



## Discrepancies in cephalometric measurements in relation to natural head position

### *Discrepancias en medidas cefalométricas en relación a la posición natural de la cabeza*

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#### ABSTRACT

The objective of this study was to determine the cephalometric discrepancy of some reference planes and angles in relation to the natural head position. 78 patients were admitted at the Orthodontic Service of the Mexico Children's Hospital and 2 lateral X-rays were taken from the skull of each patient. The first radiograph was in natural position. The patient positioned his head in a relaxed way looking into the horizon, with slightly separated legs, arms resting at the sides of the body, lips at rest. The second radiograph (assisted) was taken with the above mentioned parameters and without the olives pressing the external auditory meatus. A 4 x 8 cm to 1.5 m mirror was given to each patient of so that they could look into it with his or her pupils focused in the eye center and a plummet placed on the chassis of the plate (representing the true vertical) plus a profile photograph with the same indications. The measurements in both plates were traced, measured and compared. We considered the random error with a standard deviation of 0.4 mm, Houston's.<sup>1</sup> **Results:** We found a statistically significant difference ( $p = 0.004$ ) between the Frankfort plane and the true horizontal and ( $p < 0.005$ ) between nasion perpendicular to point A and between subnasal vertical to pg' in relation to the Frankfort plane and to the true horizontal unlike facial depth ( $p = 0.545$ ).

**Key words:** Frankfort plane, true horizontal plane, natural head position and natural head posture.  
**Palabras clave:** Plano de Frankfort, horizontal verdadera, posición y postura natural de la cabeza.

#### INTRODUCTION

The natural head position (NHP) is defined as an innate, physiological and reproducible position of the head obtained when the patient is in a relaxed position, sitting or standing, looking into the horizon or into an external reference point (a mirror, a mark on the wall) at eye level. It is known as the auto balance head position or natural orientation. It is important to distinguish between natural position and natural posture since posture is used to study the relationship between morphology and function, usually defined as a position in which the patient is standing keeping his or her head on its own balance in a non-strained position for a specific activity at some time.<sup>2-14</sup>

#### RESUMEN

El propósito del estudio es determinar la discrepancia cefalométrica de algunos planos y ángulos de referencia con relación a la posición natural de la cabeza. Seleccionamos los 78 pacientes que ingresaron al Servicio de Ortodoncia del Hospital infantil de México en el 2004, tomamos 2 telerradiografías por cada paciente. La primera con postura natural, el paciente posicionó su cabeza de manera relajada mirando hacia el horizonte, piernas ligeramente separadas, los brazos al costado del cuerpo, labios en reposo. La segunda (asistida) con los mismos parámetros mencionados sin que las olivas presionaran el conducto auditivo externo, adicionándole un espejo de 4 x 8 cm a 1.5 m para que el paciente mire con sus pupilas en el centro del ojo y una plomada colocada sobre el chasis de la placa (representando la vertical verdadera) más una fotografía de perfil con las mismas indicaciones. Se trazaron, midieron y compararon ambas placas. Consideramos el error aleatorio con una desviación estándar de 0.4 mm según Houston.<sup>1</sup> **Resultados:** Encontramos diferencias estadísticamente significativas ( $p = 0.004$ ) entre Frankfort y la horizontal verdadera y ( $p < 0.005$ ) en nasión perpendicular/punto A y vertical a subnasal/pg' en relación al plano de Frankfort y a la horizontal verdadera a diferencia de la profundidad facial ( $p = 0.545$ ).

The concept of natural head position is not new. Leonardo da Vinci (1452-1519) and Albrecht Dürer (1471-1528) used horizontal and vertical lines on paintings of models positioned in a «natural pose» so that the artistic and scientific replica of human heads was secured. In the XIX century, Von Baer, Wagner

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and Broca defined the natural posture of the head as the subject's posture when they are standing with their horizontal visual axis.<sup>4</sup>

Currently, lateral radiographs are one of the most important diagnosis elements and auxiliaries. With them cephalometry, which is a study that measures the skull, the face, maxillary bones and dental positions, is performed and helps the orthodontist in obtaining a more profound knowledge of the structures on which he or she works by visualizing, like in a showcase, what lies beneath the soft tissues.<sup>15,16</sup>

The Frankfort Horizontal Plane (FHP) is one of the most used planes in cephalometry. It was adopted with the purpose of orienting the skull in a similar way to the natural head position. In cephalometric practice this plane presents two difficulties: a) Problems in locating accurately its two reference points, especially Porion, b) The operator assumes that the Frankfurt plane is parallel to the true horizontal plane which does not occur in many individuals, there have been observed differences of up to 10 degrees and even more.<sup>17</sup> Arnett mentions:<sup>18</sup> no one walks with the Frankfort plane parallel to the ground and we can have a patient in natural head position but with the Frankfort Plane inclined upwards or downwards (*Figure 1*).

The Frankfort plane and others have been criticized by clinicians and investigators because of their lack of required stability but none of the suggested options has a rigorous certainty.<sup>15</sup> Measurements such as Sella-Nasion- Point A, Maxillary Depth, Facial Depth, etc. do not correlate or correspond to the patient's real malocclusion.<sup>2,4,19-26</sup>

Sometimes we observe that lateral radiographs show us that the patient's head is inclined upwards or downwards without respecting the Natural



**Figure 1.** Frankfurt plane in different head positions.

Head Position concept thus altering the position of some cephalometric landmarks such as Pogonion, Menton, etc. useful for measuring a protrusion or prognathism (Class III) or a mandibular retrusion that might suggest a skeletal Class II due to mandibular deficiency and the real appreciation of the patient's profile is lost.

Every time there is doubt regarding the correct position of the head in the lateral radiograph there is the possibility of controlling this problem by using the profile photograph.<sup>2,20,25</sup>

Every successful treatment is related directly to a correct diagnosis, the correct position of the lateral radiograph will help us obtain a reliable diagnosis for the precise application of the therapeutic measures.

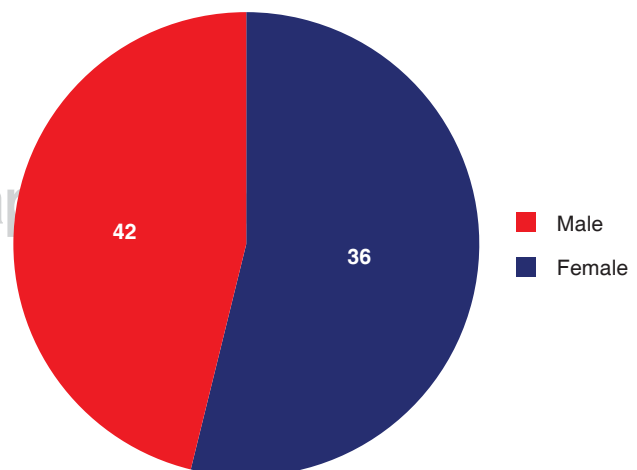
The importance of this study lies in comparing two methods for taking lateral radiographs so that the clinician is able to obtain or achieve precise and reliable cephalometric tracings, increasing the reliability of cephalometry and thus obtaining a better diagnosis.

## METHODS

The design of this study was transverse and comparative.

All 9 to 15-year-old patients that attended during 2004 to the Orthodontic Service were selected, being a total of 78 patients (sample available in the 2004 annual records) (*Figure 2*).

Two lateral head films were taken by the same operator (radiology technician) to each one of the 78 patients with the Soreedex cephalostat from the Orthodontic Service of the Children's Hospital of



**Figure 2.** Distribution by gender.

Mexico Federico Gomez, taking into consideration the following:

The first radiograph (natural posture) was taken asking the patient to position his or her head inside the cephalostat in a relaxed manner, looking into the horizon, legs slightly spread, arms at the sides of the body, lips at rest (Figure 3).

The second radiograph (assisted) was taken with a Natural Head Position. The patient was asked to position his or her head inside the cephalostat without the olives pressuring the hearing meatus or the auricular cartilage, we placed the patient sideways and in a natural position, at eye level we placed at 1.5 m a 4 x 8 cm mirror so that the patient could observe his or her pupils at the center of the mirror. We also placed



Figure 3. Lateral head film in natural posture.



Figure 4. Lateral head film in natural head position.

a lead chain over the radiographic plate's chassis thus obtaining a true vertical reference and we marked the tip of the nose and the soft pogonion (Figure 4).

Subsequently we took a photograph to confirm and obtain more precise data of the NHP taking under consideration the same indications for the radiograph at NHP. In front of the patient a lead chain was placed and so we obtained a true vertical line in the photograph and we traced a line from the tip of the nose to the soft pogonion. Then we

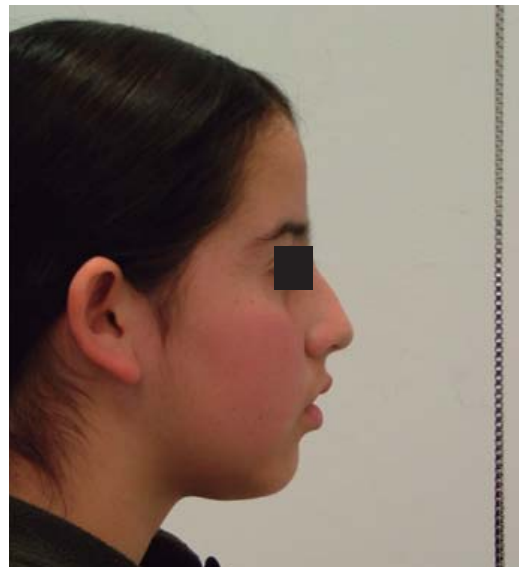


Figure 5. Lateral extraoral photograph in natural head position.

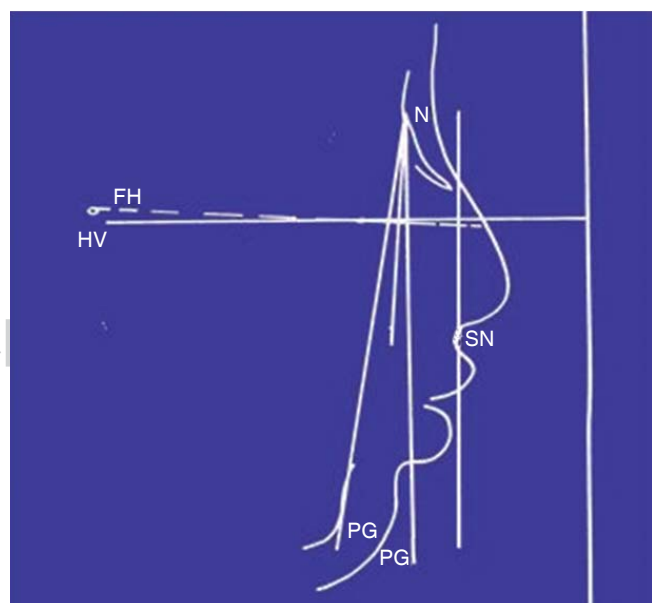


Figure 6. Cephalometric tracing.

continued that line until it reached the true vertical line, forming an angle which we transferred to the radiograph (*Figure 5*).<sup>4,6,16</sup>

The radiographs were taken at 70 KVp to secure the penetration of the bone structures and the recommended exposure time was 1 second.<sup>28</sup> The radiographs were then developed with Kodak products. The cephalometric tracing was performed (*Figure 6*). Prior to the tracing, the observer was calipered by one

of the specialists of the department who is considered an expert in the area with vast clinical experience and an opinion leader. The tracing papers were placed over the radiographs and the following cephalometric measurements were compared:

- True horizontal plane *versus* Frankfort plane.
- Perpendicular N to true horizontal line with point A.
- Perpendicular N to Frankfort plane to point A.

**Table I.** Concepts used in the study.

Natural head position (assisted)	It is defined as an innate, physiological and reproducible position of the head. It is obtained when the patient is in a relaxed position, sitting or standing, looking into the horizon or into an external reference point (mirror, mark on the wall, etc.) at eye level <sup>2-13</sup> or at the same level as the olives
Natural head posture (orthoposition)	It is the physiological position that a person shows when giving a step forward. This posture is different among individuals and may vary if the person has nasal obstruction or other physiological anomalies <sup>2,3,29</sup>
True horizontal plane True vertical	Line represented by the chain that hangs at the border of the plate. The true horizontal (physiological) is the perpendicular line to the true vertical <sup>16</sup>
Frankfort plane (FHP)	It is the line created by the opening of the external auditory meatus (Porion) and the low point on the lower margin of the infraorbital rim
Point N (Nasion)	It is located at the joint of the frontonasal suture with the nasal bones <sup>34</sup>
Point A	Also called subspinal. It is created by the lowest point of the anterior concavity of the premaxilla <sup>15,17,30-33</sup>
Subnasal point (Sn):	It is the point that connects the base of the nasal columella with the upper lip
Pogonion point (Pg):	Most anterior point of the mandible on the midsagittal plane of the symphysis <sup>15,17,30-33</sup>
Soft tissue pogonion Pg'	Most anterior point of the chin prominence traced over the soft tissue profile <sup>35</sup>
Perpendicular N to true horizontal plane with point A	Distance in mm from Nasion perpendicular to point A Normal value $0 \pm 2.7$ mm. An increase suggests a maxillary protrusion and a decrease, a maxillary retrusion
Perpendicular N to Frankfort plane with point A:	Distance in mm from Nasion perpendicular to point A Normal value $0 \pm 2.7$ mm. An increase suggests a maxillary protrusion and a decrease, a maxillary retrusion
Subnasal vertical to true horizontal plane	Line drawn from subnasale perpendicular to the true horizontal line. It is measured in mm from the perpendicular to the soft Pogonion. Normal value: $3 \pm$ mm. It is used to assess the anterior-posterior position of the chin <sup>15,17,30-33</sup>
Subnasal vertical with Frankfort,	Line drawn from subnasale and perpendicular to the Frankfort Plane. It is measured in mm. Normal value: $3 \pm 3$ mm, it is used to assess the anterior-posterior of the chin in relation to the true head position. If increased, there is an advanced position of the chin which will produce a concave profile
(TH/FD) facial depth/true horizontal	Angle formed by the true horizontal and the N-Pg line. It is measured in degrees Normal value: $87 \pm 3^\circ$ . It is used to assess the mandible in relation to the true head position
(FH/FD) facial depth/Frankfort	Angle formed by the Frankfort plane and the N-Pg line. It is measured in degrees. Normal value: $87 \pm 3^\circ$ . It evaluates the position. It is used to assess the antero-posterior position of the chin <sup>31-33</sup>

- Sub nasal vertical with horizontal plane.
- Sub nasal vertical to Frankfort.
- Facial depth to Frankfort.
- Facial depth to horizontal plane.

### ETHICS

In agreement with the Hospital Ethics Committee's Guidelines, the patients were asked to sign an informed consent. A written authorization by the patient's parents was obtained, a photograph of which is published in this paper.

### STATISTICS

Means and standard deviations of each one of the variables was obtained. Both study groups were compared with a «t» *Student* test. The random mistake was considered with a standard deviation of 0.4 mm. All calculations were performed with the statistical program SPSS 12.0 version.

### RESULTS

We found statistically significant differences ( $p = 0.004$ ) between Frankfort and the true horizontal and ( $p < 0.005$ ) in the perpendicular nasion/point A and the subnasal vertical/Pg in relation to the Frankfort plane and the true horizontal line unlike the facial depth ( $p = 0.545$ ).

The average difference between FH and the true horizontal by gender was 3.18 degrees in female patients and 4.416 degrees in male patients.

### DISCUSSION

Due to the significant variation found in the Frankfort plane when used as an intracranial reference, an extracranial line of reference, the true horizontal line has been used.<sup>2,5,7,21,36,37</sup> However the minor importance that the specialized text publications have given to an adequate head orientation draws the attention. For the beforehand

explained reason we took 146 lateral headfilms, half in natural head posture on and the other half in natural head position with the aim of determining the discrepancy in the cephalometric tracings and finding a statistical relationship.

In the patient's study sample we only found 5 patients in whom Frankfort was parallel to the true horizontal line thus resulting in a non-significant statistical difference.

In our results we found that there is a 3.75 degree difference with a statistical difference of  $p = 0.004$  between the Frankfort plane and the true horizontal, result that resembles what investigators such as Cooke mentioned in his study performed on Chinese children where he found a difference of 5.2 degrees in boys and 4 degrees in girls.<sup>27</sup> Bjerin<sup>24</sup> mentions that the difference between FHP and TH is of 4.6 degrees. The result of the present study agrees in relation to gender with a more significant difference in males.

In the study performed by Lundström et al<sup>20</sup> on 79 British children, they found statistically significant differences for both genders in the angle formed by the Frankfort plane with the true horizontal line in relation to the natural head position, where the difference was 2.6 degrees less in boys and for girls it was 4.1 degrees. In our global sample the discrepancy was bigger in males with an average difference of 4.416 degrees and 3.18 degrees respectively.

Several investigators<sup>2,4,19-23,25,26</sup> have observed that the measurements taken from planes such as SNA, maxillary depth, facial depth, etc. do not reflect the patient's real malocclusion. We found that there is variation between FHP and THL with differences or discrepancies in the studied cephalometric tracings where the subnasal vertical line, perpendicular N to point A was statistically significant ( $p = 0.545$ ) (Table II).

In this study there were 9 patients with lip palatal sequel and 69 non-affected patients diagnosed as «healthy» with an average per diagnosis between FH and the true horizontal line of 3.7464 degrees in healthy patients and 3.7778 degrees in patients with lip-palate sequel.

Table II. Statistical comparison of the variables.

Compared variables	t	p value
FH versus TH	2.98	0.004
A FH/perpendicular versus HV/perpendicular	-5.442	0.000
Subnasal vertical/FH versus Subnasal vertical/HV	-9.028	0.000
FH/FD versus HV/FD	0.607	0.545



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