, every radiology clinic may not have both these facilities for routine use.

During the positioning of the subject in the cephalostat, exposing, developing and tracing of the film, every effort was made to standardize the procedure for consistency. While stabilizing the subject’s head, ear posts and nasal rests were used since the radiographs taken without ear posts were reported to be of poor quality.8

In this present study the sample studied was a young adult group with a mean age of 22 years and 11 months.

The high standard deviations for inclination of S-N and Frankfort planes (4.2° and 4.4°) confirm earlier findings.2,4,24 They clearly exceed the standard deviations of HOR in NHP (1.46°). The difference between mean value of SN/HOR in MP I (8.452°) and MP II (7.581°) is only 0.87°. This shows that NHP varied by less than 1° from the first exposure to second exposure confirming that NHP is highly reproducible. The standard error NHP (0.262°) is very less compared to the high standard error values of FH/HOR (0.76°) and SN/HOR (0.79°) confirming the fact that NHP is more reliable.

From the above findings, it could be concluded that HOR represents a more stable base line for cephalometric analysis than S-N plane or Frankfort plane. In recommending HOR for routine use, the present study is in agreement with other authors.1,4,7 The large variation in the inclination of S-N and Frankfort planes negate the claim that they represent the head posture reliably. Whereas, the advantage of a true horizontal as a basic reference plane is its relationship to ‘true life appearance’.

Since, several researchers argued and the present study agreed that NHP is the logical reference and orientation position of the head for evaluation of craniofacial morphology, an attempt is made to present norms for five simple and
clinically practical cephalometric parameters routinely used in diagnosis, related to NHP.

Angle 1 (Y-axis/HOR) is analogous to the conventional Y-axis angle routinely measured to the Frankfort plane. This angle was interpreted by clinicians to predict the direction of growth of the chin. The advantage of the new variable is that it enables the direction of the growth of the chin to be expressed in terms of the true posture of the head. Increase in this angle indicates vertical growth pattern whereas decreased angle indicates horizontal tendency. The previous conventional measure of the Y-axis to FH, by virtue of the unreliability of the intracranial reference plane, may not describe the direction of the growth as it would manifest itself clinically in life.

In the present study mean value for this angle 1 is $55.1° \pm 3.6°$ and range is $47.9°$ to $62.3°$. These values are $8°$ to $10°$ less than the values for Chinese and Caucasian samples. The Indian population showed more horizontal tendency of growth when compared to Chinese and Caucasian population.

Angle 2 (UI/HOR) shows inclination of the upper incisor related to HOR. It describes the upper incisor inclination as it appears in life and should be interpreted in the same way as the conventional methods, which adopts either the maxillary plane or the S-N plane as the reference plane. Increased angle indicates proclination of upper incisors whereas decreased angle indicates retroclination of upper incisors. Mean value for this angle is $117.9° \pm 6.5°$ and range is $104.8°$ to $131°$. This is in agreement with the values of Hong Kong Chinese sample but around $10°$ more than Hong Kong Caucasian sample. This indicates that upper incisors are more proclined in Indian population compared to Caucasians.

Angle 3 (N-Pog/HOR) is the NHP equivalent of the Downs’ facial angle and is interpreted in the same manner. However, by adopting the true horizontal reference plane, the new angle measures the position of the chin and hence the type of the profile as these appear in life. The conventional facial (N-Pog/FH) angle describes the internal dentoskeletal structure, whereas the new method describe the dentoskeletal architectures, as they appear in life, when the head is in a natural posture. Increase in this angle suggests protrusive chin whereas decreased angle indicates retrusive chin. In the present study, the mean value of this angle is $90.1° \pm 4.1°$ and range is $82.7°$ to $99.2°$. This is $5°$ to $10°$ more than the values observed for Chinese and Caucasian subjects, indicating more horizontal growth tendency in Indian population.

Angle 4 (AB/HOR) is an improved method to assess the anteroposterior skeletal pattern. It is comparable to the much used Steiner’s ANB angle and hence, becomes meaningful and easy to interpret by the clinician. Ferrazini (1976), Binder (1979) and Lewis (1981) had shown that the assessments by angle ANB is distorted in representing the true relationship of the face, in the subjects where the nasion is markedly deviant in position from the average. Corrections to the observed measure of ANB, as devised from geometric principles, have not proved completely satisfactory. The Wits method, which gained acceptance subsequently, had the disadvantage that it measures distances and not angles and hence is not representative for vertical variation in the location of points A and B. Lastly, the clinical reproducibility of the functional occlusal plane is poor. None of the methods adopting intracranial reference planes allow for the previously described large intra- and interpopulation variances of the plane to the true vertical in NHP.

The new AB/HOR measure is simple and practical, and with the construction of the same horizontal line, a further set of useful descriptive variables is readily obtained. It eliminates the use of nasion and intracranial reference planes. AB/HOR further eliminates reference points related to the teeth and to the occlusion that are difficult to locate and difficult to reproduce accurately on cephalometric radiographs. Hence, AB/HOR angle must be viewed as a fundamentally new clinical assessment of the skeletal pattern in orthodontic diagnosis. The mean value observed for this angle is $4.45°$ and the range is $-6°$ to $+15°$. Larger positive angles indicates Class II skeletal pattern whereas larger negative angles indicate Class III skeletal pattern. The mean value is $5°$ to $10°$ less compared to Chinese and Caucasians.

Angle 5 (LI/HOR) indicates the inclination of lower incisor related to HOR. This measure allows the true protrusion of lower incisors in the subject to be expressed in the same dimensions in the cephalogram as observed in case of the upper incisor. Since, no corrections are required for variations in the maxillary or mandibular plane angles, in the expression of the above angle, the same provides an expression of how the lower incisors appear in the true life. Increase in this angle indicates proclination of lower incisors whereas decreased angle indicates retroclination of lower incisors. The mean value for this angle is $120° \pm 7.5$ and the range is $105°$ to $135°$. The mean value is $7°$ less compared to Chinese and Caucasian subjects.

In this new five factor analysis, only the reference plane has been changed to eliminate the errors inherent in analyses that use conventional intracranial reference planes. Conventional methods describe the internal architecture of the face well, but in describing true life appearance they are subject to errors, the magnitude of the errors depending upon the particular intracranial reference plane selected.

Where appropriate, and this would be in subjects in whom any conventional intracranial reference plane is not angulated within the average range, the new five factor analysis may be used to supplement the conventional cephalometric data. Thus, information is obtained that describes both the internal structural relationships of the person and also the morphology as it appears in life. The data derived using the new method to the true horizontal may serve as ‘checks’ and prevent fundamental misinterpretations in diagnosis and treatment planning, especially in patients who deviate markedly from the usual cephalometric norms.
SUMMARY AND CONCLUSION

The routinely used conventional reference planes were found to vary considerably in their inclination compared to a true horizontal in NHP, which confirmed the relative unsuitability as cephalometric reference planes for clinical purposes.

Because of the large variation of intracranial lines, the extracranial reference line (HOR), should substitute, or at least supplement, the use of intracranial reference lines for cephalometric analysis. Clinicians as well as auxiliary personnel can be trained to record lateral cephalograms in NHP, to enhance the reliability of cephalometric analysis in clinical practice and research.

A five-factor dentoskeletal analysis based on the true horizontal and natural head position was described. A special reference was made to the AB/HOR angle; an improved method for the assessment of the sagittal skeletal pattern. Analysis of individual subjects would produce differing interpretations of craniofacial form, depending upon whether the conventional intracranial reference planes were used or the true horizontal and NHP. The new five factor methods provided data that more closely describes the morphology and appearance of the subjects as they appear in real life. Hence, this data is more meaningful clinically. In individuals or groups in whom any conventional intracranial reference plane is not angulated within the average range, the new five factor analysis provides useful valid supplementary data. This data would serve as ‘checks’ and prevent significant errors in analysis, diagnosis and treatment.

REFERENCES