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Orbito-Condylion and Orbito-Basion Lines as Alternatives to Frankfurt and Sella- Nasion Lines in Cephalometry

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Abstract

Aim: Frankfurt horizontal and Sella-Nasion lines are the most widely accepted and used landmarks in cephalometric analysis. This study investigates the use of the Orbito-Condylion line extending from the Orbitale to the Condylion as a novel horizontal line for substituting the Frankfurt horizontal line. Similarly, the evaluation of the Orbito-Basion line as an alternative to the Sella-Nasion line in cephalometric analysis was done. We evaluated the reproducibility of the new horizontal lines and measured the angle between the Orbito-Condylion line and the Frankfurt line; and the angle between the Sella-Nasion and Orbitale-Basion line.

Methods: This investigation was carried out on 30 individuals. The Porion, Orbitale, Condylion, Sella, Nasion, and Basion were identified and marked. The angles between the orbito-meatal line (inferior orbital rim to the Porion; the Frankfurt line) and the Orbito-Condylion line (inferior orbital rim to the Condylion) were measured. Likewise, the angles between the Sella-Nasion line (center of sella tursica to Nasion) and the Orbito-Basion line (inferior orbital rim to Basion) were measured.

Results: Significant interobserver and intraobserver bias did not exist. The mean angle between the Frankfurt line and Orbito-Condylion line was 0.5°±2.27° and the mean angle between the Sella-Nasion line and Orbito-Basion line was 3.48°±3.11°.

Conclusion: This study showed the new lines have good reproducibility, reliability, and efficacy. The Orbito-Condylion and Orbito-Basion lines are reliable, reproducible, and easily identifiable, and has the potential as novel standard horizontal lines to supersede or complement the Frankfurt line and Sella-Nasion line in anthropological studies and clinical applications.

Keywords: Cephalometric, Frankfurt horizontal planes, orthodontics, Sella-Nasion plane, Orthodontics.

1. Introduction

The introduction of the new x-ray technique by Broadbent (1) led to cephalometry being traditionally performed by using a standardized lateral and posteroanterior cephalogram (2). In the selection of the most appropriate line for cephalometric orientation for descriptive skeletal morphology, the focus has centered on sella-nasion (SN) and the Frankfort horizontal plane (FH). The Frankfort horizontal plane, introduced by Ihering, was established at an anthropological conference in Frankfort (or Frankfurt), Germany, in the so-called Frankfort Agreement (3). It was defined as the plane passing through three points: the left orbitale, right, and left Porion points. The Orbitale is the lowest point of the lower margin of the orbit, and the right and left Porions are the uppermost points of the roof of each external acoustic opening (4). This plane is considered to be the most veritable standard plane in craniofacial studies and orthodontics. Moreover, it is regarded as the representative of the actual horizontal plane when the patient's head is in a natural position (5). Because both the Porion and Orbitale are situated in the external part of the

skull, the soft-tissue orbit and ear tragus can be seen clinically.

The sella turcica is a very important structure and the lateral cephalogram is a routine diagnostic tool used by every orthodontist. Hence, it is critical for a perceptive clinician to be completely aware of normal variants of the anatomical structure to identify abnormal deviations (6). The Sella-Nasion plane is pin pointed from the point Sella, found by observing the center of the sella tursica, and point Nasion, situated at the suture junction of the frontal bone with the nasal bone (4). The Sella-Nasion plane cannot be seen clinically; hence, it cannot be used as an instrument for actual direct clinical communication like the Frankfurt horizontal plane.

Cephalometric analysis is normally done on two-dimensional (2D) radiographs taken in the posterior-anterior and lateral views. Lateral cephalometric radiographs are the most commonly used diagnostic tool in post graduate studies as well as in clinical practice. However, although the Frankfurt line and Sella-Nasion plane are the most widely accepted reference lines in cephalometric analysis, several researchers have suggested new landmarks to overcome the challenges of identifying the intracranial landmark points (3). In addition, there may be situations that the traditional Frankfort line cannot be used when there is a missing part of the skull or the porion of the temporal bone is fractured.

In this prospective study, new orientation lines have been proposed and evaluated, the Orbito-Condylar line and Orbito-Basion line, as more easily identifiable planes passing through these lines and relatively easily identifiable anatomical structures as an alternative for the Porion and Sella, respectively. This study aimed to identify the replicability of the Orbito-Condylion line and Orbito-Basion line as novel reference lines, and measure the angles between this Orbito-Condylion and Frankfurt horizontal line as well as between the Sella-Nasion and Orbito-Basion lines.

2. Methods

Lateral cephalograms were collected from patients, aged 15-30 years, who referred to the Department of Orthodontics and Dentofacial Orthopedics, Vokkaligara Sangha Dental College and Hospital, Bangalore, India. A total of 54 patients' lateral cephalograms were taken.

The inclusion criteria were: (a) adult patients (>15 years) capable of giving consent, (b) receiving orthodontic treatment, (c) free of cleft lip or palate or other congenital deformities

Exclusion criteria was any surgical procedure undergone in the nasion, inferior orbital rim, and external auditory meatus region.

Thirty participants met the inclusion and exclusion criteria and hence, were included in the study. Twenty-four subjects were excluded owing to inefficient radiographs (presence of artifacts, overexposed radiographs, etc.) or previous surgery done.

The same operator took all the lateral cephalograms in the Natural Head Position (NHP) from the standard cephalostat; thus, improving reproducibility, and permitting cephalometric planes to be compared. The radiographs were traced manually and digitized. The landmarks were identified and positioned by two observers twice. After three weeks, intraobserver reliability was tested by retracing 10 randomly selected radiographs and analyzing them with the Bland-Altman test (7).

The cephalometric tracings were done manually by taping clear acetate tracing paper to a light box and a sharp pencil. Six landmark points were identified in the lateral cephalograms, namely Orbitale, Porion, Condylion, Basion, Sella and Nasion. Four lines were created between the (1) Orbitale-Porion, (2) Orbitale-Condylion, (3) Sella-Nasion, and (4) Orbitale-Basion. Two angles were measured: one between the Orbito-Condylion line and the Frankfurt horizontal line (Fig. 1) and the other one between the anterior cranial base (Sella-Nasion) and Orbito-Basion line (Fig. 2)

While measuring the FHP and Or-Co angle, the negative mean value means that the Condylion is located under the orbito-meatal line whereas the positive values refer to the Condylion point being above the orbito-meatal line. In the same way for measuring the angle between the anterior cranial base and Or-Ba line, the negative mean value

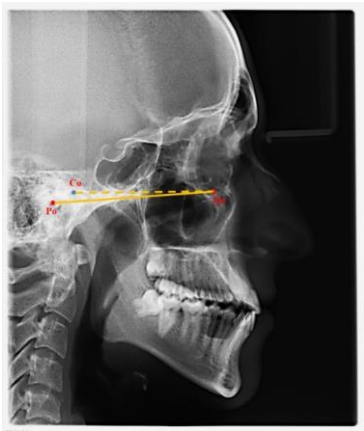

Figure 1. A lateral cephalogram image highlighting the lines drawn between the Orbitale (Or) to Porion (Po), and between the Orbitale (Or) to Condylion (Co). The angle between these lines was measured.

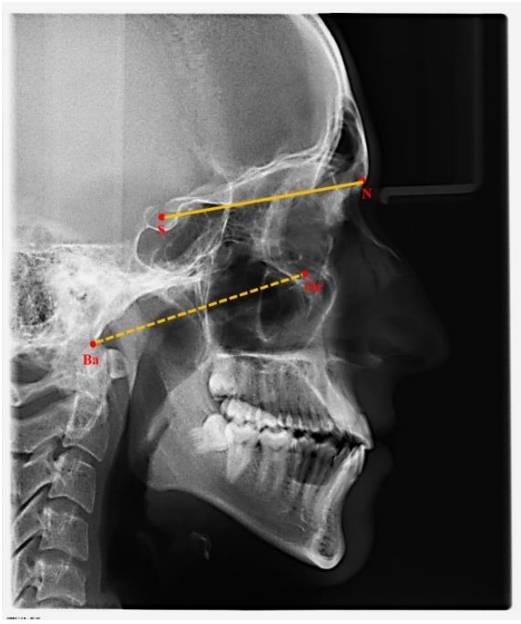

Figure 2. A lateral cephalogram image highlighting the lines between Sella (S) to Nasion (N), and between Orbitale (Or) to Basion (Ba). The angles between these lines were measured.

means, upon transposition, the Sella is located under the Or-Ba line whereas the positive values indicate that the Sella point is above the Or-Ba line.

3. Results

A Bland-Altman [7] test was carried out to evaluate the intraobserver reproducibility of the repeated measurements, which demonstrated good reproducibility. The Pearson correlation coefficients between the 2 measurements for the cephalometric planes were 0.99 for the FH plane and Or- Co, 0.978 for the SN plane - Or-Ba plane. These demonstrated good correlations between the measurements, indicating good intraobserver reliability. Descriptive data analysis was carried out to determine means, standard deviations, ranges (minimum, maximum), and coefficients of variation for the different planes. The coefficient of variation is the standard deviation divided by the mean, expressed as a percentage, and is a measure of relative variability. It helps to place the standard deviation in perspective by relating it to the size of the mean and was calculated because, for some reference planes, the mean value was small compared with the standard deviation.

Figure 3 shows the distribution of the angle between the Frankfurt line and the Orbito-Condylion line (α) as highlighted in Fig. 1. Each data point of α in the plot corresponds to an average value of the measurements obtained by the interobserver. The solid line in Fig. 3 represents the mean and the dash lines represent the +/-SD of α distribution. The overall angle between the two lines was 0.5°±2.27° (mean±SD). The angle was between –1° and +1° in 40% of cases and between –3° and +3° in 86.60% of cases.

Figure 4 shows the distribution of the angle between the Sella-Nasion line and the Or-Ba line (β) as highlighted in Fig. 2. Each data point of β in the plot corresponds to an average value of the measurements obtained by the interobserver. The solid line in Fig. 4 represents the mean, and the dash lines represent the +/-SD of β distribution. The overall angle between the two lines was 3.48°±3.11° (mean±SD). The angle was between –3° and +3° in 46% of cases and between –5° and +5° in 76.6% of cases.

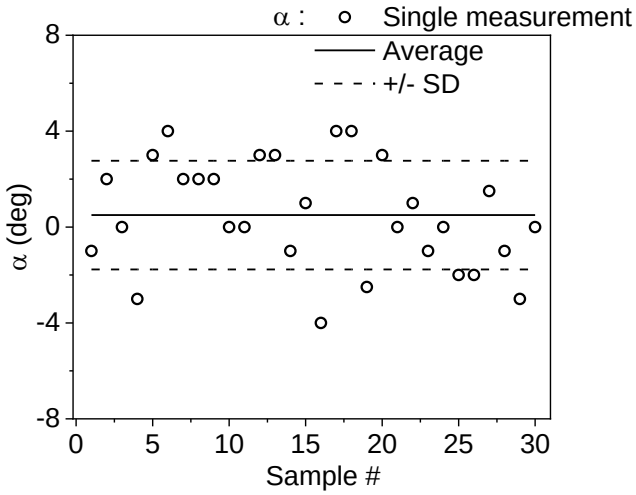

Figure 3. Data distribution for the angle α measured between FHP and Or- Co line, measured in degree (deg).

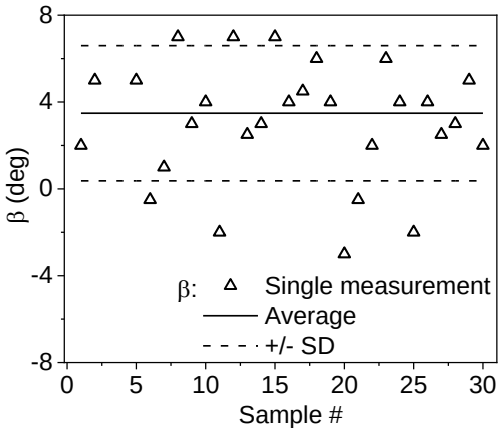

Figure 4. Data distribution for the angle β measured between anterior cranial base (sella- nasion line) and Or- Ba line, measured in degree (deg).

4. Discussion

Once cephalometric analysis was introduced to the world, the focus has been on reading or interpreting the lateral skull radiographies with the intent of developing an efficacious tool for orthodontic diagnosis and treatment planning. The elementary challenge in cephalometric interpretations is that there is no stable reference line, point, or system on the cross sectional and longitudinal patterns. Numerous reference planes have been used to resolve this challenge, including the Frankfurt horizontal plane, mid-sagittal plane, Sella-Nasion plane, and facial plane.

There is always the need to constantly search for newer methods and systems in the existing ones, newer cephalometric analyses and angles for correct diagnosis and treatment planning of patients. For example, the beta angle, proposed by YolBaik and Ververidou, gives more stable values even when jaws are rotated, and hence reflects actual changes in the sagittal relationship of the jaws, offering several advantages to its compatriots such as the ANB angle and Wits appraisal. Similarly, newer landmarks and lines proposed here, offer a broader scope for more analyses.

Most of these planes have been defined traditionally, and are developed from the intracranial anatomical points and the Frankfurt horizontal plane, which is regarded as the standard horizontal plane for displaying the natural head position (8). Similarly, the anterior cranial base has been adjudged as the most stable and practical plane to assess facial measurements and cephalometric analysis. However, the reliability and reproducibility of these planes have been challenged (8,9), with some authors calling attention to the fact that the intracranial landmarks used to define the Frankfurt horizontal plane (especially the Porion) are challenging to ascertain. Also, Sella being the constructed point, has a very high variability.

Potential mistakes errors in ascertaining the Porion are attributable to substantial variations in the position and inclination of the external acoustic meatus and in the size of the external acoustic orifice have been reported (10,11). Koski (12) suggested that the Frankfurt horizontal plane is challenging to find and does not illustrate the real horizontal plane. Hassan et al. (13) also demonstrated that the Porion was the most inaccurate landmark due to the curvature of the external acoustic meatus causing challenges in identifying the most-superior point of the external acoustic orifice. This caused Pittayapat et al. (3) to propose using the internal acoustic foramen as an option to replace the Porion. These authors demonstrated that the angle between the Frankfurt plane and a new plane connecting each Orbitale and the mid-internal acoustic foramen was less than 1°. This study discovered that the angle between the Orbito-Condylion line and the Frankfurt horizontal line was less than 1° on average, which would not be clinically significant, and ranged from only –3° to +3° in 86.6% of cases. This indicates that the line traversing through the Condylion and each Orbitale is about parallel to the traditional Frankfurt line, hence, it can be used in both clinical and anthropological researches. The Orbito-Condylion line could be particularly applicable in cases of temporal bone fracture when the Porion cannot be taken as a landmark for the Frankfurt line. Also, in anthropological and archeological investigation, the Orbito-Condylion line can enhance the use of the Frankfurt horizontal line when part of the skull is fractured or absent, or cannot be accurately located.

The SN line is commonly used to indicate the

anterior cranial base and serve as a reference to illustrate skeletal relations in both antero-posterior and vertical planes. Many studies (12,14,15) have studied the reliability of the SN line in connection with other reference planes. Studies on the anterior cranial plane have documented that the SN line, regardless of its straightforwardness in locating it, can possess numerous challenges, namely its varying length and rotations, clockwise or counter-clockwise. However, they approved its use in cephalometric analysis, was although suggesting special consideration should be given for the length and orientation of the SN line. Mills (16) showed that the significance of angle ANB varies based the size of the angle, because it is affected by the length, and can't of the SN line and the relative upward or downward relation of nasion. He proposed corrective methods to adjust angles SNA and ANB by moving points S and N pending the correct values of the angles were reached. Bishara et al. (17) showed that the spatial variability of points S and N are determinants in the relative rotation of the SN line.

Jarvinen (18, 19) demonstrated that the probable variations in recorded values of angle SNA can be somewhat due to actual variability in the antero-posterior location of the maxilla, whereas another explanation could be due to the variants in the shape of the cranial base as represented by the SN line. The major challenge of the SN line appears to be its relative rotation in the clockwise or anticlockwise direction. The challenge seems to be centered on patients having skeletal problems with a rotated SN line who require exact diagnosis and treatment planning. Basion, being an anatomical point, can be easily identified and located and hence holds better accuracy rate when manual tracings are done. This accounts for higher reproducibility as well.

The samples in this prospective study did not represent people of all ages since they were selected from the lateral cephalograms of patients ranging from 15 to 30 years. Further research including all age groups are needed to confirm that these proposed planes can be applied to the general population as well. Despite the growing preference for CT scans, radiography remains the gold standard in cephalometric analysis for clinical use. We considered that using lines instead of planes was more practical and simpler, and lines could indicate planes if there were no significant asymmetry.

We do not suggest that orthodontists completely discard any prior established cephalometric measurements and landmarks. On the contrary, these newly suggested landmarks and planes could enhance the present cephalometric tools available to the clinician and enables better diagnosis and treatment planning. Clinicians should realize of the numerous cephalometric landmarks as much as possible that could result in a greater number of analyses while using them cautiously and appropriately. Cephalometric landmarks and analyses that were established years ago without intermittently reevaluating it could cause incorrect diagnoses, hence, treatment planning based on such diagnoses can be insufficient or even harmful.

Conclusion

Anatomic reference planes are commonly used for patient head positioning, diagnosis and treatment planning, and cephalometric analyses, although they have their disadvantages, especially in orthognathic patients, where head positioning is important. Anatomic reference planes like the FH and SN plane, are regularly used as craniofacial reference planes even though variations may exist, especially in patients with significant facial deformities, leading to errors in diagnoses and selected treatment plans (20).

The present study investigated the implications of using the new lines, namely Orbito-Condylion line to replace the FHP and Orbito-Basion line to replace the Sella-Nasion plane. The mean angle between the Orbito-Condylion and FHP being less than 1°, make it accurate and highly reliable to be used by the practitioner.

There is no statistically significant difference between the mean α and β angles in males and females, making it universally applicable. The novel horizontal Orbito-Condylion line and Orbito-Basion line shows good reproducibility and so has the potential to substitute or at least supplement the standard Frankfurt horizontal line and Sella-Nasion line respectively in anthropological studies and certain clinical applications.

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