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Cephalometric evaluation of skeletal relationships after bimaxillary surgical correction of mandibular prognathism

Rendgen kraniometrijska procena skeletnih odnosa nakon bimaksilarne hirurške korekcije mandibularnog prognatizma

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Abstract

Background/Aim. In recent years, bimaxillary surgery has widely been accepted as an effective surgical procedure for the correction of mandibular prognathism. The aim of this study was to determine how bimaxillary surgical correction can change the skeletal dimensions and relations typical of mandibular prognathism and whether the postoperative results can be compared with biometric values of these dimensions in subjects with normal occlusion. **Methods.** The study included 50 subjects divided into two groups. The analyzed group consisted of 20 patients with mandibular prognathism, mean age 19.8 ± 5.3 years. The control group consisted of 30 subjects with skeletal class I and normal occlusion, mean age 21.5 ± 3.5 years. Cephalometric studies were conducted on 70 lateral cephalograms made on subjects of the analyzed group before and after surgery and in controls. All radiographs were transformed into a digital form. Using the computer program "Dr. Ceph", 30 linear and angular skeletal variables were analyzed and compared on each radiograph. The values of examined variables in the analyzed group were compared before and after surgery and with the values of the same variables in the control group. **Results.** Bimaxillary osteotomies changed most of the variables that characterize the mandibular prognathism. Changes in the sagittal plane were reflected in a significant increase of angles SNA (by 4° on the average), ANB (6°), and a significant reduction in angles SNB (3°), ArGoMe (8°), NGoMe (6.2°), Bjork's sum (7°) and the angle of skeletal convexity NAPg (2°). Changes in vertical relationships were reflected in a significant reduction in overall anterior face height N-Me (by 5 mm on average), the lower anterior face height ANS-Me (4 mm), in a significant increase in the total posterior face height S-Go (2.5–3 mm), lower posterior face height PNS-Go (4 mm), in a significant reduction of the basal angle PP/MP (5°) and angle that mandibular plane closes with the anterior cranial base NS/MP (4°). Comparison of investigated variables in the analyzed group after surgery with the same values in the control group showed that they were significantly closer to biometric standards. **Conclusion.** Bimaxillary surgery significantly alters the skeletal relationships and facial dimensions typical of mandibular prognathism and normalizes the skeletal profile and appearance in operated patients.

Key words:
malocclusion, angle class III; cephalometry; oral surgical procedures; orthognathic surgical procedures; treatment outcome.

Apstrakt

Uvod/Cilj. Poslednjih godina bimaksilarna hirurgija je široko prihvaćena kao efikasna hirurška procedura u korigovanju mandibularnog prognatizma. Cilj rada bio je da se utvrdi na koji način bimaksilarne hirurške korekcije menjaju skeletne dimenzije i odnose tipične za mandibularni prognatizam i mogućnost poređenja postoperativnih rezultata sa biometrijskim vrednostima tih dimenzija kod osoba sa normookluzijom. **Metode.** U studiju je bilo uključeno 50 ispitanika koji su bili podeljeni u dve grupe. Analiziranu grupu je činilo 20 ispitanika sa mandibularnim prognatizmom, prosečne starosti 19,8 ± 5,3 godine. Kontrolnu grupu je činilo 30 ispitanika sa I skeletnom klasom i normookluzijom, prosečne starosti 21,5 ± 3,5 godine. Rendgenkraniometrijska istraživanja su obavljena na 70 profilnih telerendgenskih snimaka glave načinjenih kod ispitanika analizirane grupe pre i nakon operacije i kod ispitanika kontrolne grupe. Pomoću kompjuterskog programa "Dr Ceph", na svakom snimku vrednovano je 30 linearnih i ugaonih skeletnih varijabli. U analiziranoj grupi upoređene su vrednosti ispitivanih varijabli pre i nakon operacije, a, takođe, te vrednosti su upoređene i sa vrednostima istih varijabli u kontrolnoj grupi. **Rezultati.** Bimaksilarne osteotomije su promenile većinu varijabli koje karakterišu mandibularni prognati

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zam. Promene u sagitalnim odnosima ogledale su se u značajnom povećanju uglova SNA (za 4°), ANB (za 6°) i značajnom smanjenju uglova SNB, ArGoMe, NGoMe, Bjorkovog poligona i ugla skeletnog konveksiteta lica NAPg. Promene u vertikalnim odnosima ogledale su se u značajnom smanjenju ukupne prednje visine lica N-Me (za 5 mm), donje prednje visine lica ANS-Me (za 4 mm), značajnom povećanju ukupne zadnje visine lica S-Go (oko 3 mm), donje visine lica PNS-Go (4 mm), značajnom smanjenju bazalnog ugla SpP/MP (5°) i ugla koji mandibularna ravan zaklapa sa prednjom kranijalnom bazom NS/MP (4°). Poređenje vrednosti ispitivanih varijabli u analiziranoj grupi nakon operacije sa istim vrednostima u kontrolnoj grupi pokazalo je da su se one značajno približile biometrijskim standardima. **Zaključak.** Bimaksilarne osteotomije značajno menjaju skeletne odnose i dimenzije lica tipične za mandibularni prognatizam i normalizuju skeletni profil kod operisanih pacijenata.

Ključne reči:
malokluzija, klase III; kefalometrija; hirurgija, oralna, procedure; hirurgija, ortognatska, procedure; lečenje, ishod.

Introduction

Mandibular prognathism is among the most serious genetic disorders of growth and development of the craniofacial skeleton. The deformity is manifested fully in the most sensitive age, the adolescent period, endangering the basic functions of the orofacial system, the appearance of the young persons, their psychological health, and quality of life. These are usually the basic motives why these patients seek orthognathic surgery.

Literature data indicate that severe forms of dentofacial deformities occur in 0.5% of people in the general population. The fact is, however, that of all patients requiring orthognathic surgery, 28%–34% are with mandibular prognathism [1].

Diagnosis and treatment of severe craniofacial disharmonies require a multidisciplinary approach and teamwork. The base of each treatment is a detailed analysis of the orofacial complex that provides objective information on the severity and phenotypic characteristics of the existing deformity. In the majority of cases, class III deformities are combined by maxillary retrognathia, mandibular prognathism, and varying degrees of vertical discrepancies [2–4].

During the past few decades, various surgical procedures have been advocated for the correction of these deformities. Until the 1980s, the surgical correction of mandibular prognathism has been mainly performed by isolated operations on the mandible [5–8]. Nowadays, it is clear that such operations, in most cases, cannot normalize the skeletal relationships and achieve the optimal aesthetic results [9–12]. Clinical experience and numerous scientific references suggest that correction of skeletal disharmonies, harmonization of occlusion, and correction of facial appearance in patients with severe mandibular prognathism can only be achieved by bimaxillary surgery, ie. by planned surgical reposition of both jaws [11–16].

The aim of this study was to determine to what extent and in what way bimaxillary surgical correction can change the skeletal dimensions and relations typical of mandibular prognathism and whether the postoperative results can be compared with biometric values of these dimensions in subjects with normal occlusion.

Methods

The sample of the study was comprised of two groups – the analyzed and the control group. The analyzed group consisted of 20 patients admitted to the Department of Maxillofacial Surgery, Faculty of Dental Medicine in Belgrade for surgical correction of mandibular prognathism from 2003–2013. There were ten female and ten male patients, mean age of 19.8 ± 5.3 years. The control group consisted of 30 young persons, mean age of 21.5 ± 3.5 years, with normal occlusion. For the purposes of cephalometric research, a total of 70 lateral cephalometric radiographs were made and divided into three groups: Group A consisted of 20 lateral cephalometric radiographs derived from the patients of the analyzed group before surgery and before orthodontic preparation; Group B consisted of 20 lateral cephalometric radiographs derived from the same patients of the analyzed group 6 months to a year after bimaxillary surgical correction of mandibular prognathism; Group C consisted of 30 lateral cephalometric radiographs made in the control group. This collection was selected from the files of our dental school (archive of the author).

Lateral cephalograms are made in the Plan-Meca Radiological Center and the Center for the Head and Neck Radiology at the Faculty of Dental Medicine in Belgrade with a special apparatus, "ORTOCEPH" (Siemens, Bensheim, Germany). The recordings were made by standard techniques at a voltage of 65 to 80 kV and a strength of 20 mA, and the exposure was from 1 to 1.5 sec. The recording was performed on the X-ray film 18 × 24 cm. All radiographs were scanned and transformed into digital form.

The choice of operative technique

Each patient of the analyzed group was subjected to special consultative review and selected for these investigations based on a precise analysis of the phenotypic characteristics of present deformity. The patients were sent to orthodontic preparation for a year and a half and then subjected to surgical correction. The surgical procedure was performed by a successive bimaxillary approach that involves LeFort I osteotomy of the maxilla and bilateral sagittal split ramus osteotomy of the mandible. The rigid fixation (mini titanium plates and screws) was used to fix the bone fragments. A combination of solid and elastic intermaxillary immobilization was applied for 6–8 weeks after surgery [9, 17, 18].

Cephalometric research

All lateral cephalograms made in the analyzed group before and after surgery, as well as in the control group, were subjected to cephalometric analysis. For this purpose, a special computer program, "Dr. Ceph" (FYI Technologies, GA, USA, last revised edition, version 9.7), was used (Figure 1). This version allows the use of over thirty well-known cephalometric analyses, as well as adaptation of any analysis to the specific needs of the research. Using this program on each cephalogram of A, B, and C groups, the values of 30 linear and angular skeletal variables were recorded and evaluated.

Examined skeletal variables

a) Examined linear variables were (Figure 2): 1. N-Se – length of the anterior cranial base; 2. N-Me – total anterior face height; 3. N-ANS – upper anterior face height; 4. ANS-Me – lower anterior face height; 5. S-Go – total posterior face height; 6. S-PNS – upper posterior face height; 7. PNS-Go – lower posterior face height; 8. S-Ar – the length of the posterior cranial base; 9. Ar-Go – the length of the ramus; 10. Co-Go – the height of the ramus; 11. PNS-A – the length of the maxillary body; 12. Go-Me – the length of the mandibular body.

b) Examined proportions of linear variables were: 1. S-Go/N-Me – the relationship of anterior and posterior face heights; 2.N-ANS/ANS-Me – the ratio of upper and lower anterior face height; 3. N-ANS/N-Me – the ratio of the upper anterior face height to total anterior face height; 4. ANS-

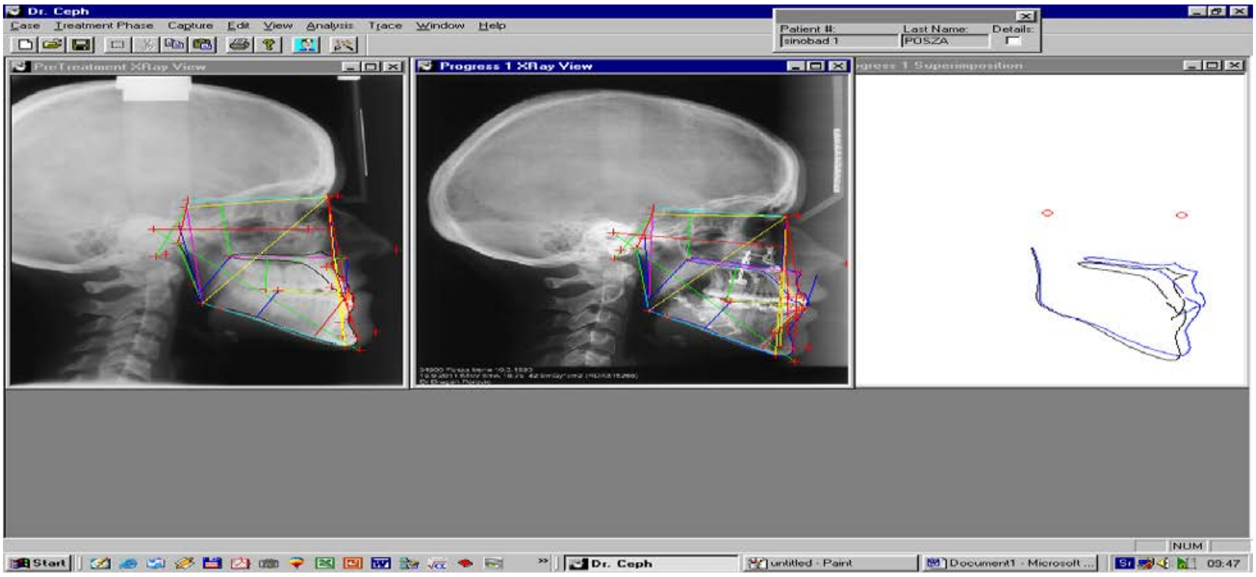

Fig. 1 – Cephalometric analysis of parameters by "Dr. Ceph" computer software.

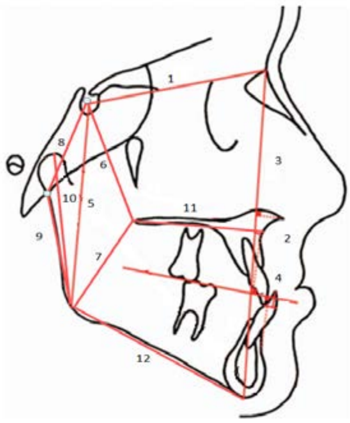

Fig. 2 – Examined linear skeletal variables.
1. N-Se – length of the anterior cranial base; 2. N-Me – total anterior face height;
3. N-ANS – upper anterior face height; 4. ANS-Me – lower anterior face height;
5. S-Go – total posterior face height; 6. S-PNS – upper posterior face height;
7. PNS-Go – lower posterior face height; 8. S-Ar – the length of the posterior cranial base;
9. Ar-Go – the length of the ramus; 10. Co-Go – the height of the ramus;
11. PNS-A – the length of the maxillary body; 12. Go-Me – the length of the mandibular body.

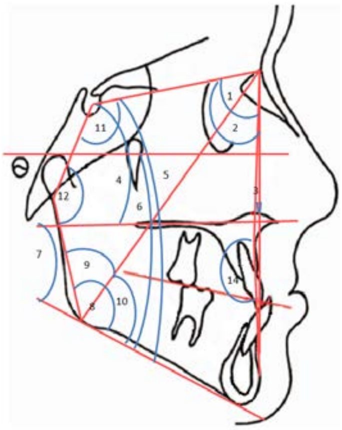

Fig. 3 – Examined angular skeletal variables.
1. SNA – anteroposterior position of the maxilla relative to the anterior cranial base;
2. SNB – anteroposterior position of the mandible relative to the anterior cranial base;
3. ANB – the relationship of the maxilla and mandible in the sagittal plane;
4. N-S/PP – the inclination of the maxilla to the anterior cranial base;
5. N-S/MP – the inclination of the mandible to the anterior cranial base;
6. FH/MP – the relationship between the Frankfurt plane and mandibular plane;
7. PP/MP – the relationship between the basic jaw planes;
8. ArGoMe – gonial angle by Bjork; 9. ArGoN – upper part of the gonial angle;
10. NGoMe – the lower part of the gonial angle; 11. NSAr – the angle of the saddle by Bjork;
12. SArGo – articular angle by Bjork.

Me/N-Me – the ratio of the lower anterior face height to the total anterior face height.

c) Examined angular skeletal variables were (Figure 3): 1. SNA – anteroposterior position of the maxilla relative to the anterior cranial base; 2. SNB – anteroposterior position of the mandible relative to the anterior cranial base; 3. ANB – the relationship of the maxilla and mandible in the sagittal plane; 4. N-S/PP – the inclination of the maxilla to the anterior cranial base; 5. N-S/MP – the inclination of the mandible to the anterior cranial base; 6. FH/MP – the relationship between the Frankfurt plane and mandibular plane; 7. PP/MP – the relationship between the basic jaw planes; 8. ArGoMe – gonial angle by Bjork; 9. ArGoN – upper part of the gonial angle; 10. NGoMe – the lower part of the gonial angle; 11. NSAr – the angle of the saddle by Bjork; 12. SArGo – articular angle by Bjork; 13. Bjork's sum – the sum of the angles NSAr, SarGo, and ArGoMe; 14. NAPg – the angle of facial skeletal convexity.

Numerical values of the examined skeletal variables were subjected to statistical analysis and compared. Due to surgical correction, the values of selected skeletal variables were compared before surgery and 6 months to a year after surgery to verify the changes in skeletal relationships.

The comparison of investigated variables between the analyzed group after surgery and the control group was used for objective evaluation of the success of bimaxillary surgery in correcting the mandibular prognathism.

Statistical analysis was performed using the computer programs MS Excel, MedCalc (MedCalc ver. 11.4 Software, Belgium), and SPSS ver. 18 (SPSS Inc, Chicago, IL). The comparison of two groups of independent data was performed using Student's *t*-test. Comparison of three sets of data was performed using the parametric analysis of variance (ANOVA) with Tukey-Snedecor *post hoc* test. The shape of data distribution was examined using the Kolmogorov-Smirnov test. This test showed that all variables had a normal distribution, and in the further course of data processing, they were portrayed as means, standard deviations, minimum and maximum values, and coefficients of variation (in %). The minimum requirement for a statistically significant difference was when the significance level (p) was less than or equal to 0.05.

Results

Comparison of values of linear skeletal variables in the analyzed group before and after surgery revealed a number of changes in their values. However, the only variables that showed significant differences between the situation before and after the operation were the following: N-Me, ANS-Me, Go-Me, PNS-A, S-Go, PNS-Go, S-Ar, and S-Go/N-Me (Table 1).

After surgery, the total anterior face height N-Me was reduced by 5 mm on average, the lower anterior face height ANS-Me by 4 mm on average, and the length of the mandible Go-Me for 3–3.5 mm. On the contrary, the values of the total posterior face height S-Go increased by 2.5–3 mm on average, and of the lower face height PNS-Go by 4 mm. The relationship between the posterior and anterior total face height changed in favor of the posterior face height. The effective maxillary length increased by 3–3.5 mm on average as a result of it shifting forward during surgery.

The surgery did not affect the length of the anterior cranial base N-S, nor the values of the anterior upper face

Table 1

The values of linear skeletal variables in the control group and the experimental group before and after surgery

Variables	Control group	Experimental group		*p*
		before operation	after operation	
N-Se	63.7 ± 6.37	66.8 ± 4.75*	66.8 ± 4.5*	<0.05
N-Me	114.9 ± 8.57	124.0 ± 6.89***	118.9 ± 7.83§§	<0.001
N-ANS	50.3 ± 4.62	53.0 ± 3.21*	52.1 ± 5.11	<0.05
ANS-Me	64.5 ± 5.79	71.0 ± 6.45***	66.7 ± 6.49§	<0.001
S-Go	78.5 ± 5.91	76.6 ± 5.20	79.3 ± 7.10§	< 0.05
S-PNS	44.0 ± 3,42	44.9 ± 3.72	44.7 ± 4.06	ns
PNS-Go	44.4 ± 4.15	38.9 ± 4.48***	42.8 ± 5.87§§	<0.001
S- Ar	36.1 ± 3.68	30.4 ± 5.59***	31.2 ± 5.07***, §§§	< 0.001
Ar-Go	46.5 ± 4.76	52.8 ± 6.49***	52.9 ± 5.24***	< 0.001
Co- Go	57.9 ± 5.03	61.8 ± 4.51**	62.0 ± 5.91*	< 0.001
S-Go/ N-Me	0.685 ± 0.0436	0.627 ± 0.05***	0.660 ± 0.06§§	< 0.001
N-ANS/ANS-Me	0.779 ± 0.0710	0.756 ± 0.10	0.773 + 0.10	ns
N-ANS/N-Me	0.438 ± 0.0256	0.430 ± 0.03	0.436 ± 0,03	ns
ANS-Me/ N-Me	0.562 ± 0.0256	0.571 ± 0.03	0.564 ± 0.03	ns
PNS-A	44.5 ± 3.43	43.6 ± 3.56	46.7 ± 3.95	ns
Go-Me	70.2 ± 5.57	77.6 ± 6.53***	74.7 ± 6.26**, §§	< 0.001

N-Se – length of the anterior cranial base; N-Me – total anterior face height; N-ANS – upper anterior face height; ANS-Me – lower anterior face height; S-Go – total posterior face height; S-PNS – upper posterior face height; PNS-Go – lower posterior face height; S-Ar – the length of the posterior cranial base; Ar-Go – the length of the ramus; Co-Go – the height of the ramus; PNS-A – the length of the maxillary body; Go-Me – the length of the mandibular body.
p* – *,**, *p* < 0.05, 0.01, 0.001 vs. control, §, §§, §§§ *p* < 0.05, 0.01, 0.001 vs. analyzed group before operation; ns – non significant (ANOVA test and *post hoc* Tukey test).**

height N-ANS, posterior upper face height S-PNS, length of ramus Ar-Go, and height of ramus mandible Co-Go.

Relations between the upper and lower anterior face height N-ANS/ANS-Me, the upper anterior and total anterior face height N-ANS/N-Me, and the relationship of the lower anterior to the total face height ANS-Me/N-Me were changed after the operation, but the differences were not significant.

Comparing linear skeletal variables in the analyzed group after surgery with the values of the same variables in the control group revealed that most linear variables after surgery returned to the level in controls (Table 1). This especially applied to the values of total anterior face height N-Me and the lower anterior face height ANS-Me which were significantly reduced by surgery, then to the values of the total posterior face height S-Go, the lower posterior face height PNS-Go, and their relationship, which significantly increased after surgery.

However, even after surgery, the posterior cranial base S-Ar remained considerably lower than in the control group, while the length and height of the ramus and even the length of the body of the mandible were significantly longer compared to their values in the control group.

Comparison of values of angular skeletal variables in the analyzed group before and after surgery revealed statistically significant differences in the following variables: SNA, SNB, ANB, NS/MP, FH/MP, PP/MP, ArGoMe, NGoMe, Bjork's sum, and NAPg (Table 2).

Due to maxillary advancement during Le Fort I osteotomy, the value of SNA angle increased to 4° on average. On the contrary, the values of the basic features of mandibular prognathism decreased significantly. The values of SNB angle decreased by an average of 3°, NS/MP angle by an average of 4°, FH/MP angle by an average of 4.7°, PP/MP angle by an average of 5°, ArGoMe angle by an average of 8°, NGoMe by an average of 6.2°, and Bjork's sum by an average of 7°.

The ANB angle with a high negative value before surgery (X = -4.7 ± 3.04°), became positive (X = 1.3 ± 1.22°) after surgery and significantly approached biometric standards (around ± 2°). The difference between the values of ANB angle before and after operation amounted to 6°.

The comparison of angular skeletal variables in the analyzed group after surgery with the values of the same variables in the control group showed that the majority of them approached the biometric norms (Table 2). This is especially true for angles SNA, SNB, NS/PP, NS/MP, FH/MP, PP/MP, ArGoN, and Bjork's sum. As the modified values of these angles are the main indicators of maxillary retrognathia and/or mandibular prognathism with a vertical type of growth, normalization of their values after surgery changed the progeny skeletal assembly in operated patients.

However, even after surgery in the analyzed group, the values of gonial angles ArGoMe and NGoMe and the angle of facial skeletal convexity NAPg remained significantly higher compared to their values in the control group, while the average value of the articular angle SarGo was significantly lower. The value of the ANB angle, which significantly increased after surgery (by 6° on the average), was still different from its value in the control group.

Table 2

The values of angular skeletal variables in the control group and the experimental group before and after surgery

Variables	Control group	Experimental group		*p*
		before operation	after operation	
SNA	81.4 ± 3.38	79.2 ± 4.66	83.7 ± 5.60§§§	ns
SNB	79.3 ± 3.06	84.0 ± 4.38 ***	82.7 ± 4.72§§	< 0.001
ANB	2.1 ± 1.30	4.7 ± 3.04 ***	1.3 ± 1.22*, §§§	< 0.001
N-S/PP	8.2 ± 3.53	8.8 ± 4.68	9.2 ± 5.63	ns
N-S/MP	30.6 ± 5.56	37.1 ± 7.30**	33.3 ± 7.24§	< 0.001
FH/MP	23.3 ± 5.57	28.9 ± 7.81**	24.2 ± 6.44§§	< 0.01
PP/MP	22.9 ± 5.58	28.2 ± 8.00**	23.4 ± 8.77§§	< 0.01
ArGoMe	123.0 ± 5.91	135.5 ± 10.85***	127.5 ± 7.43*, §§§	< 0.001
ArGoN	49.9 ± 3.20	51.3 ± 8.76	50.8 ± 5.61	ns
NGoMe	73.0 ± 4.58	82.4 ± 7.79***	76.6 ± 4.45**, §§§	< 0.001
NSAr	123.5 ± 6.66	125.1 ± 10.83	125.3 ± 8.51	ns
SArGo	144.3 ± 6.32	138.3 ± 11.92*	139.3 ± 10.63*	< 0.05
Bjork's sum	390.9 ± 5.31	398.8 ± 9.91**	392.1 ± 5.97§§	< 0.001
NAPg	176.8 ± 1.86	172.0 ± 5.70 **	170.7 ± 6.39***	< 0.001

SNA – anteroposterior position of the maxilla relative to the anterior cranial base; SNB – anteroposterior position of the mandible relative to the anterior cranial base; ANB – the relationship of the maxilla and mandible in the sagittal plane; N-S/PP – the inclination of the maxilla to the anterior cranial base; N-S/MP – the inclination of the mandible to the anterior cranial base; FH/MP – the relationship between the Frankfurt plane and mandibular plane; PP/MP – the relationship between the basic jaw planes; ArGoMe – gonial angle by Bjork; ArGoN – upper part NSAr – the angle of the saddle by Bjork; SArGo – articular angle by Bjork; Bjork's sum – the sum of the angles NSAr, SarGo, and ArGoMe; NAPg – the angle of facial skeletal convexity.
p* – *,**, *p* < 0.05, 0.01, 0.001 vs. control, §, §§, §§§ *p* < 0.05, 0.01, 0.001 vs. analyzed group before operation; ns – non significant (ANOVA test and *post hoc* Tukey test).**

Discussion

The main objectives of the surgical treatment in patients with mandibular prognathism are to normalize the facial profile, harmonize the occlusion, and rehabilitate the basic functions of the orofacial system. Correction of the main skeletal parameters within the normal range of values is usually regarded as the main aim of the treatment.

Choosing a surgical technique is certainly one of the key factors for a successful realization of these objectives. Bearing in mind the extreme variability of the craniofacial morphology in patients with mandibular prognathism [2–4], it is clear that the modality of surgical treatment must be appropriate to the basic phenotypic characteristics of the present deformity [9–15].

The modality of surgical treatment in this study was determined after a detailed clinical and cephalometric analysis in each subject. In all subjects of the analyzed group, the Le Fort I maxillary advancement is associated with mandibular setback osteotomy [9, 17, 18].

The evaluation of certain skeletal variables in the experimental group before surgery revealed that 40% of subjects had a significantly decreased SNA angle in relation to biometric standards and that maxillary length was decreased in 55% of subjects. In 85% of subjects, the relationship of the mandible to the anterior cranial base (NS/MP angle) was typical of mandibular prognathism associated with vertical discrepancies. The average value of ANB angle in the analyzed group before the operation amounted to -4.7 ± 3.04°. In 75% of subjects in this group, the deformity was a combination of maxillary retrognathia and mandibular prognathism [9].

A comparative analysis of the selected skeletal variables in the analyzed group, 6 months to one year after surgery with the values of the same variables before surgery, showed that bimaxillary operations changed more linear and angular dimensions, characteristic for mandibular prognathism. This operative procedure significantly altered the position of the maxilla and mandible in the sagittal plane, and vertically the length of the mandible and its relation to the anterior cranial base. The total anterior and lower anterior face height were reduced by 5 mm on average. The specificity of this operation is a significant increase of total posterior and lower posterior face height (by 3–4 mm on average) and the length of the posterior cranial base S-Ar. These alterations normalized the relationship between the anterior and posterior face heights and led to the harmonization of facial dimensions in operated patients. These results are consistent with the results of numerous studies which indicate the significant harmonization of facial dimensions after bimaxillary operations [11–16, 19, 20].

The significant increase of posterior face height in operated patients, especially the increase of lower posterior face height, and the posterior cranial base is a result of the anterior rotation of the proximal segment of the mandible during the bilateral ramus osteotomy, which is necessary in order to establish normal occlusal relationships.

Introducing Le Fort I osteotomy in the operative procedure significantly changed the values of SNA, SNB, ANB angles, and the angle of skeletal convexity NAPg. In that manner, bimaxillary surgery significantly altered the typical imbalance in anterior-posterior skeletal relationships in patients with mandibular prognathism. After the operation, the SNA angle increased by 4° on average, which is the specificity of bimaxillary surgical correction of mandibular prognathism. SNB angle after surgery was reduced on average by slightly more than 2° but is still higher than the biometric standard. The values of ANB angle in the analyzed group after operation increased by 6° on average, but they are still below optimum. Johnston et al. [19] also stated that values of SNA, SNB, and ANB angles after bimaxillary surgery showed significant improvement, but in 54% of treated patients, ANB angle values are still below the ideal, while 52% of patients still have great values of SNB angle.

Bimaxillary surgery also reduced the most vertical components of mandibular prognathism. Significant reduction of NS/MP, FH/MP, ArGoMe, ArGoN angles, and Bjork's sum normalized the positions of maxilla and mandible to the anterior cranial base and the mutual relation of the jaws vertically, as confirmed by other studies [14–16, 19, 20].

According to the literature, the efficiency of an operation has been expressed in the percentage of patients who have certain cephalometric dimensions brought into the framework of ideal or acceptable norms [19]. In the context of this study, the efficacy of bimaxillary surgery has been evaluated by comparing the tested skeletal parameters in the analyzed group after surgery with the values of these parameters in the control group.

These analyses revealed that values of most examined variables after surgery were significantly closer to their values in subjects of the control group. This is especially true for the values of the total anterior and posterior face heights, and the angles SNA, NS/PP, NS/MP, FH/MP, PP/MP, ArGoN, and Bjork's sum. These changes significantly altered the typical skeletal assembly of mandibular prognathism and contributed to the overall physiognomic effect in operated patients. Similar results were reported by Johnston et al. [19], Marsan et al. [15], Jakobsone et al. [16], Al-Gunaid et al. [14], and Aydemir et al. [20].

However, the operation did not remove all skeletal features of prognathism. The lengths of anterior and posterior cranial bases, the length of the ramus, and to some extent the length of the mandibular body after surgery are characteristic of mandibular prognathism. The values of the angles SNB, ANB, ArGoMe, NgoMe, and NS/MP even after surgery differ from their values in the control group. These findings are consistent with the results of Johnston et al. [19], Al-Gunaid et al. [14], and Sinobad et al. [9], who also found that surgical treatment did not lead to the full normalization of these skeletal dimensions.

Conclusion

Investigations in this study have confirmed that bimaxillary surgery significantly altered the large number of linear and angular dimensions that characterize mandibular prognathism. They normalized the overall anterior and posterior face heights in operated patients and their relationships. The maxillary advancement accompanied by mandibular setback osteotomy significantly altered the sagittal jaw relationship and normalized the overall skeletal facial convexity. The results of this study confirmed the reduction of most vertical components of mandibular prognathism. Reducing the angular values NS/MP, FH/MP, ArGoMe, ArGoN, and Bjork's sum normalized the positions of maxilla and mandible to the anterior cranial base and the mutual relation of the jaws vertically. After bimaxillary operations, the values of most linear and angular skeletal variables were significantly closer to or even completely identical with the values of these variables in patients with normal occlusion.

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