Assessment of antero-posterior skeletal relationships in adult Korean patients in the natural head position and centric relation

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Objective: This study aimed to verify the intra-individual reproducibility of the natural head position (NHP) in adult Korean patients in the centric relation (CR) position and to prove the inter-individual variability of the Frankfurt horizontal (FH) plane and sella-nasion (SN) line compared to the true horizontal line (THL). In addition, the study aimed to investigate the correlations between linear measurements from A-point and B-point to the nasion true vertical line (NTVL) and angular measurements from A-point and B-point to the SN line. **Methods:** Two lateral cephalograms were taken of 116 subjects (23 males, 93 females) with CR wax bites in a NHP at a one-week interval. **Results:** Method errors of three variables and intraclass correlation coefficients of six parameters proved the intra-individual reproducibility of NHP ($p < 0.001$). The angle of the FH to the THL was not significantly different from 0° ($p > 0.05$), but it was clinically variable (SD 3.89°) on the inter-individual level. Conversely, the angle of the SN line to the THL was significantly different from 7° ($p < 0.05$). Very low correlation was found between the linear measurements and angular measurements of A-point and B-point ($p < 0.01$). **Conclusions:** The NTVL could be a useful reference line for assessing the antero-posterior position of the maxilla and mandibleof Korean adult patients in NHP and CR. **(Korean J Orthod 2010;40(6):421-431)**

Key words: Natural head position, Centric relation, Frankfurt horizontal plane, Sella-nasion line, Nasion true vertical line

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INTRODUCTION

Many cephalometric measurements have been used to assess the antero-posterior position of the skeleton in patients since Broadbent[1] and Hofrath[2] described roentgenographic cephalometry. Downs[3] classified skeletal patterns and skeleton-to-denture relationships using the Frankfurt horizontal (FH) plane. Steiner[4] utilized sella-nasion (SN)-A and SN-B angles to assess jaw relationships in patients. Riedel[5] suggested the angle of SN to point-A for measuring the relative antero-posterior position of the maxilla. Tweed[6,7] measured the FH plane to the mandibular plane angle and the mandibular plane to the lower incisor angle focusing on mandibular position and mandibular incisor position. Ricketts[8] used A-NPog for maxillary convexity (in millimeters) as an indicator of horizontal jaw relationships. Jenkins[9] and Jacobson[10] described Wits' appraisal for measuring antero-posterior jaw disharmony. McNamara[11] suggested the McNamara line, which passes through a nasion point perpendicular to the FH plane, as a critical plane for measuring the distance from A-point or the pogonion point.

Two common intracranial reference planes exist for orthodontic diagnosis. The representative line is the SN line, which is reliable and biologically meaningful, but it has been shown to have large inter-individual variability.[12,13] The SN reference line is thought to be less valid due to this high inter-individual variability.

The other reference line is the FH plane, which was originally introduced at an anthropological conference in 1884. The FH plane was defined as extending from the orbitale to both porion points. The orbitale is defined as the lowest point of the infraorbital margin and the porion as the outer upper margin of the porus acousticus externus. The FH plane is widely used as a reference, and it may produce the most acceptable estimation of a true horizontal line. However, this reference plane also has inter-individual variability due to the positions of orbitale and porion.

The desire for facial aesthetics has been increasing. Thus, havinga reproducible and reliable reference position and plane is important for the diagnosis and treatment of orthodontic patients and two-jaw surgery patients. Orthodontists and oral surgeons do not have a common reference line for assessing the position of the maxilla and mandible with regard to facial aesthetics. As early as the 1860s, craniologists realized the natural head position (NHP) in human beings. Broca[14] defined this head position as "when man is standing and his visual axis is horizontal, he is in the natural position". The NHP was introduced into orthodontics in the late 1950s[15] and has been advocated as a craniofacial reference system because of its good intra-individual reproducibility[15-17] to a true vertical plumb line. Another characteristic of the NHP is the representation of the true-to-life appearance and ease of registration. Therefore, setting up a reliable reference line with the NHP is necessary. Orthodontists also need to have a reliable and repeatable position of the mandible to diagnose maxillo-mandibular relationships and occlusion in patients. Centric relation (CR) is known as the single most repeatable position, but few reports have addressed the reproducibility of NHP in adult Korean patients in CR or the clinical application of the NHP and CR position.

The purpose of this study was to verify the intra-individual reproducibility of the NHP in CR position and to prove the inter-individual differences in the FH plane and SN line compared to the true horizontal line (THL) in adult Korean patients. In addition, the study aimed to investigate the correlations between linear measurements from A-point and B-point to the nasion true vertical line (NTVL) and angular measurements from A-point and B-point to the SN line on the basis of the first two studies.

MATERIAL AND METHODS

Ethical approval for the present investigation was

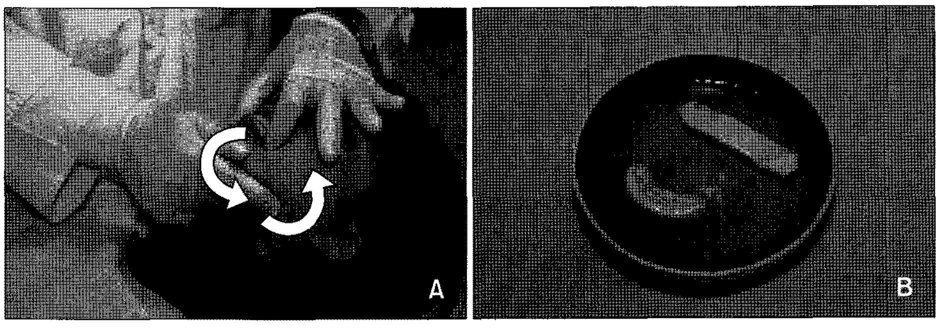

Fig 1. Registration of the centric relation wax bite. **A**, Guiding the mandible using the tripoding method; **B**, centric relation wax bite (anterior and posterior portion).

obtained from the Kangnam Sacred Heart Hospital ethics committee, Hallym University Medical Center, and written informed consent was obtained for all subjects.

Samples

A total of 116 subjects (23 males, age range 19 - 41 years and mean age 27.9 years; 93 females, age range 19 - 47 years and mean age 23.6 years) were investigated. The patients visited the Department of Orthodontics at the university hospital to receive treatment for malocclusions and skeletal discrepancies. No orthodontic treatment, orthognathic surgery, or prosthetic treatment more than a 3-unit bridge was provided in advance. Subjects with more than two missing teeth were excluded from the study.

Centric relation bite registration

The CR was recorded according to the Roth technique (power centric registration method) described by Choi[18] before taking lateral cephalograms (Fig 1).

NHP registration and lateral cephalograms

Solow and Tallgren's method[19] was used to achieve the NHP (Fig 2). The subjects were asked to stand in front of a mirror with their feet a shoulder width apart and arms relaxed, wearing eyeglasses attached to a fluid leveler. The subjects were placed 120 cm from a 30 × 40 cm mirror and asked to stare at their own eyes after exercising their head up and down. All of the

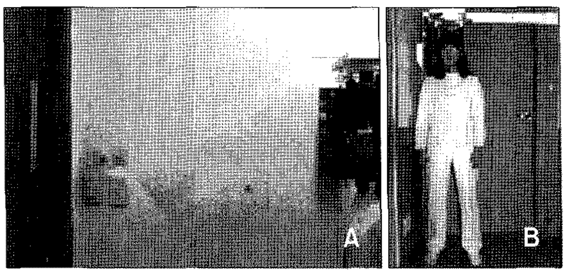

Fig 2. Registration in the natural head position and lateral cephalogram. **A**, Subjects looked into their eyes in the mirror (orthoposition); **B**, standing position with arms and chin relaxed.

subjects were asked to bite their CR wax records and to relax their lips and arms during X-ray.

An auto IIIN CM (Asahi Corp., Japan) cephalometric X-ray machine was used to take the lateral cephalograms. X-ray (69 KV, 12 mA) was irradiated for 2 seconds. Subjects were positioned in the cephalostat without ear rod insertion. A metal chain was drooped in front of the subject to draw the NTVL on the lateral cephalometric tracing. Two lateral cephalograms were taken for each subject at a one-week interval.

Tracing technique and statistical analysis

V-ceph orthodontic diagnosis program version 6.0 (Osstem Corp., Korea) was used to digitize the lateral cephalograms. The initial (T1) and second (T2) lateral cephalograms were taken with the same NHP and CR, and both were digitized and measured. Fourteen landmarks and the soft tissue profile line were digitized with the software. The NTVL was made by moving the metal chain line parallel and drawing a line through the nasion point. The data were transferred to SPSS for windows version 11.5 (SPSS Inc., Chicago, IL, USA) for analysis using intraclass correlation coefficients, one sample t-test, and Pearson correlation coefficients. The mean, standard deviation, minimum, and maximum was calculated for each variable. The

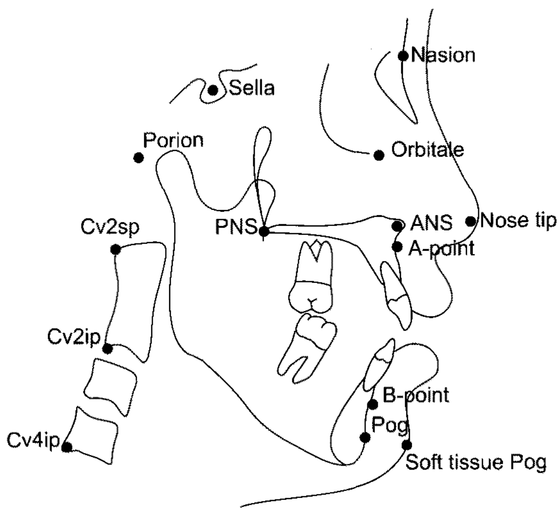

Fig 3. Reference points used in this study.

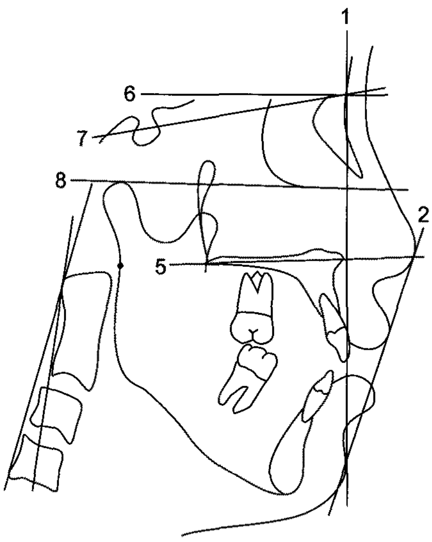

Fig 4. Reference planes used in this study. 1, Nasion true vertical line (NTVL) passing through the nasion point perpendicular to the floor; 2, E-line, tip of nose-soft tissue pogonion; 3, cervical vertebrae tangent-plane the posterior tangent to the odontoid process through cv4ip; 4, odontoid process tangent plane, the posterior tangent to the odontoid process through cv2ip; 5, palatal plane, ANS-PNS; 6, true horizontal line passing through nasion point perpendicular to the NTVL; 7, sella-nasion plane; 8, Frankfurt horizontal plane, porion-orbitale.

reference points and reference planes used in this study are illustrated in Figs 3 and 4. Six angular parameters were calculated (Fig 5A). The THL to the FH plane and SN line angles were measured (Fig 5B). The above angle compared to the THL was positive and the below angle was negative. The data for this analysis were the mean T1 and T2 measurements. In addition to linear measurements from A-point and B-point to the NTVL (Fig 6A), SN-A and SN-B angles (Fig 6B) were measured and compared by Pearson correlation coefficients using T1, T2, and mean data.

Method errors of digitizing and positioning

A method error study was performed to determine the errors in digitizing landmarks and measurements. Method errors in digitizing were calculated in 15 randomly selected subjects. Each T1 lateral cephalogram was retraced by the same observer 1 week after the initial tracing. Double determinations of three variables (SN/NTVL, SN/OPT, and OPT/THL) were calculated using Dahlberg's formula (Eq. 1).[20]

Method errors in positioning were evaluated in 116 subjects using Dahlberg's formula. Three variables (SN/NTVL, SN/OPT, and OPT/THL) were also calculated. The T1 and T2 data were used.

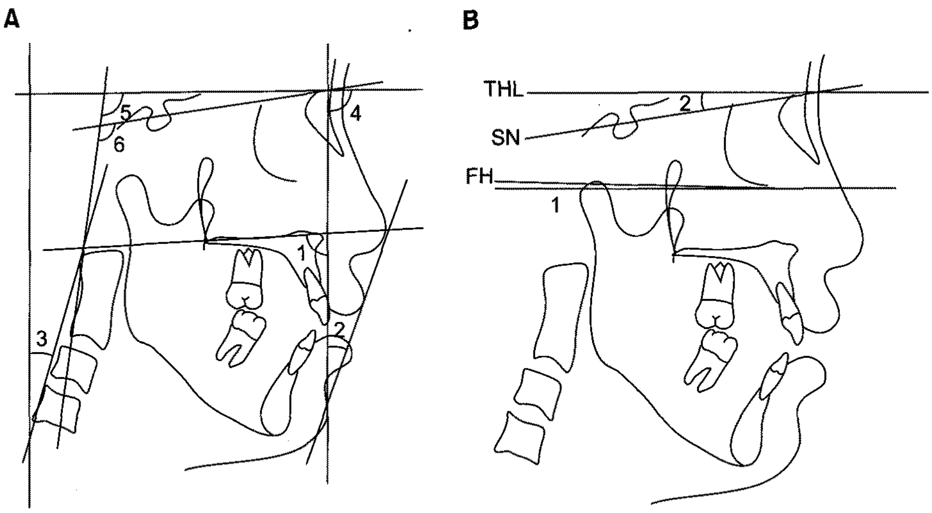

Fig 5. Angular measurements. **A**, 1, Nasion true vertical line (NTVL) to palatal plane; 2, NTVL to E-Line; 3, NTVL to cervical vertebrae tangent; 4, NTVL to sella-nasion (SN); 5, true horizontal line (THL) to odontoid process tangent (OPT); 6, SN to OPT. **B**, 1, THL to Frankfurt horizontal plane; 2, THL to SN.

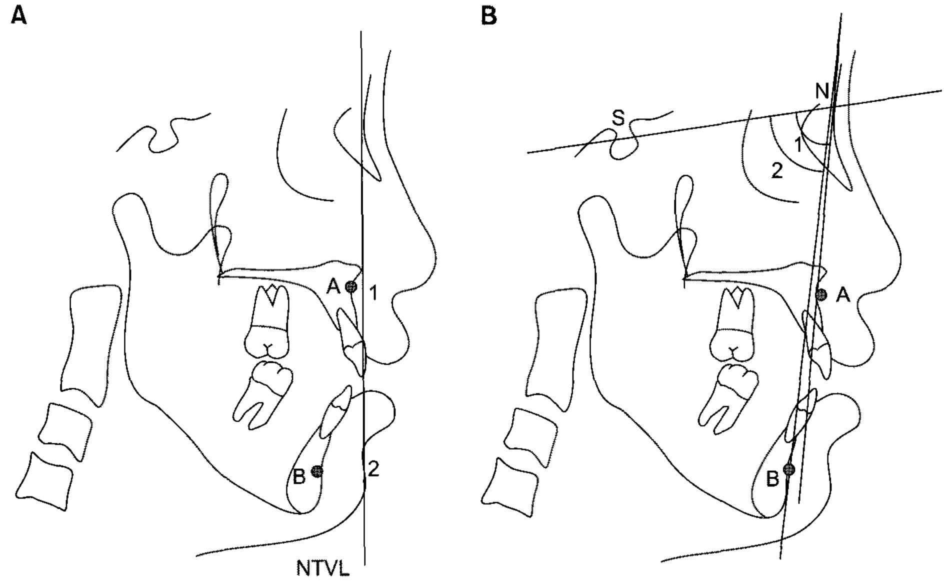

Fig 6. Linear measurements. **A**, 1, Nasion true vertical line (NTVL to A-point); 2, NTVL to B-point. **B**, 1, Sella nasion A-point (SNA) angle; 2, sella nasion B-point (SNB) angle.

Table 1. Digitizing method errors (n = 15)

Variables	Degrees
SN/NTVL	0.22
SN/OPT	0.52
OPT/THL	0.46

NTVL, Nasion true vertical line; OPT, odontoid process tangent; SN, sella-nasion; THL, true horizontal line.

$$\sqrt{\frac{\sum d^2}{2n}} \qquad \text{(Eq. 1)}$$

Where d is the difference between two measurements of a pair and n is the number of paired measurements.

RESULTS

The method errors in digitizing and positioning are summarized in Tables 1 and 2, respectively.

Six parameters were assessed to prove the reliability and reproducibility of the NHP according to intraclass correlation coefficients (Table 3, $p < 0.001$). The correlation coefficient for NTVL and the palatal plane was relatively low.

The differences between FH to THL and SN to THL compared to norms are summarized in Table 4. No significant differences were found in the angles of FH to THL according to one sample t-test ($p > 0.05$).

Table 2. Positioning method errors (n = 116)

Variables	This study (n = 116)	Huggare[18] (n = 33)	Solow & Tallgren[19] (n = 120)
SN/NTVL	1.06	1.60	1.43
SN/OPT	1.28	1.35	1.43
OPT/THL	0.77	2.10	1.95

Date are in degrees. NTVL, Nasion true vertical line; OPT, odontoid process tangent; SN, sella-nasion; THL, true horizontal line.

Table 3. Reproducibility of natural head position (NHP) by intraclass correlation coefficients (n = 116)

Variables	Average of raters (α)	p value
NTVL/E-line	0.9925	< 0.001
NTVL/palatal plane	0.6102	< 0.001
NTVL/CVT	0.9883	< 0.001
NTVL/SN	0.9703	< 0.001
SN/OPT	0.9815	< 0.001
NTVL/OPT	0.9917	< 0.001

The prerequisite for the one sample t-test was a normal FH to THL angle of 0°. In contrast, we identified sig-

Table 4. Differences in Frankfurt horizontal line (FHL) to true horizontal line (THL) and SN to true horizontal line compared to norms (n = 116)

Variables	N	Mean	SD	Min	Max	*p*-value
THL/FH	116	−0.16	3.89	−12.43	7.65	< 0.05
THL/SN	116	9.73	4.60	−2.11	17.50	< 0.05

Norms: THL/FH= 0°, THL/SN=7°. SD, Standard deviation; Min, minimum; Max, maximum.

Table 5. Correlations between linear measurements of A-point to nasion true vertical line (NTVL) and sella-naison (SN)-A angles, and linear measurements of B-point to NTVL and SN-B angles using Pearson correlation coefficients (n = 116)

	NTVL A	NTVL B	NTVL A1	NTVL B1	NTVL A2	NTVL B2
SNA	0.094					
SNB		0.314*				
SNA1			0.328*			
SNB1				0.314*		
SNA2					0.309*	
SNB2						0.287*

A and B, Mean of T1 and T2 data; A1 and B1, T1 data; A2 and B2, T2 data. *$p < 0.01$.

nificant differences in the angles of SN to THL when they were compared to the normal angle of 7° ($p < 0.05$).

The correlations between the linear measurements of A-point to the NTVL and SN-A angles, and B-point to the NTVL and SN-B angles are summarized in Table 5. Significant correlations were identified but the correlation coefficients were very low.

DISCUSSION

Intracranial reference lines, such as the SN and FH plane, have been used by orthodontists to set the antero-posterior position of the maxilla and mandible in orthodontic and orthognathic surgical cases. However, these reference lines do not always coincide with facial aesthetics. Therefore, adopting the NHP and CR is necessary to include the real appearance of patients in the diagnostic position. Some studies[21,22] have evaluated the relationships between craniocervical posture and craniofacial morphology in Korea. Kim et al.[23] showed the reproducibility of NHP irrespective of sex and type of malocclusion, but these studies were carried out in centric occlusion (CO). Studies in centric relation have not been reported. Before the clinical application of NHP and CR, lateral cephalograms should be taken with the same NHP and CR. Even if there is no CO-CR discrepancy, the operator should register the CR bite because any CO-CR discrepancy cannot be found without a guiding CR at the initial diagnostic stage.

The CR is the most important factor in reproducibly determining not only antero-posterior, but also vertical and transverse skeletal relationships. If the treatment of patients is planned without considering the CR position, relapse and temporomandibular disorder may sometimes be confronted after treatment. However, the CR determined in this study is not the real one, but if a CO-CR discrepancy can be found, finding the real CR position is possible using a CR splint.

The concept of the CR has changed since Hanau[24] defined it as the mandible position in which the condylar heads are resting on the menisci in the sockets of the glenoid fossae, regardless of the opening of the jaws. Before 1987, CR was considered to be a retruded (posterior-superior) condylar position. The latest edition of the Glossary of Prosthodontic Terms[25] defines CR as a maxillo-mandibular relationship in which the condyles articulate with the thinnest avascular portion of their respective disks with the complex in the antero-superior position against the slopes of the articular eminences. The Roth technique used in the present study relies on the latest concept of CR using masseter muscle force.

Many methods and devices have been used to precisely locate and record the CR of the mandible. For example, a pantographic recording of mandibular border movement,[26] an acrylic resin jig (Lucia jig),[27] cotton roll,[28] popsicle stick,[29] and leaf gauge[30] have all-been used for a long time. Dawson's bimanual technique[31] is also a very accurate method of recording the CR bite, but it is difficult to hold the wax bite in the mouth firmly. On the other hand, handling the registration wax and rechecking CR with the wax bite is easy with the Roth technique because of the two-step method.

Reproducibility of NHP in CR

Proving the intra-individual reproducibility of NHP is the most important step for applying it as a diagnostic position in patients. Digitizing errors must be verified before proving the intra-individual reproducibility because positioning errors include digitizing errors. The digitizing of landmarks seemed to be relatively precise as the method error was less than 1°. The data for calculating method errors in digitizing were from randomly selected subjects and digitized by one orthodontist with a 1-week interval. Random errors can arise as a result of variations in positioning of the patients in cephalostat and the greatest source of random errors is difficulty in identifying a particular landmark or imprecision in its definition.[32] The reason for selecting three variables (SN to NTVL, SN to OPT, and OPT to THL) was to compare the results of Huggare[33] and Solow and Tallgrens'[19] studies.

Method errors were relatively smaller in this study compared to the previous studies.[19,33] According to Solow and Tallgren,[19] NHP can be obtained in two positions. One position is the self-balance position determined by the subject's own feeling of natural head balance. The other position is the mirror position, so called orthoposition used in this study, in which the subject looks straight into a mirror and stares at their eyes. Solow and Tallgren carefully inserted ear rods, but ear rods were not inserted in this study because they might inhibit natural head positioning. In contrast, Cooke and Wei[34] reported no significant differences in reproducibility between NHP recorded with or without ear rods.

The smaller positioning errors were likely due to the fluid leveler on the eyeglasses. The fluid leveler showed the head position during manipulation and while taking the lateral cephalograms. Showfety et al.[35] showed that the fluid level method can be used to reproducibly register the NHP.

Many methods have been developed to record the NHP since Moorrees and Kean[15] and Bjerin[36] introduced the NHP in orthodontics. Ferrario et al.[37] suggested that the NHP can be captured on a photograph with a plumb line and superimposed onto a conventional cephalogram. Raju et al.[38] reported that the true vertical can be captured on the patient's face with light and then the cephalogram taken in a conventional manner. Uşümez and Orhan[39] used the inclinometer method to record and transfer the NHP to cephalometrics. Among the many methods, the mirror position with fluid leveler used in this study is simple and easy to determine the NHP, as well as very reproducible and repeatable.

The reproducibility of NHP is commonly reported as a Dahlberg's value. However, Bister et al.[40] suggested that this formula has a tendency to camouflage the true variability of the results and advocated the use of reproducibility coefficients. Thus, the reproducibility of NHP was also verified by intraclass correlation coefficients for six parameters. The criteria for selecting the six parameters were as follows: NTVL/E-line for reproducibility of facial aesthetics, NTVL/palatal plane as anintracranial reference line, NTVL/CVT and OPT for the cervical vertebrae, NTVL/SN for the anterior cranial base (SN), and SN/OPT for the anterior cranial base to cervical vertebrae.

Five parameters had very high correlation coefficients, but the coefficient for NTVL to the palatal plane was relatively low due to not being able to reproducibly digitize the posterior nasal spine (PNS). The PNS is hard to discriminate because it is located at the junction area between the bony hard palate and soft palate. Madsen et al.[41] also showed the intra-individual reproducibility of THL to many reference lines, including the Krogman-Walker line and the palatal plane, using paired t-test and coefficients of reliability for 39 subjects.

Variability of FH to THL and SN to THL angles

Marcotte[42] suggested that the FH line should be equal to THL and the FH to SN angle should be 7°. The results of this study showed that the FH to THL angles were not significantly different from 0°, but they were clinically variable due to a high standard deviation (3.89°) and wide range (12.43° - 7.65°). The angle above the THL was positive and the angle below was negative. The angles used in this study were the mean of the T1 and T2 measurements. Bjerin's[36] FH to THL angle range was −11.7° to +15.3° in the standing position and −13.8° to +13° in the sitting position. If orthodontists use McNamara's line[11] in the diagnosis of orthodontic cases, the FH line must coincide with the THL, otherwise many errors may occur in the antero-posterior measurements of the A-point, B-point, and Pog to nasion perpendicular.

The angle of SN to THL was significantly different from 7°, both statistically and clinically, in this study. Lundström and Lundström[43] reported a SN to THL angle of 3.8° (SD 5.6°) for 27 boys and 4.1° (SD 5.0°) for 25 girls. In regard to SN variation, Taylor[12] reported that the ANB angle is influenced by changes in the positions of its three points relative to nasion. Additionally, many reports[9,12,13] have shown that the ANB angle can differ because of variance in the length of the cranial base and/or jaw rotation. Therefore, the SN-A and SN-B angles may be a cause of misdiagnosis in antero-posterior skeletal relationships when SN severely deviates from the normal range. Bjerin[36] also reported that the range of variation in the SN to THL angle was +7.7° to −16.3° in the standing position and +7.0° to −9.4° in the sitting position. The SN to THL angle ranged from −2.11° to 17.5° in this study. The results of this study also showed large inter-individual variability in the SN to THL angle. Lundström and Lundström[44] concluded that the large variation in both intracranial reference lines (FH and SN) compared to the NHP, as well as NHO, confirmed their relative unsuitability as cephalometric references for clinical purposes.

Correlations between linear and angular measurements

The above two studies were prerequisites to investigating these correlations in terms of the NTVL. That is, the intra-individual reproducibility of NHP is inevitable and the differences in the FH plane and SN line compared to THL were also required for this study. Although statistical correlations were identified according to Pearson correlation coefficients, very low correlation coefficients were found between the linear measurements of A-point to the NTVL and SN-A angle, and B-point to the NTVL and SN-B angle. These results explain that linear measurements using the NTVL rarely coincide with angular measurements, such as the SN-A and SN-B angles.

To overcome variations in the SN-A and SN-B angles, many methods comparing angular measurements to THL have been used to determine the skeletal relationships in patients. Cooke and Wei[45] used the angle of the AB line to the THL and the antero-inferior angle between the Y-axis and THL, which is an improved method for assessing the antero-posterior skeletal pattern. Viazis[46] also suggested the angle of the nasion-point A line to the THL and nasion-pogonion line to the THL to determine the skeletal pattern. However, linear measurements are more comfortable and easy for assessing the skeleton antero-posteriorly in clinical applications. In most cases, when deciding the amount of teeth and jaw movement on the sagittal plane, orthodontists and oral surgeons want to know the linear measurements. Thus, the NTVL perpendicular to the THL could be a guide line for assessing the antero-posterior linear relationships of A-point, B-point, and Pog.

Kang et al.[47] compared the soft tissue profiles of 27 males and 20 females selected for a normal facial profile with the true vertical line (TVL). This study showed thicker lower facial tissue, longer facial length, and prominent lower face in men, but the TVL should be used in the normal antero-posterior position of the maxilla. If the TVL is not used in this way, errors may occur in determining the facial profile because the TVL can move relative to the sagittal position of the maxilla. Thus, orthodontists should assess the position of the maxilla on the basis of the NTVL in order to use the TVL as a reference line in advance.

McNamara[11] reported that the normal distance from the nasion perpendicular to the FH plane to A-point was 0.4 mm (SD 2.3) in 73 females and 1.1 mm (SD 2.7) in 38 males, and from Pog to nasion perpendicular was −1.8 mm (SD 4.5) in females and −0.3 mm (SD 3.8) in males. McNamara's samples were from 111 untreated adults with well-balanced faces and good occlusions (Ann Arbor sample). However, the nasion perpendicular line to the THL is more reliable because of the variations in the FH plane compared to the THL. Michiels and Tourne[48] reported that the A-NTVL was 0.4 mm (SD 3.3), B-NTVL −5.0 mm (SD 5.2), and Pog-NTVL −4.4 mm (SD 6.4) in 27 selected women in the NHP. In that study, the subjects were asked to sit comfortably, relax on a chair, and look into the reflection of their own eyes in the mirror during the lateral cephalogram.

However, the subjects' bites were in the CO position. Linear measurements from the NTVL to the B-point and pogonion point should be measured in the CR position because they can change according to the position of the mandible. In future studies, the linear norms from A-point, B- point, and Pog to the NTVL will need to be established in normal Korean adults in the NHP and CR. These norms could be used as guidelines for orthodontic tooth movements and orthognathic surgical movements on the sagittal plane.

Taken together, the results of the present study show that the antero-posterior position of the maxilla and mandible in patientscan be determined by linear measurements using the NTVL for orthodontic and orthognathic surgical cases in the NHP and CR instead of the SN line and FH plane.

CONCLUSION

Orthodontic and orthognathic surgical cases are difficult to diagnose reproducibly and reliably because the FH plane and SN line do not always coincide with facial aesthetics. The present study found that the NHP can be a useful position for diagnosing orthodontic and orthognathic surgical cases reproducibly and reliably. In addition, the NTVL can be used to assess the antero-posterior skeletal relationships of adult Korean patients in the NHP and CR instead of the SN line and FH plane.

- 국문초록 -

자연 두부 위치 및 안정위에서 한국 성인 환자 골격의 전·후 관계 결정

안장훈 · 배광학 · 박영주 · 홍윤기 · 남정훈 · 김미자

SN 기준선과 FH 기준선이 안모의 심미에 종종 맞지 않아서 모든 치열 교정 및 악교정 수술 증례를 이 기준선을 이용하여 반복적으로 정확히 진단하기가 매우 어렵다. 따라서, 이 연구의 목적은 한국 성인 환자를 대상으로 안정위에서 자연 두부 위치의 개인내 재현성을 확인하고 진성 수평선에 대해 SN 기준선과 FH 기준선의 개인간 다양성을 증명하는 것이다. 그리고, 상기 두 연구를 바탕으로 Na 기준 진수선에서 A점 및 B점까지의 거리가 SNA 및 SNB 각도와 상관 관계가 있는지 여부를 조사하는 것이다. 부정교합 및 악골의 부조화를 치료받기 위해 강남성심병원과 한강성심병원 교정과에 내원한 116명의 환자(남자 23명, 여자 93명)를 조사하였다. 중심위 왁스 바이트는 모든 대상들로부터 채득하였고 1주일 간격으로 자연 두부 위치와 중심위 상태에서 모든 대상자들의 측모두부방사선사진을 2번 촬영하였다. 3개의 변수에서 위치 선정의 방법 오류는 다른 연구에 비해 낮은 수치를 보였다. 그리고 6개의 변수에서 군내 상관계수를 이용하여 자연두부 위치의 개인간 재현성을 증명하였다 ($p < 0.001$). 각 환자에서 진성 수평선에 대한 FH 기준선간의 각도는 통계적으로 기준치 0도와 다르지 않았다 ($p > 0.05$). 하지만 임상적으로 다양한 수치를 보였다 (SD: 3.89^{o}). 반면 각 환자에서 진성 수평선에 대한 SN 기준선간의 각도는 기준치 7도와 매우 다르게 나타났다 ($p < 0.05$). Na 기준 진수선에서 A점 및 B점까지의 거리와 SNA 및 SNB 각도와의 피어슨 상관 계수에서 유의하지만 매우 낮은 수치를 보였다 (p <

0.01). 이에 자연 두부 위치는 치열 교정 환자 및 악교정 수술 환자의 진단을 위해 재현적이고 믿을 만한 위치이며 자연 두부 위치 및 중심위 상태에서 Na 기준 진수선은 SN과 FH 기준선을 대신하여 한국인 성인 환자에서 상악골과 하악골의 전후 관계를 결정하는데 매우 유용한 기준선으로 이용될 수 있을 것으로 생각한다.

주요 단어: 자연 두부 위치, 중심위, FH 기준선, SN 기준선, Na 기준 진수선

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