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The Influence of Natural Head Position on the Assessment of Facial Morphology

Wpływ naturalnej pozycji głowy na ocenę morfologii twarzy

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A – research concept and design; **B** – collection and/or assembly of data; **C** – data analysis and interpretation; **D** – writing the article; **E** – critical revision of the article; **F** – final approval of article; **G** – other

Abstract

Background. Skeletal relationships play a major part in determining occlusal relationships, and that is why they also affect orthodontic treatment. Facial morphology can be assessed by clinical or radiological methods. Soft tissue analysis of the face is accepted as an integral part of orthodontic diagnosis and treatment planning.
Objectives. The aim of the study was to determine the impact of the inclination between the Frankfort horizontal (FH) and the extracranial horizontal (HOR) lines with the head in the natural position (NHP) on the assessment of facial morphology.
Material and Methods. Lateral facial photographs of 200 young adult males and females were taken with the head in the natural head position and then analyzed. Each image was rotated in order to position the Frankfort line parallel to the extracranial horizontal line. Twelve landmarks on each of the 400 profile photographs (200 originals, 200 processed) were identified, and nine linear measurements and three angular measurements were assessed.
Results. The inclination angle between the extracranial horizontal line and the Frankfort horizontal line in the NHP varied from –7.1° to 5.6° (mean –1.20°). Significant correlations were found between the inclination angle FH/HOR and both sagittal and vertical morphology predictors such as the sections N-Sn ($r = 0.3737$, $p = 0.0001$), Sn-Gn ($r = 0.3231$, $p = 0.0000$), and both facial angles ($r = 0.9774$, $p = 0.0000$) and profile angles ($r = 0.9654$, $p = 0.0000$).
Conclusions. A comparison of soft tissue measurements determined with reference to the Frankfort horizontal and extracranial horizontal lines with the head in the natural position reveals significant differences (**Adv Clin Exp Med 2012, 21, 6, 743–749**).

Key words: facial morphology, natural head position.

Streszczenie

Wprowadzenie. Relacje podstaw kostnych są głównym czynnikiem determinującym zwarcie łuków zębowych, a tym samym sposób leczenia ortodontycznego. Ocena morfologii twarzy może być dokonywana zarówno w warunkach klinicznych, jak i na podstawie metod radiologicznych. Analiza tkanek miękkich twarzy jest zatem powszechnie akceptowalną częścią diagnostyki i planowania ortodontycznego.
Cel pracy. Określenie wpływu kąta inklinacji linii frankfurckiej i rzeczywistej linii poziomej (HOR) w naturalnej pozycji głowy (NHP) na ocenę morfologii twarzy.
Materiał i metody. Analizie poddano 200 fotografii profili dorosłych osób, wykonanych w naturalnej pozycji głowy. Zdjęcia poddano rotacji w celu uzyskania równoległości linii frankfurckiej do rzeczywistej linii poziomej. Na każdym z 400 zdjęć profili (200 oryginalnych i 200 poddanych obróbce) wyznaczono 12 punktów, dokonując oceny 9 pomiarów liniowych i 3 kątowych.
Wyniki. Wartość kąta inklinacji linii frankfurckiej i rzeczywistej linii poziomej wynosiła –7,1–5,6° (średnia –1,20°). Stwierdzono istotną zależność między kątem inklinacji linii odniesienia (FH/HOR) a sagitalnymi i wertykalnymi predykatorami liniowymi: N-Sn ($r = 0{,}3737$; $p = 0{,}0001$), Sn-Gn ($r = 0{,}3231$; $p = 0{,}0000$) oraz kątowymi: kąt twarzowy ($r = 0{,}9774$; $p = 0{,}0000$) i kąt profilu ($r = 0{,}9654$; $p = 0{,}0000$).

Wnioski. Porównanie pomiarów tkanek miękkich twarzy wykonanych w odniesieniu do linii frankfurckiej oraz rzeczywistej linii horyzontalnej w naturalnej pozycji głowy ujawniło istotne różnice (**Adv Clin Exp Med 2012, 21, 6, 743–749**).

Słowa kluczowe: morfologia twarzy, naturalna pozycja głowy.

The close link that exists between the occlusal relationships of the teeth and their bony supporting bases necessitates analysis not only of occlusion but also of the craniofacial skeleton [1–3]. Minor disharmonies in the relationship between the maxilla and the mandible can be compensated by changes in tooth position. However, due to the limited possibilities of tooth compensation, major discrepancies in maxillomandibular relationships are reflected in malocclusion. This is a very important reason for detailed analysis of the facial skeleton prior to any interventions leading to bite correction.

Craniofacial skeleton assessment can be performed in two ways: by visual examination and by cephalometric analysis. Neither of these methods excludes the other, and together they provide complete data. Extra- and intraoral examination should be carried out prior to the x-ray radiographs used for orthodontic assessment.

Assessment of the patient's face is based on profile analysis, which categorizes profiles into three different types: orthognathic, retrognathic and prognathic.

Assessment of the facial profile is normally performed in the lateral view in relation to two planes. Traditionally, preparing patients for orthodontic or orthognathic procedures, the intracranial reference plane known as the Frankfort horizontal (FH) plane is used to assess the soft and hard tissues of the face.

During clinical examination, the Frankfort line is constructed as a line through the skin points: the tragus (representing the external auditory meatus), and the orbital (the point closest to the bony orbit) [4–6].

The vertical plane (nasion plane or Izard's plane) is determined perpendicularly to the Frankfort plane and crosses over the nasion skin point, which is defined as the deepest point in the frontonasal curvature. The frontal-posterior plane, which crosses the orbital point, is also determined perpendicularly to the Frankfort plane [4–6].

External facial features need to be assessed in a position with the Frankfort plane parallel to the floor. For the correct profile, both the upper lip and the subnasale point are on the nasion plane, while the lower lip is only slightly withdrawn in relation to the upper one. The lower lip and chin are placed between the nasion plane and orbital plane, the surface of which is perpendicular to the Frankfort plane and crosses the orbital point. The mentolabialis sulcus is closer to the orbital plane.

When analyzing the facial features laterally, protrusion or retraction of the upper and lower lip region, sulcus mentolabialis and chin should be assessed. The upper lip position remains in a close relationship with the anterioposterior position of the maxillary incisors. Smoothing or deepening of the sulcus mentolabialis can be also recorded.

From this description of the standard clinical examination of the facial features, it becomes clear that it is very important to determine the Frankfort plane accurately, including its appropriate orientation parallel to the floor. Inappropriate facial profiling may result from incorrect determination of the Frankfort plane because of sagittal displacement of the anthropometric points furthest from the reference plane, which describe the mandible.

The validity of assessing facial morphology in relation to the Frankfort horizontal plane has been questioned because of its variability in relation to the intracranial reference planes [4–6].

Natural head position (NHP) is the position of the head with the visual axis parallel to the horizontal plane. The relationship between the extracranial horizontal plane (HOR) and the natural head position is the main alternative to the Frankfort horizontal plane, because of its lower variability [6, 7].

Further research in this matter has indicated that some patients, despite careful instruction, demonstrated unnatural head position. In such cases, natural head orientation (NHO), when the assessors involved in the studies reorient head position if necessary, is a better alternative for research purposes [8, 9].

It is very important to distinguish between natural head position and natural head posture. In clinical practice, natural head position is obtained when a patient looks at a distant point at eye level. Natural head posture occurs when the standing or seated patient feels that his or her head is in balance. This position is used to study the correlation between morphology and function [7, 10].

The aim of the study was to determine the impact of the inclination between the Frankfort horizontal (FH) and the extracranial horizontal (HOR) lines with the head in the natural position (NHP) on the assessment of facial morphology.

Material and Methods

The research was approved by the Ethics Committee of Pomeranian Medical University in Szczecin, Poland. Standard right profile photographs of 100 female and 100 male individuals were used for the study. The average age was 23.4 years (ranging from 20 to 25 years). All the pictures were taken in the same conditions. The lens-subject distance was standardized at 1 meter using a Canon IXY Digital 800 IS with a 50 mm lens.

The photographs were taken with the individual seated in a relaxed and upright position on a straight-back chair without head support, eyes open, looking at a distant point at eye level. The soft tissue of the face was relaxed, teeth were in the maximum intercuspidation, ears uncovered, with no shadow on the subject's head.

To ensure the accuracy of each measurement, a 100 mm metal ruler was placed in the vicinity of every subject. The photographs were analyzed with an IBM computer, using Adobe Photoshop software. To calibrate the size of the digitalized pictures, the ruler was adjusted to the actual size of the grid projected on the computer screen.

Each image was rotated in order to place the Frankfort line (orbital – tragus points) parallel to the extracranial horizontal line (HOR). The orbital point was located on the photographs under the lower eyelid, about a width between the upper and lower eyelid. This technique was used in the study for maximum uniformity. Twelve landmarks on each of the 400 profile photographs (200 originals, 200 rotated) were identified: the forehead: the trichion (Tr) and glabella (G); the nose: the nasion (N) and subnasal (Sn); the ear: the tragus (T); the eye: the orbital (Or); the lips: the labrale superius (Ls), stomion (St), labrale inferius (Li) and supramentale (Sm); the chin: the pogonion (Pg) and gnathion (Gn).

Linear Measurements

Nine linear vertical dimensions were measured on each of the photographs: trichion to glabella (Tr-G), glabella to nasion (G-N), nasion to subnasal (N-Sn), subnasal to labrale superius (Sn-Ls), labrale superius to stomion (Ls-St), stomion to labrale inferius (St-Li), labrale inferius to supramentale (Li-Sm), supramentale to gnathion (Sm-Gn) and subnasal to gnathion (Sn-Gn).

Angular Measurements

Three angular measurements were used to assess sagittal changes in the profile.

The inclination angle (FH/HOR) is between the Frankfort horizontal (FH) line and the extracranial horizontal (HOR) line with the head in the NHP. If the FH line is formed above the HOR line passing through the tragus point, the angle is read in positive degrees. If the FH is formed below the HOR line passing through the Tragus point, the angle is read in negative degrees (Figure 1).

The facial angle (F) is formed by the intersection of the HOR plane passing through the nasion and the line joining the nasion and subnasal. The inferior posterior angle was measured.

The profile angle (T) is formed by the intersection of the line perpendicular to the extracranial horizontal line passing through the subnasal point and the line connecting the subnasal and pogonion. If the profile angle is formed in front of the line passing through the subnasal point, the angle is read in positive degrees. If the profile angle is formed behind the line passing through the subnasal point, the angle is read in negative degrees.

The Shapiro-Wilk W test was used to check for normal distribution of the data obtained. The Mann-Whitney rank test was used to test for sex differences between the groups, while the Wil-

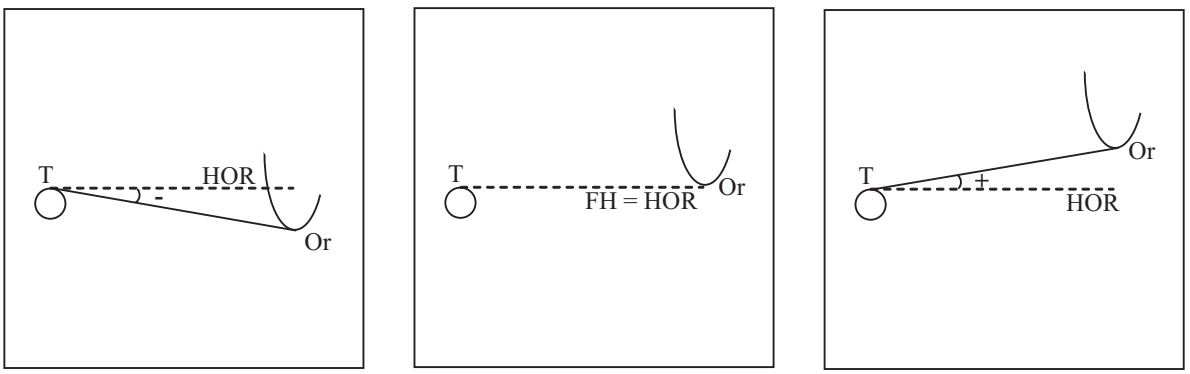

Fig. 1. Differences in the inclination angle (FH/HOR) between the Frankfort horizontal line (FH) and the extracranial horizontal line (HOR) with the head in natural head position (NHP)

Ryc. 1. Zróżnicowanie kąta inklinacji (FH/HOR) linii frankfurckiej (FH) i rzeczywistej linii poziomej (HOR) w NHP

coxon test was used to investigate differences in morphology. Linear regression analysis allowed to assess the relationship between the dependent variable of facial morphology and the independent variables of the inclination of the head in the natural head position. The threshold of statistical significance for all the analyses was set at $p \leq 0.05$. Statistica 7.0 (StatSoft. Inc.) software was used for the data analysis.

Results

The data for the inclination between the horizontal line (HOR) in relation to the NHP and the FH are presented in Table 1. The inclination angle varied from –7.1° to 5.6° (mean: –1.20°). The inclination angles tended to be higher among female study participants (mean: –1.62°) in comparison to male subjects (mean: –0.77°). The length of the face is represented by the nine linear vertical dimensions (Table 2). The results of the measurements performed in HOR and FH differed significantly for the nasion to subnasal (N-Sn) and subnasal to gnathion (Sn-Gn) measurements ($p = 0.0023$ and $p = 0.0001$, respectively). When these results were adjusted for sex, male participants showed a difference in the Sn-Gn segment only, while among women both the N-Sn and Sn-Gn measurements differed significantly.

Significant differences in positions of the head were also observed between the sagittal position of the subnasal point (facial angle, $p = 0.0010$) and chin position (profile angle, $p = 0.0015$) among female and male subjects.

The Pearson test found statistically significant associations between both sagittal and vertical morphology factors in relation to HOR/FH and their inclination angle (Table 3). Among female participants, two of the vertical morphology factors were correlated with the inclination angle: N-Sn ($r = 0.3737$, $p = 0.0001$) and Sn-Gn ($r = 0.3231$, $p = 0.0000$). Just one correlation (Sn-Gn) found among male subjects.

With regard to sagittal morphological factors, both the facial angle ($r = 0.9774$, $p = 0.0000$) and the profile angle ($r = 0.9654$, $p = 0.0000$) changes correlated with the inclination of the FH to the HOR. This pattern of correlation was similar among female and male participants.

Discussion

The research described by Fernández-Riveiro et al. [11, 12] and Fariaby et al. [13] indicate the usefulness of the photocephalometric analysis in assessing the linear and angular measurements of facial morphology in the natural head position. Ghoddousi et al. [14] also confirmed also the high precision of photocephalometric measurements.

Photocephalometric measurements performed according to the intracranial reference lines might be susceptible to error simply because they are marked on soft tissue. Moreover, the range of variance of the inclination angle of particular planes, such as those between the Frankfort plane and SN plane, must be taken into account [8, 15]. In contrast, in measurements performed in the NHP, which are independent of the intracranial planes, differences in head position due to somatic and psychosocial factors, and the influence of this variability on the assessment of morphology, should be considered [10, 15]. On the basis of an analysis of 79 cephalometric radiographs, Lundström and Lundström [8] described the variability of head position in the NHP, ranging from 5.2° for boys to 4.0° for girls. Research by Uşümez and Orhan [16, 17] using an inlinometer indicate the high reproducibility of the NHP with an error of just 1.1° in a two-year period.

To visualize the effects of differences resulting from FH/HOR inclination, nine linear vertical

Table 1. The inclination (in degrees) between the Frankfort horizontal line (FH) and the extracranial horizontal line (HOR) in the natural head position (NHP)

Tabela 1. Wartość kąta inklinacji (°) między linią frankfurcką (FH) i rzeczywistą linią poziomą (HOR) w naturalnej pozycji głowy (NHP)

FH/HOR	N	Mean (Średnia)	Median (Mediana)	S.D.	Minimum (Minimum)	Maximum (Maksimum)	p-value
Female (Kobiety)	100	–1.62	–1.50	2.88	–7.10	5.50	0.1405
Male (Mężczyźni)	100	–0.77	–1.40	2.77	–6.30	5.60	
Total (Razem)	200	–1.20	–1.40	2.85	–7.10	5.60	

Table 2. Linear (in mm) and angular (in degrees) measurements describing facial morphology in relation to two reference lines (FH and HOR)

Tabela 2. Pomiary liniowe (mm) i kątowe (°) określające morfologię twarzy wykonane w odniesieniu do dwóch linii referencyjnych (FH i HOR)

Measurement (Pomiar)	HOR/FH	Mean (Średnia)	Median (Mediana)	Minimum (Minimum)	Maximum (Maksimum)	S.D.	p-value		
							female (kobiety)	male (mężczyźni)	total (razem)
Tr-G	HOR	40.89	40.00	26.00	58.00	6.75	0.1476	0.2858	0.2189
	FH	41.36	40.00	26.00	59.00	6.73			
G-N	HOR	17.73	17.75	10.00	25.00	2.97	0.1287	0.1678	0.1438
	FH	17.35	17.00	10.00	25.00	2.74			
N-Sn	HOR	46.51	46.00	37.00	57.00	3.80	0.0000*	0.1681	0.0023*
	FH	47.80	48.00	37.00	59.00	3.94			
Sn-Ls	HOR	11.02	11.00	7.00	15.00	1.78	0.5450	0.7267	0.5087
	FH	11.06	11.00	5.00	16.00	1.94			
Ls-St	HOR	6.81	7.00	5.00	11.00	1.30	0.6908	1.0000	0.7202
	FH	6.82	7.00	4.00	11.00	1.32			
St-Li	HOR	8.98	9.00	4.00	13.00	1.61	0.0615	0.6496	0.1567
	FH	9.08	9.00	6.00	13.00	1.61			
Li-Sm	HOR	6.12	6.00	1.00	12.00	2.11	0.3044	0.2720	0.7275
	FH	6.11	6.00	0.00	10.00	2.15			
Sm-Gn	HOR	23.74	24.00	19.00	30.00	2.51	0.0564	0.2084	0.1842
	FH	23.88	24.00	18.00	31.00	2.46			
Sn-Gn	HOR	57.71	57.00	47.00	70.00	5.12	0.0000*	0.0412*	0.0001*
	FH	57.84	58.03	48.00	71.00	4.42			
F	HOR	94.26	94.30	79.40	110.30	4.52	0.0013*	0.0144*	0.0010*
	FH	95.41	95.60	87.20	107.50	3.67			
T	HOR	−14.74	−15.00	−26.90	5.90	5.70	0.0031*	0.0114*	0.0015*
	FH	−13.65	−14.20	−25.00	2.40	5.49			

* p-value ≤ 0.05.

distances and two angles were compared to assess sagittal changes in the profile.

The results showed that significant differences in measurements were associated with the nasion to subnasal and subnasal to gnathion segments, and both facial and profile angles. This is also confirmed by the relationships between the FH/HOR inclination angle and these vertical and sagittal morphological factors. In this case changes in FH/HOR inclination could have been related to the direction of gaze, the inclination of the forehead, the inclination of the columella and the chin position. With reference to the facial and profile angles, the highest determination coefficient ($r^2 = 0.95$) indicates that 95% of the angle variation might be explained by variations in the FH/HOR inclination.

In a study by Leitao and Nanda [15], fifteen morphologic variables were related to at least two independent postural variables. However, only three were significantly different in all groups, with larger values for the facial axis and lower face height, and smaller values for the face height ratio among people qualified as "extenders". Certain associations between postural and morphologic variables have a geometric component.

Additionally, most of variables based on Sella or Nasion points were statistically different in the groups where NSL/HOR (the angle between the nasion-sella line and the horizontal line) were

Table 3. Correlations between differences between the vertical and the sagittal morphology factors and the inclination angle of the Frankfort horizontal line (FH) and the extracranial horizontal line (HOR)

Tabela 3. Ocena korelacji między sagitalnymi i wertykalnymi predyktorami morfologii twarzy a kątem inklinacji linii frankfurckiej (FH) i rzeczywistej linii poziomej (HOR)

Measurement (Pomiar)	r p-value	Inclination angle FH/HOR (Kąt inklinacji FH/HOR)		
		female (kobiety)	male (mężczyźni)	total (razem)
Tr-G	r	0.0838	0.1323	0.0958
	p-value	0.6331	0.5781	0.6112
G-N	r	–0.5890	–0.3141	–0.5496
	p-value	0.2698	0.1773	0.2276
N-Sn	r	0.4471	0.2464	0.3737
	p-value	0.0000*	0.1257	0.0001*
Sn-Ls	r	0.1419	–0.0588	0.1012
	p-value	0.3451	0.8052	0.5136
Ls-St	r	–0.0725	0.1551	–0.0359
	p-value	0.5195	0.5137	0.7212
St-Li	r	–0.0635	0.0726	–0.0280
	p-value	0.5729	0.7607	0.7803
Li-Sm	r	0.0976	0.3122	0.1267
	p-value	0.3858	0.1801	0.2065
Sm-Gn	r	0.0846	0.2622	0.1267
	p-value	0.2158	0.1101	0.1895
Sn-Gn	r	0.4241	0.2464	0.3231
	p-value	0.0000*	0.0163*	0.0000*
F	r	0.9778	0.9714	0.9774
	p-value	0.0000*	0.0000*	0.0000*
T	r	0.9674	0.9351	0.9654
	p-value	0.0000*	0.0000*	0.0000*

* p-value ≤ 0.05.

highly variable and FH/HOR (the angle between the Frankfort line and the horizontal line) was invariable. This indicated that the differences were related to the inclination of the NSL rather than the head posture. This confirms Ozbek and Koklu [18], who found that interindividual variability of sella vertical position should be considered important. To overcome this problem Leitao and Nanda [12] suggested relating the maxilla and mandible to the true vertical plane, not to an intracranial reference plane.

The authors concluded that a comparison of soft tissue measurements with reference to the Frankfort horizontal and the extracranial horizontal planes with the head in the natural position discloses significant differences. Therefore, head position is of major importance in estimating the facial morphology as well as in properly comparing morphologic data obtained from research studies.

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