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# Cephalometric analysis of the middle part of the face in patients with mandibular prognathism

## Cefalometrijska analiza srednjeg dela lica kod osoba sa mandibularnim prognatizmom

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### Abstract

**Background/Aim.** The middle part of the face, that is the maxilla, has always been mentioned as a possible etiologic factor of skeletal Class III. However, the importance of the relationship of maxillary retroposition towards the cranial base is still unclear, although it has been examined many times. The aim of this study was to conduct cephalometric analysis of the morphology of maxilla, including the whole middle part of the face in patients with divergent and convergent facial types of mandibular prognathism, as well as to determine differences betweeen them. **Methods.** Lateral cephalometric teleradiograph images of 90 patients were analyzed at the Dental Clinic of the Military Medical Academy, Belgrade, Serbia. All the patients were male, aged 18–35 years, not previously treated orthodontically. On the basis of dentalskeletal relations of jaws and teeth, the patients were divided into three groups: the group P1 (patients with divergent facial type of mandibular prognathism), P2 (patients with convergent facial type of mandibular pragmathism) and the group E (control group or eugnathic patients). A total of 9 cephalometric parameters related to the middle face were measured and analyzed: the length of the hard palate – SnaSnp, the length of the maxillary corpus – AptmPP, the length of the soft palate, the angle between the hard and soft palate – SnaSnpUt, the angle of inclination of the maxillary alveolar process, the angle of inclination of the upper front teeth, the effective maxillary length – CoA, the posterior maxillary alveolar hyperplasia – U6PP and the angle of maxillary prognathism. **Results.** The obtained results showed that the CoA, AptmPP and SnaSnp were significally shorter in patients with divergent facial type of mandibular prognathism compared to patients with convergent facial type of the mandibular prognathism and also in both experimental groups of patients compared to the control group. SnaSnp was significantly shorter in patients with divergent facial type of mandibular prognathism compared to the control group, whereas SnaSnp was significantly smaller in patients with convergent facial type of mandibular prognathism compared to the control group. Additionally, there was a pronounced incisor dentoalveolar compensation of skeletal discrepancy in both groups of patients with mandibular prognathism manifested in the form of a significant upper front teeth protrusion, but without significant differences among the groups, while the maxillary retrognathism was present in most patients of both experimental groups. A pronounced UGPP was found only in the patients with divergent type of mandibular prognathism. **Conclusion.** The maxilla is certainly one of the key factors which contributes to making the diagnosis, but primarily to making a plan for mandibular prognathism treatment. Accurate assessment of the manifestation of abnormality, localization of skeletal problems and understanding of the biological potential are key factors of the stability of the results of surgical-orthodontic treatment of this abnormality.

**Key words:**
**prognathism; mandible; malocclusion; angle class III; cephalometry; maxilla; face; orthodontics.**

### Apstrakt

**Uvod/Cilj.** Srednji masiv lica, odnosno maksila, skoro uvek se pominje kao mogući etiološki faktor skeletne klase III. Međutim, značaj odnosa retropozicije maksile u odnosu na kranijalnu bazu, mada dosta proučavan, još uvek je nejasan. Cilj ovog istraživanja bio je da se kefalometrijski analiziraju morfološke karakteristike maksile kao i celog srednjeg masiva lica kod pacijenata sa divergentnim i konvergentnim oblikom mandibularnog prognatizma, kao i da se ustanove ra-

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zlike između njih. **Metode.** Analizirani su rendgenkefalometrijski snimci ukupno 90 pacijenata Klinike za stomatologiju Vojnomedicinske akademije, Beograd, Srbija. Svi pacijenti bili su muškog pola, starosti od 18 do 30 godina i nisu ranije bili ortodontski lečeni. Pacijenti su prema dentoskeletnim odnosima vilica i zuba svrstani u tri grupe: grupu P1 (pacijenti sa divergentnim mandibularnim prognatizmom), P2 (pacijenti sa konvergentnim mandibularnim prognatizmom) i grupu E (kontrolna grupa ili grupa pacijenata sa normalnom okluzijom). Izmereno je i analizirano 9 kefalometrijskih parametara koji su se odnosili na srednji masiv lica: dužina tvrdog nepca (SnaSnp), dužina korpusa maksile (AptmPP), dužina mekog nepca, ugao između mekog i tvrdog nepca (SnaSnpUt), ugao inklinacije maksilarnog alveolarnog procesusa, inklinacija gornjih frontalnih zuba, efektivna dužina maksile (CoA), posteriorna maksilarna hiperplazija (U6PP) i ugao maksilarnog prognatizma. **Rezultati.** Dobijeni rezultati su pokazali da su CoA, AptmPP, kao i SnaSnp, značajno kraći kod pacijenata sa divergentnim oblikom mandibularnog prognatizma u odnosu na pacijente sa konvergentnim, a takođe i kod obe eksperimentalne grupe pacijenata u odnosu na kontrolnu. SnaSnp značajno je kraća kod pacijenata sa divergentnim oblikom mandibularnog prognatizma nego kod pacijenata kontrolne grupe, dok je SnaSnpUt značajno manji kod pacijenata sa konvergentnim oblikom mandibularnog prognatizma u nego kod pacijenata kontrolne grupe. Takođe, postoji izražena dentoalveolarna incizalna kompenzacija skeletne disharmonije kod obe grupe pacijenata sa mandibularnim prognatizmom u vidu značajne protruzije gornjih frontalnih zuba, ali bez značajne razlike među grupama, dok je retrognatizam maksile prisutan kod većine pacijenata obe eksperimentalne grupe. Izražena UGPP ustanovljena je samo kod pacijenata sa divergentnim tipom mandibularnog prognatizma. **Zaključak.** Gornja vilica svakako je jedan od bitnih faktora koji doprinose dijagnozi ali pre svega donošenju plana terapije kod mandibularnog prognatizma. Tačna procena ispoljenosti anomalije, lokalizacija skeletnog problema i razumevanje biološkog potencijala glavni su faktori postojanosti rezultata ortodontskohirurške terapije tog deformiteta.

**Ključne reči:**
**prognatizam; mandibula; malokluzija; klase III; kefalometrija; maksila; lice; ortodoncija.**

## Introduction

Mandibular prognathism and skeletal Class III malocclusion are often used as synonyms, although they are not, because the importance of occlusal relationships is emphasized by the use of occlusal dental terms in describing skeletal intermaxillary relationships. Generally, mandibular prognathism is usually a part of skeletal Class III and includes morphological, dimensional and positionally modified mandible which gives a characteristic picture of skeletal Class III malocclusion together with modifications primarily found in the cranial base and probably in the middle part of the face. Accordingly, Nakasima et al. [1] and Thompson and Winter [2] emphasized a familiar tendency to mandibular prognathism. Mandibular prognathism also occurs as a part of numerous congenital anomalies: craniosynestosis (Apert and Crouzon's syndrome), cleidocranial dysostosis (*dysostosis cleidocranialis*), ectodermal dysplasia, achondroplasia, trisomy 21 chromosomes, Binder's syndrome, congenital cleft of the primary and secondary palate, which additionally proves its genetic etymology. Besides, Mackay et al. [3] identified 5 subgroups of Class III malocclusion manifested in mandibular prognathism. On the other hand, Class III malocclusion is not such unique and clear diagnostic clinical entity, because it is a combination of numerous skeletal and dentoalveolar components. Additionally, its etyology is still not clear enough. The results of various authors on the presence of mandibular prognathism in Class III are usually similar. They show that the frequency of mandibular prognathism is over 50% [4, 5] in the aforementioned malocclusion and different combination of intermaxillary relationships and relationships with other craniofacial structures.

There are 2 basic types of the real mandibular prognathism: divergent and convergent [6]. Divergent type is characterized by a divergent mandibular, occlusal and palatal plane [in other words, the nasion–sella line (NS) planes form larger angles compared to the reference ones], more obtuse gonial angle and open bite. Convergent type is characterized by the planes forming significally smaller angles with the NS plane, sharper gonial angle and vertical overlap of the front teeth. This classification is quite rough, so there is a necessity to classify these patients according to the other cephalometric criteria.

The maxilla is connected with the middle cranial fossa through numerous fissures and therefore their growth is interdependent. After the completion of cranial base growth, the maxilla continues to grow forward, laterally and downward in relation to the middle cranial fossa in numerous centers of its growth (sphenopalatine suture, sphenozigomatic suture and sphenoethmoidal suture). Hence, it can be concluded that the shape and position of the middle cranial fossa, (especially the large wings of the sphenoid bone) have an important role in the position of the back edge of the middle part of the face and its relationship with other parts of cranial base.

Diewert [7] found that the growth of the midfacial complex in a sagittal direction is closely connected to the cranial base, whose growth is almost completed in prenatal period, so that maxilla also takes its final sagittal position quite early, when all the changes related to the anterior cranial base are completed, enabling it to form Class I intermaxillary relationships. If any teratogenic factor influences the growth and development of the maxilla in this late embryonic period, it can cause irreversible changes on the morphology or position of the maxilla.

Using functional matrix hypothesis, many authors tried to explain a postnatal forward and downward growth of the middle part of the face. Moss suggested a passive role of the septal cartilage, Oyen assumed that masticatory function was the key factor of the growth of the midfacial complex, Latham found the anteroposterior lagging in the development of the complex in dogs, if their vomer was not removed [8].

Bones of the middle part of the face, but primarily the maxilla, have the pronounced compensatory growth mechanisms on various sutures, so if their growth on one suture is blocked by any external factor (bad habit, bad position such as inclination, teeth, etc), they will grow more intensively on the sutures which are not blocked. Thus, if there is an oral inclination of the upper incisors, the maxilla will be "locked" and the mandible will generate a pseudo-progenia bite, so that the growth and development of the aforementioned bones could be modified. In that case, primary dental malocclusion can be developed into skeletal malocclusion. On the contrary, in the primary development of skeletal Class III malocclusion, a dentoalveolar compensatory mechanism (protrusion of the upper front teeth) can sometimes camouflage the anomaly. Therefore, usually after a dramatic growth during puberty, all compensatory mechanisms of the middle face are overcome due to deficient orthocephalization of the cranial base and increased anteroposterior growth of the mandibular corpus [8, 9] and skeletal Class III is manifested [8–10].

Guyer et al. [11] found that the maxilla measured by the angle of maxillary prognatism (SNA) in 15-year-old adolescents with mandibular prognathism was almost all the time in retroposition, as well as its length which was measured by the effective maxillary lenght (CoA) parameter. Mouakeh [4] also published similar results.

Analyzing the middle part of the face in patients with mandibular prognathism, Chang et al. [12] found that the palatal and maxillary lengths presented in cephalometric parameters [the length of the hard palate (SnaSnp) and the length of the maxillary corpus (APtmPP)] were significantly shorter compared to the control group. However, for vertical dimensions, they did not find a statictically important difference.

Assessing the craniofacial growth in patients with mandibular prognathism in their longitudinal study, Reyes et al. [13] among other things found that there were no significant differences in the patients from the age of 6 to 16 compared to the control group, regarding the position of the maxilla measured by angular and linear parameters. In addition, they recorded that the extrusion of the upper molars was almost a constant finding during the growth of children with mandibular prognathism, whereas Ellis and McNamara [14] found a larger extrusion of the upper first molars in patients with mandibular prognathism and more open bite compared to the patients who did not have an open bite.

Abu Allhaija [15] compared uvulo-glosso-pharyngeal dimensions of the midfacial complex in patients with different intermaxillary relationships and found among the other things that the soft palate in patients with mandibular prognathism was significantly thicker compared to the patients with skeletal Class I. Searching for differences in the airway and corresponding soft tissues of hyperdivergent and normodivergent facial patterns, Joseph at al. [16] found that the angle between the soft and hard palate was significantly larger in hyperdivergent facial patterns, probably due to the maxillary retroposition and more narrow nasopharynx. Dostalova et al. [17] found that the length of the soft palate (SnpUt) in patients with acromegaly was significally increased and the angle between the soft and palatal plate substantially reduced. These changes are not correlated with the concentration of growth hormone, but with the duration of the disease.

When all the aforementioned is taken into consideration, it seems that the variability of the maxilla and the whole midfacial complex in Class III malocclusion is the result of growth deficiency on sutures and especially on the transversal palatine suture, but it is often camouflaged by compensatory mechanisms (inclination of the upper front teeth, elongation of the anterior part of the midface, etc) [9, 10]. However, the final facial profile depends on the sagittal and vertical relationship of the aforementioned structures with a morphologically altered and antepositioned mandible, modified cranial base and soft tissues [8, 18].

Numerous studies have emphased the importance of selecting most appropriate treatment options for mandibular prognathism, which primarely depend on the localization and combination of skeletal relationships in adult patients with this deformity [19, 20].

The aim of this study was to conduct a cephalometric analysis of the morphological characteristics of the maxilla and the whole midfacial complex in patients with divergent and convergent facial type of mandibular prognathism and also to determine their differences.

**Methods**

For the purpose of this study, lateral teleradiograph images of 90 orthodontic patients were analyzed which were taken before their treatment at the Dental Clinic of the Military Medical Academy, Belgrade, Serbia.

According to the literature data on gender differences and dynamics of changes in growth [13, 21, 22], male subjects, aged 18–30 year were examined.

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

The group P consisted of the remaining 60 patients with mandibular prognathism diagnosed on the basis of the following criteria: SNB $\geq 80°$; ANB $\leq 0°$; B $\geq 30°$; Björk $\geq$ 396°; anterior crossbite and relationship of the first permanent molars in Class III.

On the basis of the two cephalometric criteria, the group P was divided into two subgroups: the group P1 consisted of 30 patients with divergent type of mandibular prognathism who met the following criteria: B $\geq$ 300; Björk $\geq$ 396°; the group P2 consisted of 30 patients with convergent type of mandibular prognathism who met the following criteria: B $\leq 30°$; Björk $\leq 396°$.

All the patients from the group P were planned and later treated by orthodontic-surgical therapy including monomaxillary or bimaxillary surgical procedure, which was performed by the same team and lateral teleradiograph images in this study were taken before each therapy.

The obtained results were compared between the group E and the group P1, the group E and the group P2 and the group P1 and P2.

*Cephalometric analysis*

Lateral teleradiograph images of the skull were taken for each patient under standard conditions. The head was fixed in a cephalostat, and recording was conducted at the distance of 1.5 m. Analysis of the lateral teleradiograph images was preceded by drawing the corresponding structures on the tracing paper fixed on the film. Afterwards, the numerous points and surfaces were marked for analyzing certain angular and linear parametres taken from the analyses of Steiner, Jacobson, Rickettc, Downs and Björk. The measurements were performed twice by the same examiner, on different days, with accuracy of 0.5 mm or 0.50. Statistically significant differences did not appear between these 2 measurements.

The difference analysis of the 9 cephalometric parametres (Figure 1) was conducted between the patients with divergent type of mandibular prognathism and the patients with convergent type of mandibular prognathism and between these 2 groups and the control group of eugnathic patients.

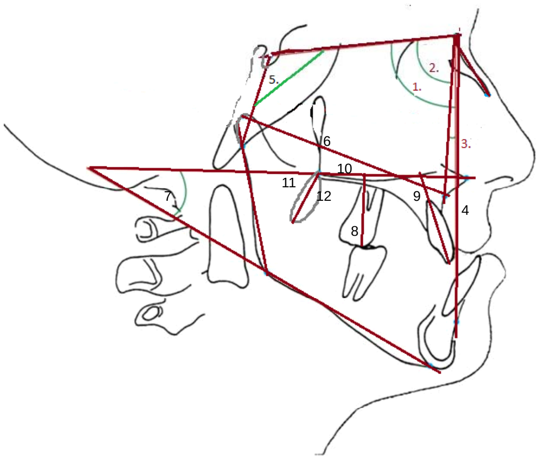


**Fig. 1 – Cephalometric parameters**

**1 – SNA (the angle of maxillary prognathism); 2 – SNB (the angle of mandibular prognathism); 3 – ANB (the angle of sagittal intermaxillary relationships) 4 – SnaAPr (the angle of inclination of the maxillary alveolar process) 5 – NSAr (the angle of cranial base) 6 – CoA (the effective maxillary length) 7 – B (the angle of the vertical intermaxillary relationships) 8 – U6PP (the posterior upper dental height or posterior maxillary alveolar hyperplasia (perpendicular distance betweeen the mesial knob of the first permanent molar and the palatal plate) 9 – IPP (the angle of inclination of the upper front teeth) 10 – SnaSnp [the length of the hard palate (APtmPP – the length of the maxillary corpus is a projection of the points A and Ptm on the palatal plate)] 11 – SnpUt (the length of the soft palate); 12 – SnaSnpUt (the angle between the hard and soft palate).**

*Statistical analysis*

On the basis of the data collected by cephalometric x-ray analysis, for each patient and each feature, the data base was formed in the SPSS12 windows program and the following statistical methods were used in statistical analysis: tables and graphical presentations, descriptive statistics methods and Bonferroni test to detect intergroup differences.

**Results**

Table 1 shows the statistical results of the following analyzed parametres of the maxilla: SnaSnp, AptmPP, SnpUt, SnaSnpUt, the angle of inclination of the maxillary alveolar process (SnaAPr), the angle of inclination of the upper front teeth (IPP), CoA, the posterior maxillary alveolar hyperplasia (U6PP) and SNA.

**Table 1**

**Results of the analyzed parameters of the maxilla in the eugnathic examinees (E) and examinees with divergent (P1) and convergent type (P2) of mandibular prognathism**

| Parameters | N | $\bar{x}$ ± SD | (min – max) |
|---|---|---|---|
| SnaSnp | | | |
| E | 30 | 54.48 ± 3.48 | (45.00 – 61.00) |
| P1 | 30 | 45.50 ± 2.93 | (40.00 – 51.00) |
| P2 | 30 | 49.17 ± 3.96 | (41.00 – 55.00) |
| Total | 90 | 49.72 ± 5.06 | (40.00 – 61.00) |
| AptmPP | | | |
| E | 30 | 53.93 ± 3.74 | (45.00 – 63.00) |
| P1 | 30 | 46.03 ± 3.14 | (41.00 – 52.00) |
| P2 | 30 | 49.62 ± 4.17 | (40.00 – 57.00) |
| Total | 90 | 49.86 ± 4.90 | (40.00 – 63.00) |
| SnpUt | | | |
| E | 30 | 37.20 ± 4.12 | (29.00 – 46.00) |
| P1 | 30 | 33.37 ± 4.33 | (25.00 – 43.00) |
| P2 | 30 | 35.50 ± 4.34 | (26.50 – 46.00) |
| Total | 90 | 35.36 ± 4.50 | (25.00 – 46.00) |
| SnaSnpUt | | | |
| E | 30 | 129.00 ± 7.92 | (114.00 –142.00) |
| P1 | 30 | 125.45 ± 8.32 | (111.00 –141.00) |
| P2 | 30 | 121.92 ± 6.19 | (111.00 –135.00) |
| Total | 90 | 125.46 ± 7.99 | (111.00 –142.00) |
| SnaAPr | | | |
| E | 30 | 144.37 ± 8.73 | (125.00 – 164.00) |
| P1 | 30 | 141.70 ± 6.15 | (132.00 – 160.00) |
| P2 | 30 | 138.72 ± 9.66 | (118.00 – 155.00) |
| Total | 90 | 141.59 ± 8.54 | (118.00 – 164.00) |
| IPP | | | |
| E | 30 | 107.23 ± 8.31 | (88.00 – 121.00) |
| P1 | 30 | 113.57 ± 6.69 | (93.00 – 125.00) |
| P2 | 30 | 113.23 ± 7.56 | (101.00 – 130.00) |
| Total | 90 | 111.34 ± 8.02 | (88.00 – 130.00) |
| CoA | | | |
| E | 30 | 94.25 ± 5.80 | (84.00 – 108.00) |
| P1 | 30 | 86.37 ± 4.15 | (79.00 – 95.00) |
| P2 | 30 | 90.92 ± 3.96 | (80.00 – 96.00) |
| Total | 90 | 90.51 ± 5.68 | (79.00 – 108.00) |
| U6PP | | | |
| E | 30 | 24.95 ± 2.54 | (19.00 – 29.00) |
| P1 | 30 | 29.57 ± 1.47 | (27.00 – 32.00) |
| P2 | 30 | 25.57 ± 1.92 | (22.00 – 28.00) |
| Total | 90 | 26.69 ± 2.87 | (19.00 – 32.00) |
| SNA | | | |
| E | 30 | 82.38 ± 4.05 | (73.00 – 89.00) |
| P1 | 30 | 77.67 ± 4.29 | (71.00 – 86.50) |
| P2 | 30 | 79.77 ± 3.14 | (74.00 – 86.00) |
| Total | 90 | 79.94 ± 4.28 | (71.00 – 89.00) |

**SnaSnp – the lenght of the hard palate; AptmPP – the lenght of the maxillary corpus; SnpUt – the lenght of the soft palate; SnaSnpUt – the angle between the hand and soft palate; SnaAPr – the angle of inclination of the maxillary alveolar process; IPP – the angle of inclination of the upper front teeth; CoA – the effective maxillary length; U6PP – posterior maxillary alveolar hyperplasia; SNA – the angle of maxillary prognathism.**

A statistically significant difference was found in the values of all the measured parameters between the groups of examinees, including maxillary parameters and intermaxillary sagittal and vertical relationships parameters (Table 2).

**Table 2**

**Results of one-factor analysis of the variance for all the measured parameters**

| Parameter | F | P |
|---|---|---|
| SnaSnp | 50.525 | 0.000 |
| AptmPP | 34.142 | 0.000 |
| SnpUt | 6.080 | 0.003 |
| SnaSnpUt | 6.633 | 0.002 |
| SnaAPr | 3.466 | 0.036 |
| IPP | 6.686 | 0.002 |
| CoA | 21.195 | 0.000 |
| U6PP | 46.006 | 0.000 |
| SNA | 11.247 | 0.000 |

**For key to abbreviations see under Table 1.**

SnaSnp showed the highest values in the eugnathic subjects, statistically significantly lower values in the patients with convergent type of mandibular prognathism and the lowest values in the patients with divergent type of mandibular prognathism. Using one-factor analysis of variance (Table 2), we recorded a highly statistically significant difference in SnaSnp values among the groups of examinees ($F = 50.525$; $p = 0.000$). A highly statistically significant difference in SnaSnp values between the group E (54.48 ± 3.48) and the groups P1 (45.50 ± 2.93) and P2 (49.17 ± 3.96) was found. Additionally, there was a highly statistically significant difference between the groups P1 and P2 (Table 3).

AptmPP showed the highest values in the eugnathic subjects, significantly lower values in the patients with convergent type of mandibular prognathism and the lowest values in the patients with divergent type of mandibular prognathism. Using one-factor analysis of variance (Table 2), a highly statistically significant difference in AptmPP values was recorded among the groups of examinees ($F = 34.142$; $p = 0.000$). A highly statistically significant difference in AptmPP values between the group E (53.93 ± 3.74) and the groups P1 (46.03 ± 3.14) and P2 (49.62 ± 4.17) was found. Additionally, there was a highly statistically significant difference between the groups P1 and P2 (Table 3).

SnpUt showed the highest values in the eugnathic subjects, significantly lower values in the patients with convergent type of mandibular prognathism and the lowest values in the patients with divergent type of mandibular prognathism. Using one-factor analysis of variance (Table 2), we recorded a highly statistically significant difference in SnpUt values among the groups of examinees ($F = 6.080$; $p = 0.003$). A highly statistically significant difference in SnpUt values between the group E (37.20 ± 4.12) and the group P1 (33.37 ± 4.33) was found, while a statistically significant difference between the group E and the group P2 (35.50 ± 4.34) was not established. Additionally, a statistically significant difference between the group P1 and the group P2 was not found (Table 3).

SnaSnpUt showed the highest values in the eugnathic subjects, significantly lower values in the patients with divergent type of mandibular prognathism and the lowest values in the patients with convergent type of mandibular prognathism. Using one-factor analysis of variance (Table 2), a highly statistically significant difference in SnaSnpUt values was recorded among the groups of examinees ($F = 6.633$; $p = 0.002$). A statistically significant difference in SnaSnpUt values between the group E (129.00 ± 7.92) and the group P1 (125.45 ± 8.32) was not found, while a highly statistically significant difference between the group E and the group P2 (121.92 ± 6.19) was measured. A statistically significant difference between the group P1 and the group P2 was not found (Table 3).

**Table 3**

**Results of intergroup differences of the characteristics measured on the maxilla by Bonferroni test**

| Parameter | (J) Group | Average value difference | *p* |
|---|---|---|---|
| SnaSnp | | | |
| E | P1 | 8.98 | 0.000 |
| E | P2 | 5.32 | 0.000 |
| P1 | P2 | -3.67 | 0.000 |
| AptmPP | | | |
| E | P1 | 7.90 | 0.000 |
| E | P2 | 4.32 | 0.000 |
| P1 | P2 | -3.58 | 0.001 |
| SnpUt | | | |
| E | P1 | 3.83 | 0.002 |
| E | P2 | 1.70 | 0.379 |
| P1 | P2 | -2.13 | 0.168 |
| SnaSnpUt | | | |
| E | P1 | 3.55 | 0.214 |
| E | P2 | 7.08 | 0.001 |
| P1 | P2 | 3.53 | 0.218 |
| SnaAPr | | | |
| E | P1 | 2.67 | 0.653 |
| E | P2 | 5.65 | 0.030 |
| P1 | P2 | 2.98 | 0.505 |
| IPP | | | |
| E | P1 | -6.33 | 0.005 |
| E | P2 | -6.00 | 0.008 |
| P1 | P2 | 0.33 | 1.000 |
| CoA | | | |
| E | P1 | 7.88 | 0.000 |
| E | P2 | 3.33 | 0.022 |
| P1 | P2 | -4.55 | 0.001 |
| U6PP | | | |
| E | P1 | -4.62 | 0.000 |
| E | P2 | -0.62 | 0.724 |
| P1 | P2 | 4.00 | 0.000 |
| SNA | | | |
| E | P1 | 4.72 | 0.000 |
| E | P2 | 2.62 | 0.031 |
| P1 | P2 | -2.10 | 0.114 |

**E – eugnathic examinees; P1 – divergent and P2 – convergent type of mandibular prognathism examinees; For key to abbreviations see under Table 1.**

SnaAPr showed the highest values in the eugnathic subjects, significantly lower values in the patients with divergent type of mandibular prognathism and the lowest values in the patients with convergent type of mandibular prognathism. Using one-factor analysis of variance (Table 2), we recorded a highly statistically significant difference in SnaAPr values among the groups of examinees ($F = 3.466$; $p = 0.036$). A statistically significant difference in SnaAPr values between the group E (144.37 ± 8.73) and the group P1 (141.70 ± 6.15) was not found, while a statistically significant difference between the group E and the group P2

(138.72 ± 9.66) was measured. A statistically significant difference between the group P1 and the group P2 was not found (Table 3).

IPP showed the highest values in the eugnathic subjects, while the average values between the experimental groups were slightly different. Using one-factor analysis of variance (Table 2), a highly statistically significant difference in IPP values was recorded among the groups of examinees (F = 6.686; $p$ = 0.002). A highly statistically significant difference in IPP values between the group E (107.23 ± 8.31) and the group P1 (113.57 ± 6.69) and P2 (113.23 ± 7.56) was found. A statistically significant difference between the group P1 and the group P2 was not found (Table 3).

CoA showed the highest values in the eugnathic subjects, significantly lower values in the patients with convergent type of mandibular prognathism and the lowest values in the patients with divergent type of mandibular prognathism. Using one-factor analysis of variance (Table 2), a highly statistically significant difference in CoA values among the groups of examinees (F = 21.195; $p$ = 0,000). A highly statistically significant difference in CoA values was recorded between the group E (94.25 ± 5.80) and the group P1 (86.37 ± 4.15) and P2 (90.92 ± 3.96) was measured. Additionally, a highly statistically significant difference between the group P1 and the group P2 was found (Table 3).

U6PP showed the highest values in the eugnathic subjects, higher values in the patients with convergent type of mandibular prognathism and the highest values in the patients with divergent type of mandibular prognathism. Using one-factor analysis of variance (Table 2), a highly statistically significant difference in U6PP values was found among the groups of examinees (F = 5.125; $p$ = 0,008). A highly statistically significant difference in U6PP values between the group E (85.97 ± 7.79) and the group P1 (91.52 ± 7.29) was found, but not between the group E and the group P2 (87.17 ± 5.99). Additionally, a highly statistically significant difference between the group P1 and the group P2 was found (Table 3).

SNA showed the highest values in the eugnathic subjects, significantly lower values in the patients with convergent type of mandibular prognathism and the lowest values in the patients with divergent type of mandibular prognathism. Using one-factor analysis of variance (Table 2), a highly statistically significant difference in SNA values was found among the groups of examinees (F = 11.247; $p$ = 0,000). A highly statistically significant difference in SNA values between the group E (82.38 ± 4.05) and the groups P1 (77.67 ± 4.29) and P2 (79.77 ± 3.14) was found. A statistically significant difference between the group P1 and the group P2 was not found (Table 3).

## Discussion

Many studies have proved a significant reduction of the linear dimensions and retroposition [8, 11, 12, 23] of the maxilla in most patients with Class III malocclusion. Therefore, Singh [5] and Singh et al. [8] in their great study on the aforementioned malocclusion, emphasized its unclear entity and etiology, so that it is almost impossible to classify it. Hence, for the purpose of this study, we selected patients with mandibular prognathism and on the basis of vertical parameters, and classified them into the devergent and convergent types. These vertical parameters change mostly during the growth period, as it has been demonstrated in many studies dealing with Class III malocclusion growth and development, thus their estimation influences stability of the obtained treatment results [21–25].

Taking into consideration gender differences presented by a number of authors, primarely regarding the linear cephalometric parameters in adult patients [24, 25], and their dynamics of changes during the growth period [13 21, 22], only male patients were examined in this study in order to provide homogeneous samples.

The middle part of the face, that is the maxilla, has always been mentioned as a possible etiologic factor of skeletal Class III. However, the importance of the relationship of maxillary retroposition towards the cranial base is still unclear, although it has been examined many times. While one group of authors argues that there is a clear correlation between them the other group refutes it [5]. We estimated the maxillary anteroposterior position towards the cranial base, based on the SNA angle and obtained the results showing that the SNA angle was significantly reduced and similar in the both groups. In most patients with mandibular prognathism, the maxilla is in retroposition and there is no difference in the degree of retroposition between the divergent and convergent type of this anomaly.

AptmPP, SnaSnp and CoA are parameters which showed significant differences between the divergent and convergent type of mandibular prognathism in this study. All the three parameters were significantly lower in both groups compared to the control group, while they were the lowest in the patients with divergent type of mandibular prognathism. Similar results for skeletal Class III were found by Miyajima et al. [26], Guyer et al. [11], Reyes et al. [13] and Chang et al. [25].

Upper front teeth protrusion and the whole alveolar process, also recorded in this study, is one of many compensatory mechanisms of the midfacial complex growth formed to overcome skeletal discrepancy [10, 13, 27, 28].

Many authors used cephalometric analysis to examine differences in the pharyngeal area and corresponding structures between hyperdivergent and normodivergent facial patterns [15, 16]. The general view is that the pharyngeal area in the hyperdivergent facial pattern is significantly more narrow, which is explained by the maxillary and mandibular retrusion and increased vertical growth. Abu Allhaija et al. [15] noted that the soft palate was significantly thicker in patients with mandibular prognathism than in eugnathic patients. Dostalova et al. [17] found the increased SnpUt and smaller SnaSnpUt in patients with acromegaly who have a significant elongation of the mandible. In our study, we found a significantly reduced SnpUt in the patients with divergent type of mandibular prognathism which is in accordance with the aforementioned picture of the hyperdivergent facial pattern described by Joseph et al. [16] and Abu Allhaija et al. [15] In patients with convergent type of mandibular prognathism, we recorded a smaller SnaSnpUt. Given the fact that in the previous study on mandibular prognathism we found a significant anteposition of temporomandibular joint (reduced GoArNS angle) with the mandible moved forward and a significantly larger SNB angle in the covergent type compared to the divergent type, the currently obtained result can be in line with it [18].

Measuring a distance from the mesial cuspid of the first permanent upper molar to the palatal plate (U6PP), it was quite larger in the divergent type of mandibular prognathism compared to the control group and convergent type, whereas there were no differences in the convergent type compared to the control group, which speaks in favour of the posterior mandibular hyperplasia in the divergent type. Reyes et al. [13] also noted the increase in the U6PP parameter in patients with skeletal Class III in all developmental phases from the age of 6 to 16, which can cause elongation of the front lower facial height later in life and compromise the results of early treatment. Additionally, the posterior maxillary hyperplasia was in a pronounced correlation with the anterior and posterior facial height and the angle between the basic jaw planes (B), but only in patients with divergent type of mandibular prognathism. Thus, it is crucial to estimate vertical components, especially in younger age, when they can be camouflaged by various compensatory mechanisms.

Besides highly demanding orthodontic-surgical treatment of sagittal discrepancies in patients with mandibular prognathism, more attention has recently been paid to vertical discrepancies, which many authors consider as key factors for relapse [27–29].

In order to achieve esthetically satisfying and long term stability results in patients, a surgical correction must provide a bite closing, reduction of the mandibular plane angle and the angle between the basic jaw planes, but also the correction of the posterior maxillary hyperplasia as a main condition for the stability of results [28–31]. In our study, the posterior maxillary hyperplasia was found only in patients with divergent type of mandibular prognathism. In most patients, an adequate surgical treatment must include a surgical intrusion of the posterior maxilla, which will correct posterior maxillary hyperplasia and increased angle between the basic jaw plates. The posterior maxillary intrusion will allow the mandible to rotate around its axis without ramus elongation during bite closing and thus reduce the angle between the basic jaw planes and lower facial height with temporary deterioration of mandibular protrusion. However, since sagittal split osteotomy of the mandible is also performed along with maxilla intruded in this way, it will be retruded without stretching of masticatory muscles. In this manner, the stability of surgical results is significantly increased [32, 33].

In order to achieve satisfying therapy effects, it is necessary to accurately estimate a degree of the abnormality manifestation, problems of localization and understanding of the bilogical potential.

## Conclusion

The effective maxillary length, the length of the maxillary corpus and the length of the hard palate are significantly shorter in the patients with divergent facial type of mandibular prognathism compared to the patients with convergent type and also in both experimental groups of patients compared to the control one. The length of the hard palate is significantly shorter in patients with divergent type of mandibular prognathism compared to the control group, whereas the angle between the soft and hard palate is significantly smaller in the patients with convergent type of mandibular prognathism compared to the control group. In addition, there is a pronounced incisor dentoalveolar compensation of skeletal discrepancy in both groups of patients with mandibular prognathism in form of a significant upper front teeth protrusion, but without a significant difference among the groups, while the maxillary retrognathism is present in most patients of both experimental groups.

A pronounced posterior maxillary hyperplasia was found only in the patients with divergent type of mandibular prognathism.

The maxilla is certainly one of the key factors which contribute to making the diagnosis, but primarily to making a plan for mandibular prognathism treatment. Nevertheless, it contributes to the apperance of the aforementioned deformity in more variable way than other craniofacial components (cranial base, mandible), primarely due to its morphology, way and time of growth completion as well as numerous compensatory mechanisms.

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