ORIGINAL ARTICLE

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Changes in cranial base morphology in different malocclusions

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Structured Abstract
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Objectives – To evaluate the differences in cranial base flexure between skeletal and dental Class I, Class II and Class III malocclusions.
Design – Lateral cephalometric radiographs, matched for age, of skeletal Class I, Class II and Class III patients with an average vertical growth pattern were analyzed and compared.
Setting and sample population – A total of 75 patients having skeletal Class I (n = 25), Class II (n = 25) and Class III (n = 25) malocclusions of Baskent University.
Experimental variable – Anterior (SN) and posterior (SBa) cranial base lengths, cranial base angle (N-S-Ba, N-S-Ar) and both anterior (SN-FH) and posterior (SBa-FH) cranial base inclinations were measured on the pretreatment lateral cephalograms.
Outcome measure – Size and shape differences in cranial base between different malocclusions.
Results – Anterior and posterior cranial base lengths, and cranial base angles did not show statistically significant differences between the three groups studied. Both anterior and posterior cranial base inclinations were increased significantly in the Class III group compared with Class I and Class II groups.
Conclusions – No differences were observed in anterior and posterior cranial base lengths, and cranial base angles between the three malocclusions. However, cranial base inclinations were increased in Class III malocclusions.

Key words: cephalometry; malocclusion; orthodontics; skull base

Dates:
Accepted 1 July 2007

To cite this article:
Polat ÖÖ, Kaya B:
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Orthod Craniofacial Res 10, 2007; 216–221

Introduction

The cranial base supports the brain and provides adaptation between the developing neurocranium and viscerocranium during growth (1, 2). Located on a junction point between the cranium, midface and glenoid fossa, the cranial base may affect the development of both the face and the cranium. It is reported that the first growth spurt of the cranial base occurs between 14 and 32 weeks of fetal life and the second spurt occurs during the first year after birth (3). Besides, the cranial base reaches 90% of its adult size at the 13th year of life, much later than the head circumference. George (4) noted that the saddle angle decreases from birth through the first year of life. Lewis and Roche (5) reported that the cranial base angle becomes more acute during infancy and stays constant after the age of 2 years. Similarly, Kerr (6) observed the saddle angle to be one of the constants that shows very little change during the growth period from the age of 5 to 15.

The cranial base plays a key role in craniofacial growth, helping to integrate, spatially and functionally, different patterns of growth in various adjoining regions of the skull such as components of the brain, the nasal cavity, the oral cavity, and the pharynx. Depending on the fact that the maxilla is connected with the anterior part of the cranial base and the rotation of the mandible is influenced by the maxilla, a relationship can be found between the cranial base variations and sagittal malpositions of the jaws. It has been reported that Class III patients demonstrated smaller linear and angular measurements than others, whereas Class II patients showed increased cranial base angle leading to a more posterior position of the mandible (7–11). Hopkin et al. (12) found that the cranial base length and angle increase from Angle Class III through Class I to Class II division I malocclusion. Anderson and Popovitch (13) observed that the individuals with the largest cranial base angle showed a Class II tendency. Järvinen (14) noted that Class II patients showed a higher ArSN angle than Class III patients. Kerr and Adams (15) examined a larger BaSN angle in Class II patients than Class I patients. Some other researches have reported similar findings, and concluded that the cranial base flexure is more obtuse, S-N (anterior cranial base) and S-Ba (posterior cranial base) lengths are longer and the condylar neck is positioned more posteriorly in Class II individuals (16–21). Dibbets (19) emphasized that BaSN angle closed and the legs of the angle (SN and SBa) shortened systematically from Class II, over Class I, to Class III subjects.

Among the studies that have tried to find the effect of cranial base development on the developing sagittal jaw discrepancies, some have failed to demonstrate a relation. Hildwein et al. (22) found no significant difference for the cranial base angle BaSN in Class II and Class I subjects. Varrela (23, 24) examined the characteristic properties of Class II patients between 3 and 7 years of age, and did not find the cranial base to be different from that of the Class I control group. Depending on these findings, the author emphasized that the cranial base is not an early etiologic factor in Class II relationship. Kasai et al. (25) investigated the relationship of the cranial base and maxillofacial morphology in Japanese crania and did not find differences between Class I and Class II samples. Similarly, Wilhelm et al. (26) did not observe any differences for the cranial base measurements between the Class I and Class II skeletal patterns. Different studies sustaining these findings are also present (27, 28).

Different factors like basicranial morphology, head and neck posture and soft tissue stretching are thought to influence the occurrence of a skeletal malocclusion. The influence of cranial base angulation as a factor in the etiology of sagittal jaw discrepancies is still a matter of debate. While investigation of a longitudinal data can show the cause–effect relationship of this problem, a cross-sectional sample may search for morphological differences in different skeletal classes. Therefore, the purpose of this cross-sectional retrospective study was to investigate any possible differences in the shape and position of the cranial base in Class I, Class II, and Class III skeletal patterns.

Material and methods

Lateral cephalometric films were obtained from the initial records of 75 patients, presented for orthodontic treatment. Patients were included in each group according to the following criteria:

Group 1: Skeletal Class I malocclusion with an ANB angle of $2 \pm 2°$, favorable overjet and overbite and minimal crowding of both arches.

Group 2: Skeletal Class II malocclusion with an ANB angle of $+5°$ or more, increased overjet.

Group 3: Skeletal Class III malocclusions with an ANB angle of $-1°$ or less negative overjet.

Patients, who presented any oral habit (as determined from the history) were excluded from the study.

All of the patients were at the past pubertal growth spurt stage according to cervical vertebrae maturation index (CV4 developmental stage) and showed normal vertical growth pattern, as determined by GoGnSN angle (GoGnSN = 32 ± 6).

Twenty-five patients were included in each group. The mean ages of the patients were 15.74 ± 4.28 for the

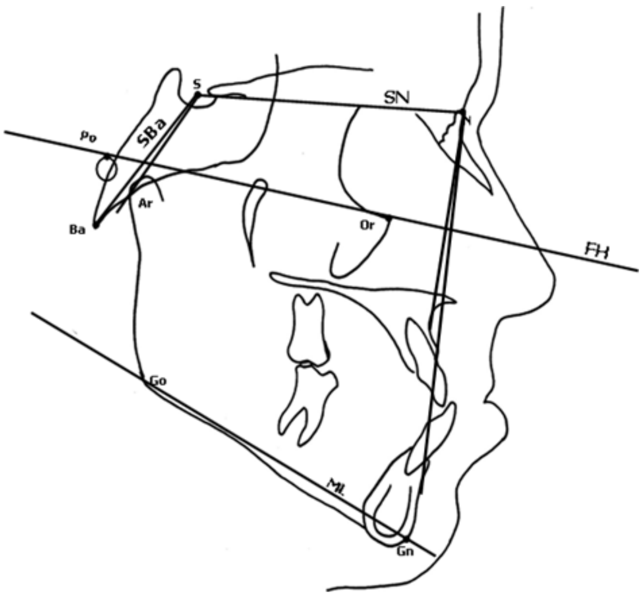

Fig. 1. Points and reference lines used in this study: SNA, SNB, ANB, GoGn-SN, linear cranial base measurements (S-N, S-Ba), angular cranial base measurements (N-S-Ar, N-S-Ba), cranial base inclinations (SN-FH, SBa-FH).

Class I group (12 male, 13 female), 15.64 ± 3.06 for the Class II group (11 male, 14 female) and 14.34 ± 3.00 for the Class III group (13 male, 12 female).

Cephalometric analysis

The lateral cephalometric radiographs of each subject were taken with a Planmeca cephalometer (PM 2002 EC; Proline, Helsinki, Finland). All subjects were positioned in the cephalostat with the sagittal plane at a right angle to the path of the X-rays, the Frankfort plane parallel to the horizontal, the teeth in centric occlusion, and the lips slightly closed. The radiographs were hand-traced and measured by the same investigator (O.P.O.). The following landmarks were used for cephalometric analysis: point A (A), point B (B), sella (S), nasion (N), articulare (Ar), basion (Ba), gonion intersection (Go), gnathion (Gn), porion (Po), orbitale (Or). The following measurements were used (Fig. 1):

Angular measurements for the assessment of sagittal growth pattern: SNA, SNB, ANB.

Angular measurement for the assessment of vertical growth pattern: GoGn-SN.

Linear measurements for the assessment of cranial base dimensions: S-N, S-Ba.

Angular measurements for the assessment of cranial base flexure: N-S-Ar, N-S-Ba.

Angular measurements for the assessment of anterior and posterior cranial base inclinations: SN-FH, SBa-FH.

Statistical analysis

The mean and standard deviations were estimated for each cephalometric variable in each group. Differences between the groups were evaluated using ANOVA and Tukey tests. Significance for all tests was predetermined as $p < .05$. All statistical analysis was performed using Statistical Package for Social Sciences software package. (SPSS for Windows, Version 10.0, Chicago, IL, USA).

Twenty radiographs were selected at random from the observation group to determine the errors associated with radiographic measurements. The tracings and measurements were repeated 3 weeks after the first measurements. Dahlberg's formula was used to calculate the method error and the error was found to be within the range 0.24–0.63 mm for linear measurements and 0.20–0.44° for angular measurements.

Results

The mean and standard deviations for SNA, SNB, ANB, and GoGnSN angles are given in Table 1. The linear and angular measurements of the cranial base morphology of the three study groups are presented in Table 2.

The anterior cranial base length (S-N) and posterior cranial base length (S-Ba) showed no significant differences between the groups ($p > 0.05$). The cranial base flexure was evaluated according to both N-S-Ba and N-S-Ar angular measurements. N-S-Ba angle showed a gradual increase from Class III to Class II,

Table 1. **Mean and standard deviation of sagittal and vertical measurements**

	CL I		CL II Div 1		CL III	
	Mean	SD	Mean	SD	Mean	SD
SNA	81.44	2.31	82.04	3.31	79.02	2.82
SNB	79.08	2.47	76.28	3.12	82.18	3.22
ANB	2.36	1.04	5.76	0.95	−2.94	1.79
GoGNSN	33.32	2.89	33.02	3.32	32.74	2.36

Table 2. **Mean and standard deviations of the measurements and comparison of groups with ANOVA and Tukey tests**

	CL I		CL II Div 1		CL III					
	Mean	SD	Mean	SD	Mean	SD	*p*	CL I–CL II Div 1	CL I–CL III	CL II Div 1–CL III
SN length	65.62	3.37	67.8	3.03	67.92	5.4	NS			
SBa length	44.12	1.97	45.38	2.9	45.58	3.74	NS			
N-S-Ba	128.36	5.28	126.94	4.06	125.56	5.6	NS			
N-S-Ar	123.48	5.2	121.04	5.46	119.62	6.34	NS			
SN-FH	7.77	1.88	8.02	2.59	10.6	3.34	***		***	***
SBa-FH	59.46	4.78	61.06	2.55	64.76	5.49	***		***	***

NS, not significant.
*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$.

division I via Class I. The N-S-Ar angle also showed the same gradual increase from Class III to Class II, division I via Class I. However, no significant differences were measured between the groups for both two parameters ($p > 0.05$).

For the assessment of anterior cranial base inclination, the SN-FH angle was measured. Significant difference was calculated between the groups ($p < 0.001$). According to the results of the Tukey test, significant differences were found between Class I–Class III groups ($p < 0.001$) and Class II, division I–Class III groups ($p < 0.001$).

The posterior cranial base inclination was also assessed by measuring the SBa-FH angle. Similar to the anterior cranial base inclination, this parameter also revealed significant difference between the groups ($p < 0.001$). Group comparisons showed that Class I–Class III groups ($p < 0.001$) and Class II, division I–Class III groups ($p < 0.01$) indicated significant differences.

Discussion

Description and diagnosis of a malocclusion is the primary objective of the orthodontist. The diagnosis can dictate the treatment objectives and treatment mechanics for the patient; therefore, it is important to find out if an underlying skeletal dysplasia is associated with a dental malocclusion. The location and magnitude of a skeletal dysplasia can influence various treatment decisions.

In the assessment of orthodontic problems involving anteroposterior malrelationships of the jaws, the problem is usually the result of size, form, and position of the jaw. Despite the effects of head posture, breathing mode or even spine position that have been shown to influence craniofacial morphology, cranial base flexion has been put forward to be a possible indicator of a skeletal malocclusion. Several researchers have tried to find a correlation between the cranial base and anteroposterior jaw position. The results of Hopkin (9), Anderson and Popovitch (13) and Järvinen (14) showed an increase in cranial base angle from Class III through Class I and to Class II malocclusions. Conversely, researchers like Kasai et al. (25), Wilhelm et al. (26) and Dhopatkar et al. (28) failed to demonstrate any differences in cranial base flexure in different malocclusions. Due to the present controversy in the current literature, the main purpose of the present study was to investigate, in a cross-sectional sample, whether the cranial base flexure or the shape of the cranial base could show morphological differences in skeletal Class I, II and III malocclusions.

It is difficult to exclude all possible factors that influence the occurrence of a skeletal dysplasia. However, in choosing the Class II and III samples of the study group, care was given not to choose among the subjects who have extremely small or huge jaws. Mouth breathers or patients who have any other oral habits were also excluded to minimize the effects of any other etiological factors that play a role in development of a specific skeletal class. Facial divergence may also affect the position of the jaws. Previous studies have tried to find a correlation between cranial base flexure and sagittal malocclusions (Class I, II and III); however, none of these have paid attention to vertical height differences in the samples studied. This study aimed to eliminate possible changes in facial divergence, and the SN/MP angle was similar in all three groups.

Previous studies that investigated the role of the cranial base in malocclusions have mainly focused on anterior and posterior cranial base lengths and cranial base angle which is determined either by using basion or articulare as the posterior reference point. Even though high levels of correlation between N-S-Ba and N-S-Ar were demonstrated (29–31), measuring both the angles for the accuracy of the results was preferred in this study. In addition to cranial base lengths and angles, anterior and posterior cranial base inclinations were also used.

The results of this study failed to demonstrate any differences between the three groups studied in anterior and posterior cranial base lengths and cranial base angle measured either from basion or articulare. These results were consistent with the findings of Hildwein et al. (22), Kasai et al. (25) and Wilhelm et al. (26). However, the cranial base angle may fluctuate within a very wide range, with a standard deviation of 5° or more (18, 32–34). Bacon et al. (18) assumed that this relatively large variability explains why significant differences in this angle are rarely described in group comparisons.

In this study, both anterior (SN-FH angle) and posterior cranial base (SBa-FH angle) inclinations were found to be increased significantly in the Class III group than in the Class I and Class II groups. The changes in both of the angles were found to be similar, preventing any change in cranial base angle. It has been suggested that cranial base flexure influences mandibular prognathism by determining the anteroposterior position of the condyle relative to the facial profile (30). The results of this study did not demonstrate a significant difference in the cranial base angle among the malocclusions studied. However; the Class III group showed increased cranial base inclinations that might have resulted in forward positioning of the jaw. This change still shows an anterior positioning of the basion in class III patients which is masked by counterclockwise inclination of the anterior cranial base.

Clearly, the cranial base angle is not the only factor in determining a malocclusion. According to Scott (35), three main factors influence facial prognathism – opening of the cranial base angle, the relative forward movement of components such as the maxilla and the mandible to the cranium, and the amount of surface deposition along the facial profile between the nasion and menton. Despite the genetic influence in the occurrence of malocclusions, the role of soft tissues in the position of the jaws should not be underestimated. Solow and Kreiborg (36) hypothesized that factors inducing cranial extension, such as impairment of nasal airflow, will influence craniofacial development, because of increased 'pressure' from the soft tissue of the anterior regions of the face and neck. There are also several reports mentioning about the relationship between the cervical angle and mandibular position. Festa et al. were able to determine a statistically significant correlation between distal jaw position, sagittal mandibular length, and increased cervical lordosis (37). D'Attilio et al. found a statistically significant correlation with mandibular position and length, overjet, and the mandibular plane angle to the cervical curvature (38).

The present study failed to find any differences in cranial base angle between sagittal malocclusions. Cranial base inclinations were found different in Class III groups. However, before relating these differences in cranial base inclinations to the development of different malocclusions, further studies with a large longitudinal sample should be performed.

Conclusions

- Linear variables such as anterior and posterior cranial base lengths were not found different in Class I, Class II and Class III subjects.
- Cranial base angle measurements (N-S-Ba, N-S-Ar) did not demonstrate statistically significant differences between the malocclusions.
- Both anterior and posterior cranial base inclinations relative to the Frankfort horizontal reference line were increased in Class III subjects.

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