EDITORIAL

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Single Jaw Surgeries Performed in Treating Mandibular Prognathism – Literature Review

Operacje jednoszczękowe wykonywane w leczeniu progenii – przegląd piśmiennictwa

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A – concept, **B** – data collection, **C** – statistics, **D** – data interpretation, **E** – writing/editing the text, **F** – compiling the bibliography

Abstract

Progenism (mandibular prognathism) is a cranial-maxillary-occlusal disorder involving the excessive growth of the mandible in relation to the maxilla. This defect affects not only the facial appearance – protrusion of the chin and lower lip, but also may lead to different types of functional disorders, including dysfunction of the temporomandibular joint. This paper presents a historical background of the orthognatic surgeries applied for prognathism correction and an overview of current operative techniques as well as postoperative complications reviews. Currently, bilateral sagittal split osteotomy (BSSO) stands as the most popular surgical method in correction of mandibular prognathism. Despite the fact that the BSSO method is becoming increasingly popular, some centres in Poland and all over the world still tend to perform external vertical ramus osteotomy (EVRO) and intraoral vertical ramus osteotomy (IVRO). In majority of performed mandibular osteotomies complications are related with sensory disturbances within the area of inferior alveolar nerve and more commonly concern patients undergoing bilateral sagittal split osteotomy (**Dent. Med. Probl. 2013, 50, 4, 387–403**).

Key words: mandibular prognathism, surgical treatment, bilateral sagittal split osteotomy, vertical ramus osteotomy, complications.

Streszczenie

Progenia (przodożuchwie morfologiczne, prognatyzm żuchwy) jest wadą czaszkowo-szczękowo-zgryzową polegającą na nadmiernym wzroście doprzednim żuchwy w stosunku do szczęki. Wada ta wpływa negatywnie nie tylko na wygląd twarzy – wysunięcie bródki oraz dolnej wargi, lecz również może prowadzić do wystąpienia różnego rodzaju zaburzeń czynnościowych, w tym dysfunkcji stawów skroniowo-żuchwowych. W pracy przedstawiono rys historyczny dotyczący metod korekcji progenii oraz przegląd aktualnych technik zabiegowych z uwzględnieniem ich powikłań pooperacyjnych. Aktualnie najbardziej popularną metodą operacyjną jest obustronna strzałkowa osteotomia gałęzi żuchwy (bilateral sagittal split osteotomy – BSSO). Pomimo jej rozpowszechnienia nadal w niektórych ośrodkach zarówno w Polsce, jak i na świecie jest wykonywana operacja metodą obustronnej pionowej osteotomii gałęzi żuchwy z cięcia zewnątrzustnego (external vertical ramus osteotomy – EVRO) i wewnątrzustnego (intraoral vertical ramus osteotomy – IVRO). W większości przypadków osteotomii gałęzi żuchwy powikłania są związane z zaburzeniami czucia w obrębie nerwu zębodołowego dolnego i częściej dotyczą pacjentów poddawanych zabiegom obustronnej strzałkowej osteotomii gałęzi żuchwy (**Dent. Med. Probl. 2013, 50, 4, 387–403**).

Słowa kluczowe: przodożuchwie morfologiczne, metody chirurgicznego leczenia, obustronna strzałkowa osteotomia gałęzi żuchwy, pionowa osteotomia gałęzi żuchwy, powikłania.

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Progenism (mandibular prognathism) is a cranial-maxillary-occlusal defect associated with excessive anterior growth of the mandible in relation to the maxilla as classified by Orlik-Grzybowska [1] it is enumerated among anterior-posterior disorders. This malformation of facial bones is characterised by prolonged mandibular body, sometimes also mandibular ramus, as well as extension of mandibular angle, indicated to a variable extent. Facial features reveal extended chin and lower lip in front of the biometric field and smoothing the labiogingival sulcus. Mandibular prognathism is classified as a gnathic disorder of the masticatory organ. Usually occlusion reveals features of complete mesiocclusion with enlarged negative overjet. Molar teeth are positioned in Angle class III, while third molars in canine class III. Unlike functional prognathism, progenism is associated with negative test [2–4].

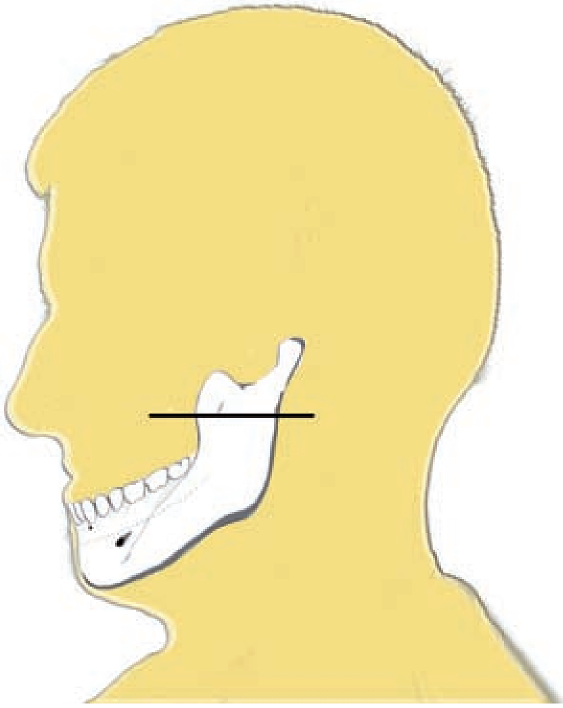

Fig. 1. Ramus osteotomy – Kostečka technique

Ryc. 1. Osteotomia gałęzi żuchwy metodą Kostečki

Historic Outline

The first surgical procedure aiming to correct an open occlusion within the frontal segment was performed by Hullihen [5] in 1849 and was based on partial osteotomy of mandibular body within its anterior segment. Extra-oral approach in mandibular ramus osteotomy was described by Blair [6] in 1907. Whereas Babcock [7] introduced horizontal osteotomy of mandibular ramus using a lateral cutaneous approach, known as "the Swedish approach". Subcondylar osteotomy was primarily performed by Kostečka [8] – originally this procedure was performed with a Gigli saw, without cutaneous access to mandibular ramus. (Fig. 1) Smith and Johnson [9] introduced modifications to this method and for a while it remained quite popular among maxillofacial surgeons [10]. In the past, commonly procedures performed on mandibular ramuses were: oblique osteotomy by Thoma (performed at the base of the condylar process) [11], semi-circular Köle's osteotomy [12], Smith-Robinson procedure (osteotomy performed at the base of condylar process with excision of rectangular bone fragment in the area of mandibular incision) [13] and Letterman-Caldwell method (intraoral vertical ramus osteotomy – with excision of bone fragment from the mandibular incision to its angle and osteotomy performed at the base of the coronoid process) [14].

Apart from ramus osteotomy, orthognathic procedures performed in mandibular prognathism include osteotomies of mandibular bodies, which are always associated with bilateral excision of mandibular body fragments in order to reduce the anterior-posterior mandibular dimension and to retract the anterior part of the

Fig. 2. Stages of the mandibular body osteotomy – Dingman technique

Ryc. 2. Etapy operacji osteotomii trzonu żuchwy według Dingmana

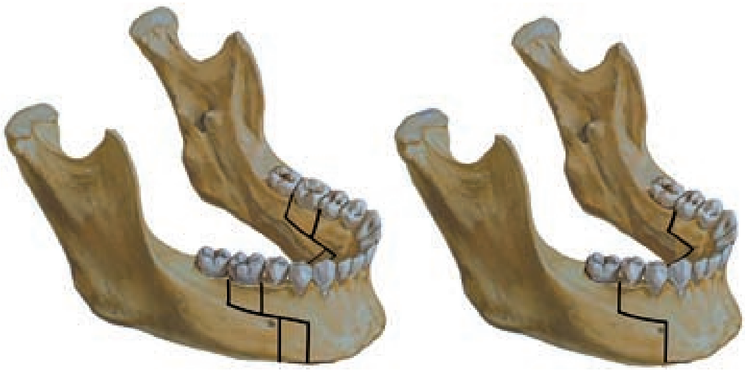

Fig. 3. The step osteotomy

Ryc. 3. Osteotomia schodkowa (zaznaczone linie osteotomii)

dental arch together with the chin and to fix osteotomy fragments. As far as surgical procedures performed within the body of the mandible are concerned, Dingman [15] popularised a two-step method based on 2 approaches – intraoral and extraoral, which aimed to maintain the inferior alveolar nerve undamaged (Fig. 2). The first phase included mucous membrane approach and separating alveolar part of the mandible until unveiling the mandibular canal. Then, after the healing period, the treatment continued with an extraoral approach by means of osteotomy fragments separation, repositioning and fixation with the use of bony sutures [15]. Step osteotomy also seems to be an interesting procedure, performed on the mandibular body and it is particularly practical in patients with multiple tooth losses [16] (Fig. 3).

Initially, surgical corrective procedures of the mandible were limited to the mandible body and characterized by a high rate of complications, most frequently sensory disorders and insufficient skeletal defect correction [5–7]. The Dingman technique of mandibular body osteotomy with a segmental resection of a defined bone fragment was introduced to preserve the inferior alveolar nerve. This procedure, by reducing the size of mandibular dental arch, could correct the open bite in selected cases. Unfortunately, delayed or non-union was quite frequently observed after this type of osteotomy [15]. Moreover, mandibular body osteotomies were connected with more conspicuous scars than the procedures performed on the ramus. To reduce the complication rate, the osteotomy was moved from the body of the mandible to the mandibular ramus. Different modifications of ramus osteotomy did not prevent such complications as variable outcomes, anterior open bite and pseudoarthrosis, to name the most common ones [11–14]. Kostečka method [8] stands out among corrective surgical techniques of mandibular prognathism. The surgery was performed without visual control of cutting tissues. An undeniable advantage of this method was almost invisible scaring on the face and the possibility to avoid contact between bone's wound and patient's saliva during surgery, which prevented bacterial infection of the bone wound. Unfortunately, this method was associated with a number of severe complications. The postoperative complications were the following: injury of the mandibular nerve, lower alveolar neurovascular bundle, facial nerve, external carotid artery, parotid gland and Gilgi's saw wedging or breakage during the surgery. Other complications were the following: the risk of asymmetric or incorrect osteotomy of the mandibular ramus – too high level of osteotomy, at the base of the mandibular

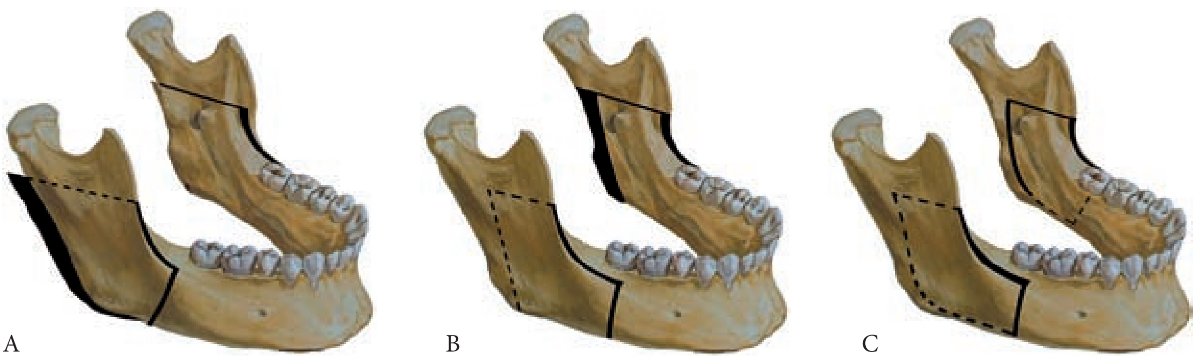

Fig. 4. A. The sagittal split ramus osteotomy of the mandible – Obwegeser technique. **B.** The sagittal split ramus osteotomy of the mandible – Dal Pont modification. **C.** The sagittal split ramus osteotomy of the mandible – Hunsuck modification.

Ryc. 4A. Osteotomia strzałkowa gałęzi żuchwy metodą Obwegesera. **B.** Modyfikacja Dal Ponta osteotomii strzałkowej gałęzi żuchwy. **C.** Osteotomia strzałkowa gałęzi żuchwy w modyfikacji Hunsucka

Fig. 5. The vertical ramus osteotomy

Ryc. 5. Osteotomia pionowa gałęzi żuchwy

Fig. 6. The inverted L-osteotomy

Ryc. 6. Odwrócona L-osteotomia gałęzi żuchwy

condyle, section only one of mandibular condyle or too low level of osteotomy (below the mandibular foramen). Moreover, during Kostečka horizontal ramus osteotomy there was a possibility of lack or insufficient surface area of bone fragments in contact.

High risk of complications and imperfection of the above surgical methods led to the cessation of their application in mandibular prognathism correction. However, it should be emphasized that these techniques have contributed to the development of orthognatic surgery.

Orthognathic Surgeries

Currently, bilateral sagittal split osteotomy (BSSO) stands as the most popular surgical method in correction of mandibular prognathism. Schuchardt was the first one to describe sagittal osteotomy in 1942, although nowadays this procedure is performed based on the description elaborated by Trauner and Obwegeser in 1957 [17] (Fig. 4A). Sagittal split osteotomy was quite often modified, and all these modifications aimed to reduce the frequency of postoperative complications, mainly sensory disorders within the area of the inferior alveolar nerve, as well as an improper excessive shifting of condylar processes [18–21]. According to the modification implemented by Dal Pont [22], an osteotomy is performed right above the mandibular lingula in the direction from the anterior to posterior margin of the mandibular ramus, and then downwards along the lateral alveolar ridge, along the oblique line, thus finally reaching the vestibular surface of the second molar tooth (Fig. 4B). The modification offered by Ćwioro [23] resided in cutting the lamina plate of mandibular body close to the second molar tooth. It is worth mentioning that Ćwioro [24] introduced tools that he individually invented. Other modifications were described by Hunsuck, Gallo, Epker [25–27]. In order to decrease the frequency of undesired mandibular splits and to obtain better fixation of osteotomy fragments, Hunsuck [25] suggested that the osteotomy line should not reach the posterior mandibular margin (Fig. 4C). Gallo [26] proposed that the vertical incision in the retromolar area should start close to the external oblique line and should continue until the middle of the basis of the mandibular body. As far as Epker's [27] procedure is concerned, it starts above mandibular lingula and then it follows laterally and downwards above the lower mandibular margin, and similarly to Hunsuck's [25] proposal, the lower incision is made through mandibular body. Soft tissue detachment is performed above mandibular lingula, and the posterior margin of mandibular ramus remains intact.

Despite the fact that the BSSO method is becoming increasingly popular, some centres in Poland and all over the world still tend to perform external vertical ramus osteotomy (EVRO) and intraoral vertical ramus osteotomy (IVRO) [28, 29]. In the external approach, the cutaneous incision is initially led 1–2 cm below auricular concha, and then to the front and to the bottom about 2 cm below the lower mandibular margin. Whereas in the intraoral approach, mucosal incision is performed along the anterior margin of mandibular ramus starting from the basis of coronoid process, and then it is prolonged laterally until the vestibular area close to the first molar tooth [29]. A mandibular bone incision is performed bilaterally from the semilunar notch to the mandibular angle (Fig. 5). To establish and to maintain the desired occlusion, a stiff traction made of wire ligature is placed on individual splints (during the subsequent phase of the therapeutic process, the stiff traction is replaced with a flexible one). It is also essential to conduct an excision of bone triangles from distal bone fragments (with their bases facing mandibu-

Table 1. Sensory disturbances of the lower alveolar nerve

Tabela 1. Zaburzenia czuciowe nerwu zębodołowego dolnego

Authors	Number of patients	Paresthesia within region innervated by interior alveolar nerve				Comments
		n.V 00M – 01 M	n. V 03M	n. V 06M	n. V 12M	
Sensory disturbances after BSSO						
MacIntosh et al. 1981[53]	N = 155 F = 124, M = 31 Average age = 23	132 (85%)	N/A	N/A	14 (9%)	This research additionally discusses also other complications. Prolonged paraesthesia is more common for persons > 40 years old.
Coghlan et al 1986[47]	N = 19 including N = 10 patients after BSSO and N = 9 after inverted L osteotomy	Subjective examination: Lip numbness N = 3 (33% from 10) Chin numbness N = 2 (22% from 10)				
Nishioka et al. 1987[44]	N = 21	Light touch test n = 19 sides (45.2%) Brush stroke direction test n = 22 sides (52.4%) Two-point discrimination test n = 3 sides (7.1%)				The probability of paraesthesia after BSSO surgery increases with aging.
Yoshida et al. 1989[48]	N = 23 patients after BSSO n = 46 sides	n = 17 (37%)	N/A	N/A	n = 7 (15%)	Evaluation of sensory disorders (neurosensory disturbances) was based on the presence of subjective symptoms and neurological tests.
Karas et al. 1990[37]	N = 33 (n = 6 BSSO, n = 9 IVRO, n = 18 other surgical methods)	Neurosensory disturbances in: 1) static light touch test: n = 5 sides (72%) 2) moving touch discrimination test: n = 4 sides (67%)	Neurosensory disturbances in: 1) static light touch test: n = 2 sides (25%) 2) moving touch discrimination test: n = 4 sides (5%)	n = 1 side (10%)	N/A	Sensory disorders disappear more slowly in patients who underwent BSSO surgery. The research presents an analysis of the paraesthesia after different orthognatic surgeries (BSSO, IVRO, genioplasty, LeFort osteotomy). Sensory disturbance was determined on the basis of an objective neurological examination: – Static light touch (SLT) – Moving touch discrimination (MTD) – Two-point discrimination (TPD) The authors found no correlation between the severity of primary sensory abnormalities, and time of normal sensation recovery.
Leira et al. 1991[60]	N = 25 n = 50 sides	Subjective assessment: n = 27 sides (54%) Objective assessment: n = 17 sides (34%)	Subjective assessment: n = 21 sides (42%) Objective assessment: n = 10 sides (20%)	Subjective assessment: n = 17 sides (34%) Objective assessment: n = 4 sides (8%)	N/A	Sensory symptoms were closely related to the degree of intraoperative nerve tension.

Table 1. Sensory disturbances of the lower alveolar nerve (continued)

Tabela 1. Zaburzenia czuciowe nerwu zębodołowego dolnego (cd.)

Authors	Number of patients	Paresthesia within region innervated by interior alveolar nerve				Comments
		n.V 00M – 01 M	n. V 03M	n. V 06M	n. V 12M	
Naples et al. 1994[39]	N = 10 patients after BSSO and N = 9 after inverted L osteotomy	N/A	N/A	N/A	N = 3 (33%) mild hypoesthesia of the lip N = 2 (22%) mild hypoesthesia of the chin	Subjective questionnaire tests and objective neurological BSSO examination. Patients who underwent BSSO surgery more often marked in questionnaire occurrence of subjective symptoms.
Jääskaläinen et al. 1995[42]	N = 10 (F = 6, M = 4) Average age = 27 (17 to 42 years old)	Nerve injury: n = 15 sides (75%) Including heavy injuries: n = 5 sides (25%).	Nerve injury: n = 12 (60%) sides including heavy injuries: n = 2 sides (10%)	N/A	N/A	The authors assessed sensory disturbances on the basis of the SNAP (sensory nerve action potentials). The results were divided into three groups: 1) abnormal written record of serious damage 2) partially invalid entry 3) completely correct record. SNAP were recorded intraoperatively at three stages: 1) before the split, 2) after splitting of the mandible and possible mobilization of the IAN from the proximal bone fragment, and 3) at the end of the operation after fixation of the proximal and distal fragments with screws.
Posnick et al. 1996[68]	N = 115 Average age = 19 1) BSSO N = 7 (19+/–2) 2) BSSO + GENIO N = 21 (19+/–3)	N/A	N/A	N/A	N = 16 (55,2%) including: 1) after BSSO N = 2 (6,9%) 2) after BSSO+GENIO N = 14 (48,3%)	The assessment of sensory disorders was based on neurological examination. A high percentage of patients after parallel BSSO and genioplasty with impaired sensation in subjective examination and confirmed objectively by neurological examination may be explained by double risk of nerve damage (associated with the possibility of double exposure of the nerve).
Pratt et al. 1996[43]	N = 90* (data from medical documentation) N = 67** (data from questionnaire) N = 21*** (data from neurological examination)	N/A	N/A	N/A	N = 19 (21,1%)*	It was observed that sensory disturbances occur significantly more often after using intraoral stabilization screws (intermaxillary fixation – IMF). The results on the prevalence of sensory disorders were obtained from combination of record analysis (*), postal questionnaire – subjective feelings of patients (**) and objective neurological examination (***). Medical documentation analysis showed that two years after the operation N = 6 (6.7%) * of people had numbness (paraesthesia), and three years after the treatment this number was reduced to N = 4 (5%) *. Two years after surgery in the survey N = 4 patients (5.9%) ** showed abnormal touch sensation. In the objective examination *** 15.1% of the patients showed persistent impaired sense of touch.

Ylikontiola et al. 1998[49]	N = 30 n = 60 sides	n = 38 sides (61%) Light touch test n = 26 sides (43%) Two-point discrimination test n = 31 sides (52%) Thermal stimuli test n = 32 sides (53%) Tactile discrimination test n = 22 sides (36%)	Subjective evaluation n = 13 sides (22%) Light touch test n = 1side (2%) Two-point discrimination test n = 12 sides (20%) Thermal stimuli test n = 5 sides (9%) Tactile discrimination n = 4 sides (7%)	Light touch test n = 0 sides Two-point discrimination test n = 5 sides (8%) Thermal stimuli test n = 1 side (2%) Tactile discrimination n = 5 side (8%)	Subjective evaluation n = 0 sides Objective evaluation: Light touch test n = 0 sides Two-point discrimination test n = 4 sides (7%) Thermal stimuli test n = 0 sides Tactile discrimination n = 1 side (2%)	
Fujioka et al. 1998[46]	N = 114 N = 83 (BSSO) including: Bicortical screws N = 45, Monocortical screws N = 38	N/A	N/A	N/A	Bicortical screws n = 21 (47%) * n = 26 (58%) ** Monocortical screws n = 6 (16%) * n = 6 (16%) **	The study evaluated the frequency of sensory disorders in relation to the application of mono and bicortical screws in patients undergoing BSSO surgery due to various maxillofacial and occlusal defects. Analysis of sensory disorders was based on a patients' subjective assessment (*) and neurological examination. (**) Sensory disturbances were also tested 2 and 3 years after the surgery. Sensory impairment subjectively assessed by patients after 3 years of treatment occurred in 10 operated sides (6%), and in four of the analyzed sides (2%) they were confirmed in neurological examination. The monocortical screws system is connected with lower rate of the inferior alveolar nerve damage.
Westermark et al. 1998[57]	N = 818 (F = 515, M = 303) BSSO n = 710 sides including BSSO+GENIO n = 162 sides	N/A	N/A	N/A	N/A	The aim of this study was to compare the postoperative sensory defects after different methods of orthognatic surgery – BSSO, IVRO, EVRO, GENIO. Genioplasty does not increase the number of sensory disturbances, when performed in a single step with BSSO. The objective and subjective survey examination were performed 2 years after the surgery. After BSSO sensory disturbances occurred in n = 216 sides (39%) and after BSSO + GENIO in n = 216 sides (39%).
Panula et al. 2001[35]	N = 655 (F = 275, M = 180) N = 574 patients after mandible osteotomy including: N = 70 after BSSO with shortening the mandible branch	N = 201 (35% of 574)	N/A	N/A	N/A	Author conducted different orthogantic surgeries (ramus osteotomy – BSSO, Kole's segmental osteotomy) in patients with various defects. BSSO was performed in 70 patients with mandibular prognathizm. The correlation between the occurrence of sensory disorders and the age of patients (older significantly more) was shown.

Table 1. Sensory disturbances of the lower alveolar nerve (continued)

Tabela 1. Zaburzenia czuciowe nerwu zębodołowego dolnego (cd.)

Authors	Number of patients	Paresthesia within region innervated by interior alveolar nerve				Comments
		n.V 00M – 01 M	n. V 03M	n. V 06M	n. V 12M	
Bothur et al. 2003[50]	N = 80 (F = 48, M = 32)			n = 78 (48,75%)		Sensory disturbances were assessed with a survey, carried that was from 6 months to 4 years after the surgery. Researchers observed that the frequency of sensory disorders increase with patient's age and more often affect women.
Yang et al. 2007[51]	N = 63 (F = 41, M = 22)	N/A	N/A	N = 15 (23,8%)	N/A	Assessment of sensory disorders after BSSO 6 months after the surgery.
Gaszyńska et. al. 2008[28]	N = 37 (F = 20, M = 17) N = 17 patients after BSSO (F = 10, M = 7)	N = 14 (37,84%)	N/A	N/A	N = 2 (5,41%)	There was no correlation between the frequency of complications, and patients' age or sex. BSSO is associated with a higher risk of inferior alveolar nerve sensory disorders.
Yamauchi et al. 2011[58]	N = 30 (F = 21, M = 9)	n = 15 sides (25%)	n = 9 sides (15%)	n = 7 sides (11,7%)	N/A	The incidence of inferior alveolar nerve dysfunction depends not only on the anatomical position of the mandibular canal, but also on the length of the angle of the mandible (lateral course of the mandibular canal and a long mandibular angle is a risk factor for inferior alveolar nerve damage).
Sensory disturbances after IVRO						
Hall et al. 1987[64]	N = 89 n = 178 sides	n = 64 sides (36%)	N/A	N/A	n = 14 (8% sides of 178)	The aim of this study was to investigate frequency of nerve dysfunction after IVRO.
Karas et al. 1990[37]	N = 9	N = 1 (11%) (Light touch test), N = 18% (Two-point discrimination test)	N/A	N/A	N/A	The aim of this study was to compare the postoperative sensory disturbances after different orthognatic surgeries – BSSO, IVRO, EVRO, GENIO. Symptoms of sensory impairment disappear more slowly in patients undergoing BSSO surgery in comparison to other surgical methods. There is no correlation between the intensity of the original sensory disturbances, and the time of normal sensation recovery.
Westermark et al. 1998[57]	N = 818 (F = 515, M = 303) n = 704 sides after IVRO including: n = 54 sides after IVRO+GENIO	N/A	N/A	N/A	N/A	The article was previously listed in the table. After 2 years of treatment sensory disturbances occurred in n = 60 sides (9%) in the IVRO group and in n = 10 sides (19%) in the IVRO + GENIO group. IVRO is the method associated with the lowest risk of sensory disturbances. Genioplasty increases the number of complications in terms of sensory disorders when is performed in the same time with IVRO.

Sensory disturbances after EVRO						
Walter et al. 1979[66]	N = 36 n = 72 sides BSSO and IVRO	Subjective assessment: N = 25 (69,4%) Objective assessment: n = 39 (54%)				More cases of sensory abnormalities were noted after BSSO (84%).
Zaytoun et al. 1986[65]	N = 26 n = 52 sides BSSO and IVRO	n = 15 (28,8%)				Sensory disturbances were more frequent after BSSO.
Wester-mark et al. 1998[57]	N = 818 (F = 515, M = 303) n = 140 sides after EVRO	N/A	N/A	N/A	N/A	The article was previously listed in the table. After 2 years of treatment, sensory disturbances occurred in 19% of treated sides (n = 26). After EVRO surgery numbness (paraesthesia) occur less frequently than after BSSO.
Gaszyńska et. al. 2008[28]	N = 37 (F = 20, M = 17) Average age = 25±7 N = 20 patients after EVRO (F = 10, M = 10)	N = 3 (15%)	N/A	N/A	N/A	The article was previously cited. Additionally, the authors also analyzed the incidence of other complications of orthognatic surgery. It was found that EVRO is associated with a higher risk of facial nerve paralysis.
Sensory disturbances after Inverted L osteotomy						
Naples et al. 1994[39]	N = 10 patients after BSSO N = 9 patients after inverted L osteotomy	N/A	N/A	N/A	N = 3 (34%) moderate hypoesthesia of the lip N = 1 (11%) moderate hypoesthesia of the chin	The article was previously cited. Subjective questionnaire tests and objective neurological examinations was performed. Patients after BSSO reported in a survey more frequently sensory disturbances had more often subjective symptoms.

N – number of patients.
n – number of sides.
N/A – no data available.
F – female.
M – male.
n. V – parastesia within region innervated by interior alveolar nerve, recorded 3, 6, 12, 18, 24, 36 months after surgery.
n. VII – marginal mandibular branch paresis, recorded after 6, 12 months after surgery.
BSSO – bilateral sagittal split osteotomy.
IVRO – intraoral vertical ramus osteotomy.
EVRO – extraoral vertical ramus osteotomy.
IVSRO – intraoral vertico-sagittal ramus osteotomy.
IMF – intermaxillary fixation.

Table 2. Number of temporomandibular joint disfunctions before and after surgery

Tabela 2. Liczba dysfunkcji stawu skroniowo-żuchwowego przed i po zabiegu chirurgicznym

Authors	Number of patients	Presence of TMJ disfunction	
		Before surgery	After surgery
BSSO			
Karabouta et al. 1985[72]	N = 280	N = 114 (40.8%)	N = 41 (14.68%)
Ueki et al. 2001[74]	N = 42	N = 26 (62%)	N = 8 (19%)
Lai et al. 2002[75]	N = 23 including N = 10 patients after BSSO and N = 13 after USSO+IVRO	N = 5 (26%)	N = 1 (4%)
Landes et al. 2004[76]	N = 30 including N = 14 patients with Angle's II class and N = 16 with Angle's III class	N = 3 (21%)	N = 0
Nishimura et al. 2004[77]	N = 25 including N = 15 (n = 30 sides) after BSSO	n = 0	n = 1 side (5%)
Aoyama et al. 2005[78]	N = 37 patients after BSSO	N = 11 (29.7%)	N = 14 (37.8%)
Yang et al. 2007[51]	N = 63	N = 6 (9.52%)	N = 2 (3.17%)
Ueki et al. 2007[79]	N = 45 including N = 23 patients after BSSO and N = 22 patients after BSSO+LeFort I	N = 15 (33%) (BSSO) N = 3 (6.7%) (BSSO+LeFort I)	N = 3 (6.7%) (BSSO) N = 2 (4.4%) (BSSO+LeFort I)
Ozdemir et al. 2009[80]	N = 57	N/A	1
Baek et al. 2010[81]	N = 23	N = 0	N = 0
IVRO			
Jung et al. 2009[82]	N = 217	n = 158 sides (37.33%)	n = 29 sides of 420 (6.9%)
Nishimura et al. 2004[77]	N = 25 including N = 10 (n = 20 sides) after IVRO	0	n = 12 sides (40%)
IVSRO			
Fujimura et al. 2004[83]	N = 19 n = 38	n = 34 sides	n = 2 sides
EVRO			
Anthanasiou et al. 1992[84]	N = 36	N = 14 (38.9%)	N = 4 (11.1%)
Anthanasiou et al. 1996[85]	N = 43 including N = 26 after EVRO	N = 16 (62%)	N = 20 (77%)

N – number of patients.
n – number of sides.
F – female.
M – male.
N/A – no data available.
TMJ – temporomandibular joint.
BSSO – bilateral sagittal split osteotomy.
IVRO – intraoral vertical ramus osteotomy.
EVRO – extraoral vertical ramus osteotomy.
IVSRO – intraoral vertico-sagittal ramus osteotomy.
USSO – unilateral sagittal split osteotomy.

lar incision), so as to adjust osteotomy fragments. During the following phase bone fragments are fixed with miniplate osteosynthesis or a bone suture. Stratified suturing is the final part of the surgical procedure [29, 30].

In case of considerable intensification of the mandibular defect, sometimes a reversed mandibular ramus L-osteotomy can be preferred (Fig. 6). It is often used in secondary correction of prognathism when the patient had undergone initial sagittal split osteotomy [31]. The approach in this method is identical to the IVRO procedure. The only difference lies in the line of the osteotomy incision – it is directed towards the anterior margin of the mandibular ramus above the mandibular foramen and it has the shape of a reversed letter *L*. This osteotomy method enables a posterior mandibular shift and vertical prolongation, as well as a shortening of the mandible, without influencing the main mastication muscles.

Orthognathic procedures used in order to correct mandibular prognathism are most commonly used within the mandibular area, although sometimes there are indications to conduct a bimaxillary procedure – mandibular osteotomy and Le Fort I maxillary osteotomy. Köle [12] was the first one to perform partial, segmental mandibular as well as maxillary osteotomy in 1959 [32]. Obwegeser was the surgeon, who started performing bimaxillary procedures in order to correct maxillary-occlusal abnormalities [32]. Le Fort I osteotomy line of bone incisions are conducted right above the nasal duct and further above the basis of the alveolar process and backwards to maxillary tuberosity. In case of high Le Fort I osteotomy the bone incisions are conducted below infraorbital foramen, zygoticomaxillary suture and inferior nasal concha [33].

Different Methods of Stabilization of Osteotomized Fragments

Together with different surgical approaches, methods of stabilization of bone fragments have also evolved. Currently, intermaxillary fixation as well as bone sutures are methods rarely used for fixation bone fragments during orthognatic surgeries (presently they are used mainly during vertical ramus osteotomy). Miniplates with monocortical screws and bone plates with bicortical screws are preferred techniques for bone stabilization, especially during BSSO. These methods of rigid fixation eliminate the use of any form of intermaxillary fixation following surgery. Although both these methods are connected with some disadvantages they ensure good bone stabilization and thorough proper bone healing. Complications connected with rigid fixation are generally rare [34]. Miniplates osteosynthesis may occasionally lead to the displacement of bone fragments and in the worst scenario to their distortion. This can result in improper position of bone fragments and malocclusion. On the contrary, bicortical screws guarantee better bone fixation than monocortical ones; however, their placement is connected with the use of transbuccal trochar instrumentation, which is connected with the risk of facial nerve damage and a facial scar [35]. Stabilizing osteotomized fragments during IVRO is especially difficult, irrespective of the applied method of rigid fixation. Some authors prefer to maintain mandibulomaxillary fixation for 2–6 weeks instead of performing rigid internal fixation during this method of mandibular osteotomy.

Complications After Mandibular Orthognathic Surgeries

In the majority of performed mandibular osteotomies, complications are related to sensory disturbances in the area of the inferior alveolar nerve and more commonly concern patients undergoing bilateral sagittal split osteotomy [28, 36–40]. Due to the differences in methodology concerning the evaluation of sensation abnormalities, their frequency ranges within extended limits and depends on the time of observation and on the operating technique (Table 1).

Frequency concerning sensory disorders after BSSO procedures ranges between 0% and 85% [37–40, 42–53]. The pace of alveolar nerve regeneration depends on the severity and mechanism of its damage; however, it does not depend on the initial subjectively felt intensification of sensory disturbances [39]. Relatively often, the location of split osteotomy is close to mandibular canal and hence quite considerable part of the sensation disorders may result from expanding and pressing the nerve when separating osteotomy fragments, or they may be caused by surgical tools [36, 54–61]. The moment of repositioning and fixation of bone fragments may be decisive, as far as the occurrence of postoperative sensory disorders is concerned. The inferior alveolar nerve may be also expanded during repositioning of bone fragments and it may be bound between fragments during the osteosynthesis. Using too long screws when performing osteosynthesis or introducing screws too low may lead to mechanical damage of the nerve in the mandibular canal [34]. Also the postoperative haematoma in mandibular canal may cause pressure related neuropathies [62]. Some authors described ischaemic nerve damage as a phenomenon resulting from the damage in the nerve's feeding blood supply. Literature presents several cases of posttraumatic neuroma of the inferior alveolar nerve occurring after sagittal split ramus osteotomy [61–64].

After vertical IVRO and EVRO osteotomy complications such as sensory abnormalities within the lower lip area and chin are quite rare, whereas long-term sensation disorders are observed in about 2–4% of people undergoing this method of surgery [28, 57, 65–67].

Whereas in genioplasty procedures the frequency related with sensory disturbances maintained for more than a year ranges, according to various authors, between 0% and 20% [39, 69, 70]. Obviously, with simultaneous mandibular sagittal split osteotomy and genioplasty, the risk of postoperative sensory disorders increases significantly. While in the case of sole genioplasty complications were observed in about 10% of patients, and after sole osteotomy this percentage ranged between 22% and 30%, yet when these medical procedures were performed at the same time, the percentage of complications differed among authors and reached even as much as 70% [39, 59, 60, 69–71].

Complications resulting from blood supply disorders occurring after sagittal split osteotomy occur rather infrequently and may appear in the form of periodontal diseases, dental pulp necrosis, impaired healing process and infections within postoperative wounds, next to delayed bone healing. Nonetheless, the literature describes cases of severe ischaemic complications mainly after performing vertical ramus osteotomy, namely lack of bone healing, bone infections or ischaemic bone necrosis [72].

Another quite rarely observed complication is considerable bleeding after orthognathic procedures, although, during mandibular ramus osteotomy there are numerous vessels within the operative field, and wounding these vessels could lead to significant blood loss. These vessels include the maxillary artery, the inferior alveolar artery, the masticator muscle feeding vessels, the retromandibular vein and the pterygoid plexus [73].

Dysfunction within temporomandibular joints (TMJ) preceding the treatment occurs more frequently among patients suffering from mandibular prognathism when compared to the general population, 40% (and according to some authors even 62%) vs. about 20–25% [53, 74–87]. In prospective studies 9–73% of patients with mandibular prognathism reveal TMJ disorders prior to the surgical procedure. Symptoms of TMJ dysfunction can be observed even up to 4 years after the BSSO procedure among 28–60% of patients [75]. Among 3.7–7% of patients who did not observe any ailments within the TMJ, report such ailments after the BSSO procedure [88]. Yet, the majority of studies indicate an improvement in TMJ function after orthognathic procedures among patients with prognathism and other maxillofacial and occlusal impairments, taking into consideration the fact that several percent of people who did not report any symptoms may suffer from TMJ ailments after the procedure [74, 88]. It is worth indicating that patients, who underwent vertical osteotomy less frequently report TMJ disorders [75]. The literature presents data concerning the frequency of postoperative condylar process resorption ranging between 1% and 31% [37, 89–91]. In his prospective thesis, Panula reported that more than 6% out of 11% of people who suffered from postoperative condylar process resorption also observed this condition before the surgery. The frequency of this phenomenon is not associated with age; however, it much more often affects women, people with preoperative TMJ dysfunction symptoms, significant fragment shift and their rotation in an anti-clockwise direction [41, 90, 92, 93]. Jaw opening disorders appearing after the surgical procedure, which can be a sign of TMJ functional disorders, should be differentiated from intra-articular haematoma resulting from reposition and fixation of osteotomy fragments, as well as contortion of condylar process in TMJ [92, 94, 95].

Postoperative occlusal complications, usually taking the form of open occlusion within the anterior segment, mainly result from the improper setting of osteotomy fragments. A shift in the medial line results from the twist/rotation of the proximal fragment [28].

Fractures of bone fragments of osteotomy performed in locations other than the desired ones mainly occur during the BSSO procedure. The frequency of performing bone fragment separation in an improper location ranges between 3 and 23% of patients [36, 37, 55, 57, 96].

Lingual nerve damage is a quite rare complication after orthognathic procedures and in most cases sensory disorders fade in an idiopathic manner, although there are reports indicating permanent sensory disturbances [97–102]. The main reason underlying its occurrence is the introduction of a drill or bicortical screws in the area of third molar teeth close to the upper mandibular margin [100].

Damage of the facial nerve during sagittal mandibular ramus osteotomy occurs in 0.4–1.0% of cases [54, 55, 101, 103, 104]. Maintaining symptoms of its damage may be related with too extended mandibular reverse and prolonged bone incision to the posterior mandibular margin [55, 102, 104].

During a vertical ramus osteotomy facial nerve impairment is more common; however, function is usually restored within one year after the operation [28]. Infection within the operated area is nowadays quite a rare phenomenon due to routinely administered antibiotic prophylaxis [37, 106]. An increased percentage of infections within the osteotomy area may be influenced by several factors – intaoperative extraction of third molar teeth [107, 108], introducing screws too close to the upper margin of fragments, resulting in ischaemic necrosis within the cortical bone [109], improper placing of the plate during osteosynthesis (impaired healing due to worsened blood supply and too large stress) [110], as well as nicotinism [111].

Other complications following orthognathic surgeries are extremely rare. Accidental damage of the tracheotomy tube and pilot tube were described [112]. The postoperative soft tissue oedema may lead to pressure within the respiratory tract [37]. The literature also describes complications in the form of mechanical dentition damage caused by surgical tools [32]. Other complications may also occur within the stomatognathic organ, such as dental root resorption, although this complication is much more frequent after orthodontic therapy [112]. Periodontal diseases may sometimes develop, even leading to dental losses [32, 60].

The recurrence of mandibular prognathism after orthognathic procedures is quite another issue. It is worth mentioning that the average recurrence of the defect is observed about one year after the procedure in 10% to 26% of surgical mandibular shift (reverse) [113, 114].

To conclude, it is worth mentioning that operating techniques and surgical tools used in orthognathic procedures faced an extremely intense development from the 19^{th} century. Classical mandibular osteotomy procedures faced a multitude of modifications, which aimed to decrease the number of complications. Despite the various available techniques, the bilateral sagittal split osteotomy still remains to be the most frequently performed orthognathic procedure within the mandible. It is worth indicating that orthognathic procedures are still associated with complications that are often inconvenient for the patient (mainly the ones related with sensory disorders within the area of the inferior alveolar nerve), although their number decreased considerable since the time when the first mandibular osteotomy has been performed. Despite multiple inconveniences, which the patient is forced to face during the preoperative and post-operative period, these procedures are a chance to improve facial aesthetics, maxillary-occlusal conditions, and hence improve the personal acceptance, enhance interpersonal relations and social functioning.

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