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Original Article

Cephalometric Evaluation of Anterior Cranial Base Slope in Patients with Skeletal Class I Malocclusion with Low or High SNA and SNB Angles

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Main points:

- The SN plane, anterior cranial base inclination (ACB), is frequently used by orthodontists as a reference plane.
- In our study, the relationship between low or high SNA, SNB and ACB was evaluated in patients with skeletal Class I malocclusion.
- According to the findings, high values of SNA and SNB were caused by flatter ACB and the low SNA and SNB values were the result of the steeper ACB slope.

ABSTRACT

Objective: In the cephalometric analyses, it is observed that both SNA and SNB angles are higher or lower than normal for some skeletal Class I patients. The aim of this study was to assess the correlation between low or high SNA, SNB angles, and anterior cranial base (ACB) slope.

Methods: One hundred and seventeen skeletal Class I patients (45 males with a mean age of 14.5 years, 72 females with a mean age of 14.4 years) were evaluated in three groups. Group 1(n=40): Control group, individuals with normal SNA(82°±2°), and SNB(80°±2°) values. Group 2 (n=37): Patients with SNA>84° and SNB >82°, Group 3 (n=40): Patients with both SNA and SNB values lower than 78°. On the cephalometric radiographs, three angulars (SN / FH; anterior cranial base, Ba-S / FH; posterior cranial base, SN-Ba; total cranial base) and seven linear (S-FH, N-FH, Δ, Ba-S, Ba-N, Ba-A, Ba-B) measurements were performed to analyze the vertical and horizontal positions of the S and N points and thereby the ACB slope. One-way ANOVA and Kruskal Wallis tests were used for statistical analysis.

Results: The ACB slope was observed to be relatively flatter in Group 2, and steeper in Group 3 ($p<0.05$). The location of the S and N points in the sagittal plane did not significantly affect the SNA and SNB. However, the vertical position of the S and N points was a factor determining the inclination of the ACB, therefore the SNA and SNB.

Conclusion: ACB slope directly affected SNA and SNB measurements. ACB might lead to misleading results when used as a reference plane.

Keywords: Cephalometric analysis, cranial base, skeletal Class I malocclusion

INTRODUCTION

Cephalometric analysis has been a decisive factor in orthodontic treatment planning for years (1). During the analyses, numerous measurements are performed on dentofacial structures using certain reference planes (2, 3). One of these planes used as a reference in the measurements is the anterior cranial base (Sella-Nasion) (4). The anterior cranial base (ACB) might be affected by both the direction and degree of the growth of the craniofacial structures. Several studies have shown that its angular slope or length enhances the development of sagittal or vertical skeletal malocclusions (5). The degree of its slope could also vary depending on the race or area in which the research was carried out (6, 7). Nevertheless, ACB is still considered as relatively stable throughout craniofacial growth compared with other reference planes (8). Therefore, ACB is generally preferred for superimposing initial and final cephalometric radiographs (9).

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The literature involves numerous studies investigating the relationship between cranial base slope and skeletal malocclusions. According to some of these reports, the cranial base inclination affects the formation or severity of the malocclusion (10, 11). However, the cranial slope has not been identified as a factor in other studies (12, 13). The slope, length, and stability of ACB are critical to accurately predict complex growth mechanisms of craniofacial structures. Renfroe (14), Bjork (15), and Ricketts (16) emphasized the importance of this reference plane.

ACB is commonly used for superimposition of cephalometric radiographs. Because the growth of ACB is completed earlier than other craniofacial structures and is highly stable in the first decade of life (17). Throughout intrauterine life, the cranial base slope is almost flat. However, as the brain grows exponentially, the slope increasingly becomes steeper (18). In the first 5 years of life, ACB shows rapid development and completes its growth by 90% (19, 20). During growth, the cranial base, moving forward and downward, determines maxillary and mandibular growth and development pattern.

Sometimes in initial cephalometric measurements, both SNA and SNB are seen to be low (SNA, SNB <78°) or to be high (SNA>84° and SNB >82°) and this is not an uncommon circumstance. These patients, however, have good facial esthetics and occlusal relations, and neither bimaxillary retrusion nor bimaxillary protrusion is seen in the extraoral examination of these patients. In this scenario, what are the factors that caused this situation? This study was based on the null hypothesis that there is no correlation between high or low SNA and SNB values and ACB slope and length.

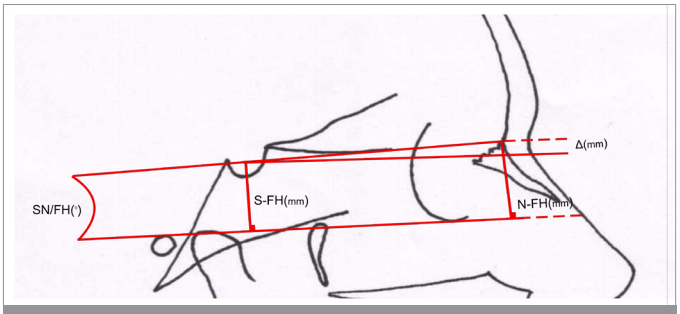

Figure 1. Vertical assessment of S and N points. ACB slope calculation with SN / FH angle

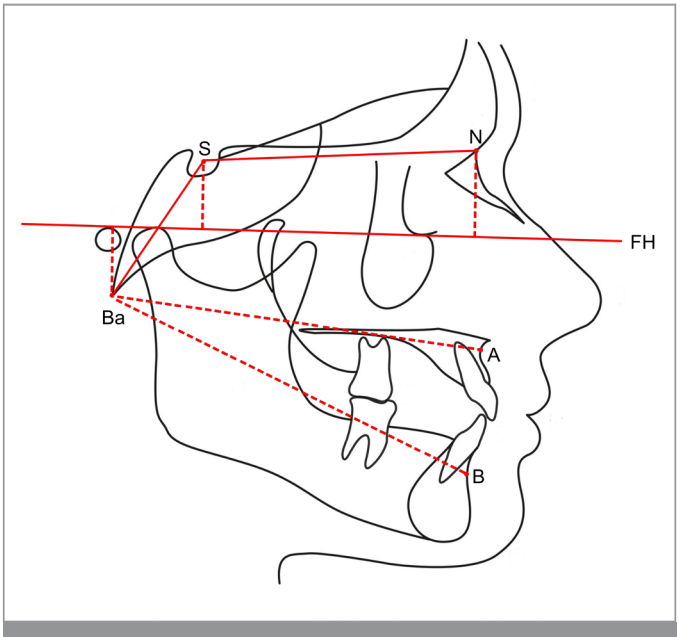

Figure 2. Horizontal assessment of S, N, A and B points

METHODS

The experimental protocols of this retrospective study were approved (02.08.2019-253) by Afyonkarahisar Health Sciences University Clinical Research Ethics Committee. Written informed consent forms were obtained from all the patients included in the study. The study was conducted on lateral cephalometric films of the patients who applied to orthodontic department of Afyonkarahisar Health Sciences University. All cephalometric radiographs were taken as routinely performed in the natural head position. In the power analysis to determine sample size, it was revealed that at least 37 patients were required for each group in order to obtain sufficient statistical power (n>37, α=0.05, and 1-β=0.80). One hundred and seventeen skeletal Class I patients (45 males with a mean age of 14.5 years, 72 females with a mean age of 14.4 years) were included in the study. The following criterias of the patient selection were considered:

- High quality cephalometric radiographs for easy identification of the anatomical landmarks
- Healthy patients without systemic diseases, congenital deformities or significant facial asymmetry
- No history of previous orthodontic treatment

The selected patients were divided into three groups based on the following criterias. The definitions of the groups were as follows: Group 1 (n=40): Control group, individuals with normal SNA (82°±2°) and SNB (80°±2°) values. Group 2 (n=37): Patients with SNA>84° and SNB>82°, Group 3 (n=40): Patients with both SNA and SNB values lower than 78°. The following measurements were performed on the lateral cephalometric radiographs routinely used for diagnostic purposes (21, 22) (Figure 1 and 2):

- SNA: Angle formed by the intersection of sella-nasion and nasion- A lines
- SNB: Angle formed by the intersection of sella-nasion and nasion- B lines
- ANB: Angle formed by the intersection of nasion- A and nasion- B lines
- SN / FH: Angle between anterior cranial base and Frankfort horizontal plane
- SN-Ba angle: Total cranial base angle
- Ba-S / FH: Angle between posterior cranial base and Frankfort horizontal plane
- S-FH length: Perpendicular distance from Sella to the Frankfort horizontal plane
- N-FH length: Perpendicular distance from Nasion to the Frankfort horizontal plane
- Delta (Δ): Difference between the N-FH and S-FH
- Ba-S length: Distance between Ba and S projected on FH plane
- Ba-N length: Distance between Ba and N projected on FH plane
- Ba-A length: Horizontal distance between Basion and A
- Ba-B length: Horizontal distance between Basion and B

Table 1. Intra-class correlation coefficients (ICCs) testing inter-observer reliability

Measurements	SNA	SNB	SN/FH	SN-Ba	S-FH	N-FH	Δ	Ba-A	Ba-B
Correlation coefficient	0.950	0.974	0.923	0.970	0.958	0.946	0.921	0.985	0.990

S: Sella; N: Nasion; FH: Frankfurt horizontal; Δ: Delta; Ba: Basion

Table 2. Comparison of the measurements with one-way ANOVA test and Kruskal Wallis test between the groups

		N	Mean±SD	p
SN/FH(°)	Group 1	40	7.52±2.57	0.000***
	Group 2	37	5.03±2.56	
	Group 3	40	11.88±3.31	
SN-Ba(mm)	Group 1	40	125.59±4.43	0.000***
	Group 2	37	123.40±4.64	
	Group 3	40	132.26±4.19	
Ba-S/FH(°)	Group 1	40	118.04±4.19	0.064
	Group 2	37	118.52±4.95	
	Group 3	40	120.36±4.66	
S-FH(mm)	Group 1	40	18.98±2.64	0.000***
	Group 2	37	19.47±2.41	
	Group 3	40	16.18±2.34	
N-FH(mm)	Group 1	40	27.26±2.55	0.000***
	Group 2	37	24.98±3.36	
	Group 3	40	29.27±3.18	
Δ (mm)	Group 1	40	8.29±2.70	0.000***
	Group 2	37	5.66±2.91	
	Group 3	40	13.08±3.50	
Ba-S(mm)	Group 1	40	20.78±3.20	0.887
	Group 2	37	21.02±3.17	
	Group 3	40	21.10±2.85	
Ba-A(mm)	Group 1	40	83.42±5.61	0.007**
	Group 2	37	86.92±5.38	
	Group 3	40	82.73±4.13	
Ba-B(mm)	Group 1	40	80.08±5.72	Ψ0.000***
	Group 2	37	84.50±6.72	
	Group 3	40	77.84±4.66	
Ba-N(mm)	Group 1	40	83.83±6.10	Ψ0.661
	Group 2	37	84.94±5.12	
	Group 3	40	84.23±4.91	

S: Sella; N: Nasion; FH: Frankfurt horizontal; Ba: Basion; Δ: Delta; ANOVA: Analysis of variance
Ψ: p values for Kruskal Wallis test
p values for one way ANOVA test; ** p<0.01, ***p<0.001

All measurements were performed by a single experienced researcher for the reliability of the study (F.S.). AudaxCeph Version 5.X software (Ljubljana, Slovenya) was used for the cephalometric measurements.

Statistical Analysis

The Statistical Package for Social Sciences version 22.0 software (IBM Corp.; Armonk, NY, USA) was used to calculate the mean values and standard deviations of each parameter. One-way ANOVA test and post hoc Tukey test were performed to compare homogeneous datas among groups. Analysis of non-homogeneous datas (Ba-N and Ba-B) were conducted with Kruskal-Wallis and the post hoc Tamhane test.

Table 3. Results of Tukey multiple comparison tests of the normally distributed variables

Dependent Variable	Group 1/ Group 2	Group 2/ Group 3	Group 1/ Group3
SN/FH(°)	0.001**	0.000***	0.000***
SN-Ba(mm)	0.081	0.000***	0.000***
Ba-S/FH(°)	0.893	0.067	0.190
S-FH(mm)	0.664	0.000***	0.000***
N-FH(mm)	0.004**	0.000***	0.011*
Δ (mm)	0.001**	0.000***	0.000***
Ba-S(mm)	0.936	0.993	0.885
Ba-A(mm)	0.009**	0.001**	0.813

S: Sella; N: Nasion; FH: Frankfort horizontal; Δ: Delta; Ba: Basion; *p<0.05, ** p<0.01, ***p<0.001

Table 4. Results of Tamhane test of the non-normally distributed variables

Dependent Variable	Group 1/ Group 2	Group 2/ Group 3	Group 1/ Group3
Ba-N(mm)	0.770	0.899	0.984
Ba-B(mm)	0.008**	0.000***	0.169

Ba: Basion; ** p<0.01, ***p<0.001

Error of the Method

In ten randomly selected patients, all parameters were remeasured one month later by the same researcher (F.S.). The initial and repeated measurements were compared using the intra-class correlation coefficients (ICCs) test to ensure the inter-observer reliability (Table 1).

RESULTS

The descriptive statistics, the comparisons among groups by one way ANOVA and Kruskal Wallis tests, and the results of post hoc Tukey and Tamhane tests were given in Table 2, Table 3 and Table 4. Ba-S measurements showed that there was no statistically significant difference between the groups in terms of the anteroposterior position of the S point (p>0.05). In other words, sagittal location of the S point had no effect on the ACB slope.

The S point in Group 3 was positioned more inferiorly than the other two groups according to S-FH measurements. The only statistically significant difference was observed between Group 3 and the other two groups (p<0.01).

The N point was at the highest position in Group 3 and the lowest position in Group 1 according to N-FH values. This measurement showed significant difference between the groups (p<0.01). In

the Ba-S measurements, the sagittal position of the N point did not show any statistically significant difference between groups (p>0.05) (Figure 3).

The length of Delta (Δ) indicating the vertical distance between S and N points was the highest in Group 3 and the lowest in Group 2. This finding suggested that the slope of the anterior cranial base was steeper in Group 3 and flatter in Group 2.

In Group 2, points A and B were located more anteriorly than the other two groups, according to the measurements of Ba-A and Ba-B. This revealed that the high value of both the SNA and the SNB was caused not only by the relatively flat S-N plane but also by the more anterior location of the A and B points.

The highest values for the SN / FH findings were found in Group 3 and the lowest in Group 2. This variation between the groups was statistically significant (p<0.01). The SN-Ba angle of Group 3 was significantly higher than other two groups (p<0.01).

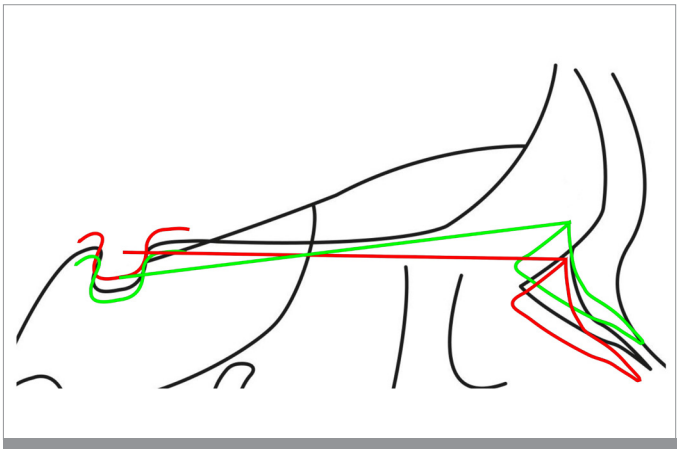

Figure 3. Schematic illustration of ACB slopes of the groups. Black: Control group, Green: Group 2, Red: Group 3

DISCUSSION

The primary prerequisite for effective orthodontic treatment is an accurate description and diagnosis of the malocclusions. However, the reference planes used in the diagnosis of the malocclusions may sometimes provide misleading results. The cranial base inclination or anatomical variations of other reference planes might play a role in the type and severity of the malocclusions (23). Previous researchers investigating the relationship between cranial base and malocclusion have generally assessed lengths and angles of the anterior and posterior cranial base (24). In addition to the length and angle of the cranial base, the vertical and sagittal locations of the S and N points were evaluated in our study. Sella represents the posterior part of the cranial base and Nasion represents the upper part of the middle face. Besides the vertical and horizontal position of the nasion, the slope of the ACB could alter the SNA and SNB angles considerably. For instance, two people with almost identical facial prognathism in their natural head position may display a significant difference in the slope of the SN plane (25). This causes confusion over the reliability of intracranial reference planes.

Numerous studies have investigated the accuracy and reliability of SN and FH planes (26,27). SN plane largely completes its development in the first decades of life. Throughout the development of craniofacial structures, S and N points relocate (8). Particularly the migration of point N migration continues parallel to the facial development for many years. In the same way, the development of craniofacial structures affects the FH plane. The FH plane was used as a reference for determining the degree of inclination of the SN plane and the vertical position of the S and N points. The reasons for selecting FH were because it is located close to the anterior cranial base and very small relocation in semi-circular ear canals and lower border of orbita occur during the early ages of life (28-31).

However, FH also has some disadvantages: its accuracy and reproducibility rely on the natural head position, difficulty in identification of the right and left orbita or meatus acusticus exter-

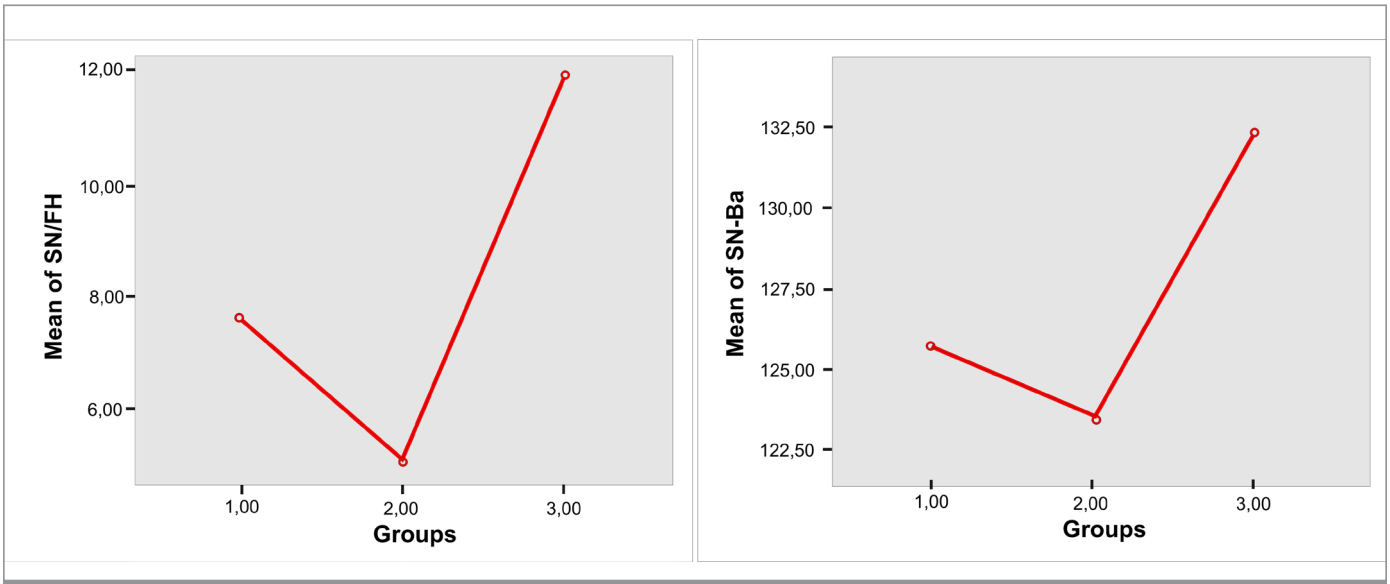

Figure 4. The diagrams showing SN / FH and SN-Ba values distribution between the groups

nus, and the presence of contradictory findings in the literature on the variation of this plane.

Since Basion was used as a reference, the measurements of S and N points in the sagittal direction may have been affected. Because the position of Basion could differ horizontally and vertically, depending on the growth and development of the cranium. However, Pelo et al. (32) have reported that the use of Ba as a reference point provides reliable results.

The anteroposterior or up-down tipping of the posterior (Ba-S) and anterior base (S-N) has an impact on the cranial base angle (SN-Ba) (20). The steep posterior base causes the lower jaw to displace anteriorly and changes the position of the B point. The increased SN-Ba angle leads to a posterior localization of the mandible. In the literature, several researchers reported a correlation between cranial base angle and skeletal malocclusions (11, 33). However, contradictory findings have also been stated (34, 35). An explanation for inconsistent findings is that not only the cranial base inclination or angle but several variables are involved in the development of malocclusions (36). Therefore, only skeletal Class I patients were included in our research to eliminate malocclusion-related factors. However, in this retrospective study, other factors could not be eliminated. In addition, patient selection without age and sex consideration was another limitation of this study. The variations in the age and sex of subjects were a factor affecting the results. Because the morphological maturation of the human skull differs among men and women in terms of duration and its final size (17).

The mean SN / FH angle value was reported at 7^0, and remains relatively stable throughout the growth (37). Our findings in SN / FH measurements were close to normative values for Groups 1 and 2, but this value was higher in Group 3. Graphical distributions of SN / FH and SN-Ba angle measurements among groups were identical (Figure 4). This finding allows claiming that the common variable of both angles, namely SN, was the primary factor determining the two measurements. It also revealed that the FH plane and the Ba point used as a reference had no negative impact on the measurements.

Although the ACB is known as a stable plane, it should be noted that its slope may affect cephalometric measurements. Since the vertical or horizontal positions of the S and N points vary depending on age and gender, further longitudinal studies are needed with larger and more specific sample groups.

CONCLUSION

Lower position of the point N, more forward position of the point A and B were responsible for the increased SNA and SNB. High SNA-SNB Group data (S-FH, Ba-S) were not affected by the sagittal and vertical displacement of the S point. Also, the position of the N point in the sagittal plane did not affect SNA and SNB. In addition, the slope of ACB was flatter in this group.

Low SNA and SNB values were due to the more inferior localization of the S point. Another reason was the superior location of the N point. In low SNA-SNB Group, the sagittal position of the points S and N did not affect the SNA and SNB. The slope of ACB was steeper.

Our null hypothesis was rejected. ACB slope affected SNA and SNB measurements.

Ethics Committee Approval: This study was approved by Ethics committee of Afyonkarahisar Health Sciences University (Approval No: 02.08.2019-253).

Informed Consent: Written informed consent forms were obtained from all the patients included in the study.

Peer-review: Externally peer-reviewed.

Author Contributions: Supervision – H.C.; Design – H.C., F.S.; Supervision – H.C.; Resources – H.C.; Materials – H.C.; Data Collection and/or Processing – H.C., F.S.; Analysis and/or Interpretation – H.C., F.S.; Literature Search – H.C.; Writing Manuscript – H.C.; Critical Review – H.C., F.S.

Conflict of Interest: The authors have no conflict of interest to declare.

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