Original Article

Cranial Base Features in Skeletal Class III Patients

Peter Proff[a]; Florian Will[b]; Ivan Bokan[c]; Jochen Fanghänel[d]; Tomas Gedrange[e]

ABSTRACT

Objective: To investigate the cranial base configuration in skeletal Class III patients to clarify the conflicting findings from literature.

Materials and Methods: Initial lateral radiographs of 54 skeletal Class III patients and 54 matched controls (Class I, II/1, II/2) aged 14 to 24 years were analyzed retrospectively for 21 cephalometric basicranial variables and jaw lengths relative to anterior cranial base length.

Results: In contrast to overall cranial base length, the anterior (N-S) and posterior (S-Ba, S-Ar) sections failed to show a significant reduction in Class III patients. The significantly more acute angles Ca-S-Ba and Se-S-Ba reflected increased cranial base flexure. Resulting anterior condylar displacement was shown by significant reduction of Se-S-Cd and Ar-Ca. Relative mandibular length was significantly increased.

Conclusions: Decreased basicranial angulation associated with Class III mandibular protrusion was clearly confirmed for skeletal Class III patients. Overall shortening of the cranial base apparently resulted from various minor alterations. The results are compatible with the deficient orthocephalization hypothesis of Class III morphogenesis. The basicranial-maxillary relationship in skeletal Class III remains unclear.

KEY WORDS: Skeletal Class III; Mandibular prognathism; Cranial base; Cephalometric analysis

INTRODUCTION

In Class III patients, several aberrant cephalometric features have been reported that included the cranial base.[1,2] The cranial base is a pivotal structure forming the floor of the cranial vault. For cephalometric purposes, the sella point (S) divides the cranial base into the anterior leg, defined by the extension to the frontal-nasal suture (N), and the posterior leg, extending to the anterior border of the foramen magnum, defined as basion (Ba). The two legs form a flexion that is usually measured radiographically as the angle between the nasion-sella-basion (or -articulare) points. The cranial base angle is relatively stable but shows large individual variations.[3] Since the cranial base consists of two segments articulating either with the maxilla or the mandible, respectively, any changes in flexure due to variations in shape and size of this region may alter the anteroposterior skeletal relationship of the jaws, thus influencing the type of malocclusion.[2]

Most traditional cephalometric studies measure the relationship of the maxilla and mandible to the cranial base. Yet relatively little emphasis has been placed on the morphological characteristics of the cranial base in Class III malocclusion. Craniofacial features reported to be associated with this anomaly include an acute cranial base angle and a shortened cranial base length as compared with Class I subjects.[2,4–17] This configuration was characterized by Guyer et al[18] as cranial kyphosis associated with the appearance of a prognathic facial morphology.[1] However, the role of the cranial base is discussed controversially,[16] and some authors even contend that Class III cranial base morphology does not differ from that associated with a normal Class I profile.[19]

Therefore, this controlled study aims to investigate various cephalometric parameters of the cranial base in skeletal Class III patients to clarify the conflicting findings reported in literature.

[a] Research Scientist, Department of Orthodontics, University of Greifswald, Greifswald, Germany.

[b] Private practice, Wuerzburg, Germany.

[c] Private practice, Verden, Germany.

[d] Professor and Department Chair, Department of Oral Anatomy, University of Greifswald, Greifswald, Germany.

[e] Professor and Department Chair, Department of Orthodontics, University of Greifswald, Greifswald, Germany.

Corresponding author: Dr. Dr. Peter Proff, Department of Orthodontics, University of Greifswald, Rotgerberstrasse 8, Greifswald, Mecklenburg-Vorpommern 17489, Germany (e-mail: p.c.proff@gmx.net)

Accepted: May 2007. Submitted: January 2007.

Table 1. Inclusion/Exclusion Criteria for the Present Study

- Growth largely completed after the pubertal peak (males >15 years, females >13 years)
- Exclusion of craniofacial disorders (eg, cleft anomalies, craniosynostoses)
- Skeletal Class III (test group)
  - ○ ANB − ANB_{ind} (ANB_{diff}) < −1°
  - ○ Wits appraisal < −1 mm
  - ○ Presence of a mesial occlusion
- Non-Class III (control group)
  - ○ ANB − ANB_{ind} (ANB_{diff}) ≥ 0°
  - ○ Wits appraisal ≥ −1 mm
  - ○ Absence of a mesial occlusion

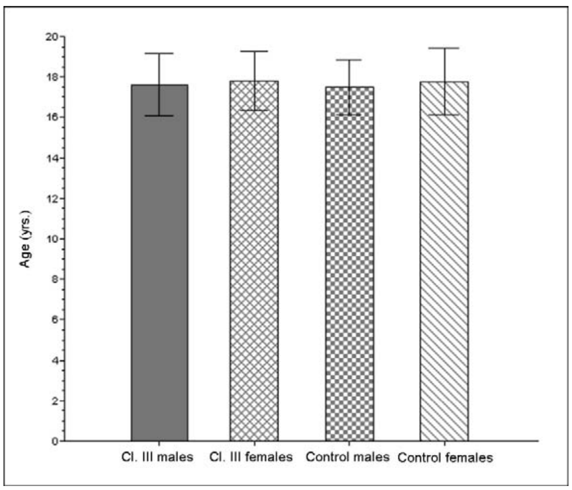

Figure 1. Distribution of patient age (means ± standard deviations) broken down by gender and group.

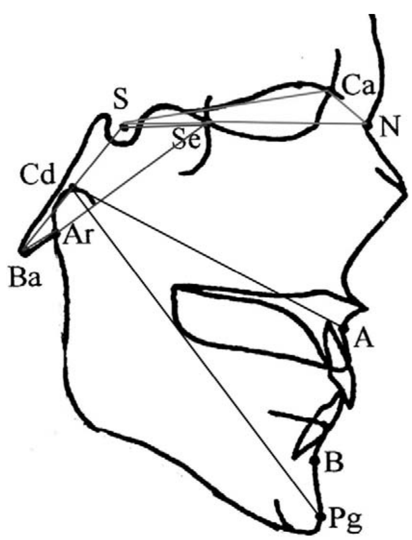

Figure 2. Cephalometric measurement points and lines.

MATERIALS AND METHODS

This retrospective study was based on the pretreatment records (cephalograms, plaster casts, extraoral pictures) of white patients from the Orthodontic Department of Greifswald University and a large orthodontic practice. Patients met the following criteria for inclusion (Table 1): skeletal classification was mainly based on a negative difference of 1° or more between the ANB angle and individualized ANB angle[20] and a negative Wits appraisal of 1 mm or more,[4] both of which represent a Class III maxillo-mandibular relationship. Patients with craniofacial disorders such as cleft anomalies, craniosynostoses, or other syndromal diseases were excluded. The pubertal growth peak was passed.

The test group was recruited (n = 54), and an equal number of non–Class III subjects (Figure 3) matched for skeletal age classes and gender was selected using computerized random numbers to form the control group (Class I, 22.2%; Class II/1, 51.9%; Class II/2, 25.9%). The groups were composed of 50% females and males, respectively (one-half each). The patients' ages ranged from 14 to 24.5 years (mean ± SD = 17.7 ± 3.05 years; Figure 1).

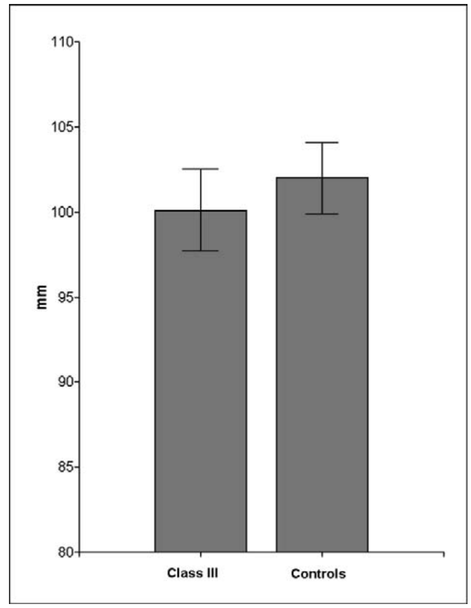

Figure 3. Distribution of /Ba-Ca broken down by group.

Cephalometric Analysis

Analysis of the lateral radiographs was performed using a modified Bergen analysis.[21] In addition, the basicranial landmarks sphenoidale (Se) and foramen cecum (Ca)[3] were included (Figure 2). The landmarks used are given in Table 2. The linear and angular cranial base parameters suggested in the literature[2,15,22–27] were determined from these points (Table 3).

To estimate the reliability of cephalometric analysis, 36 randomly selected lateral radiographs were traced twice by the same investigator at an interval of 1 month. Sufficient reliability (.85 ≤ r ≤ .98) and mea-

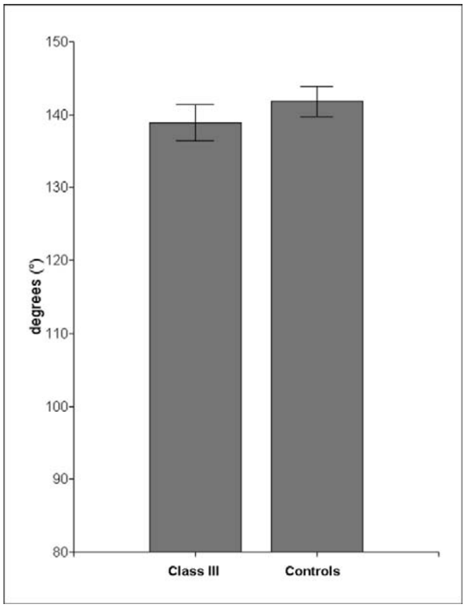

Figure 4. Distribution of ∠Ca-S-Ba broken down by group.

surement accuracy were obtained by calculating the error of method[28] and Houston's coefficient of reliability.[29] Random errors ranged from 0.15 to 0.83 mm for linear measurements and from 0.41 to 1.97 mm for the angular measurements, and Houston's reliability ranged from .88 to .98. No systematic errors were detected at the 10% level of significance.

Statistical Data Analysis

The mean differences between both groups were tested for significance using Student's *t*-test for independent samples. Pearson's product–moment correlations were calculated between the parameters of the sagittal jaw relationship and cranial base angles (see Table 3). If the requirements of normal distribution and/or homogeneity of variance were not fulfilled, the Mann-Whitney *U*-test and Spearman's rank correlation were used instead.

To take account of multiple testing of numerous geometrically interdependent measurements, the global significance level of $\alpha = .05$ was corrected according to the Bonferroni-Holm procedure.[30] Sequential adjustment of α level was applied to comparisons involving identical measuring points (one shared measuring point in linear measures, two shared points in angular measures). The minimum local α_k required to establish significance amounted to .0035 for intergroup comparisons involving the fundamental points N and S ($k = 14$).

RESULTS

In the test group with a skeletal Class III anomaly, the mean (±SD) value was −1.2° (±3.0°) for the ANB angle, −4.2° (±1.6°) for the ANB_{diff} angle, and −4.8 (±1.9) mm for the Wits appraisal.

The corresponding values of the control group,

Table 2. Cephalometric Landmarks Used in the Study

A	A point: deepest point of the anterior outline of the upper alveolar process between anterior nasal spine and limbus alveolaris of the upper incisors (midsagittal plane)
Ar	Articulare: constructed intersection of lower rim of the cranial base and the posterior outline of the collum mandibulae
B	B point: deepest point of the anterior outline of the mandibular alveolar process (midsagittal plane)
Ba	Basion: most posteroinferior point of the clivus in the midsagittal plane, corresponding to the anterior-most point of the foramen magnum
Ca	Foramen caecum: intersection between the outline of the orbital roof and the cerebral surface of the frontal bone
Cd	Condylion: superior-most point of the mandibular condyle
N	Nasion: most anterior point of the frontonasal suture in the midsagittal plane
Pg	Pogonion: anterior-most point of the bony chin in the midsagittal plane
S	Sella: constructed midpoint of the bony contour of the sella turcica in the midsagittal plane
Se	Sphenoidale: intersection of the ala major ossis sphenoidalis and the anterior cranial fossa, corresponding to the intersection of the anterior outline of the medial cranial fossa and the inferior contour of the anterior cranial fossa

Table 3. Cephalometric Parameters

	Anterior	Posterior Cranial Base	Total
Lines	N-S, S-Se, N-Ca, S-Ca, Se-Ca	S-Ba, S-Ar, S-Cd, Ar-Se	N-Ar, N-Ba, Ba-Ca
Angles	N-S-Se, S-Ca-N	Se-S-Cd, SeSBa, S-Ar-Se	N-S-Ba, N-S-Ar, N-S-Cd, Ca-S-Ba, S-Ba-Ca
Ratios	Relative maxillary length (RMX)		
	Cd-A: N-S (%)		
	Relative mandibular length (RMD)		
	Cd-Pg: N-S (%)		

Table 4. Means, Standard Deviations, Minima, and Maxima for Test and Control Groups

/ (mm) ∠ (°), %	Test Group				Control Group				
	x̄	SD	Min	Max	x̄	SD	Min	Max	Significance
/ N-Ar	93.9	5.4	80.1	110.2	95.7	6.1	82	110.2	—
/ N-Ba	105.1	5.6	90.2	121.8	107.9	6.0	94.8	120.2	—
/ N-S	70.6	3.6	64.5	83.9	70.9	3.4	64.5	80.3	—
/ N-Ca	13.9	2.4	10.7	19.8	12.6	2.6	5.7	22.9	*
/ S-Ca	60.9	3.1	55.5	72.0	61.1	3.4	55.2	69.1	—
/ S-Se	24.8	2.2	18.9	29.9	24.4	2.3	18.8	30.7	—
/ S-Cd	22.8	3.3	13.8	32.8	23.1	3.5	13.2	31.2	—
/ S-Ba	45.2	3.7	32.4	56.2	46.4	3.6	38.6	53.6	—
/ S-Ar	34.6	3.7	25.1	45.2	35.7	3.4	27.7	45.1	—
/ Ba-Ca	100.1	4.8	88.2	113.0	102.0	4.2	92.8	116.9	*
/ Ar-Ca	90.2	4.6	80.1	101.5	92.8	4.3	89.5	106.1	*
∠N-S-Ba	128.4	4.9	117.1	141.3	131.0	4.5	116.8	142.6	**
∠Ca-S-Ba	138.9	5.0	126.9	150.1	141.8	4.2	130.8	152.3	*
∠Se-S-Ba	132.6	5.8	117.9	145.5	135.9	4.8	121.5	152.6	*
∠N-S-Ar	122.9	5.7	109.9	134.2	125.2	5.1	109.5	135.1	—
∠N-S-Cd	126.1	7.7	109.1	145.6	129.2	8.1	107.0	149.6	—
∠N-S-Se	−3.5	4.5	−16.1	5.9	−4.4	4.9	−16.2	4.5	—
∠Se-S-Cd	129.8	5.6	106.8	152.1	134.9	5.9	115.7	156.3	*
∠S-Ba-Ca	24.5	2.2	17.2	31.9	22.2	2.6	17.1	28.9	*
∠S-Ar-Se	21.4	3.3	14.1	28.8	20.2	3.7	14.2	30.1	—
∠S-Ca-N	109.9	8.4	89.2	135.1	107.1	9.9	87.8	142.1	—
∠Ar-Se	37.0	4.2	27.5	45.8	36.5	3.9	26.6	44.2	—
∠Se-Ca	38.6	2.7	34.1	42.1	39.8	3.2	34.5	43.4	—
%RMD	177.5	5.3	162.3	195.5	170.9	4.8	160.9	184.3	*
%RMX	127.8	4.1	122.6	131.0	130.5	4.5	124.8	136.0	—

* Significant at $P \leq \alpha_k$; ** tendency at $P \leq \alpha_{k-1}$; dash indicates no significance.

which was composed of all remaining skeletal classes, amounted to 4.4° (±3.4°) for the ANB angle, 2.7° (±2.1°) for the ANB_{diff} angle, and 3.3 (±1.9) mm for the Wits appraisal. The cranial base–related findings are given in Table 4.

In the skeletal Class III patients, the cranial base in total revealed a significant mean reduction of the Ba-Ca and Ar-Ca lengths, amounting to −1.9 mm and −2.6 mm, respectively. For the anterior cranial base section, the N-Ca distance was significantly increased by +1.3 mm as compared with the controls.

The cranial base angle Ca-S-Ba showed a significant decrease of −2.9° in the test group (Figure 4); the corresponding angular differences of S-Ba-Ca (+2.3°) and—as a tendency—N-S-Ba (−2.6°) were also significant. Moreover, angular bending between the mid and posterior cranial base was significantly increased. This is depicted by reductions of Se-S-Cd and Se-S-Ba amounting to −5.1 mm and −3.3 mm in the Class III group, respectively. Finally, relative mandibular length was shown to be significantly greater in the test group (relative mandibular length [RMD] = 1.78) as compared to the control group (RMD = 1.71).

A correlation analysis conducted across the whole study sample revealed associations amounting to $r^2 \leq .12$ between parameters of cranial base flexure and sagittal jaw base relations. Significance was not reached except for the correlations between the Wits appraisal[31] and the Ca-S-Ba and N-S-Ba angles and the correlation between ANB_{diff} and Ca-S-Ba angles (Table 5).

Table 5. Correlations r_{xy} Between Parameters of Cranial Base Flexure and Jaw Relationship

r_{xy}	∠ANB	$∠ANB_{diff}$	/WITS
∠N-S-Ba	0.21	0.28	0.31
∠Ca-S-Ba	0.22	0.32	0.34

DISCUSSION

The etiology and expression of a malocclusion must be understood before it can be clinically corrected. The available literature on Class III anomalies shows that the number of studies on clinical management and therapeutic outcomes clearly outweighs those focusing on morphological and developmental aspects of these malocclusions.

The cranial base sections were analyzed in detail using a larger complement of landmarks since morphometric approaches suggested the existence of local shape and size differences in the skeletal Class III cranial base.[32,33] Moreover, the shortcomings of controversial conventional landmarks such as nasion point[25,34] or basion versus articulare[2,3,9,22,35] were thus evaded. In fact, we found parameters involving the foramen cecum or basion landmarks to be more likely to yield significant differences than those involving the nasion or the articulare. Finally, Bonferroni-Holm's procedure for multiple testing was applied to correct for statistical dependence of related cephalometric parameters that share a line or point.

An increase of the sagittal mandibular length in association with a normally sized or shortened maxilla has been reported to be an invariable trait in Class III anomalies across subjects of white and Asian descent of various ages.[4,13,14,16,18,32,36–41] In the present study, the jaw lengths were measured relative to the anterior cranial base length (N-S),[13,42] yielding a significant increase of 3.9% for mandibular size in the test group, whereas relative maxillary size (−2%) was nonsignificant. Condylar hyperplasia with concomitant remodeling has been suggested to account for these findings.[43–45]

A size reduction of the anterior and posterior cranial base in Class III anomalies was reported by several authors.[2,5,7–9,15,17,46] A significant decrease of total cranial base extension between the foramen cecum and the basion or articulare points is also supported by the present study.

A closer analysis reveals differential effects in the anterior and posterior sections of the cranial base. Some authors consider the cranial base as a guide rail for the development of the maxilla and the midfacial complex.[7,8,34] This might lead one to expect noticeable alterations of the anterior cranial base if the maxillary position is involved in Class III pathogenesis. Singh et al[12] found local distortions in the frontonasal suture region, which, however, showed variability depending on age. In the present study, however, the total length of the anterior cranial base (N-S) showed only minimal, nonsignificant shortening by 0.3 to 0.5 mm on average in the test group, thus resembling the results of several previous studies.[6,16,18] Isolated lengthening of N-Ca was observed in the anterior-most part of the cranial base.

The sella-related parameters involving the anterior cranial base (ie, Se-Ca, S-Se, and N-S-Se) were all nonsignificant and failed to provide a consistent picture in the present study. However, the findings are not in conflict with the anteroposterior and vertical deformation of the sella-sphenoidal region reported by Singh.[12] Whether an altered anteroposterior growth pattern of the sphenoid bone in Class III anomaly is induced by the sphenooccipital synchondrosis[47] or rather results from pneumatization effects[12] has not been clearly determined yet. Global shortening of the anterior cranial base was not confirmed by the present study.

The posterior cranial base appears to plays a more important role in Class III morphogenesis by virtue of its proximity to the mandibular complex. Articulation at the glenoid fossa does provide potential for influence from the cranial base. Most cephalometric studies reported shortening of the posterior cranial base for Class III patients as compared to Class I and II division 1 cases.[2,5,7–9,15,17,46] These observations are supported by a slight yet nonsignificant trend indicating reductions of the S-Ba and S-Ar distances in the present study. They are compatible with the morphometric findings of Singh,[48,49] who observed a horizontal compression of the posterior cranial base with marked local deformations in the basion and articulare area in Class III patients. Similarly, Chang et al[46] reported distinct shortening of the posterior cranial base region.

The most marked and best-proved cranial base finding in Class III anomalies is a decreased angulation between the anterior and posterior cranial bases, reflected by a closed cranial base angle.[1,2,4–16,19] This is confirmed by the results of the present study. Significance was obtained for the decrease of both the Ca-S-Ba angle and, as a trend, the N-S-Ba angle, as well as for the complementary increase of the S-Ba-Ca angle in the skeletal Class III patients. The angles between Se-S and the basion/condylion proved significant as well.

The more acute cranial base angle is considered to affect condylar articulation,[9,50] even though the temporomandibular joint positioned at the lateral edges of the cranial base is considerably separated spatially from the midsagittal reference plane.[51] Anterior displacement of the condyles is a codeterminant of mandibular morphology and advancement in skeletal Class III[1,2,4,37,52–54] and was proved to represent an ethnically and methodically invariable finding.[5,11,32,40] In fact, the Se-S-Cd angle related to the temporomandibular joint was significantly decreased in the present study. Also, the reduction of Ar-Ca length is in favor of anterior condylar displacement in the Class III subjects. Similarly, S-Ar length was reduced, but not significantly.

A developmental disorder in the posterior cranial fossa area was suggested to account for the aberrant cranial base morphology in skeletal Class III.[22,47,50] Resulting from precocious synostosis with deficient proliferation in the petro-spheno-occipital cartilages, physiologic horizontalization of the cranial base (angle) during ontogenesis, the so-called orthocephalization, is considered incomplete.[49] Since cranial base angulation depends on variations of either leg,[55] the deficient horizontalization hypothesis suggesting insufficient dorsal orientation of the posterior cranial base leg[49] is not supported by increased bending of the cranial base alone but only in association with marked size and shape differences of the posterior cranial base and anterior displacement of the condyles. Thus, our results are not in conflict with this hypothesis.

Since Young suggested a possible association between cranial base angulation and malocclusion,[56] some authors have even assumed a systematic decrease of the cranial base angle as well as anterior and posterior cranial base length from Class II through Class I to Class III anomalies.[2,7–9,15] The present correlation analyses of the pooled test and control groups yielded a significant yet modest association between cranial base angulation and the anteroposterior relation of the jaw bases, showing reduced values of Ca-S-Ba and N-S-Ba with increasing mandibular prognathism. This finding is in agreement with those of other authors who failed to reveal a linear covariation between cranial base morphology and facial prognathism.[19,22] Rather, cranial base morphology may have a more prominent role in establishing malocclusions at the extremes of the scale.[55]

To further clarify the role of the cranial base and particularly its relationship with the midfacial-maxillary complex in skeletal Class III anomalies, future research is recommended to focus on local changes of cranial base size and shape[50] and to consider clinical and/or statistical subtypes representing discrete craniofacial patterns.[57]

CONCLUSIONS

- Mandibular length relative to anterior cranial base length is increased in skeletal Class III, whereas maxillary length is not consistently affected.
- The reduction of total cranial base length observed in skeletal Class III apparently results from various minor local changes rather than from shortening of the anterior and/or the posterior cranial base legs.
- Cranial base flexure is clearly more prominent in skeletal Class III. Tentatively, this is related to changes in the posterior cranial base and to anterior displacement of the condyles and the mandible.
- The linear correlation between cranial base morphology and the maxillo-mandibular relationship is only modest across different malocclusion classes.

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