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Skeletal changes in patients with mandibular prognathism after mandibular set back and bimaxillary surgery – A comparative cephalometric study

Skeletne promene kod bolesnika sa mandibularnim prognatizmom nakon mandibularne i bimaksilarne hirurgije – komparativna rendgenkraniometrijska studija

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Abstract

Bacground/Aim. Recently, maxillary and bimaxillary surgery gained the primacy in the surgical correction of class III deformities. The aim of this investigation was to compare the changes in the skeletal relationships in patients with mandibular prognathism after bimaxillary surgery. **Methods.** The study included 70 subjects divided into three groups. Twenty class III patients of the experimental group 1 underwent bilateral sagittal ramus osteotomy and twenty patients of the experimental group 2 were subjected to bimaxillary surgery. The control group consisted of 30 subjects with skeletal class I and physiological occlusion. Cephalometric research was conducted on 110 lateral cephalometric radiographs made in subjects of the experimental groups 1 and 2 before and after surgery and in subjects of the control group. Using the computer program "Dr. Ceph", 30 linear and angular skeletal variables were analyzed on each radiograph. **Results.** Bimaxillary osteotomies changed most of variables that characterize the mandibular prognathism. The changes in the sagittal plane included the significant increase of sella-nasion to the A point (SNA) angle (by 4º on the average) and the A point to B point (ANB) angle (6°), and significant reduction in angles sella-nasion to the B point (SNB) (3º), gonial angle (ArGoMe) (8°), gonial angle inferior (NGoMe) (6.2º), and Björks sum (7°). The vertical relationships were normalized by significant reduction in overall anterior face height N-Me (by 5 mm on the average), the lower anterior face height ANS-Me (4 mm), significant increase in the total posterior face height S-Go (2.5–3 mm), lower posterior face height PNS-Go (4 mm), and significant reduction of the basal and mandibular plane angles. **Conclusion.** Compared to the isolated mandibular operations, bimaxillary surgery changes more efficiently the sagittal and vertical skeletal relations in patients with class III deformities and harmonizes more successfully the entire skeletal facial profile.

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

Apstrakt

Uvod/Cilj. Maksilarna i bimaksilarna hirurgija dobila je nedavno primat u hirurškim korekcijama deformiteta klase III. Cilj ovog istraživanja je bio da se uporede promene u skeletnim odnosima kod bolesnika sa mandibularnim prognatizmom posle bimaksilarne operacije. **Metode.** Ispitivanjem je obuhvaćeno 70 ispitanika podeljenih u tri grupe. Dvadeset ispitanika klase III eksperimentalne grupe 1 podvrgnuto je bilateralnoj sagitalnoj ramus osteotomiji, a dvadeset ispitanika eksperimentalne grupe 2 podvrgnuto je bimaksilarnoj operaciji. Kontrolnu grupu činilo je 30 ispitanika sa skeletnom klasom I i fiziološkom okluzijom. Rendgen-kraniometrijsko istraživanje obavljeno je na 110 bočnih telerendgen snimaka urađenih kod ispitanika u eksperimentalnim grupama 1 i 2 pre i posle operacije i ispitanika kontrolne grupe. Koristeći kompjuterski program „Dr.Ceph", na svakom telerendgenu analizirano je 30 linearnih i ugaonih skeletnih varijabli. **Rezultati.** Bimaksilarna osteotomija promenila je većinu varijabli koje karakterišu mandibularni prognatizam. Promene u sagitalnoj ravni uključuju značajan porast ugla maksilarnog prognatizma (SNA) (od 4º u proseku) i ugla gagitalnog odnosa tela gornje i donje vilice (ANB) ugla (6°), značajno smanjenje uglova

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ugao mandibularnog prognatizma (SNB) (3º), ganialnog ugla (ArGoMe) (8°), donjeg gonialnog ugla (NGoMe) (6,2º), i Bjorkovog poligona (7°). Vertikalni odnosi su normalizovani značajnim smanjenjem ukupne prednje visine lica N-Me (od 5 mm u proseku), prednje donje visine lica (ANB-Me) (4 mm), povećanjem ukupne zadnje visine lica M-Go (2,5–3 mm), zadnje donje visine lice PNS-Go (4 mm), i značajnim smanjenjem mandibularnih uglova. **Zaključak.** U poređenju sa izolovanom mandibularnom operacijom bimaksilarna hirurgija menja efikasnije sagitalne i vertikalne skeletne odnose kod bolesnik sa deformitetima klase III i uspešnije harmonizuje ceo skeletni profil lica.

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

Introduction

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 those with mandibular prognathism [1].

The treatment modalities in patients with class III deformities have been altered and perfected over the time. It turned out that efforts of classical orthodontic therapy in the childhood and adolescence were often insufficient to achieve optimal functional and aesthetic results in these patients [2]. The decision to apply a surgical treatment depends on many factors which include primarily phenotypic characteristics of the present deformity, age of the patient, and then, various psychological and social moments.

Investigation of phenotypic characteristics of class III deformities have revealed the great variety of underlying skeletal and dental patterns that are mainly related to different ethnical groups. In the majority of cases, class III deformities are the combination of maxillary retrognathia, mandibular prognathism and varying degrees of vertical dyscrepances [3–5].

The results of these researches significantly changed approaches and modalities in correcting class III deformities. Until the 80s of the last century, isolated mandibular operations were commonly used in surgical correction of mandibular prognathism, because the opinion prevailed that increased mandible was the primary cause of deformity. Beginning with Obwegeser who introduced the bilateral sagittal split ramus osteotomy (BSSRO) in the early sixties of the last century, this surgical technique has been until today successfully used in correcting class II and III deformities. The procedure and the numerous advantages of this method are detailed in scientific literature sources [6–8]. The fact is, however, that this operation does not provide the best results for all patients with class III deformities. Numerous studies indicate that most of the skeletal dimensions in these patients even after surgery remain typical of mandibular prognathism [9–11].

Extensive research of craniofacial morphology in patients with class III deformities and improvement of surgical techniques resulted in new trends in their surgical correction [1, 12–14]. In the recent years maxillary and bimaxillary surgery gained primacy in the surgical correction of class III deformities and the adequate orthodontic preparation became a necessary overture to a successful surgical correction [14–18].

The aim of this investigation was to compare the changes in the skeletal relationships in patients with mandibular prognathism after BSSRO with changes in these relations after bimaxillary surgery, in order to objectively examine the results of each of these operative techniques and accurately define the indication area for each of them.

Methods

The Ethical Review Board of our Faculty of Dental Medicine had approved this study.

The sample of the present study comprised 70 subjects divided into three groups: two experimental groups and the one control group. Each experimental group (1 and 2) consisted of 20 patients, mean age 19.8 ± 5.3 years, who were admitted at the Department of Maxillofacial Surgery, Faculty of Dental Medicine in Belgrade, for surgical correction of mandibular prognathism in the period from 2003–2013. The control group consisted of 30 young persons, mean age 21.5 ± 3.5 years, with skeletal class I and physiologic occlusion.

For the purposes of cephalometric research, totally 110 lateral cephalometric radiographs were made and divided into five groups (the groups A1, B1, A2, B2 and C).

The group A1 consisted of 20 lateral cephalometric radiographs derived from the patients of the experimental group 1 [patients underwent bilateral sagittal ramus osteotomy according to Obwegeser and Dal Pont (BSSRO)] before surgery and before orthodontic preparation. Diagnosis of mandibular prognathism in this group was based on the analysis of linear and angular skeletal parameters – the basic indicators of prognathism [anterior total facial height (N-Me) = 122.7 ± 7.78 mm; anterior lower facial height (ANS-Me) = 71.1 ± 6.13 mm; length of mandibular body (Go-Me) = 77.2 ± 7.01 mm; posterior total facial height (PNS-A) = 43,2 ± 4,00 mm; posterior total facial height (S-Go) = 78.4 ± 7.3 mm; anterioposterior position of the maxillar relative to the anterior cranial base (SNA) = 81.2 ± 4.36º; anterioposterior position of the mandible relative to the anterior cranial base (SNB) = 85.9 ± 5.60º; relationsip of the maxilla and mandible in the sagital plane (ANB) = -4.7 ± 2.50º; gonial angle by Bjö rk (ArGoMe) = 132.7 ± 7.91º; Björks sum = 385.9 ± 6.60º)] [11]. The Group B1 consisted of 20 lateral cephalometric radiographs derived from the same patients of the experimental group 1, 6 months to a year after bilateral sagittal ramus osteotomy.

The group A2 (consisted of 20 lateral cephalometric radiographs derived from the patients of the experimental group 2 (patients operated on by bimaxillary approach that involved Lefort I osteotomy of the maxilla and bilateral sagittal ramus osteotomy of the mandible) before surgery and before orthodontic preparation. Diagnosis of mandibular prognathism in this group was based on the analysis of linear and angular skeletal parameters – the basic indicators of prognathism (N-Me = 124.0 ± 6.89 mm; ANS-Me = 71.0 ± 6.45 mm; Go-Me = 77.6 ± 6.53 mm; PNS-A = 43.6 ± 3.56 mm; S-Go = 76.6 ± 5.20 mm; SNA = 79.2 ± 4.66º; SNB = 84.0 ± 4.38º; ANB = -4.7 ± 3.04º; ArGoMe = 135.5 ± 10.85º; Björks sum = 398.8 ± 9.91º) [18].

The group B2 consisted of 20 lateral cephalometric radiographs derived from the same patients of the experimental group 2, 6 months to a year after bimaxillary surgery.

The group C consisted of 30 lateral cephalometric radiographs made in subjects of the control group. This collection was selected from the files of our dental school (archive of the author).

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

The choice of operative technique

All subjects of the experimental groups were referred to presurgical orthodontic therapy for a period of one and a half year, and then subjected to surgical correction.

Analysis of linear and angular skeletal parameters in the experimental groups A1 and A2 indicated that mandibular prognathism in both experimental groups showed similar chephalometric parameters. The fact is, however, that some specificities were observed in the experimental group A2. The analyses of linear skeletal parameters showed that the total anterior face height and lower anterior face height were greater in the group A2 than in the group A1. The posterior face height was lower in the experimental group A2 than in the group A1.

The analyses of angular sceletal parameters showed lower mean values of SNA angle in the experimental group A2 than in the group A1, and mean values of Björks sum where greater in the experimental group A2 then in the group A1 [18].

The previous research indicated that in the experimental group A2 before surgery, there were significantly more subjects with SNA angle values below the biometrick norm (40%), and significantly less subjects with SNA values within the biometric norm (25%). As SNA angle is one of the indicators of sagittal maxillary position, it could be concluded that 40% of subjects in the experimental group A2 had a pronounced maxillary retrusion.

According to these values, the largest number of subjects in the experimental group A2 had an underdeveloped maxilla associated with the pronounced mandible (over 50%) or normally developed mandible (25%). Increased vertical facial dimension was found in 85% of subjects [18].

The results of preliminary cephalometric research in the experimental group A1 were decisive for the selection of surgical techniques in this group. As the deformity in patients of the experimental group A2 was mainly due to deficient maxilla, normally developed or pronounced mandible, with differently expressed increased vertical face parameters of viscerocranium, a successive bimaxillary approach was used in surgical correction.

The subjects in the experimental group 1 underwent bilateral sagittal ramus osteotomy according to Obwegeser and Dal Pont (BSSRO). A wire fixation was used to fix the bone fragments. After surgery, a combination of solid and elastic intermaxillary immobilization was applied for a period of 6–8 weeks.

The surgical procedure in subjects of the experimental group 2 was performed by a successive bimaxillary approach that involved Lefort I osteotomy of the maxilla and bilateral sagittal ramus osteotomy of the mandible. The rigid fixation (mini titanium plates and screws) were used to fix the bone fragments. A combination of solid and elastic intermaxillary immobilization was applied for a period of 6–8 weeks after surgery.

Cephalometric analysis

All lateral cephalograms, made in the experimental groups 1 and 2 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).

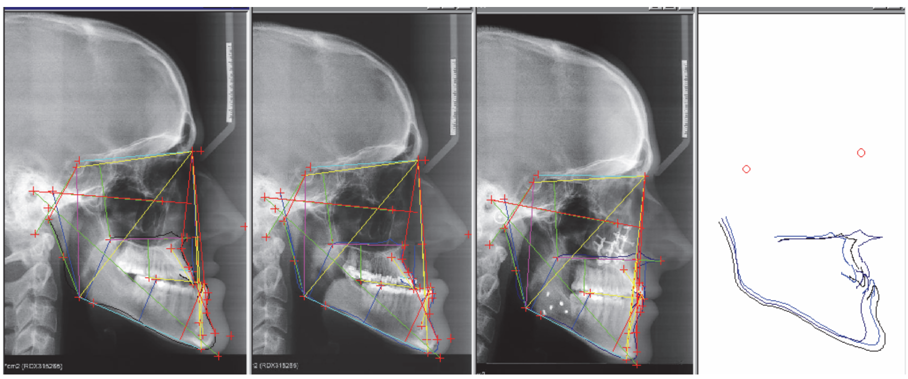

Fig. 1 – Cephalometric analysis of parameters by the „Dr.Ceph" computer software.

Thanks to the possibilities of the computer software "Dr Ceph", on each cephalogram (the groups: A1, B1, A2, B2 and C) the values of 30 linear (Figure 2) and angular (Figure 3) skeletal variables and proportions of certain linear parameters were recorded and evaluated.

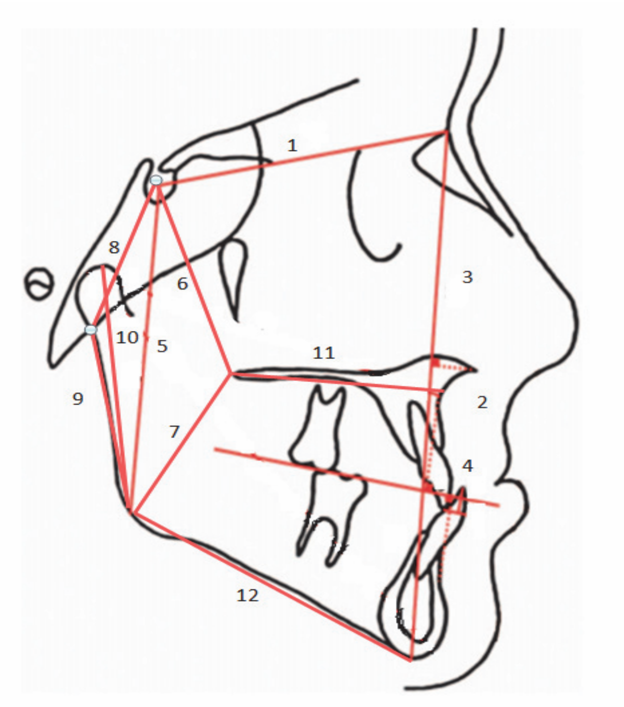

Fig. 2 – Examined linear variables:

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

Numerical values of the examined skeletal variables were subjected to statistical analysis and compared. To verify the changes in skeletal relationships due to surgical correction, the values of selected skeletal variables derived from subjects of the experimental groups 1 and 2 were compared before and 6 month after surgery. The results of this part of investigation are presented in previous studies [11, 18].

In this paper the mean postoperative values of investigated skeletal variables were compared between the experimental groups 1 and 2 and the control group in order to evaluate the success of applied surgical technique in correcting the mandibular prognathism.

In adition, the quantitative differences in the values of examined variables before and after surgery were evaluated in groups operated by different surgical techniques.

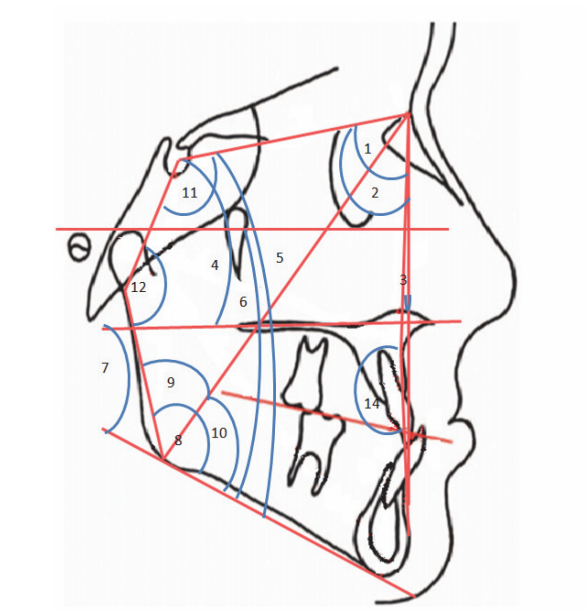

Fig. 3 – Examined angular variables:

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 – relationship of the maxilla and mandible in the sagittal plane;
4. N-S/PP – inclination of the maxilla to the anterior cranial base;
5. N-S/MP – 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 Björk;
9. ArGoN – upper part of the gonial angle;
10. NGoMe – lower part of the gonial angle;
11. NSAr – angle of the saddle by Björk;
12. SArGo – articular angle by Björk;
13. Björk sum – the sum of the angles NSAr, SArGo and ArGoMe;
14 NAPg – angle of facial skeletal convexity.

Results

Comparison of mean values of linear skeletal variables in patients treated with BSSRO with the mean values of these variables in patients operated by bimaxillary osteotomies revealed the significant differences in postoperative values of 8 linear skeletal variables: S-Go, PNS-Go, S-Ar, Ar-Go, Co-Go, S-Go/N-Me, PNS-A and Go-Me (Table 1).

The anterior total facial height N-Me, and the anterior lower facial height ANS-Me were significantly reduced by both operative techniques compared to the situation before surgery, although the reduction was greater after bimaxillary surgery (Table 2). Unlike BSSRO which had no impact on dimensions of the posterior facial height, bimaxillary surgery increased significantly the posterior total facial height (S-Go) ($d = 2.67 \pm 3.52$ mm) and the posterior lower facial height (PNS-Go) ($d = 4.1 \pm 1.39$ mm) (Table 2).

Table 1

Comparison of mean values of linear skeletal variables and proportions of certain linear parameters after BSSRO (the experimental group 1) and after bimaxillary surgery (the experimental group 2) with the values in the control group

Variables	Control group mean ± SD	Experimental group 1 mean ± SD	Experimental group 2 mean ± SD	ANOVA-test *p*	
N-Se	63.7 ± 6.3	65.0 ± 4.5	66.8 ± 4.7	0.236	ns
N-Me	114.9 ± 8.5	119.7 ± 10.3	118.9 ± 7.8	0.132	ns
N-ANS	50.3 ± 4.6	51.3 ± 3.9	52.1 ± 5.1	0.452	ns
ANS-Me	64.5 ± 5.8	68.4 ± 7.7	66.7 ± 6.5	0.102	ns
S-Go	78.5 ± 5.9	77.3 ± 6.6[a]	79.3 ± 7.1[b]	0.046	< 0.05
S-PNS	44.0 ± 3.4	45.8 ± 4.4	44.7 ± 4.1	0.255	ns
PNS-Go	44.4 ± 4.18	41.1 ± 4.45[a]	42.8 ± 5.87[b]	0.036	< 0.05
S-Ar	36.1 ± 3.6	33.1 ± 3.7[a]	31.2 ± 5.1[a]	0.029	< 0.05
Ar-Go	46.4 ± 4.7	52.9 ± 5.2[aaa]	48.2 ± 4.7[bb]	0.0004	< 0.001
Co-Go	57.9 ± 5.0	60.9 ± 4.8	62.0 ± 5.9[a]	0.018	< 0.05
S-Go/N-Me	0.685 ± 0.043	0.652 ± 0.073[a]	0.700 ± 0.060[b]	0.021	< 0.05
N-ANS/ANS-Me	0.779 ± 0.071	0.755 ± 0.075	0.775 ± 0.095	0.356	ns
N-ANS/N-Me	0.438 ± 0.025	0.429 ± 0.024	0.436 ± 0.031	0.245	ns
ANS-Me/N-Me	0.562 ± 0.025	0.572 ± 0.024	0.564 ± 0.031	0.212	ns
PNS-A	44.5 ± 3.4	42.7 ± 4.0	46.7 ± 4.0[bb]	0.006	<0.01
Go-Me	70.2 ± 5.5	72.1 ± 7.0	74.7 ± 6.3[a]	0.047	<0.05

BSSRO – bilateral sagittal ramus osteotomy according to Obwegeser and Dal Pont; N-Se – length of the Anterior Cranial base; N-Me – anterior total facial height; N-ANSL anterior upper facial height; ANS-Me – anterior lower facial height; S-Go – posterior total facial height; S-PNS – posterior upper facial height; PNS-Go – posterior lower facial height; S-Ar – lenght of the posterior cranial base; AV-GO – lenght of the ramus; Co-Go – height of the ramus; S-Go/N-Me – posterior total lower faciheight/anterior total facial height; N-ANS/ANS-Me – anterior upper facial height/anterior lower facial height; N-ANS/N-Me – anterior upper facial height/anterior botal facial height; ANS-Me/N-Me – anterior lower facial height/anterior total facial height; PNS-A – lenght of the maxillary body; Go-Me – lenght of the mandibular body. – analysis of variance.

[a, aa, aaa] – *p* < 0.05, 0.01, 0.001 – significant difference in relation to the control group; [b, bb, bbb] – *p* < 0.05, 0.01, 0.001 – significant difference in relation to the experimental group 1 (BSSRO).

Table 2

Differences in the values of linear skeletal variables before and after surgery in groups operated on by various surgical techniques

Variables	dA1-B1 ± SD (BSSRO)	dA2-B2 ± SD (Bimaxillary surgery)	*t* - test *p*	
N-S	-1.24 ± 3.43	0.03 ± 0.08	0.224	ns
N-Me	-3.01 ± 6.75	-5.07 ± 6.58	0.358	ns
N-ANS	-0.28 ± 3.12	-0.88 ± 3.25	0.258	ns
ANS-Me	-2.67 ± 5.06	-4.32 ± 6.09	0.125	ns
S-Go	-0.90 ± 4.62	2.67 ± 3.52	0.009	**
S-PNS	-0.49 ± 2.44	-0.21 ± 2.57	0.244	ns
S-Ar	0.05 ± 3.13	0.77 ± 1.51	0.315	ns
Ar-Go	-1.56 ± 4.80	0.03 ± 6.10	0.533	ns
Co-Go	-1.49 ± 4.19	0.19 ± 6.25	0.474	ns
SGo/N-Me	0.009 ± 0.043	0.033 ± 0.044	0.033	*
N-ANS/ANS-Me	0.023 ± 0.056	0.017 ± 0.082	0.369	ns
N-ANS/N-Me	0.005 ± 0.019	0.007 ± 0.027	0.327	ns
ANS-Me/N-Me	-0.005 ± 0.019	-0.007 ± 0.027	0.444	ns
PNS-A	-0.51 ± 1.92	3.09 ± 3.17	0.0003	***
Go-Me	-5.06 ± 4.98	-2.92 ± 3.61	0.221	ns
PNS-Go	1.2 ± 0.16	4.1 ± 1.39	0.0002	***

BSSRO – bilateral sagittal ramus osteotomy according to Obwegeser and Dal Pont; 1 – the experimental group 1 (BSSRO); 2 – the experimental group 2 (bimaxillary surgery);
A – before surgery; B – 6 months after surgery; d – differences between experimental groups; N-S – lenght of anterior cranial base; N-Me – anterior total facial height; N-ANS – anterior upper facial height; ANS-Me– anterior lower facial height; S-Go – posterior total facial height; S-PNS – posterior upper facial height; S-Ar – lenght of the posterior cranial base; Ar-Go – lenght of the ramus; Co-Go – height of the ramus; SGo/N-Me – posteror total facial height/anterior total facial height; N-ANS/ANS-Me – anterior upper facial height/anterior lower facial height; N-ANS/N-Me – anterior upper facial ehight/anterior total facial height; ANS-Me/N-Me – anterior lower facial height/anterior total facial height; PNS-A – length of the maxillary body; Go-Me – length of the mandibular body; PNS-Go – posterior lower facial height.
significance levels: *p < 0.05, **p < 0.01, ***p < 0.001, ns – not significant.

The relationship between posterior and anterior total facial heights after bimaxillary surgery changed in favor of posterior facial height, which led to harmonization of facial dimensions in operated patients. After bimaxillary surgery the values of these linear variables were very similar to the values of the same variables in the control group.

Length of the posterior cranial base (S-Ar) was slightly increased by bimaxillary surgery, but even after the surgery the value of this variable was significantly lower than that value in the control group.

Length and height of the mandibular ramus (Ar-Go) and (Co-Go) did not change significantly after operative techniques used, although the mean value of the ramus lenght Ar-Go was much closer to its value in the control group after bimaxillary surgery (Table 1).

After LeFort I maxillary advancement, the effective length of the maxilla PNS-A was significantly increased when compared to the value before the operation. The length and the position of the maxilla did not change after BSSRO. On the contrary, the length of the mandibular body Go-Me was much more reduced by BSSRO, because the disharmony in jaw relations using this operative technique was compensated only by shortening the mandibular body and by set back of its proximal segment (Table 1). By analyzing the differences in the values of these variables before and after surgical procedures, it was obvious that maxilla was moved forward by Lefort I osteotomy by an average of 3.09 ± 3.17 mm, while the mandible within the same operation was moved distally to 2.92 ± 3.61 mm. On the contrary, with BSSRO, mandible was shortened by an average of -5.06 ± 4.98 mm, which was supposed to be a disadvantge of this operative procedure (Table 2).

Comparison of the mean values of angular skeletal variables in patients treated by BSSRO with the mean values of these variables in patients operated by bimaxillary osteotomies indicated that there were significant differences among 9 angular skeletal variables: SNB, ANB, NS/MP, FH/MP, PP/MP, ArGoMe, NGoMe, SArGo and NAPg (Table 3).

It turned out that bimaxillary surgery, compared to isolated operations on the mandible, changed far more efficiently the values of mentioned angular variables, and made them closer to their values in the control group. The amount of these changes was far more illustrative in the Table 4, which presents the differences in the values of examined angular variables after BSSRO and after bimaxillary surgery. After bimaxillary surgery, the angle SNA increased by an average of 4.5º, while BSSRO failed to change it. On the contrary, the angle SNB was much more reduced by BSSRO than by bimaxillary surgery, for the simple reason that with the first operative technique mandible was shortened and moved back to more than 5 mm, which consequently led to distal shift of the point B.

The angle ANB was more significantly normalized by bimaxillary surgery, where the difference between the pre- and postoperative values amounted to around 6º. This was a direct result of an increase in the SNA angle after Lefort I maxillary advancement and reduction of the SNB angle by bilateral sagittal ramus osteotomy in the same operative procedure.

Table 3

Comparison of mean values of angular skeletal variables after BSSRO (the experimental group 1) and after bimaxillary surgery (the experimental group 2) with the values in the control group

Variables	Control group mean ± SD	Experimental group 1 mean ± SD	Experimental group 2 mean ± SD	ANOVA test *p*	
SNA	81.4 ± 3.4	81.6 ± 4.1	83.8 ± 5.6	0.360	ns
SNB	79.3 ± 3.1	81.6 ± 4.3[a]	82.8 ± 4.7[aa]	0.003	< 0.01
ANB	2.22 ± 1.31	-0.03 ± 1.11[aaa]	1.42 ± 1.23[bb]	0.0004	< 0.001
NS/PP	8.3 ± 3.5	7.2 ± 3.5	9.2 ± 5.6	0.255	ns
NS/MP	30.7 ± 5.6	35.0 ± 8.1[a]	33.4 ± 7.2	0.033	< 0.05
FH/MP	23.3 ± 5.6	27.3 ± 7.4[a]	24.3 ± 6.4	0.028	< 0.05
PP/MP	22.9 ± 5.6	28.0 ± 8.7[a]	23.5 ± 8.8[b]	0.022	< 0.05
ArGoMe	123.1 ± 5.9	130.5 ± 10.0[aa]	127.5 ± 7.4	0.005	< 0.01
ArGoN	50.0 ± 3.2	51.4 ± 5.7	50.8 ± 5.6	0.169	ns
NGoMe	73.1 ± 4.6	79.1 ± 6.5[aaa]	76.7 ± 4.5	0.0006	< 0.001
NSAr	123.5 ± 6.7	120.3 ± 6,8	125.3 ± 8.5	0.211	ns
SArGo	144.3 ± 6.3	144.0 ± 8.4	139.3 ± 10.6[a]	0.023	< 0.05
Björk sum	390.9 ± 5.3	394.7 ± 8.4	392.1 ± 6.0	0.364	ns
NAPg	176.8±1.86	174.0 ± 4.2[a]	170.8 ± 6.4[aa,b]	0.007	<0.01

BSSRO – bilateral sagittal ramus osteotomy according to Obwegeser and Data Pont; SNA – anteroposterior position of the maxilla relative to the anterior cranial base; SNB – antеropsterior position of the mandible relative to the anterior cromal base; ANB – relationship of the maxilla and mandible in the sagital plane; NS/PP – inslination of the masilla to the anterior cranial base; NS/MP – inclination of the madible to the anterior chronial base; FH/MP – the ralationship between the Frankfurt plane and mandibular plane; PP/MP – the selationship between the basic jaw planes; ArGoMe – gonial angle by Björk; ArGoN – upper fast of the gonial angle; NGoMe – lower past of the gonial angle; NSAr – angle of the saddle by Björk; SArGo – articular angle by Björk; NAPg – angle of facial seeletal convexity.

[a, aa, aaa] – $p < 0.05$, 0.01, 0.001 – significant difference in relation to the control group; [b, bb, bbb] – $p < 0.05$, 0.01, 0.001 – significant difference in relation to the experimental group 1 (BSSRO).

Table 4
Differences in the values of angular skeletal variables before and after surgery in groups operated by various surgical techniques

Variables	dA1-B1 ± SD (BSSRO)	dA1-B1 ± SD (Bimax. sur.)	*t*-test	*p*
SNA	0.2 ± 1.3	4.5 ± 3.2	0.00003	***
SNB	-4.4 ± 2.5	-1.3 ± 3.0	0.00042	***
ANB	4.7 ± 2.0	-3.4 ± 3.5	0.00002	***
NS/PP	0.5 ± 2.0	0.4 ± 5.0	0.766	ns
NS/MP	0.1 ± 6.3	-3.8 ± 6.9	0.033	*
FH/MP	-1.8 ± 8.2	-4.7 ± 6.5	0.322	ns
PP/MP	-0.2 ± 6.0	-4.7 ± 7.4	0.024	*
ArGoMe	2.2 ± 10.3	-8.0 ± 6.7	0.012	*
ArGoN	-0.9 ± 5.2	-0.5 ± 8.6	0.288	ns
NGoMe	-1.3 ± 6.9	-5.7 ± 5.5	0.011	*
NSAr	1.3 ± 5.4	0.2 ± 6.1	0.711	ns
SArGo	0.8 ± 8.9	0.9 ± 10.4	0.622	ns
Björk sum	-0.2 ± 6.1	-6.7 ± 9.2	0.039	*
NAPg	-6.1 ± 4.8	-1.3 ± 10.0	0.005	**

BSSRO – bilateral sagittal ramus osteotomy according to Obwegeser and Data Pont; the experimental group 1 (BSSRO); 2 – the experimental group 2 (bimaxillary surgery); A – before surgery; B – 6 months after surgery; d – differences between experimantal groups; SNA – anteroposterior position of the maxilla relative to the anterior cranial base; SNB – anteropsterior position of the mandible relative to the anterior cromal base; ANB – relationship of the maxilla and mandible in the sagital plane; NS/PP – inslination of the masilla to the anterior cranial base; NS/MP – inclination of the madible to the anterior chronial base; FH/MP – the ralationship between the Frankfurt plane and mandibular plane; PP/MP – the selationship between the basic jaw planes; ArGoMe – gonial angle by Björk; ArGoN – upper fast of the gonial angle; NGoMe – lower past of the gonial angle; NSAr – angle of the saddle by Bjö rk; SArGo – articular angle by Björk; NAPg – angle of facial seeletal convexity.
significance levels: *$p < 0.05$, ** $p < 0.01$, *** $p < 0.001$, ns – not significant.

Bimaxillary surgery reduced also more efficiently angular values NS/MP, FH/MP, PP/MP, ArGoMe, NGoMe and Björk sum, what can be seen by comparing the differences between pre- and postoperative values of these angles after each operative technique (Table 4). After bimaxillary surgery, these angular values were much closer to their values in the control group, while after BSSRO their values remained characteristic for mandibular prognathism (Table 3).

Comparison of differences in pre- and postoperative values of these angles revealed that the NS/MP angle after bimaxillary surgery decreased nearly for 4º, the relationship between the Frankfurt plane and mandibular plane (FH/MP) and the relationship between the basic jow planes (PP/MP) angles for almost 5º, the ArGoMe angle for 8º, the NGoMe for almost 6º and Björk sum by approximately 7º. After BSSRO the values of these angles remained almost unchanged (Table 4).

It is interesting that the angle of skeletal convexity NAPg was much more reduced after BSSRO than after bimaxillary surgery as a result of greater distal displacement of the proximal mandibular segment and the point PG during bilateral sagittal ramus osteotomy.

Discussion

Cephalometric studies indicate the high variaty of skeletal morphology in patients with class III deformities. In various ethnic groups, these deformities are presented in different phenotypic forms that have an obvious genetic background [3–5]. In accordance with a large number of studies, in 50–60% of patients class III deformities are the combination of maxillary retrognathia, mandibular prognathism and varying degrees of vertical dyscrepances [3–5, 19, 20].

The results of these studies have significantly changed approaches and modalities in correcting class III deformities. The isolated mandibular operations have been used for years in surgical correction of mandibular prognathism. Today, most clinicians and researchers prefer the maxillary and bimaxillary surgery. Advantages and disadvantages of these operative procedures in correcting class III deformities are still debated in the professional literature and in clinical practice.

This study was conducted in order to compare the results of bilateral sagittal ramus osteotomy (BSSRO) and the results of bimaxillary operations in patients who were operated at the Clinic for Maxillofacial Surgery at the Faculty of Dental Medicine in Belgrade. A detailed overview of the results related to these operative techniques in correcting mandibular prognathism is presented in the master's and doctoral thesis of the author [11, 18].

Comparison of outcomes of bimaxillary surgery and BSSRO in correcting the class III deformities in this study clearly speaks in favor of bimaxillary surgery. Comparative analysis of mean values of selected linear and angular skeletal variables after surgery revealed that BSSRO altered significantly only 2 linear variables (the lower anterior face height ANS-Me and the length of the mandible Go-Me) and three angular variables (SNB, ANB and the angle of facial skeletal convexity - NAPg).

It turned out, that BSSRO neither had an effect on the overall posterior face height, the length of the mandibular ramus, the lenght of maxilla, nor on angular relationships between these cranial structures and the mandible. The values of gonial angles ArGoMe, NGoMe, the relationship of mandibular plane to the anterior cranial base SN/MP, and the values of the basal angle PP/MP are typical for mandibular prognathism after these operations.

Vukadinovic [21] in 1985, Gjorup and Athanasiu [22] in 1991, Pike and Sundheim [23] in 1997, Joss and Thuer [24] in 2008, Sinobad [11] in 2010, state similar results stressing that BSSRO could not solve the extreme vertical imbalance in facial proportions, often present in patients with class III deformities. The relationship of the mandible to the anterior cranial base, the basal angle and the relationship of the occlusal plane to the mandibular plane remain mostly unchanged after such operations.

Although the value of the ANB angle after this operation increased by an average of 4°, it still shows negative mean value (-0.03 + 1.11°), indicating that progeny jaw relationship persists in most treated patients. Similar postoperative values of this angle were found by Vukadinovic [21] in 1985. (-0.21°), Gjorup [22] in 1991. (0°), Pike and Sundheim [23] in 1997 (-0.3°), Joss and Thuer [24] in 2008 (-0.95°), Sinobad [11] in 2010 (-0.03 ± 1.11).

By comparing the mean values of examined skeletal variables in the experimental group 1 after BSSRO with the values of the same variables in the control group, significant differences in the values of most skeletal variables were observed, particularly to angles ANB, ArGoMe, NGoMe, basal angle PP/MP, as well as the relationship of mandibular plane to the anterior cranial base SN/MP, which after surgery remained typical for mandibular prognathism.

These results actually suggest that bilateral sagittal ramus osteotomy did not change essentialy the basic craniofacial skeletal assembly, typical for mandibular prognathism. Due to significant distal displacement of mandibular proximal segment (more than 5 mm) BSSRO changed significantly the jaw relationships in the sagittal plane and skeletal facial convexity. However, its impact on the vertical relationships was almost insignificant, what is in agreement with the results of similar studies [11, 21, 22, 25–27].

The fact is, however, that reduction of the lower anterior face height in treated patients, and thus the total anterior facial height, shortening of the mandible by an average of 5.7 ± 4.2 mm, an increase in ANB angle by an average of 4° and the angle of skeletal convexity NAPg by an average of 8.1° led to a significant correction of facial profile and thus the apearance of operated patients which is an undoubted success of this operation.

Unlike the BSSRO, bimaxillary surgery changed significantly 8 linear and almost all angular variables, which led to essential changes of skeletal relations and to harmonization of facial dimensions in operated patients. These operations alter in a specific way the effective lengths of the maxilla and mandible. Maxilla, and thus the middle segment of the face were moved forward on the average of 3.9 ± 3.17 mm, while the body of the mandible was shortened much less than after BSSRO, on the average of 2.9 ± 3.6 mm.

According to the results of some studies, a large amount of distal displacement and significant elongation of the last part of mandibular body after BSSRO may endanger the normal function of surrounding muscles (masseter, pterygoid. med., pterigomasseteric connection), which is a potential risk of subsequent relapse [24, 26]. The introduction of maxillary osteotomy reduces the need for large distal movement of the proximal mandibular segment and thus elongation of posterior mandibular body in the osteotomy site. This also reduces the need for large rotation of the proximal mandibular segment in order to compensate open bite in the frontal area, and optimise the lower anterior face height [16–18, 22, 25–28].

Specificity of bimaxillary operations was a significant increase in the total posterior and lower posterior face heights (on average by 2.67 ± 3.52 mm and 3.9 ± 1.3 mm, respectively) and length of the posterior cranial base S-Ar (on average by 0.77 ± 1.51 mm), which normalized the relationship between overall anterior and posterior face heights in operated patients. These dimensions remained unchanged after BSSRO.

Due to maxillary repositioning during Lefort I osteotomy, bimaxillary surgery changed significantly the angular values SNA, SNB and ANB. Judging by differences between the values of these variables after each operative procedure, the angle SNA was increased by an average of 4.5 ± 3.2º by LeFort I osteotomy, which is a specifity of this operative procedure and the SNB angle was reduced by an average of slightly more than 2º. This is in agreement with the results of Johnston et al. [26], Al Gunaid et al. [16], Al Delayme et al. [27], Sinobad [18], Aydil et al. [28], Van Sickls and Walender [29].

After isolated operations on the mandible the values of the SNA angle do not change, but changes in the values of SNB angle are far more significant, because of the greater distal displacement of the proximal mandibular segment [11, 21, 24]. The angle of facial skeletal convexity NAPg was also significantly changed after BSSRO due to greater distal displacement of the Pg point during this procedure. Similar results are found in other cephalometric studies [11, 22, 24–26].

Bimaxillary surgery reduced most of the vertical components of mandibular prognathism [30].

Judging by differences between the values of angles NS/MP, FH/MP, ArGoMe, ArGoN and Björk's sum after BSSRO and after bimaxillary surgery, it is obvious, that bimaxillary surgery reduced more efficiently these indicators of prognathism and made their values significantly closer to biometric standards. The SNA angle after bimaxillary osteotomy increased by 4.5 ± 3.2º, the angle NS/MP decreased by 3.8 ± 6.9º, the angle FH/MP decreased by 4.7 ± 6.5º, the ArGoMe decreased by 8.0 ± 6.7º, the NGoMe by 5.7 ± 5.5º and Björk's sum by 6.7 ± 9.2º. On the contrary, these angular values were almost unchanged after BSSRO.

However, bimaxillary operations did not eliminate all skeletal indicators of mandibular prognathism. The values of angles SNB and ANB after surgery were still significantly different from the biometric values. This is confirmed by Johnston et al. [26] who note that the values of SNB and ANB angles after bimaxillary surgery are significantly improved, but even after treatment, in 54% of patients the ANB angle values are still below the ideal, while 52% of patients still have the great values of the SNB angle.

Compared to many positive effects of bimaxillary surgery these are certainly nonsignificant disadvantages, but in any case, it should point to the need of much greater attention in the course of orthodontic preparation of these patients for surgical intervention and the orthodontist obligation to harmonize the occlusal relationships in the postoperative period.

Conclusion

Bimaxillary surgery changed more significantly the sagittal and vertical jaw relationships as well as relation of the jaws to the anterior cranial base compared to the isolated operations on the mandible. Most of linear and angular skeletal dimension, which had been deformed before surgery, after surgery were much closer to, or even the same as biometric standards.

Bimaxillary operations acted simultaneously on the middle and lower facial segment and therefore harmonized more successfully the facial dimensions and entire skeletal facial profile. The special benefits of these operations were the significant increase in the posterior facial height, posterior cranial base and thesaddle angle NSAr, as well as significant reduction of the value of Björks sum.

Le Fort I maxillary advancement had a particularly good effect in patients where deformity was caused by retrognathia and maxillary dysplasia. Anterior displacement of the maxilla surgically is moderate, reduced to a distance of about 3–3.5 mm. Distal displacepment of proximal mandibular segment was reduced to amounts of 3 mm on average, what is an advantage of bimaxillary surgery.

The isolated mandibular operations could not solve the extreme vertical imbalance in facial proportions, often present in patients with class III deformities. The relationship of the mandible to the anterior cranial base, the basal angle and the relationship of the occlusal plane to the mandibular plane remained mostly unchanged after such operations.

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