ORIGINAL ARTICLE

UDC: 616.314-089.23:616.716.1/.4-007]:[611.714:572.087
DOI: 10.2298/VSP121212011C

A cephalometric analysis of the cranial base and frontal part of the face in patients with mandibular prognathism

Kefalometrijska analiza kranijalne baze i prednjeg dela lica kod osoba sa mandibularnim prognatizmom

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Abstract

Bacground/Aim. The literature suggests different views on the correlation between the cranial base morphology and size and saggital intermaxillary relationships. The aim of this study was to investigate the cranial base morphology, including the frontal facial part in patients with mandibular prognathism, to clarify a certain ambiguities, in opposing viewspoints in the literature. **Methods.** Cephalometric radiographies of 60 patients were analyzed at the Dental Clinic of the Military Medical Academy, Belgrade, Serbia. All the patients were male, aged 18–35 years, with no previous orthodontic treatment. On the basis of dental and sceletal relations of jaws and teeth, the patients were divided into two groups: the group P (patients with mandibular prognathism) and the group E (the control group or eugnathic patients). A total of 15 cephalometric parametres related to the cranial base, frontal part of the face and sagittal intermaxillary relationships were measured and analyzed. **Results.** The results show that cranial base dimensions and the angle do not play a significant role in the development of mandibular prognathism. Interrelationship analysis indicated a statistically significant negative correlation between the cranial base angle (NSAr) and the angles of maxillary (SNA) and mandibular (SNB) prognathism, as well as a positive correlation between the angle of inclination of the ramus to the cranial base (GoArNS) and the angle of sagittal intermaxillary relationships (ANB). *Sella turcica* dimensions, its width and depth, as well as the nasal bone length were significantly increased in the patients with mandibular prognathism, while the other analyzed frontal part dimensions of the face were not changed by the malocclusion in comparison with the eugnathic patients. **Conclusion**. This study shows that the impact of the cranial base and the frontal part of the face on the development of profile in patients with mandibular prognathism is much smaller, but certainly more complex, so that morphogenetic tests of the maxillomandibular complex should be included in further assessment of this impact.

Key words:
mandible; prognathism; cephalometry; skull; facial bones; sella turcica.

Apstrakt

Uvod/Cij. U litetaruri postoje različiti stavovi o povezanosti morfologije i veličine kranijalne baze i sagitalnih međuviličnih odnosa. Cilj ovog rada bio je da se ispita morfologija kranijalne baze, uključujući i prednji deo lica, kod ispitanika sa mandibularnim prognatizmom da bi se razjasnile nedoumice donekle suprotnih stavova u literaturi. **Metode.** Analizirani su rendgenkefalometrijski snimci ukupno 60 bolesnika Klinike za stomatologiju VMA. Svi bolesnici bili su muškog pola, starosti od 18 do 35 godina koji ranije nisu bili ortodontski lečeni. Bolesnici su prema dentoskeletnim odnosima vilica i zuba bili svrstani u dve grupe: grupu P (bolesnici sa mandibularnim prognatizmom) i grupu E (kontrolna grupa ili grupa eugnatih bolesnika). Izmereno je i analizirano 15 kefalometrijskih parametara koji su se odnosili na kranijalnu bazu, frontalni deo lica kao i sagitalne međuviličke odnose. **Rezultati.** Dobijeni rezultati ukazuju da ni dimenzije kranijalne baze, ni njen ugao ne igraju značajnu ulogu u nastanku mandibularnog prognatizma. Analizom me-

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đuzavisnosti ustanovljeno je da postoji statistički značajna negativna korelacija između ugla kranijalne baze (NSAr) i uglova maksilarnog (SNA) i mandibularnog (SNB) prognatizma, kao i pozitivna korelacija između ugla nagiba ramusa prema kranijalnoj bazi (GoArNS) i ugla sagitalnih međuviličnih odnosa (ANB). Dimenzije sedlaste jamice (*sella turcica*), njena širina i dubina, kao i dužina nosne kosti statistički su značajno povećane kod bolesnika sa mandibularnim prognatizmom, dok ostale analizirane dimenzije prednjeg dela lica nisu bile izmenjene kod ove malokluzije u odnosu na eugnate bolesnike. **Zaključak**. Pokazalo se da je uticaj kranijalne baze i prednjeg dela lica na ispoljavanje profila kod bolesnika sa mandibularnim prognatizmom mnogo manji ali svakako složeniji, pa bi u dalja istraživanja trebalo uključiti morfogenetska ispitivanja maksilomandibularnog kompleksa kod ocenjivanja ovog uticaja.

Ključne reči:
mandibula; prognatizam; kefalometrija; lobanja; lice, kosti; sela turcika.

Introduction

The cranial base plays an important role in the development of face, especially in achieving sagittal and vertical intermaxillary relationships, primarily because of the different ways of ossification of its synchondrosis. It also represents a central skeletal axis which achieves its final size very early – long before the face.

All the bones that form the cranial base (apart from temporal) are of cartilaginous origin and created by enchodral ossification which already begins prenatally and ends in early childhood (especially the growth of sphenoethmoidal and sphenofrontal synchondroses ends early), following the growth of sphenooccipital synchondroses which is completed approximately at the age of 12–16, so that the length of the frontal cranial base becomes defined in a very early period [1, 2]. In postnatal period, especially in puberty, the frontal sinus enlargement and remodelling of its frontal surface occur, which also influence the nasal bone [3].

The opinions, that the growth, dimensions and shape of the cranial base influence the middle face growth have been accepted. Apposition and remodelling of the cranial base sutures until the age of 5 affect the growth and position of the maxilla, thus forming the maxillary sagittal position to the cranial base very early. Afterwards, when the growth of the cranial base sutures stops, it is replaced by the growth of the sutures connecting the maxilla with the cranial base, thus moving the maxilla forward and downwards. According to another theory, the growth of the entire cranial complex gradually decreases from the age of 3–7 years, when remains active only in the mandibular condyle, so that the mandible grows smoothly, changing partially its sagittal position to the cranial base until general somatic growth is completed [4].

Anatomically speaking, the middle face is set in such a way that the maxilla is attached to the anterior cranial base by its sutures, whereas the mandible is connected to the posterior cranial base by the temporomandibular joint. Due to the anatomy, any change in dimensions or the angle of the cranial base, results in changes of the maxilla or mandible position as well as their interrelationship.

Many cephalometric studies have confirmed that the shape and dimensions of the cranial base vary in patients with different sagittal intermaxillary relationships [4–10]. Mandibular prognathism (MP) is a genetic, complex cranio-dento-facial developmental disorder, where disordered intermaxillary sagittal and vertical relationships dominate, primarely as a result of overdevelopment of the mandible. There are still dilemmas, whether the cranial base really plays such a decisive role in etiology, as the authors have often reported. In mandibular prognathism, the cranial base angle is sharper and the cranial base is shorter in comparison with skeletal Class I patients, while the case of skeletal Class II patients is completely opposite [3, 5, 6, 10].

Some authors believe that the temporomandibular joint is placed in more anterior position precisely because of the reduction of the cranial base angle, which results in a prognathic facial profile. However, Singh et al. [6, 7, 9] and Proff et al. [5] have demonstrated in their extensive studies that the biological basis of anterior positioning of the temporomandibular joint lies in the posterior cranial base. The same authors suggest that the reason could be the premature cessation of the growth of petro-spheno-occipital complex, in other words, that a premature synostosis is responsible for deficient orthocephalization (horizontalization) of the cranial base angle in Class III malocclusion. Therefore, the reduced posterior part of the cranial base can be a primary factor in skeletal Class III etiology.

Consequently, the shape of cranial base could determine facial profiles and represent the key factor in developing skeletal class malocclusions. Is this really true since that MP is a developmental disorder, which reaches its full manifestation until after puberty, and the cranial base ossification occurs in early childhood?

In almost all cephalometric analyses of the neurocranium and the viscerocranium, *sella turcica* (ST) takes a central place. More precisely, the cental point (*sella* point – S) is a part of many reference planes by which other structures are oriented. Thus, ST shape, dimensions and position in relation to the surronding structures are of great importance. For a long time, authors have had a tendency to determine ST dimensions as precise as possible, primarily because of its close relationship with a pituitary gland. Today, however, it is well-known that ST enlargement does not imply that the pituitary gland is also enhanced, and *vice versa* [1, 11–13].

It has been found that changes in ST shape and dimensions are caused by many congenital anomalities: cleft lip and palate [14], lumbosacral myelomeningocele [15], Seckel syndrome [16], Rieger's syndrome [17], congenital craniofacial deviations [18–20], even by congenital dental anomalies, such as a palatal position of the upper fangs and hypodontia of mandibular second premolars [21]. A *sella turcica* bridge in patients with various craniofacial deviations treated by surgical-orthodontic means to correct the existing deformities was investigated by Becktor et al. [18], Jones et al. [19] and Alkofide [22]. All the authors found significant differences between study groups and general population, emphasizing that the majority of patients with craniofacial deviations were later treated by surgery on mandible.

Čutović et al. [20], analyzing *sella turcica* dimensions in patients with mandibular prognathism, found that all the three ST measured dimensions (surface, width and depth) were significantly higher in patients with mandibular prognathism than in eugnathic subjects, but the degree of the manifested anomaly did not have any influence on the size of changes in the abovementioned dimensions.

The anterior cranial base, whose growth ends very early, has a weak influence on positioning the frontal facial parts, that is, only the orbital part directly depends on it. Since the floor of eye socket is also the roof of maxilla, Enlow [4] assumed that the dimensions and the position of the orbital cavity should be correlated with the position of maxilla. However, Holly et al. [23] tested this hypothesis on 32 primates and found that the correlation was too weak.

The growth of the frontal facial parts later in puberty is mostly seen in the increase of the frontal sinuses volume changing the shape of supraorbital ridge and also indirectly affecting the nasal bone [3]. Singh et al. [9] found that the elongation of the anterior cranial base, particularly around the age of 9, directly influenced the enlargement of the frontal sinus, significantly affecting the morphological changes of supraorbital and nasal structures. In the literature available to us, we found that the cephalometric changes of supraorbital ridge and frontal sinus had been recorded only by Dostalova et al. [24], who investigated a number of cephalometric abnormalities in patients with acromegaly, and among other things, came to a conclusion that the frontal sinus was increased and the supraorbital ridge pronounced in these patients in comparison with the control group. The changes were more prominent in men than women and did not depend on the growth hormone, but on the duration of the illness.

The nasal bone consists of two bones, forming the skeleton of nose and is located between the frontal extensions of the maxilla and frontal bone.

Dostálová et al. [24] measured the nasal bone length and inclination to the cranial base in healthy subjects and patients with acromegaly and found that the dimensions of nasal bone were not changed in patients with acromegaly.

Singh et al. [9] found a negative correlation between the frontonasal angle and the cranial base angle. In patients with skeletal Class III, the cranial base angle is normally reduced, so that the frontonasal angle is increased, resulting in a flat midface profile, which is a common feature of this dentofacial deformity.

The aim of this study was to conduct a cephalometric analysis of morphological characteristics of the cranial base, including *sella turcica* and frontal facial part (supraorbital ridge, frontal sinus, nasal bone) in patients with mandibular prognathism, as well as of their correlation with the indicators of sagittal intermaxillary relationships.

Methods

Lateral cephalometric images of 60 orthodontic patients, were taken and analyzed before their treatment at the Dental Clinic, Military Medical Academy.

Using the findings from the literature on gender differences and growth changes dynamics [25, 26], we decided to study male subjects, aged 18–30 years.

The group P consisted of 30 patients with mandibular prognathism, diagnosed on the basis of the following criteria: the angle of mandibular prognathism (SNB) $\geq 80°$; the angle of sagittal intermaxillary relationship (ANB) $\leq 0°$; the angle B $\geq 30°$; Bjork $\geq 396°$; reverse overlap of the frontal teeth and relationship of the first permanent molars in Class III.

The control group, the group E, consisted of 30 patients with normal intermaxillary relationships (skeletal Class I, eugnathic subjects): SNB $\leq$ 80°; ANB = 0 - 5°; normal overlap of the frontal teeth and relationship of the first permanent molars in Class I.

All the patients from the group P were planned for and later treated with orthodontic-surgical therapy, which was performed by the same team.

A cephalometric analysis

Lateral cephalometric images of the head were taken for each patient under standard conditions. The head was fixed in a cephalostat, and recording conducted at the distance of 1.5 m. Analysis of lateral cephalogram images was preceded by drawing the corresponding structures on a tracing paper fixed on a film. Afterwards, numerous points and planes were marked for analyzing certain angular and linear parameters taken from the analyses of Steiner, Jacobson, Ricketts, Downs and Bjork. Measurements were performed twice by the same examiner, on different days, with the accuracy of 0.5 mm or 0.5°. Statistically significant differences did not appear between these two measurements.

Analysis of the following cephalometric parameters was carried out between the patients with mandibular prognathism and the control group of eugnathic patients: SN – the anterior cranial base length; SAr – the posterior cranial base length; NAr – the total cranial base length; NSAr – the cranial base angle; SG – supraorbital ridge; F1F2 – the frontal sinus range; SGN – the angle of protrusion of the supraorbital ridge; Ss – the width of *sella turcica* (the largest anteroposterior diameter); Ds – the depth of *sella turcica* (from the line connecting clinoid extensions to the lowest point of the floor); NR – the nasal bone length; SNR – the angle of the inclination of the nasal bone; SNA – the angle of maxillary prognathism; SNB – the angle of mandibular prognathism; ANB – the angle of sagittal intermaxillary relationships; GoArNS – the angle of inclination of the ramus to the cranial base (Figure 1).

According to the data collected by lateral cephalometric analysis for each patient and each feature, the database was formed in the SPSS12 Program for Windows and the following statistical methods were used in the statistical analysis: tables and graphical presentations, descriptive statistics methods, the Bonferroni test for detecting intergroup differences and the linear correlation method.

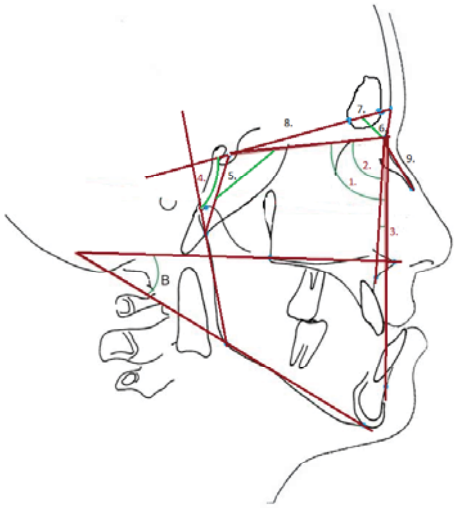

Fig. 1 – Angular and linear measurements:
1. SNA – maxillary prognathism angle; 2. SNB – mandibular prognathism angle; 3. ANB – angle of sagittal intermaxillary relationships; 4. GoArNS – angle of inclination of the ramus to the cranial base; 5. NSAr – cranial base angle; 6. SGN – protrusion angle of the supraorbiatal ridge; 7. F1F2 –frontal sinus range; 8. SG – supraorbital ridge; 9. NR – nasal bone length.

Results

Tables 1, 2 and 3 show the statistical results of analyzing the following parameters of the cranial base, the frontal facial part and sagittal intermaxillary relationships: the anterior cranial base (SN), the posterior cranial base length (SAr), the total cranial base length (NAr), the cranial base angle (NSAr), supraorbital ridge (SG), the frontal sinus range (F1F2), the angle of protrusion of the supraorbital ridge (SGN), the width of *sella turcica* (Ss), the depth of *sella turcica* (DS), the nasal bone length (NR), the angle of inclination of the nasal bone (SNR), the angle of maxillary prognathism (SNA), the angle of mandibular prognathism (SNB), the angle of the sagittal intermaxillary relationships (ANB), the angle of inclination of the ramus to the cranial base (GoArNS).

Sella turcica (Ss) width showed higher values in the patients with mandibular prognathism than in the eugnathic subjects. The average value of the *sella turcica* width in the eugnathic subjects is 9.53 mm ± 1.34, whereas it was 11.07

Table 1
Analyzed parameters values for the cranial base in the eugnathic subjects (E) and the patients with mandibular prognathism (P) (descriptive statistical indicators)

Analyzed parameters		n	$\bar{x}$	SD	Min	Max
S-N	E	30	77.90	4.20	65.00	84.50
	P	30	76.07	4.07	69.00	83.00
	Total	60	77.40	4.20	65.00	88.00
S-Ar	E	30	39.30	3.82	31.00	47.00
	P	30	37.37	3.62	29.00	45.50
	Total	60	38.51	3.94	29.00	47.00
NAr	E	30	104.08	7.03	88.00	117.00
	P	30	100.13	6.79	90.00	116.00
	Total	60	101.66	11.57	11.50	117.00
NSAr	E	30	120.55	5.59	110.00	133.00
	P	30	118.90	7.81	101.00	135.00
	Total	60	119.32	6.58	101.00	135.00
Ss	E	30	9.53	1.34	6.50	12.00
	P	30	11.07	1.45	7.50	15.00
	Total	60	10.49	1.61	6.00	15.00
Ds	E	30	7.55	1.75	3.00	11.00
	P	30	9.33	1.66	6.00	13.00
	Total	60	8.38	1.73	3.00	13.00

SN – anterior cranial base length; SAr – posterior cranial base length; NAr – total cranial base length; NSAr – cranial base angle; Ss – width of *sella turcica* (the largest anteroposterior diameter); Ds – depth of *sella turcica* (from the line connecting clinoid extensions to the lowest point of the floor).

Table 2
Analyzed values parameters of the frontal facial part in the eugnathic subjects (E) and patients with mandibular prognathism (P) (descriptive statistical indicators)

Analyzed parameters		n	$\bar{x}$	SD	Min	Max
F1-F2	E	30	14.43	4.50	5.00	25.00
	P	30	14.07	2.69	8.00	19.00
	Total	60	14.53	3.86	5.00	25.00
S-G	E	30	84.27	4.48	71.00	91.50
	P	30	82.85	4.89	74.00	90.00
	Total	60	84.26	4.58	71.00	96.00
SGN	E	30	57.20	5.49	38.50	66.00
	P	30	54.73	6.49	41.00	66.00
	Total	60	55.95	5.90	38.50	72.00
NR	E	30	24.70	3.54	17.00	33.00
	P	30	27.58	3.65	20.00	35.00
	Total	60	26.40	3.57	17.00	35.00
SNR	E	30	118.10	9.34	104.00	135.00
	P	30	117.82	6.92	105.00	133.00
	Total	60	118.98	7.40	104.00	135.00

F1F2 – frontal sinus range; SG – supraorbital ridge; SGN – angle of protrusion of the supraorbital ridge; NR – nasal bone length; SNR – inclination angle of the nasal bone.

Table 3

Analyzed parameters values of the sagittal intermaxillary relationships in the eugnathic subjects (E) and the patients with mandibular prognathism (P)

Analyzed parameters		n	x̄	SD	Min	Max
SNA	E	30	82.38	4.05	73.00	89.00
	P	30	77.67	4.29	71.00	86.50
	Total	60	79.94	4.28	71.00	89.00
SNB	E	30	79.30	4.18	72.00	87.50
	P	30	83.92	2.74	77.00	90.50
	Total	60	83.54	4.73	72.00	93.00
ANB	E	30	3.15	1.70	0.50	7.00
	P	30	-6.22	3.13	-12.00	-0.50
	Total	60	-3.54	5.50	-15.00	7.00
GoArNS	E	30	82.58	5.34	71.00	94.00
	P	30	80.18	5.13	72.00	99.00
	Total	60	79.73	5.65	68.00	99.00

SNA – angle of maxillary prognathism; SNB – angle of mandibular prognathism; ANB – angle of sagittal intermaxillary relationships; GoArNS – angle of inclination of the ramus to the cranial base.

mm ± 1.45 in the patients with mandibular prognathism. Table 4 shows a statistically significant difference in the Ss values between the group E and the group P ($p < 0.001$).

Sella turcica depth (Ds) shows higher values in the patients with mandibular prognathism than in the eugnathic subjects. The average value of the depth of *sella turcica* in the eugnathic subjects is 7.55 mm ± 1.75, whereas it is 9.33 mm ± 1.66 in the patients with mandibular prognathism. Table 4 shows a statistically significant difference in the Ds values between the group E and the group P ($p < 0.001$).

Nasal bone length (NR) showed higher values in the patients with mandibular prognathism than in the eugnathic subjects. The average value of the nasal bone length in the eugnathic subjects is 24.70 mm ± 3.54, whereas it was 27.58 mm ± 3.65 in the patients with mandibular prognathism. Table 4 shows a statistically significant difference in the NR values between the group E and the group P ($p < 0.001$).

Maxillary prognathism angle (SNA) shows higher values in the eugnathic subjects than in the patients with mandibular prognathism. The average value of the SNA in the eugnathic subjects is 82.38 ± 4.05, whereas it is 77.67 ± 4.29

eugnathic subjects is 79.30 ± 4.18, whereas it was 83.92 ± 2.74 in the patients with mandibular prognathism. Table 4 shows a statistically significant difference in the SNB values between the group E and the group P ($p < 0.001$).

Sagittal intermaxillary relationships angle (ANB) shows higher values in the eugnathic subjects than in the patients with mandibular prognathism. The average value of this angle in the eugnathic subjects is 3.15 ± 1.70, whereas it is -6.22 ± 3.13 in the patients with mandibular prognathism. Table 4 shows a statistically significant difference in the ANB values between the group E and the group P ($p < 0.001$).

The angle of ramus inclination to the cranial base (GoArNS) shows higher values in the eugnathic subjects than in the patients with mandibular prognathism, but they are statistically insignificant**.** The average value of this angle in the eugnathic subjects is 82.58 ± 5.34, whereas it is 80.18 ± 5.13 in the patients with mandibular prognathism.

For the remaining cranial base parameters (SN, SAr, NAr, NSAr, SG, F1F2, SGN, SNR), the Bonferroni test did not show any statistically significant difference between the two groups of examinees (Table 4).

Table 4

Boniferri test results, examining intergroup differences (eugnatics subjects *vs* patients with mandibular prognatism) by using all the cranial base, frontal facial part and sagittal intermaxillary relationships analyzed parameters

Parameters	Differences in average values	*p*
Ss	-1.53333	0.000
Ds	-1.78333	0.000
NR	-2.88333	0.004
SNA	4.72	0.000
SNB	-4.62	0.000
ANB	9.37	0.000

Ss – *sella turcica* width; Ds – *sella turcica* depth; NR – nasal bone length; SNA – angle of maxillary prognathism; SNB – angle of mandibular prognathism; ANB – the angle of sagittal intermaxillary relationships.

in the patients with mandibular prognathism. Table 4 shows a statistically significant difference in the SNA values between the group E and the group P ($p < 0.001$).

Mandibular prognathism angle (SNB) shows higher values in the patients with mandibular progmathism than in the eugnathic subjects. The average value of the SNB in the

By analyzing interrelationships between 5 parameters in mandibular prognathism: (NSAr, SNA, SNB, ANB, and GoArNS, given in Table 5, a statistically significant and highly negative correlation was found between the cranial base angle and NSAr and SNA ($p = -0.567$) and SNB ($p = -0.676$) angles. The GoArNS showed a statistically significant and positive correlation with the ANB ($p = 0.385$), whereas the SNA and SNB angles showed a statistically significant, interrelated and positive correlation ($p = 0.674$) (Table 5).

Table 5

Correlation matrix of the analyzed parameters in the group with mandibular prognathism

Group P (n = 30)	NSAr	SNA	SNB	ANB	GoArNS
NSAr	1				
SNA	-0.567(**)	1			
SNB	-0.676(**)	0.674(**)	1		
ANB	-0.200	0.787(**)	0.076	1	
GoArNS	-0.230	0.161	-0.189	0.385(*)	1

NSAr – cranial base angle; SNA – maxillary prognathism angle; SNB – mandibular prognathism angle; ANB – angle of sagittal intermaxillary relationships; GoArNS – inclination angle of the ramus to the cranial base. *Correlation is significant at the 0.05 level (2-tailed); **Correlation is significant at the 0.01 level (2-tailed).

In the present study, measuring the ST depth, as a normal distance from the line connecting clinoid extensions to the lowest point of the floor contours, a statistically significant difference was obtained between the patients with mandibular prognathism and eugnathic subjects. Namely, in the patients with mandibular prognathism, the ST depth was significantly higher (9.33 mm *vs* 7.55 mm, $p < 0.01$). Besides, the largest anteroposterior diameter used to present the ST width, was significantly higher in the patients with mandibular prognathism than in the eugnathic subjects (11.07 mm *vs* 9.53 mm, $p < 0.01$).

Discussion

The morphology of the cranial base is not the only factor which influences the formation of sagittal malocclusions, or the degree of its manifestation. In the literature, there are different and even opposing views on the interrelationship of the cranial base morphology and the size on the one hand, and sagittal malocclusions on the other one. These dilemmas have induced us to examine the dimensions of the cranial base and frontal facial part, trying to determine their influence on the development of profile in patients with mandibular prognathism. According to all the analyzed parameters of the aforementioned structures, it was found that only the dimensions of the *sella turcica* and nasal bone were different between the eugnathic subjects and the patients with mandibular prognathism.

The NAr, NS and SAr, NSAr showed lower values in the patients with mandibular prognathism than in the eugnathic subjects, but they were statistically insignificant. Although many authors [27–29] found that the cranial base angle was significantly reduced in mandibular prognathism, specifying it, as an important etiologic factor and one of the early indicators of anomaly development, some recent studies, where present results fit, suggest that there are changes of the size and shape of the cranial base, but they are not decisive. Thus, the relationship between the cranial base and malocclusions is much more complex [3, 5, 8]. The present study also detected a statistically negative correlation between the NSAr and the SNA and the SNB prognathism, which certainly indicated the connection between the cranial base angulation and sagittal intermaxillary relationships. Singh et al. [9] and Singh [28] have explained that the changed inclination of the posterior cranial base moves the condyle and the entire mandible anteriorly, whereas the changed inclination of the anterior cranial base is responsible for the maxilla repositioning, both resulting in Class III facial profile.

Anderson and Popovich [10] tried to establish the relationships between the cranial base size and shape and all the three skeletal class intermaxillary relationships. They found that the cranial base angle in skeletal Class III was smaller, and the condyle placed more anteriorly. Besides, they detected a strict correlation between the cranial base and maxilla length and a weak correlation with the mandible length. However, according to these authors, the size of maxilla does not have impact on prognathism, whereas the cranial base angle is in a strict correlation with the SNB angle, the angle of mandibular prognathism. Thus, they concluded that the size and shape of the cranial base influenced mandibular prognathism through the anteroposterior condylar position. In the present study, a statistically insignificant reduction of the angle of inclination of the ramus to the GoArNS in mandibular prognathism and a significantly positive correlation of this angle with the ANB were also found, indicating more anterior position of the temporomandibular joint. This finding indicates that the position of mandible depends on the morphological characteristics of the cranial base in the examinees of this study.

The results of morphogenetic tests conducted by Ellis and McNamara [27] showed that in skeletal Class III there were a significant bending of the cranial base, reduction of its posterior part and the angle between the ramus and the general cranial base plane. Singh [28] added that the glenoid fossa in skeletal Class III was placed more anteriorly than in Class I and II, which resulted in moving the temporomandibular joint anteriorly. Proff et al. [5] also found the reduction of the cranial base angle, its total length and posterior part in patients with mandibular prognathism. Their morphometric study suggests that a primary etiologic factor in the development of skeletal Class III might be an early ossification of petro-spheno-occipital complex synostosis, causing the insufficient horizontation of the cranial base and consequently anterior displacement of the condyle [30, 31].

Since the ST is a part of the cranial base, the cranial base shape and dimensions influence the ST position and dimensions. On the other hand, the cranial base shape and dimensions depend on the sagittal intermaxillary relationships [3]. This leads to the conclusion that the ST dimensions and position also depend on the sagittal intermaxillary relationships. The clinical picture of mandibular prognathism actually shows abnormal intermaxillary relationships as its dominant symptom.

Examining the *sella turcica* dimensions in the patients with dentofacial deformities, several autors [18–20] found that all the three measured dimensions of *sella turcica* (surface, width and depth) were statistically much higher in the patients with deformities than in the eugnathic subjects, but the degree of the anomaly manifestation did not influence the size of changes in the aforementioned dimensions. Investigating correlations, they found that the depth of *sella turcica* had a positive correlation with the ST surface. This could be related to the fact that the ST floor, anterior and posterior wall are most susceptible to changes [14, 17, 24]. Alkofide [22] found that the largest anteroposterior diameter in patients with skeletal Class III was significantly higher than in patients with other analyzed classes.

Having in mind that several studies have recently proved the increase in *sella turcica* dimensions in mandibular prognathism, it can be expected that future studies will find the cause and relationship between these phenomena [18–22].

The patients with mandibular prognathism also showed a significant increase in the nasal bone length. The nasal bone length and inclination to the cranial base in healthy subjects and patients with acromegaly were measured by Dostálová et al. [24], and they found that the nasal bone did not change its dimensions in the patients with acromegaly. In addition, these results showed that the average value of the nasal bone length in healthy women and men was similar approximately 23 mm, (in our study, the average value was 24.7 in the eugnathic subjects, whereas it was 27.58 mm in the patients with mandibular prognathism). The angle between the nasal bone and cranial base was 115° in the eugnathic subjects (in present study, the average value was 118.10° in the eugnathic subjects and there were no statistically significant differences between the analyzed groups).

Singh et al. [9] found a negative correlation between the frontonasal angle and the cranial base angle. In patients with skeletal Class III, the cranial base angle is actually reduced, so that the frontonasal angle is increased, resulting in a flat mid-face profile, which is a frequent characteristic of this dentofacial deformity. The angle of protrusion of the supraorbital ridge, which we measured, although reduced in mandibular prognathism, did not show any statistically significant differences between the groups.

As mentioned at the beginning, in both mandibular prognathism and developmental malocclusion, a significant increase in the mandible and change in mandibular shape occur during rapid growth at puberty. This change is primarily caused by the opening of the gonial angle, particularly characteristic for a hyperdivergent facial profile. It certainly results in changing the inclination of the ramus to the cranial base. The condylar cartilage is still active, therefore it is also very likely to have the remodeling growth of condyle and glenoid fossa changing their position and shape in this type of malocclusion [1, 2]. Thus, the inclination of the ramus to the cranial base causing the anterior mandibular positioning, does not strictly depend on the length of the posterior cranial base and its angulation, but most likely on other growth processes, such as the opening of gonial angle which occurs much later.

When discussing skeletal Class III, one should also think about mandibular prognathism and its developmental nature, which often camouflages by compensatory mechanisms (in rare cases potentiates) some important indicators in certain life phases. Therefore, the results of many studies are contradictory. It should not be forgotten that many growth and developmental studies have found that the mandible grows more intensively and longer through all life phases, even a year longer after the completion of general somatic growth [25, 26, 29]. Since the cranial base growth ends early, it can be considered as one of the etiologic factors of mandibular prognathism, but certainly not the decisive one, and although existing, the cranial base correlation with mandibular prognathism is not as simple as previously thought.

Conclusion

The results of this study show that the cranial base dimensions and angle do not play a significant role in the development of mandibular prognathism.

An interrelationship analysis indicated a statistically significant negative correlation between the NSAr and the SNA and the SNB prognathism, as well as a positive correlation between the GoArNS and the ANB.

Sella turcica dimensions, width and depth, as well as the nasal bone length were significantly increased in patients with mandibular prognathism, while the other analyzed dimensions of frontal part of the face were not changed by the malocclusion in comparison with eugnathic patients.

The impact of the cranial base and frontal part of the face on facial profile in patients with mandibular prognathism is much smaller, but certainly more complex than previously thought, and therefore it suggests, that morphogenetic tests of the maxillomandibular complex should be included in further assessment of this impact.

Acknowledgments

This study was a part of the project of the Ministry of Education, Science and Technological Development of the Republic of Serbia (III 41017).

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Received on December 12, 2012.
Revised on January 10, 2013.
Accepted on January 11, 2013.
OnLine-First February 2014.