Incidence of Neurosensory Disturbances Post-Orthognatic Surgery: ASystematic Review

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Abstract

Backgroud

One of the most frequent concern in performing orthognathic surgery is the occurence of neurosensory disturbance (NSD) post-surgery. Many studies have reported the incidence of various NSDs that could occur post-surgery. Clinicians should be aware of the risk of potential occurence of NSD by identifying risk factors and evaluating incidences by surgery type.

Objective

The aim of this study is to assess the incidences of NSD among different orthognatic surgery procedures.

Methods

The literature search was performed on September 2021 through the following scientific databases: PubMed, Scopus, ScienceDirect, and Cochrane Library limited to articles published between the year 2000-2020.

Results

A total of 869 records were found, 21 of which were included. Total sample size of the included studies were 8,891 patients from various countries. The orthognathic procedures of interest were BSSO only, BSSO with genioplasty, BSSO with Le Fort I osteotomy, BSSO in combination with Le Fort I osteotomy and genioplasty, SSO only, SSO with genioplasty, IVRO only, genioplasty only, and Le Fort I osteotomy only. Incidence of NSD is ideally assessed objectively and subjectively.

Conclussion

Incidence of NSD post-orthognathic procedure frequently comes from an insult to the inferior alveolar nerve. Current data showed that IVRO currently have the lowest incidence among other procedures and the highest incidence is BSSO combine genioplasty. Factors that are known to influence the incidence of NSD were age at the time of surgery, bone marrow space, length of mandible angle, prior history of another mandible procedures, type of material used to fixate the mandible during BSSO, and the surgeon's expertise and experience.

Keywords : BSSO, genioplasty, Le Fort I osteotomy, neurosensory disturbance, orthognathic surgery,SSO

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INTRODUCTION

Orthognatic surgery is a combination of orthodontics and maxillofacial surgery that aims to correct dentofacial deformities that cannot be corrected by reguler orthodontics procedure.[1] The origin of orthognatic surgery was limited to only mandibular surgery with the first recorded orthognatic surgery was a surgery to correct malocclusion performed using Hullihen's procedure which was carried out in 1849.[2] The most frequently used orthognatic surgeries are Le Fort I osteotomy because of it's versatility and allows the surgeon to movein all three planes.[1,3] This procedure was first described in 1867 and it is used to treat class II and III malocclusions as well as dentofacial asymmetries.[2,3] Bilateral sagital split osteotomy (BSSO) is a type of orthognatic surgery where the lower jaw is separated and repositioned. It was first described by Schuhardt in 1942 and now indicated to treathorizontal mandibular excess, deficiency, and/or asymmetry.[2,4] Intraoral vertical ramus osteotomy (IVRO) is a procedure aimed to create a full thickness vertical osteotomy through the mandibular ramus posterior to the mandibular foramen and its used to treat horizontal mandibular excess, mandibular asymmetry, and correction of minor mandibular deficiency.[5]

Genioplasty is a procedure mainly used to correct chin deformity that consist of an osteotomy of inferior border of mandible that allows for three dimensional movement of thechin and positions it in its desired position. It was first done by extraoral approach and then modified into an intraoral approach with its recent advancement using 3D-printing that could improve the results of the intervention by a three-dimensional pre-operative simulation.[6] One concern in performing orthognatic surgery is the occurence of post-surgeryneurosensory disturbance (NSD). Many study have reported the incidence of NSD after orthognatic surgeries. One study reported that NSD, measured by light touch sensation, of patients who underwent SSO had a worsening of sensation until 1 week post-surgery and only recovered after 1 month post-surgery.[7] Another study is a comparison study comparingNSD among different procedures. IVRO is a procedure known to preserve inferior alveolarneurovascular bundle and one comparative study shows that IVRO have lower incidence ofNSD when compared to BSSO.[8,9] Considering NSD is a well-known complication of orthognathic surgery, clinicians should be aware of the risk of potential occurence of NSD by identifying risk factors and evaluating incidences by surgery type. This paper aims to systematically assess the incidences of NSD among different orthognatic surgery procedures.

METHODS

This review was conducted based on Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) protocol.

The literature search was performed on September 2021 through following scientificdatabases: PubMed, Scopus, ScienceDirect, and Cochrane Library. The literature search onPubMed was performed using Medical Subject Headings (MeSH) search with the followingkeywords: ("orthognathic surgical procedures"[MeSH Terms]) AND ("peripheral nerve injuries"[MeSH Terms] OR "facial nerve injuries"[MeSH Terms] OR "mandibular nerve injuries"[MeSH Terms] OR "nerve injuries"). While the literature search on the other databases was performed using the following keywords: ("orthognathic surgery" OR "orthognathic procedures" OR "orthognathic") AND ("neurosensory disturbance" OR "nerve complication" OR "sensory disturbance" OR "sensory impairment" OR "sensory deficit" OR "nerve injury" OR "alveolar inferior nerve" OR "nerve palsy"). Manual handsearching was also performed to find relevant literatures that were not found using thekeywords.

The inclusion criteria were: (1) English language and human subjects articles; (2) The research subjects included patients post-orthognathic surgery (Le Fort I osteotomy, BSSO, IVRO, genioplasty and combination BSSO and genioplasty or IVRO and genioplasty); (3) Article published from 2000—2020; (4) Original studies using the following study designs: randomized or non-randomized controlled trial, clinical trial, prospective or retrospective cohort, case control, and case report; (5) Full-text availability;
(6) at least display percentage of NSD incidence at one of orthognathic surgery procedures (Le Fort I osteotomy, BSSO, IVRO, genioplasty, or combination BSSO and genioplasty or IVRO and genioplasty). The exclusion criteria were: (1) Review papers, editorial letters andmanuscripts; (2) Article not published in English; (3) Studies conducted on animals in vivoand/or in vitro; (4) Full-text unavailable; (5) Studies that heavily modify the standard orthognathic surgery procedures through techniques, instruments, or materials.

Risk of bias assessment for randomized controlled trial was conducted using Cochrane Risk of Bias tools that analyzed seven aspects of bias. Risk of bias on non-randomized interventional studies were assessed using ROBINS-I tool. Risk of bias on observational studies were assessed using the Newcastle-Ottawa Scale (NOS). The risk of bias analysis in any found individual study were assessed using the Quality Apprisal of Case Series Studies Checklist (QACSS) by Institute of Health Economic (IHE), Edmonton, Canada.

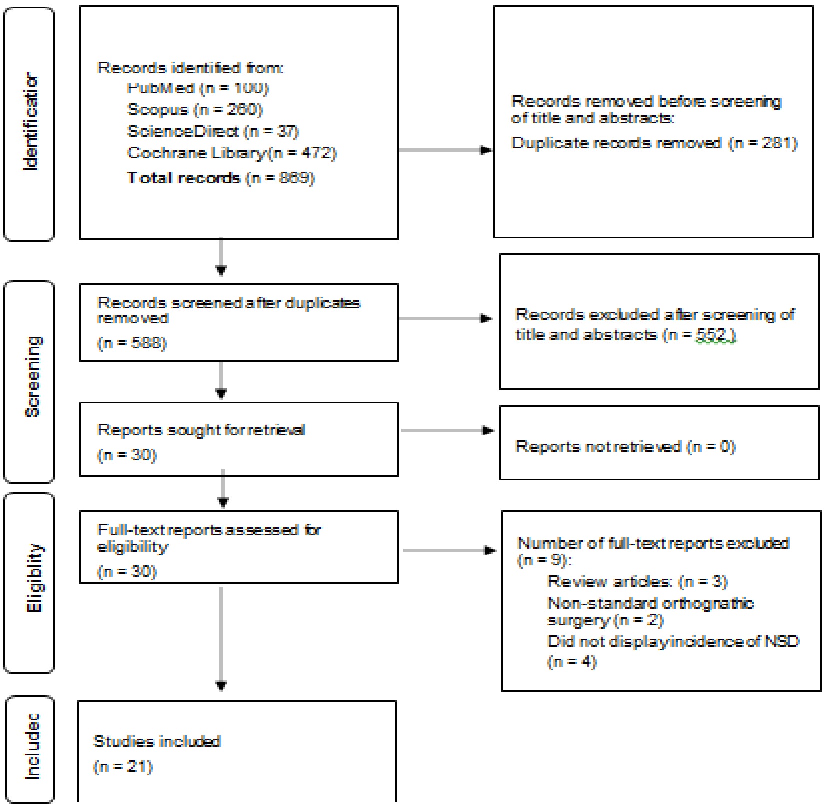

Figure 1. Flow-chart of the literature search strategy

RESULTS

The initial search resulted in a total of 869 records, 281 of which were duplicates. After deduplication, 588 records were screened of their title and abstracts and 552 records were excluded due to not fulfilling the inclusion criteria. Thirty records were sucessfully retrieved and assessed of their full-text report for eligibility. Nine records were excluded dueto being review articles (3 records); using non-standard orthognathic surgery (2 records); or did not explicitly display incidence of NSD post-orthognathic surgery (4 records). The remaining 21 studies were included in this review. The PRISMA flowchart of literature search process is displayed in **Figure 1.**

Characteristics of included studies are displayed in **Table 1**. The result of critical appraisal of included studies based on critical appraisal for incidence studies are displayed in **Table 2**. Risk of bias assessment using ROBINS-I tool for non-randomized interventional studies are displayed in **Table 3**; using NOS for observational studies are displayed in **Table 4**; and using Cochrane Risk of Bias Tool for randomized controlled trial are displayed in **Table 5**. This review included studies from various countries: Italy (n = 4), United States (n=2), Sweden (n=3), Japan (n=2), Republic of Korea (n=3), Hong Kong (n=2), and one study each from Netherlands, Taiwan, Belgium, Austria, and Norway. The total sample size of the included studies are 8,891 patients that were, mostly, of equal male to female ratio. The orthognathic procedures of interest in the included were BSSO only, BSSO with genioplasty, BSSO with Le Fort I osteotomy, BSSO in combination with Le Fort I osteotomy and genioplasty, SSO only, SSO with genioplasty, IVRO only, genioplasty only, and Le Fort I osteotomy only. Most of the included studies evaluated post-orthognathic occurence of NSD by objective and subjective assessment. Objective assessment included two-point discrimination test, brush stroke detection, contact detection, or light touch, thermal testing, sharp blunt discrimination, and pin prick test. Majority of subjective asessment was performed through a questionnaire evaluating the patient's self-reported incidence of NSD,while others were judged by the clinician.

Table 1. Characterisics of included study

No	Author (year)	Country	Study design	Sample size	Intervention of interest	Results	Conclusion
1	Gianni et al	Italy	Non-rando	50 patients	Genioplasty only or in associati	No persistent anesthesia in all groups.	Combination of genioplasty and SSO affects lip sensibility

	(2002)		mized interv ention al study	(24 mal e, 26 fem ale)	on with maxillary osteotom y or vertical mandibul ar ramus osteotom y, SSO only, SSO with genioplas ty	Normal or slight hypoesthesia in group 2 (17%)and group 3 (30%); increased sensory deficit in group 4 (40%)	more than each procedure alone. Thermal sensation is less affected than other sensations. Subjectively sensory deficit was never considered disabling by the patients
2	Van Sickels et al (2002)	Uni ted Sta tes	Rando mized contr ollled trial	127 patients	BSSO only	Highest incidence of nerve injury occured in younger age group <24 years (10.3%), 24-35 years (2.4%), >35 years (4.5%)	Older age and combination with genioplasty increases the risk of a neurosensory injury. In older patients, large advancements further increase this risk.
3	Al-Bishri et al (2004)	Swede n	Prosp ective observ ationa l study	121 patients (61 male, 60 femal e), 131 sides of SSO, 54 sides in combi nation	SSO alone and in combina tion with geniopla sty.	Sensory disturbance reported in 48/131 (37%) operated sides in sagittal split osteotomies alone, while 2054 (37%) operated sides in combination with genioplasty.	Combination with genioplasty did not increase the incidence of sensory disturbance

				with genioplasty			
4	Al-Bishri et al (2005)	Sweden	Prospective observational study	129 patients (56 male, 73 female), 212 sides	IVRO only, SSO only	Long lasting NSD reported in 7.5% through questionnaire, 3.8% through record after intraoral vertical ramus osteotomy and 11.6% through questionnaire, 3.8% through records after SSO	There is disagreement between judgement of surgeon and patient's opinion regarding NSD
5	Nesari et al (2005)	Sweden	Retrospective observational study	68 patients (24 male, 44 female), 136 sides	BSSO only	Incidence of reduced sensitivity: 84 sides (62%) at 2 months, 52 sites (38%) at 6 months, 43 sides (32%) at 1.5 years and 32 sides (24%) at 2.5 years.	Most important factors to post-operative nerve function are age, fixation method, and perioperative position of inferior alveolar nerve
6	Kobayashi et al (2006)	Japan	Observational study	66 patients (24 male, 42 female),	BSSO only intraoral inverted L ramus	Abnormal thresholds for 2 measurement techniques present more in SSRO group	Post-operative NSD of lower lip and chin occur more frequently in SSRO patients by surgeon

				132 sides	osteotomy	than ILRO and at 6 months post surgery	with less experience
7	Essick et al (2007)	United States	Randomized controllled trial	184 patients (29 male, 71 female)	BSSO only	Impairment in contact detection and two point discrimination significantly differ at 6 months among groups.	Clinical judgement regarding sensory dysfunction after orthognathic surgery should not be based on threshold testing results without subjective report of altered sensation by the patient
8	Kim et al (2007)	South Korea	Retrospective observational study	301 patients (141 male, 160 female)	BSSO only, BSSO and genioplasty, BSSO and Le Fort I osteotomy, BSSO and Le Fort I osteotomy and genioplasty, genioplasty only, Le Fort osteotomy only	The most common complication is sensory disturbance 196 cases (65.1%)	Despite great variety of reported post surgery complications, the frequency seems low thus orthognathic surgery appears to be a safe procedure
9	Wijbenga et al (2009)	Netherlands	Retrospective	91 patients (38 male, 53 female	BSSO only and distracti	Long lasting NSD occur in 27 cases (30%) in BSSO group with overall	There was no significant difference in

			observational study	), 182 inferior alveolar nerve	on osteogenesis only	prevalence of 8% and 21 cases (23%) in distraction osteogenesis group with overall prevalence of 10%	objectively measured and subjectively reported NSD between groups
10	D'Agostino et al (2010)	Italy	Retrospective observational study	50 patients (16 male, 34 femal e), 100 nerves	BSSO only	Objective measurement found no lesion in 52% of nerves, and significant lesion in 24% nerves. Subjective evaluations found 74% described the discomfort as "absent to mild"/"mild to moderate", 10% as "moderate to serious", and 4% as "serious"	Percentage of significant nervous lesion is relatively low, and capacity of central nervous system to compensate or hide for functional deficit due to nerve lesions was confirmed between objective and subjective evaluations
11	Choi et al (2010)	Taiwan	Retrospective observational study	3,105 patients	SSO of the mandible	6 patients (0.1%) of postoperative unilateral facial nerve palsy were reported	Most facial nerve palsy post-mandibular SSO are caused by neurapraxia or axonotmesis due to nerve compression or traction, complete recovery can be expected,

							conservative management is recommended
12	Kim et al (2011)	South Korea	Retrospective observational study	47 patients (26 male, 21 female)	BSSO only, BSSO and genioplasty, BSSO and Le Fort I, BSSO and Le Fort I and genioplasty	Sensory alteration occured at the lip (27.3%) and chin 55.7%). Visual analog scale for postoperative altered sensation in 1, 3, and 6 months were significantly different.	Altered sensation after orthognathic surgery may be an unavoidable complication, but may resolve spontaneously with time. It is associated with concurrent genioplasty but not age or concurrent maxillary surgery.

13	Yamauchi et al (2012)	Japan	Prospective observational study	30 patients (9 male, 21 female)	BSSO only	NSD occured on 15 sides (25%) at 1 month, 9 sides (15%) at 3 months, 7 sides (11.7%) at 6 months postoperatively	The frequency of NSD post-BSSO depend on position of mandibular canal and length of mandibular angle. Lateral course of mandibular canal, and long mandibular angle has a high risk of injury to inferior alveolar nerve.
14	Ianetti et al (2013)	Italy	Retrospective observational study	3,236 patients (1,319 male, 1,917 female)	Majority BSSO and Le Fort I osteotomy, Le Fort I only, BSSO only	Most frequent complication was mandibular nerve sensory deficit (19%), irreversible in 2% of cases.	Orthognathic surgery complications are rare and are considered surgical mistakes related to surgeon's experience or real complications to orthognathic surgery
15	Politis et al (2013)	Belgium	Retrospective observational study	163 patients (63 male, 100 female)	SSO only	Overall rate of self-reported alteration in sensibility was 15.1%(49/324; 13% ont he right side, 17.3% on the left). Of 16 patients (9.9%) with hypoesthesia on the right side and 25	Age and genioplasty were significant pedictors of hypoesthesia. A 1 year increase in age increased the odds of hypoesthesia by 5%. Concocurrent genioplast had 4.5 times higher odds

						patients (15.4%) on the left, 10 experienced bilateral hypoesthesia.	of hypoesthesia.
16	Bruckmoser et al (2013)	Austria	Retrospective observational study	128 patients (44 male, 84 female)	BSSO only, BSSO + Le Fort I osteotomy, BSSO + genioplasty, BSSO + Le Fort I osteotomy + genioplasty	Normal subjective sensibility found in 74.6% of the regions after 6 months and 77.2% after 12 months.	NSD of inferior alveolar nerve after BSSO is influenced by age, age and total operating time. Higher incidence occur on chin region.
17	Choi et al (2013)	South Korea	Retrospective observational study	168 patients (26 male, 142 female)	BSSO only or BSSO + Le Fort I osteotomy	Injury rate of inferior alveolar nerve in patients with history of mandible contouring was 3 cases (11.5%) and primary SSO patients 5 cases (1.6%).	Patients with history of mandibular contouring surgery had a significantly greater risk of inferior alveolar nerve injury
1	Alolayan et	Hong	Retrospective	238 patients	SSO	Incidence of NSD after maxillary procedures (Le Fort I	Age is a short term (<24 months) risk

8	al (2014)	Kong	e observational study	(90 male, 148 female), 476 sides	only, Le Fort I osteotomy only	osteotomy) were 16.2%, 13%, and 9.8% at postoperative 6, 12, and 24 months respectively. While after mandibular procedures at postoperative 6, 12, and 24 months were 35.4%, 36.6%, and 34.6% respectively.	factor to NSD post-orthognathic surgery, and specific mandibular procedures have higher risk of NSD
19	Hågensli et al (2014)	Norway	Retrospective observational study	38 patients (12 male, 26 female)	BSSO only	44.7% patients had normal/almost normal sensation to the lower lip/chin, 50% had neurosensory alterations on the side to which the chin was deviating, compared to 28.9% patients affected on the opposite side	Correction of mandibular assymetry by BSSO is stable, rotation of the distal segment during surgery may increase risk of sensory impairment on the deviating side

20	Alolayan et al (2017)	Hong Kong	Prospective observational study	66 patients (23 male, 43 female), 132 sides	SSO or IVRO, and anterior mandibular surgery (anterior subapical surgery and/or genioplasty) or combination of both	Overall occurence of NSD 78.8% at 2 weeks, 64.4% at 6 weeks, 55.3% at 3 months, 34.8% at 6 months, 19.7% at 1 year, 13.8% at 2 years	The severity of NSD reduced over time in the first 2 post-operative years. Highest incidence occur using combination of ramus surgery (IVRO/SSO) and anterior mandibular surgery at post-operative 3 months. Age, gender, and surgeon experience were not risk factors.
21	Zaroni et al (2019)	Italy	Retrospective observational study	485 patients (170 male, 315 female),	BSSO only and Le Fort I osteotomy only	Total of 19.2% complications were reported, 9.6% of which were inferior alveolar nerve injury	Inferior alveolar nerve injury is one of the most prevalent complication in orthognathic surgery and seem to be related to gender, duration and number of surgery, surgical site, and type of osteotomy.

Bilateral sagital split osteotomy (BSSO), sagital split osteotomy (SSO), intraoral vertical ramus osteotomy (IVRO), neurosensory disturbance (NSD)

Table 2. Critical appraisal of included studies based on critical appraisal for incidence studies

No	Author (year)	Critical Appraisal								
		Was the sample frame appropriate to address the target population?	Were study participants sampled in an appropriate way?	Was the sample size adequate?	Were the study subjects and the setting described in detail?	Was the data analysis conducted with sufficient coverage of the identified sample?	Were valid methods used for the identification of the condition?	Was the condition measured in a standard, reliable way for all participants?	Was there appropriate statistical analysis?	Was the response rate adequate, and if not, was the low response rate managed appropriately?
1	Gianni et al (2002)	Yes	Unclear	Unclear	Yes	Yes	Yes	Yes	Yes	Yes
2	Van Sickels et al (2002)	Yes	Yes	Unclear	Yes	Yes	Yes	Yes	Yes	Yes
3	Al-Bishri et al (2004)	Yes	Unclear	Unclear	Yes	Yes	Unclear	Unclear	No	Yes
4	Al-Bishri et al (2005)	Yes	Unclear	Unclear	Yes	Yes	Unclear	Unclear	No	Yes
5	Nesari et al (2005)	Yes	Unclear	Unclear	Yes	Yes	Unclear	Unclear	Yes	Yes
6	Kobayashi et al (2006)	Yes	Unclear	Unclear	Yes	Yes	Yes	Yes	Yes	Yes
7	Essick et al	Ye	Uncl	Uncl	Yes	Ye	Yes	Yes	Yes	Yes

	(2007)	s	ear	ear		s				
8	Kim et al (2007)	Yes	Unclear	Unclear	Yes	Yes	No	No	No	Yes
9	Wijbenga et al (2009)	Yes	Unclear	Unclear	Yes	Yes	Yes	Yes	Yes	Yes
10	D'Agostino et al (2010)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes
11	Choi et al (2010)	Yes	Yes	Unclear	Yes	Yes	Yes	Yes	No	Yes
12	Kim et al (2011)	Yes	Unclear	Unclear	Yes	Yes	Yes	Yes	Yes	Yes
13	Yamauchi et al (2012)	Yes	Unclear	Unclear	Yes	Yes	Yes	Yes	Yes	Yes
14	Ianetti et al (2013)	Yes	Yes	Unclear	Yes	Yes	No	No	No	Yes
15	Politis et al (2013)	Yes	Unclear	Unclear	Yes	Yes	No	Yes	Yes	Yes
16	Bruckmoser et al (2013)	Yes	Unclear	Unclear	Yes	Yes	Yes	Yes	Yes	Yes
17	Choi et al (2013)	Yes	Unclear	Unclear	Yes	Yes	Yes	Yes	Yes	Yes
18	Alolayan et al (2014)	Yes	Unclear	Unclear	Yes	Yes	Yes	Yes	Yes	Yes
19	Hågensli et al (2014)	Yes	Unclear	Unclear	Yes	Yes	Yes	Yes	Yes	Yes
20	Alolayan et al (2017)	Yes	Unclear	Unclear	Yes	Yes	Yes	Yes	Yes	Yes
21	Zaroni et al (2019)	Yes	Unclear	Unclear	Yes	Yes	No	No	Yes	Yes

Table 3. Results of ROBINS-I tool risk of bias assessment for non-randomized interventional studies

No	Author (year)	Pre-Intervention		At Intervention	Post-Intervention				Overall risk of bias
		Bias due to confounders	Bias due to selection of participants	Bias due to classification of interventions	Bias due to deviation from intended intervention	Bias due to missing data	Bias due to outcome measurement	Bias due to selection of reported outcome	
1	Gianni et al (2002)	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk

Table 4. Results of NOS risk of bias assessment of observational studies

No	Author (year)	Selection				Comparability	Outcome		
		No bias due to confounders	No bias due to selection of participants	Measurable intervention	Absence of outcome prior to study	Able to compare intervention used with study design/analysis	Blinded assessment of outcome	Adequate follow-up duration	Adequate follow-up number of patients
1	Al-Bishri et al (2004)	Yes	Yes	Yes	No	No	No	Yes	Yes
2	Al-Bishri et al (2005)	Yes	Yes	Yes	No	No	No	Yes	Yes
3	Nesari et al (2005)	Yes	Yes	Yes	No	No	No	Yes	Yes
4	Kobayashi et al (2006)	Yes	Yes	Yes	No	No	No	Yes	Yes
5	Kim et al (2007)	Yes	Yes	Yes	No	No	No	Yes	Yes
6	Wijbenga et al (2009)	Yes	Yes	Yes	No	No	No	Yes	Yes
7	D'Agostino et al (2010)	Yes	Yes	Yes	No	No	No	Yes	Yes
8	Choi et al (2010)	Yes	Yes	Yes	No	No	No	Yes	Yes
9	Kim et al (2011)	Yes	Yes	Yes	No	No	No	Yes	Yes
10	Yamauchi et al (2012)	Yes	Yes	Yes	No	No	No	Yes	Yes
11	Ianetti et al (2013)	Yes	Yes	Yes	No	No	No	Yes	Yes
12	Politis et al (2013)	Yes	Yes	Yes	No	No	No	Yes	Yes
13	Bruckmoser et al (2013)	Yes	Yes	Yes	No	No	No	Yes	Yes
14	Choi et al (2013)	Yes	Yes	Yes	No	No	No	Yes	Yes
15	Alolayan et al (2014)	Yes	Yes	Yes	No	No	No	Yes	Yes
16	Hågensli et al (2014)	Yes	Yes	Yes	No	No	No	Yes	Yes
17	Alolayan et al (2017)	Yes	Yes	Yes	No	No	No	Yes	Yes
18	Zaroni et al (2019)	Yes	Yes	Yes	No	No	No	Yes	Yes

Table 4. Results of Cochrane Risk of Bias Tool assessment for randomized controlled trial studies

		Selection bias		Performance bias	Detection bias	Attrition bias	Reporting bias	
No	Author (year)	Random sequence generation	Allocation concealment	Blinding of participants and personnel	Blinding of outcome assessment	Incomplete outcome data	Selective reporting	Other bias
1	Van Sickels et al (2002)	Low risk	High risk	High risk	High risk	Low risk	Low risk	Low risk
2	Essick et al (2007)	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk

DISCUSSION

In this review, reported incidence of NSD mostly comes from injury of the inferior alveolar nerve. Alveolar nerve are separated into two based on their branching origin. Maxillary nerve will branch into superior alveolar nerve that innervates maxillary region thatincludes maxillary sinus, premolar, inferior meatus, cheeks, and gingivae. Mandibulary nerve will branch into inferior alveolar nerve that innervates mandible gingivae and will also branch into mylohyoid nerve and mental nerve. Inferior alveolar nerve provides sensory innervation to lower teeth, gingivae, lower lip and chin.[10] Some studies assessed the incidence of NSD in a general population of patientst that underwent orthognatic surgery. Alolayan, et al reported that in a population with patient that underwent BSSO, IVRO, and anterior mandibular surgery, the overall incidence of 2 weeks NSD post-surgery is 78.8% and decreased into 34.8% in 6 months and only 19.7% and 13.8% had NSD in 1 year and 2 years post-surgery.[11] Bruckmoser, et al reports NSD incidence in a population of patients that underwent BSSO, Le Fort I, Genioplasty, or BSSO combined with either Le Fort I osteotomy or genioplasty. In this study, NSD incidence at 6 months post-surgery is reportedto be 25.4% with 12% reported severe NSD. NSD incidence at 12 months is 22.8% with 10.7% having a severe NSD.[12] Both Alolayan, et al and Bruckmoser, et al reports the almost same percentage of NSD incidence (34.8% vs 25.4% at 6 months and 19.7% vs 22.8% at 12 months) because both have relatively similar sample size, 132 sides and 154 patients.[11,12] This number seems to be smaller when extracted from larger sample size. Zaroni, et al assessed the complication incidence including NSD in 485 patients who underwent orthognatic surgery between 2008 and 2014. In this study, NSD incidence is reported to be just 9.6%.[13] Iannetti, et al with 3236 patients from 1989-2009 in Rome that underwent orthognatic surgery showed that NSD incidence is 19.03% with 80.19% of patients with NSD resolved within the first 6 months.[14] It is shown that the overall incidence of NSD post-orthognatic surgeries highly varied from one study to another.

BSSO currently have the most abundant data regarding it's incidence of NSD. Current data showed that NSD incidence right after BSSO surgery ranged from 15.1% to 64% and decreased to 3.5%-24% in more than 1 year.[15–21] For comparison, another systematic review by Jędrzejewski, et al with more than 44 studies included showed that NSD incidence rate in a non-specific timestamp is 50%.[22] Al-Bishri reports that NSD incidence are different when assessed subjectively using questionnaire and the clinician's judgement or objectively by screening patient's medical record patients NSD status (by combining subjective judgement and objective sensory tests). In this study, NSD incidence immediately after surgery in subjective and objective measurement are 29% and 38.4% respectively while after 1 year (long-lasting NSD) the incidence are 11.6% and 8.1% respectively.[18] In this study it seems that the patients often underestimate and overlook the sensory disturbance while after 1 year patients tend to overestimate their NSD. One systematic review assessed the difference in these two NSD measurement methods. Colela, et al measure NSD incidence both subjectively and objectively, and measure the Cohen's kappa between the two to measure its interchangeability. This study shows that subjective measurement is not accurate enough when used to measure NSD until 1 week post-surgery. Only until 2 weeks post-surgery that subjective measurement of NSD can safely replace objective measurement while maintaining accuracy. The more time passes, the more accurate subjective measurement become when compared to objective measurement as the gold standard.[23] Based on that study, Al-Bishri, et al's measurement for NSD incidence right after surgery is 38.4% while the 29% incidence measured with subjective methods were not accurate.[18] Chortrakarnkij, et al used BSSO with a modified Obwegeser-Dal Pont technique that found it could achieve low rates of inferior alveolar nerve exposure and injury.[19] Similarly, D'Agostino, et al measured NSD incidence in BSSO not in a conventional Obwegeser's method, instead using Hunsuck's method. In this study however, the incidence of NSD is relatively no different from other studies with the percentage of NSD being 48% which is similar to 50% incidence reported by Jędrzejewski, et al in a systematic review.[20,22]

There are one study in this review that reported the incidence of facial nerve palsy after orthognatic surgery. Choi, et al reported six unilateral facial nerve palsy cases in 3,105 patients (0.1%) after orthognatic surgery with 1 patient diagnosed as Bell's palsy. Among those 6 patients; 5 had a complete recovery after 6 months and 1 patient had a permanent impairment of frontal branch of the facial nerve.[24] The frequency reported by Choi, et al seems to be higher when compared to a larger study presented in another systematic review. Bowe, et al reported in a systematic review that among 7,492 osteotomy sides that includes both BSSO and IVRO procedures, risk of temporal facial nerve palsy is 0.30 per 100 nerves while risk of permanent facial nerve palsy is 0.06 per 100 nerves. This study also stated that incidence of permanent nerve palsy is significantly higher in IVRO than in BSSO while there is no significant different in the incidence of temporary nerve palsy.[25] Facial nerve palsy, as a reported NSD, is considered a rare complication in orthognatic surgery. Facial nerve palsyafter orthognatic surgery are likely due to facial nerve compression or traction as argued by Choi, et al.[24] Bisatto, et al elaborated that facial nerve compression is probably due to the close relationship between the posterior border of the mandibular ramus and the facial nerve in the open-mouth position adopted for BSSO.[26] Another possible etiology of facial nerve palsy after orthognatic surgery are incomplete nerve transection, nerve traction, and nerve ischemia due to excessive vasoconstrictor injection in perimandibular region.[27]

IVRO is an orthognatic surgery known to better preserve inferior alveolar nerve as demonstrated by Caldwell, et al.[8] Based on this, NSD incidence should be lower in IVRO when compared to BSSO or other types of orthognatic surgery. All of the study included in this review showed that NSD incidence of IVRO is lower than other orthognatic surgeries. Al-Bishri, et al previously described the incidence of NSD in IVRO and SSO both measured subjectively and objectively. In this report, NSD incidence of IVRO is lower than BSSO both immediately after surgery and 1 year after surgery. NSD incidence of IVRO immediately after surgery measured subjectively and objectively are 10.4% and 7.5% respectively, while NSD incidence 1 year after surgery are 7.5% and 3.8% respectively.[18] Alolaya, et al also previously described NSD incidence in a sample of patients who underwent isolated IVRO surgery and they showed that NSD incidence of IVRO alone is lower in overall NSD incidence of all orthognathic surgeries and also lower than IVRO combined with genioplasty. This study showed that NSD incidence after 2 weeks post-IVRO is 65.3%, decreased into 23% after 6 months, and 0% after 2 years.[11] Data for incidence of NSD after IVRO ranged from 7.5%-65.3%, however these data were extracted from only two studies and therefore insufficient. More research is needed to properly establish the accurate number. All of the study included agreed that NSD incidence after IVRO is lower than BSSO. The preservation of inferior alveolar nerve is also the advantage of IVRO when compared to BSSO.

Genioplasty are often studied together with BSSO and compared between each procedure alone or comparing it to other combination procedures. In a study by Vansickels,et al comparing BSSO (fixation using wired or rigid fixation) and combination of BSSO and
genioplasty, they showed that sensory impairment degree is higher in the combination group only until 1 week post-surgery. There is no significant difference in the degree of NSD in both group after 1 week post-surgery. The assessment of sensory function was done using light touch and brush stroke methods.[28] In a study by Wijbenga, et al, NSD incidence after surgery seems to be lower in genioplasty group (57%) than in BSSO group (68%). In this study, the most common site for sensory impairment is in both chin and lower lip with hypoesthesia being the most common form of sensory impairment.[29] In line with Wijbenga, et al, a study by Gianni, et al reports a significant difference between genioplasty and BSSO. In this study, NSD is in the form of slight hypoesthesia reported in genioplasty group to be 17% while in BSSO group is 30%. Concomitant SSO with genioplasty increased itsincidence to 40%. While BSSO is associated with higher incidence rate, this study shows that tactile sensitivity, location test, and sharp-blunt discrimination decreased more in genioplasty than in BSSO. There are no difference in two-point discrimination and thermal sensitivity.[30] In contrast, Al-Bishri, et al reports no significant difference in NSD incidence between BSSO ony and BSSO and genioplasty combination surgery.[31] Conflicting data alsoreported by Alolayan, et al. They reported the incidence of NSD in BSSO is lower than genioplasty (2.1% and 10.9% respectively). This study agrees that combination surgery with BSSO increase NSD incidence (23.5%).[32] For comparison, a systematic review by McLeod,et al also showed that combination of BSSO and genioplasty significantly increase NSD incidence when compared to BSSO alone.[33] In relation to IVRO, Alolayan, et al showed thatcombination surgery of IVRO and genioplasty have higher NSD incidence (83.8%) than in genioplasty alone (50%). They also showed that recovery of NSD in IVRO and genioplasty combination is significantly better than BSSO and genioplasty because in BSSO andgeniopolasty combination there seem to be no decrease in incidence between 2 week post- surgery and 3 months post-surgery, thus suggesting a delayed recovery in this group.[11] Based on these studies, NSD incidence after genioplasty ranged from 10.9%-57%. While comparison to BSSO still cannot be established due to conflicting result, the fact that combination surgery of BSSO and genioplasty had higher NSD incidence seems to be already established. Higher NSD incidence were also observed when genioplasty is combined with IVRO but only one paper included in this review studied this combination.

Le Fort I osteotomy is different in all other three procedure because Le Fort I osteotomy procedure focused in manipulating maxilla while the other three are focused on mandible. One study by Alolayan, et al reported that NSD incidence after Le Fort I osteotomy is 24.4% and this number increased when segmental pieces involved in Le Fort I

increased. This study reported that in 2 segmental pieces Le Fort I Osteotomy, NSD incidence increases to 25.2% while in 4 segmental pieces it increases to 50.4%.[32] Another study by Zaroni, et al do not specify NSD incidence and instead reported the all incidence of complications that includes hemorrhage, malocclusions, NSD, infection, etc. In this study, complication rate of Le Fort I osteotomy is 17.4%.[13] In a retrospective study done by Kim, et al it is reported that Le Fort I osteotomy's incidence of NSD is 33.3%. Le Fort I osteotomy seems to have lower overall complication rate and NSD incidence when compared to BSSO.[13,21] There are insufficient data measuring NSD incidence in Le Fort I specifically and most data that include Le Fort I osteotomy are presented in a pooled data of all orthognatic surgery. In this review, there are only two studies reporting Le Fort I osteotomy's incidence of NSD and one study reports its overall complication rate. Only one paper studied factors influencing NSD incidence after Le Fort I osteotomy and that is the relationship between Le Fort I osteotomy segmental pieces and NSD incidence. Currently, there is a lack of research data assessing NSD incidence after Le Fort I osteotomy and factors affecting it.

There are several factors that were found to affect NSD incidence after orthognatic surgeries. Some studies showed the correlation of age and NSD incidence after orthognatic surgeries. Nesari, et al showed that NSD incidence in a population of patient under 30 yearsold that underwent BSSO is significantly lower in a group of patients over 30.[15] Bruckmoser, et al with a sample of patients who underwent mixed BSSO or combined with either Le FortI osteotomy or genioplasty showed that positive correlation of age and NSD incidence are observed both at 6 months and 12 months post-surgery.[12] In a population of patients who underwent Le Fort I osteotomy, BSSO, and genioplasty, Alolayan, et al showed NSD correlates with higher age after maxillary procedure at 6 moths and 12 months post-surgery and in mandible procedures at 6 months post-surgery.[32] Politis, et al showed that in patient underwent genioplasty, age is a significant predictor for the incidence of hypoesthesia and a 1 year increase in age at surgery increased odds of hypoesthesia by 5%.[16] All of these studies described the positive correlation between age and NSD incidence after orthognatic procedure both in a population of a specific type of orthognatic surgery or the general population. Two study agrees that this correlation are observed until 12 months after the procedure. Another factors affecting NSD incidence after orthognatic surgeries are bone marrow space[34], length of mandible angle[34], prior history of another mandible procedures[35], type of material used to fixate the mandible during BSSO[12,15], and surgeon's expertise and experience.[36] All of these factors still lack research and thus still to early to draw conclusionfrom it.

CONCLUSION

Incidence of NSD post-orthognathic procedure frequently comes from an insult to the inferior alveolar nerve. Current data showed that IVRO currently have the lowest incidence among other procedures and the highest incidence is BSSO combine with genioplasty. Factors that are known to influence the incidence of NSD were age at the time of surgery, bone marrow space, length of mandible angle, prior history of another mandible procedures, type of material used to fixate the mandible during BSSO[1], and surgeon's expertise and experience. More research are needed to properly establish the accurate percentage and correlation especially in assessing NSD incidence after Le Fort I osteotomy and other unknown factors that may influence the sensory outcome after orthognatic surgery.

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