치의학석사 학위논문

Frankfort 평면과 Sella-Nasion 선 사이의 각도의 일관성

9년간의 종단 연구

Constancy of the angle between the Frankfort horizontal plane and the Sella-Nasion line

A nine-year longitudinal study

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서울대학교 치의학대학원

치의학과

허 영 재

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이 논문을 치의학 석사 학위논문으로 제출함

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Abstract

Constancy of the angle between the Frankfort horizontal plane and the Sella-Nasion line A nine-year longitudinal study

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Objective : To investigate the constancy of the angle between the Frankfort horizontal plane (FH) and the sella-nasion line (SN) using longitudinal data.

Materials and Methods : Longitudinal lateral cephalometric data of 223 children (116 girls and 107 boys) from 6 to 14 years of age were used. The angle between FH and SN (SNFH), the distance from FH to the nasion (NFH), the distance from FH to the sella (SFH), and the differences between the NFH and SFH (⊿) were also measured. All data were analyzed statistically using independent t-tests and mixed-effect regression model analysis.

Results : The mean SNFH values showed some minor fluctuations, ranging from 9.26° to 9.74° in girls and 8.45° to 8.95° in boys. The mean NFH and SFH values gradually increased according to age irrespective of sex. There were statistically significant differences by sex for all measurements at several ages. The annual change in SFH and Δ showed sexual dimorphism.

Conclusions : There are variations among individuals in the angle between the FH and SN. However, within an individual, the angle does not vary significantly over time during the observation period.

Keywords : Frankfort horizontal plane, Sella–Nasion line, Longitudinal study.
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I. Introduction

An understanding of craniofacial growth has been the fundamental basis of orthodontic practice.[1] The advent of the cephalogram[2] in the early 1930s allowed large−scale longitudinal studies on growing subjects, and numerous subsequent studies have unveiled many features of complicated craniofacial complex growth.[3,4] Establishing references and coordinate systems is of the utmost importance for comparative measurements of longitudinal changes in the face.[5]

Different anatomic reference systems have been proposed for conventional cephalometry. In fact, it can be stated that the world of orthodontics is now full of orientation and reference planes.[6] The best−known of these are based on the Frankfort horizontal plane (FH) and the anterior cranial base (sella to nasion line [SN]). They are widely used despite their individual variability, and several researchers support the alternative use of natural head position based on the reproducibility of this method.[7–10]

Since it was introduced, the FH has been favored as the reference plane of choice for the analysis of the facial structures by anthropologists. By definition, the FH is constructed by a line connecting from porion at the superior external auditory meatus to orbitale on the inferior margin of the orbit. Its popular use is due to the belief that it may produce the most acceptable estimation of the true horizontal plane.[11]

The cranial base reference, SN, was initially mentioned by Renfroe,[12] Bjork,[13] and Ricketts.[14] This line is not only reliable but also biologically meaningful, as it represents the anterior cranial base. Other authors stated that establishing the cranial base's role should be advanced in evaluating problems related to an inadequate relationship between the jaws and the dental arches.[15–18]

The literature suggests that the angle between these lines is relatively constant at 7°, and the true horizontal axis or constructed FH is obtained by tracing a line in a clockwise direction approximately 7° from SN.[19–21] However, this constancy has not yet been sufficiently proven by reliable evidence. In addition, the angle between the FH and SN should remain constant during growth if this approximation is to be used safely in cephalometric analysis.

Until now, longitudinal changes in the angle between FH and SN in growing children have been the subject of few studies. The present study investigates this angle using longitudinal cephalometric data of normal children from 6 to 14 years of age. The aim of the present study was to evaluate the constancy of the relationship between the FH and SN during growth.

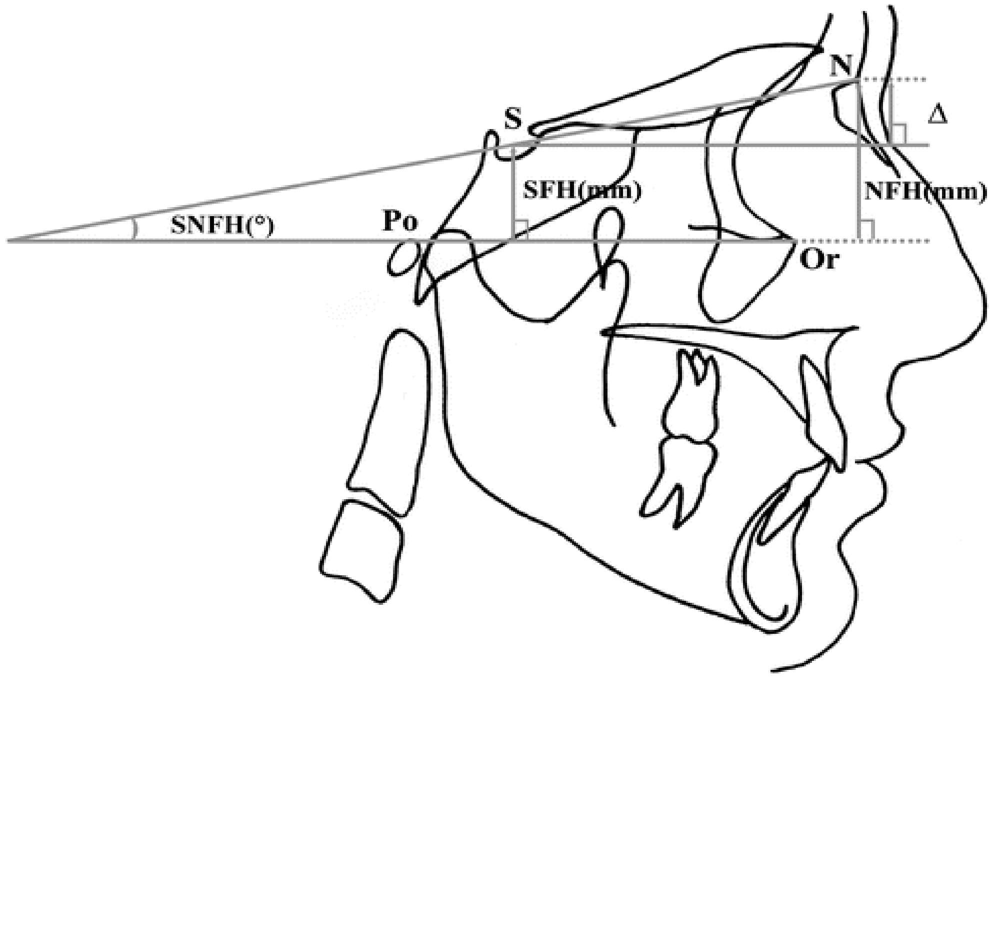
II. Materials and methods

The study subjects were selected from participants in the Korean Dental Growth Study,[22,23] which took place from 1995 to 2003. A total of 407 subjects from northern Gyeonggi-do, Korea, participated in this study, and they were all healthy without systemic diseases or developmental anomalies. None had received any treatments interfering with growth, and all had no records of orthodontic treatment before or during the observation period. The parents/guardians of all subjects provided written, informed consent. We examined lateral cephalometric radiographs from 223 children who had full sets of data available (107 males and 116 females) and had been followed annually from 6 to 14 years of age, with the exception of their 10th year, when the study was temporarily suspended due to financial reasons. The Institutional Review Board for the Protection of Human Subjects reviewed and approved the research protocol (S-D2010013).

All radiographs were traced by a single observer in order to eliminate interexaminer variability and were analyzed using Vceph version 6.0 (Osstem, Seoul, Korea). Landmarks, reference planes, and measurements are shown in Figure 1. The following three measurements were taken from cephalometric radiographs of all children at all ages in order to investigate the growth changes occurring with regard to the relationship between FH and SN: 1) the angle between FH and SN (SNFH), 2) the closest distance from the FH to the nasion (NFH), and 3) the closest distance from the FH to the sella (SFH). The difference between the NFH and SFH (Δ) was also calculated. To test the reliability, 10 cephalometric radiographs were randomly selected, measured again, and compared using an intraclass correlation coefficient 1 month after the initial measurements.

SPSS software (SPSS for Windows, version 12.0; SPSS Inc, Chicago, Ill) was used to calculate the means and standard deviations of all measurements, and independent t−tests were used to determine significant differences between genders according to age. Since the serial measurements were correlated for individual subjects, a mixed−effects regression model (MRM) analysis was performed using the language R.[24] The analysis model for the data was written as $y_{ij} = \mu + \beta_1 sex_i + \beta_2 age_{ij} + \beta_3 sex_i * age_{ij} + b_{i1} + b_{i2} * age_{ij} + e_{ij}$, where μ is the total mean, β_1 is the sex effect, β_2 is the age effect, β_3 is the interaction effect between sex and age, and b_i ($i = 1, 2, \cdots, 223$) is the random effect for an individual subject. Significance was set at the .05 level of confidence, but was also assessed at the .01 level of confidence.

Figure1. Landmarks: nasion (N), sella (S), porion (Po), orbitale (Or). Angular (SNFH) and linear measurements (NFH, SFH, and ⊿).



III. Results

Intra-examiner reliability coefficients ranged from .927 to .976. In terms of root mean square values, the random errors of estimation were less than 0.53 mm for linear measurements and 1.02° for angular measurements. None of the variables were significantly different between test and retest measurements.

Descriptive statistics and results of the comparison between sexes are shown in Table 1. The mean values of SNFH showed some fluctuations in both girls and boys according to age; however, the ranges were relatively small (9.26° to 9.74° in girls and 8.45° to 8.95° in boys) considering the size of the random error in measurements. The mean values of NFH and SFH gradually increased according to age, irrespective of sex. The values of ⊿ also tended to increase, except in 13- and 14-year-old boys (Figure 2). There were statistically significant differences in SNFH values between sexes at 6, 7, 8, 12, 13, and 14 years; in NFH values at 6, 9, 11, 12, 13, and 14 years of age; and in ⊿ at 8, 12, 13, and 14 years of age. There were statistically significant differences in SFH values in all ages throughout the investigation period (Table 1).

MRM analysis revealed that the SNFH showed significant individual differences but did not differ significantly with respect to annual change or sex. In contrast, NFH, SFH, and ⊿ showed statistically significant differences within individuals as well as in the magnitude of annual changes. In addition, there was a significant interaction between age and sex with regard to SFH and ⊿ (Table 2). The individual random variability of the initial value was quite large compared with that of the annual increase (Table 3).

Figure2. Longitudinal data for four measurements according to sex. The values at age 10 years in the graphs are the arithmetic mean values at age of 9 and 11.

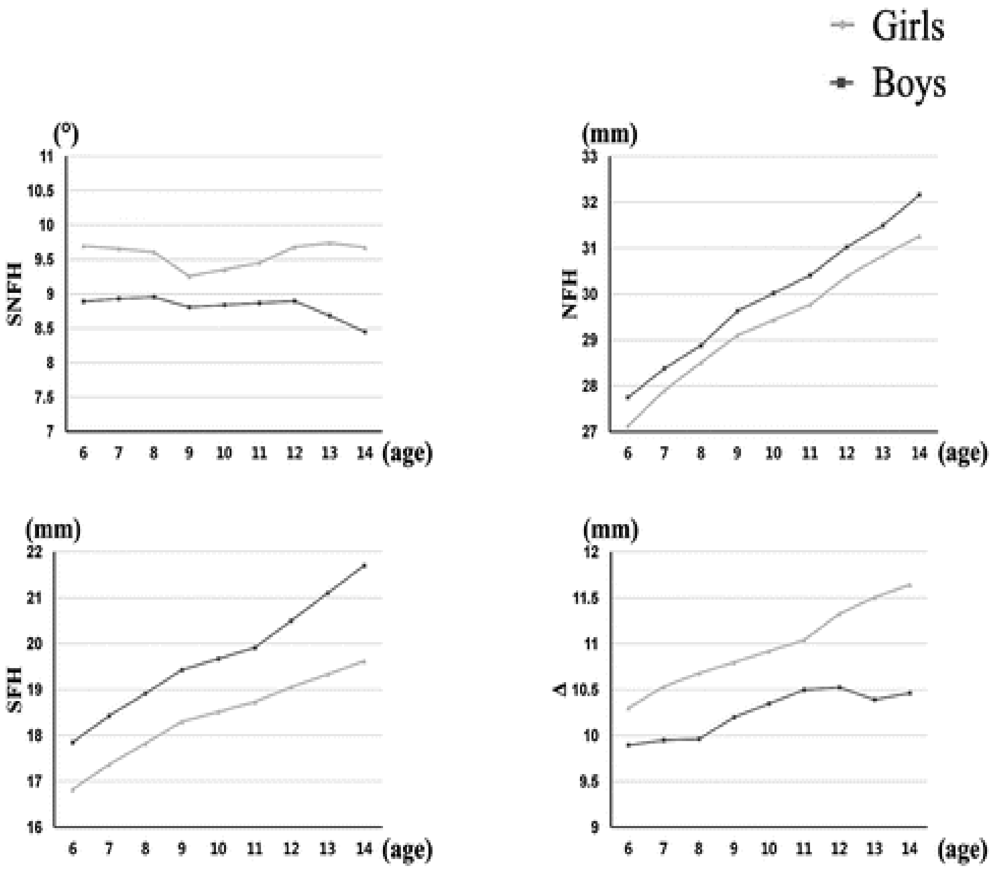


Table1. Descriptive Statistics of the Measured Variables According to Age and Sex[a]

		Girls	Boys	Total		
Variables	Age	Mean (SD)	Mean (SD)	Mean (SD)	Max	Min
SNFH, °	6**	9.70 (2.20)	8.89 (2.27)	9.31 (2.26)	15.49	3.08
	7*	9.66 (2.39)	8.93 (2.04)	9.31 (2.25)	16.79	3.19
	8*	9.61 (2.27)	8.95 (2.21)	9.29 (2.26)	15.45	2.96
	9	9.26 (2.21)	8.81 (2.18)	9.04 (2.20)	14.99	2.47
	11	9.45 (2.39)	8.87 (2.03)	9.17 (2.24)	15.88	2.80
	12*	9.68 (2.53)	8.90 (2.22)	9.31 (2.41)	16.59	2.73
	13**	9.74 (2.53)	8.68 (2.17)	9.23 (2.42)	15.87	1.82
	14**	9.68 (2.66)	8.45 (2.37)	9.09 (2.59)	16.41	2.95
NFH, mm	6*	27.12 (1.98)	27.75 (2.10)	27.42 (2.06)	35.25	21.03
	7	27.90 (1.97)	28.38 (1.96)	28.13 (1.98)	33.60	21.19
	8	28.50 (1.93)	28.88 (1.93)	28.68 (1.93)	34.74	22.78
	9*	29.10 (1.88)	29.63 (1.81)	29.35 (1.86)	35.05	24.12
	11**	29.77 (1.80)	30.41 (1.71)	30.08 (1.78)	35.22	25.26
	12**	30.38 (1.84)	31.02 (1.67)	30.69 (1.79)	35.96	25.63
	13**	30.84 (2.00)	31.49 (1.68)	31.15 (1.88)	37.24	25.55
	14**	31.26 (1.90)	32.16 (1.83)	31.69 (1.92)	37.91	25.50
SFH, mm	6**	16.82 (1.85)	17.85 (1.70)	17.32 (1.85)	22.02	12.54
	7**	17.37 (1.88)	18.43 (1.71)	17.88 (1.87)	22.28	13.12
	8**	17.82 (1.91)	18.91 (1.68)	18.35 (1.88)	22.59	13.09
	9**	18.30 (1.86)	19.43 (1.79)	18.84 (1.91)	23.98	13.92
	11**	18.73 (1.97)	19.91 (1.71)	19.30 (1.94)	24.88	14.03
	12**	19.06 (2.01)	20.50 (1.80)	19.75 (2.04)	25.56	14.20
	13**	19.34 (2.07)	21.10 (1.92)	20.18 (2.18)	25.97	14.26
	14**	19.62 (2.14)	21.70 (1.98)	20.62 (2.31)	27.39	14.45
Δ, mm	6	10.30 (2.55)	9.90 (2.42)	10.11 (2.49)	19.62	3.95
	7	10.53 (2.49)	9.95 (2.48)	10.25 (2.50)	19.21	3.40
	8*	10.68 (2.47)	9.96 (2.30)	10.33 (2.41)	18.26	4.49
	9	10.80 (2.44)	10.20	10.51 (2.36)	18.52	4.47
	11	11.04 (2.50)	10.50	10.78 (2.33)	19.01	4.90
	12*	11.33 (2.62)	10.52	10.94 (2.41)	20.63	5.12
	13**	11.50 (2.80)	10.39	10.97 (2.63)	20.32	4.05
	14**	11.64 (2.75)	10.46	11.08 (2.69)	20.35	3.99

[a] SNFH indicates the angle between the Frankfort horizontal plane and the sella-nasion line (SN); NFH, the distance from FH to the nasion; SFH, the distance from FH to the sella; Δ, the difference between the NFH and SFH.

* There were statistically significant differences between girls and boys ($P < .05$);

** there were statistically significant differences between girls and boys ($P < .01$).

Table2. Summary of Fixed Effects According to the Mixed-Effects Regression Model Analysis[a]

Variables	Components of Fixed Effects			
	μ	β_1	β_2	β_3
SNFH	9.563**	0.003	−0.289	−0.05
NFH	24.213**	0.510**	0.292	0.036
SFH	14.872**	0.346**	0.130	0.129**
Δ	9.309**	0.166**	0.161	−0.091*

[a] SNFH indicates the angle between the Frankfort horizontal plane and the sella-nasion line (SN); NFH, the distance from FH to the nasion; SFH, the distance from FH to the sella; Δ, the difference between the NFH and SFH.

* Statistically significant ($P < .05$);

** statistically significant ($P < .01$).

Table3. Effect of Individual Random Variability From Age 6 Years to the Annual Increases Over Time[a]

Variables	Components of Individual Random Variability			
	Initial Value at Age 6	Annual Increase	Residuals	Ratio*
SNFH	2.089	0.159	1.184	13.14
NFH	2.256	0.134	0.934	16.84
SFH	1.624	0.107	0.812	15.18
Δ	2.676	0.186	1.048	14.39

[a] SNFH indicates the angle between the Frankfort horizontal plane and the sella-nasion line (SN); NFH, the distance from FH to the nasion; SFH, the distance from FH to the sella; Δ, the difference between the NFH and SFH.

* The ratio of the initial individual variability at age 6 years to the annual increases from ages 6 to 14 years. The variability of annual increase was substantially small in comparison to the initial value at age 6 years.

IV. Discussion

In the present study, the constancy of the angle between FH and SN during growth was investigated using longitudinal cephalometric data. In a study of macerated skulls,[21] it was reported that the angle increased from 5.2° at 2.5–5 years to 8.3° at 18–20 years. However, the nature of the study was not longitudinal, and the results should, therefore, be interpreted accordingly. On the other hand, several studies have indirectly provided the angle between the FH and SN in comparison with other reference planes, such as true vertical or true horizontal.[11,25–29] The reported data ranged from 3.7° to 10.01°. The subjects of those investigations were mostly of European decent, with the exception of the study by Madsen et al.,[30] whose subjects were from a variety of ethnic backgrounds.

In this regard, the universal use of 7° as a constant angle is hard to justify. The results of the present study support this conclusion in many respects. First, the average SNFH ranged from 9.04° to 9.31°, which is somewhat higher than 7°. However, this difference may also be the result of the subject population composition. Second, there were statistically significant differences between sexes, which may indicate that this angle has some degree of sexual dimorphism. Third and most important, the SNFH showed very large individual differences on MRM analysis.

On the other hand, the SNFH remained relatively constant, although some degree of fluctuation was detected during the observation period. The degree of change was minimal when considering measurement error. In addition, the annual changes in SNFH as a fixed effect showed no statistical significance, in contrast to the NFH, SFH, and ⊿. The relatively small random variability in the annual increase in comparison to the initial SNFH was in line with these results. This finding can be interpreted to mean that a gradual increase or growth in NFH and SFH does occur, while SNFH does not change because of its particular spatial orientation. Greiner et al.[21] suggested the cause of this constancy is the sagittal growth component between the porion and orbitale. The displacing effect of the spheno-occipital synchondrosis upon the anterior cranial base may be the cause of this sagittal growth.[31]

The dimensional measurements in this study suggested there might be sexual dimorphism in the relationship between the cranial base and porion and orbitale. First, the absolute dimensions of the average NFH and SFH were larger in boys than in girls. However, the difference, ⊿, was larger in girls than in boys. Second, the SFH and ⊿ showed some difference between sexes, whereas the NFH showed a relatively similar increase in both sexes. In the SFH curves, the increment after age 11 was large in boys in comparison with girls. Therefore, the ⊿ begins to increase after this age. This interpretation is consistent with the results of MRM analysis. A statistically significant interaction between age and sex was observed as a fixed effect with regard to the SFH and ⊿. In other words, annual increments differed between sexes. Unfortunately, cephalometric data were not available for the study subjects after age 14 years, which is the age at take-off or age at peak height velocity, especially in boys.

The results of the present study indicate there is a wide range of angles, although the relative constancy of the SNFH was verified. Well-planned longitudinal studies could provide further insight; however, gathering appropriate sample data is quite difficult. In order to better examine the sexual dimorphism and individual growth patterns in the general population, further studies should be performed with subjects classified in a more sophisticated fashion.

V. Conclusions

The SNFH angle differed considerably among individuals, ranging from 1.82° to 16.59°.

However, the value remained relatively constant in each individual during the observation period, from 6 to 14 years of age, despite the minute change.

The NFH and SFH increased during the growth period, and there were statistically significant sexual differences in all the measurements at several ages.

The annual change in the SFH and Δ showed sexual dimorphism.

The SNFH angle seems stable over the period of the study, but, due to wide individual variation, use of the population average should be used with caution.

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국문초록

Frankfort 평면과 Sella–Nasion 선 사이의 각도의 일관성

9년간의 종단 연구

1. 연구 목적

이 논문에서는 성장 과정에 있는 어린이의 측방 두부규격방사선사진의 종단 자료 분석을 통해 Frankfort 평면과 Sella–Nasion 선 사이의 각도를 측정하고 이 각도가 성장 과정에서 일관성 있게 유지되는지 알아보고자 하였다.

2. 연구 방법

6세에서 14세 사이의 어린이 223명(여자 어린이 116명, 남자 어린이 107명)의 측방 두부규격방사선사진의 종단 자료를 분석하였다. 대상 어린이들의 측방 두부규격방사선사진을 트레이싱 하여 해부학적 계측점을 표시하고, Frankfort 평면과 Sella–Nasion 선 사이의 각도(SNFH), Frankfort 평면에서 Nasion까지의 거리(NFH), Frankfort 평면에서 Sella까지의 거리(SFH), NFH와 SFH 간의 차(⊿)를 측정하였다. 측정된 모든 결과는 independent t–test와 mixed–effect regression model analysis를 이용하여 통계적으로 분석하였다.

3. 연구 결과

SNFH의 평균값은 여자 어린이에서는 9.26° 에서 9.74° , 남자 어린이에서는 8.45° 에서 8.95° 사이의 값으로 측정되어 약간의 차이는 있었으나 그 폭은 측정 오차를 고려했을 때 비교적 작았다. NFH와 SFH의 평균값은 성별과 관계없이 어린이들이 성장할수록 점진적으로 증가하는 경향을 보였으며, 여러 연령들에서 각 측정값들이 성별에 따라 통계적으로 유의한 차이를 보였다. 또한 성장에 따른 SFH와 의 변화양상은 성별에 따른 차이를 보였다.

4. 결론

Frankfort 평면과 Sella-Nasion 선 사이의 각도는 개인별로 약간의 편차는 있었으나, 관찰 기간 동안 성장에 따라 통계적으로 유의미한 변화 없이 비교적 일정하게 유지되었다.

주요어 : Frankfort 평면, Sella-Nasion 선, 종단 연구.

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