INVITED REVIEW ARTICLE

https://doi.org/10.5125/jkaoms.2017.43.1.3
pISSN 2234-7550·eISSN 2234-5930

Complications associated with orthognathic surgery

Young-Kyun Kim, D.D.S., Ph.D.
Editor-in-Chief of JKAOMS
Department of Oral and Maxillofacial Surgery, Section of Dentistry, Seoul National University Bundang Hospital, Seongnam, Korea

Abstract (J Korean Assoc Oral Maxillofac Surg 2017;43:3-15)

While most patients undergo orthognathic surgery for aesthetic purposes, aesthetic improvements are most often followed by postoperative functional complications. Therefore, patients must carefully decide whether their purpose of undergoing orthognathic surgery lies on the aesthetic side or the functional side. There is a wide variety of complications associated with orthognathic surgery. There should be a clear distinction between malpractice and complications. Complications can be resolved without any serious problems if the cause is detected early and adequate treatment provided. Oral and maxillofacial surgeons must have a full understanding of the types, causes, and treatment of complications, and should deliver this information to patients who develop these complications.

Key words: Complication, Orthognathic surgery

[paper submitted 2017. 2. 2 / accepted 2017. 2. 9]

I. Introduction

Various postoperative complications of orthognathic surgery have been reported, which have led to serious problems in a number of cases. A majority of these complications can be managed through proper treatment and with a sufficient understanding of their causes. Jung et al.[1] reported a rate of complication of 9.76% (67/686 sites) among 343 patients (686 sites) who had undergone orthognathic surgery for mandibular prognathism between January 1990 and December 2002. Individual rates of different types of complications were 4.08% (28/686) for infections, 2.49% (17/686) for fixation device fracture, 1.89% (13/686) for inferior alveolar nerve injury, 1.02% (7/686) for temporomandibular disorder (TMD), and 0.29% (2/686) for facial nerve problems. Kim et al.[2] investigated the rate of complications among 418 patients who had undergone orthognathic surgery between January 1998 and February 2009. They observed intraoperative complications including inadequate osteotomy, bleeding due to vascular injuries, nerve exposure and damage, dental injuries, and soft tissue injuries among the patients, as well as postoperative complications including paresthesia due to nerve injuries, dyspnea, cervical pain, gastrointestinal diseases, infections, open bite, relapse, TMD, and malunion or nonunion of bone fractures. Ahn et al.[3] reported that postoperative complications such as open bite, infections, TMD, and relapse can occur following orthognathic surgery. In an analysis of complication rates by the type of materials used in bone-fracture fixation, the rate of complications was 8.6% when titanium plates were used, and 18.3% when resorbable plates were used. The rate of complications was higher when resorbable plates were used, and this was especially true for open bite. Therefore, it was concluded that resorbable plates should be used only when indicated. Jędrzejewski et al.[4] reviewed complications associated with orthognathic surgery, and reported that the rate of nerve injury was the highest at 50%, followed by TMD (14%), hemorrhage (9%), hearing problem (7%), infections (7%), and relapse (4%).

While most patients undergo orthognathic surgery for aesthetic purposes, aesthetic improvements are most often followed by postoperative functional complications. Therefore, patients must carefully decide whether their purpose of

Young-Kyun Kim
Department of Oral and Maxillofacial Surgery, Section of Dentistry, Seoul National University Bundang Hospital, 82 Gumi-ro 173beon-gil, Bundang-gu, Seongnam 13620, Korea
TEL: +82-31-787-7541 FAX: +82-31-787-4068
E-mail: kyk0505@snubh.org
ORCID: http://orcid.org/0000-0002-7268-3870

undergoing orthognathic surgery lies on the aesthetic side or the functional side. During an interview of patients with mandibular prognathism with low mandibular plane angles, it was observed that most of the patients chose to undergo orthognathic surgery for aesthetic purposes rather than functional improvement. Patients, who answered 'no' to a question that asked if the patients would undergo the same surgery again in the future, answered so because of postoperative paresthesia in the lower lip. The rate of complications after orthognathic surgery is more than 40%; therefore, it is important that patients receive a detailed explanation on the complications related to orthognathic surgery before they decide to undergo the procedure[5].

II. Intraoperative Complications

1. Hemorrhage

Severe bleeding can occur if the inferior alveolar, superior alveolar, maxillary, retromandibular, facial, and sublingual vessels become damaged. Bleeding can be stopped by applying pressure, using bone wax or resorbable hemostatic materials, or by performing thrombin or epinephrine impregnated gauze packing or electrocautery. Vessel ligation or angiography must be performed for large vessel injuries to prevent secondary delayed hemorrhage. Arterial bleeding that occurs during Le Fort I osteotomy can be a sign of severe nasal hemorrhage that occurs two weeks after surgery. It must be, therefore, treated immediately by performing one of the following procedures: anterior and/or posterior nasal packing, packing of the maxillary antrum, reoperation with clipping or electrocoagulation of bleeding vessels, application of hemostatic agents in the pterygomaxillary region, external carotid artery ligation, and selective embolization of the maxillary artery. However, these hemostatic therapies can cause the aseptic necrosis[6]. The severity of intraoperative bleeding and the possibility of developing complications vary from patient to patient. For this reason, it is important to measure the relative blood loss during intraoperative bleeding by using a patient-specific measure. Extensive surgery and reduced body mass index are associated with increased intraoperative relative blood loss[7].

Lee et al.[8] reported severe swelling, ecchymosis, and irregular menstrual cycles among female patients who underwent orthognathic surgery. Physical stress following surgery was attributed to early menstruation and bleeding tendency in these patients. Basu[9] claimed that fibrinolysis increases during menstruation, which reflects the increased risk of bleeding during this period. Lin et al.[10] reported that hypotensive anesthesia using sevoflurane can effectively reduce bleeding and secure excellent vision during surgery.

2. Bad split/segment fractures

The rate of bad splits during sagittal split ramus osteotomy (SSRO) has been reported to be approximately 2.3%. Proximal segment buccal plate fracture and distal segment lingual fracture frequently occur during SSRO. Different methods for treating these fractures must be studied. It has been reported that the risk of buccal cortical plate fracture is especially high when the forced separation of bone segments is performed after incomplete osteotomy of mandibular inferior border[11-13].

Causes and risk factors of segment fracture include inadequate vertical osteotomy at the inferior border, horizontal osteotomy performed too high above the lingula, exertion of excess force when separating the proximal and distal segments, and impacted third molars. There is much controversy among scholars regarding whether impacted teeth should be extracted 6-9 months before SSRO or at the same time as SSRO.

1) Notion 1. Impacted teeth can be extracted during SSRO[14-16]

Precious et al.[14] examined 1,256 patients who underwent SSRO, and had their third molars extracted, either during SSRO or six months before SSRO. Among 24 patients who had an unfavorable fracture (1.9%), five underwent extraction during SSRO and 19 underwent extraction six months before SSRO. Although no statistically significant difference was found between the two groups, the rate of mandibular fracture was higher among patients who underwent extraction six months before SSRO. Posnick et al.[15] reported no 'bad splits' following extraction of impacted third molars performed during SSRO and claimed that the extraction of impacted teeth does not increase the rate of 'bad' splits and delay bone healing.

2) Notion 2. It is safer to extract impacted teeth 6-9 months before SSRO[17-19]

Reyneke et al.[17] observed four cases of fracture among 70 patients who underwent a total of 139 SSRO procedures within six months. Since impacted teeth interfere with SSRO and increase the rate of fracture in the proximal or distal segments, they recommended that impacted teeth be extracted

6-9 months prior to orthognathic surgery. Extraction of impacted teeth during SSRO leads to thinning of the cortical bone due to the presence of empty sockets. This may render fixation using metal plates or screws difficult and increase the risk of fracture in the proximal or distal segments[18,19].

III. Postoperative Complications

1. Relapse

Factors associated with relapse include muscle-related physiological effects that are influenced by the direction of bone rotation and the amount of bone movement, asymmetry between the left and right mandibles, changes in teeth position after surgery, change in condylar position, change in ramus inclination, change in mandibular plane, type of fixation, improperly produced final splint, and unresolved misalignment of the upper and lower jaws during orthodontic procedures performed before surgery[18,20].

1) Gap between proximal and distal segment

Creation of gaps between bony segments after SSRO is inevitable. Forced fixation can lead to changes in condyle positions and relapse[21]. Bony interference between bony segments may be causally related to relapse, changes in the position of condyles or articular discs, and condylar resorption. Bending the distal segment posterior to the last molar, performing a bone graft in the area of the segment gap, and bending plate fixation have been introduced as a means to treat these conditions[22-28].

2) Condyle malposition

Uckan et al.[29] reported cases of severe anterior open bite that occurred immediately after the release of the maxillomandibular fixation, and mentioned that it is caused by condyle malposition. In their study, screws placed in front of metal plates were removed from both sides of the jaw after exposing the surgical site, and posterior acrylic bite-blocks were attached. Orthodontic treatment was performed by using chin cups. Open bites were fixed 10 days after the orthodontic treatment.

3) Pterygomasseteric tension

Mandibular setback osteotomy can lead to changes in the physiological equilibrium of the pterygomasseteric sling, which may subsequently affect the functioning of the muscles of mastication. These changes in the muscles tend to rotate the proximal segment counterclockwise to set it back to its original position. Angle ostectomy can change the length of the pterygomasseteric sling, and reduction of the pterygomasseteric tension can lower the rate of relapse after surgery[30].

Kim et al.[31] argued that relapse can be prevented in patients with an open bite by using the modified Epker technique or by performing detachment of the pterygomasseteric sling, overcorrection, angle shaving, or genioplasty during SSRO.

4) Clockwise rotation of the proximal segment

Han et al.[32] claimed that the safety of SSRO decreases with an increase in the counterclockwise rotation of the proximal segment, and that even when the mandibular setback distance is large, postoperative relapse can be prevented by minimizing the rotation of the proximal segment. Relapse tendency increases when the proximal segment that previously rotated clockwise starts to rotate counterclockwise after surgery[33,34]. Jakobsone et al.[35] argued that superior repositioning of the posterior maxilla or repositioning of the proximal segment to its original position, which prevents clockwise rotation of the segment, can lower the rate of relapse. Superior repositioning of the posterior maxilla increases the safety of mandibular setback surgery. When the direction of the movement of the mandibular distal segment changes from the posterior to the posterosuperior direction, the difference of height between the inferior borders of the proximal and distal segments decreases, decreasing the clockwise rotation of the proximal segment. Han et al.[36] reported that superior repositioning of the posterior maxilla and mandibular angle resection can minimize the occurrence of relapse following a mandibular setback surgery.

2. Neurologic injury

Neurologic injuries associated with orthognathic surgery mainly affect the inferior alveolar nerve, mental nerve, incisive nerve, and the infraorbital nerve. Occasional direct or indirect damage to facial nerves can occur. Le Fort I osteotomy induces changes in the maxillary teeth, buccal mucosa, palatal mucosa, and facial skin sensation. While skin sensation tends to recover over time even after direct damage to the sensory nerves, it may not completely recover to the condition that was present before surgery[37]. SSRO induces more neurological problems than intraoral vertical ramus osteotomy (IVRO). Neurological problems have been observed until 24 weeks after SSRO at various sites, and recovery tended to be slower after SSRO than after IVRO[38].

Verweij et al.[39] reported that hypoesthesia following SSRO occurred in 4.8% of patients aged less than 19 years, in 7.9% of patients aged between 19-30 years, and in 15.2% in patients aged 31 years or older. Although the rate of permanent hypoesthesia that persisted until one year after SSRO was low, the mean recovery time from hypoesthesia was relatively long for older patients. In other words, old age is a risk factor for permanent hypoesthesia. The rate of inferior alveolar nerve injury varies from study to study due to the lack of standardized assessment and reporting methods. Therefore, a majority of assessments of inferior alveolar nerve injury performed to date has used subjective methods. An international consensus meeting must be organized with the purpose of establishing standardized methods of assessing the degree of nerve injuries[40].

de Vries et al.[41] reported nine cases of facial nerve paralysis among 1,747 patients who underwent SSRO. The rate of facial nerve paralysis reported by other scholars varies from 0.17% to 0.75%. Causes of facial nerve paralysis after orthognathic surgery include ischemic paralysis of the facial nerve caused by deep injection of vasoconstrictors, physical damage by a chisel or osteotome used for segment separation, fracture of the styloid process with posterior displacement, slipping of a drill or a bur to the perimandibular soft tissues during medial osteotomy, and facial nerve compression due to a posteriorly displaced segment, and surgical retractors or hematoma. Since the distance between the ascending ramus posterior border and facial nerve is less than 1 to 2 cm while the mouth is open, the facial nerve may become pressed or directly damaged[42-44]. Use of steroids during or after surgery can effectively prevent temporary injuries by reducing pressure created by edema. If functional recovery does not occur within 4-8 months, re-exploration with nerve grafting or reanimation surgery must be considered[33,44].

3. Neuropathic pain

Ongoing pain was reported by 21.4% of the patients after orthognathic surgery, 7.1% of whom experienced neuropathic pain and 14.3% experienced musculoskeletal pain[45]. Politis et al.[46] investigated the types of pain experienced by patients who underwent orthognathic surgery between 2001 and 2011. Among 982 cases of bilateral sagittal split ramus osteotomy (BSSRO), 536 cases of Le Fort I osteotomy, and 335 cases of surgically assisted rapid palatal expansion procedures, six cases of debilitating chronic neuropathic pain were observed. For the cases of BSSRO, direct damage to the inferior alveolar nerve and its bone environment that had become exposed may have been the cause of partial axonal injuries. Teerijoki-Oksa et al.[47] claimed that pain that persists up to one month after surgery indicates axonal damage, and that the pain can continue for even a longer period if axonal damage does not heal completely. A third of the patients with axonal damage never show complete recovery. Neuropathic pain has been observed to persist even until one year after surgery; therefore, early diagnosis and adequate management of neuropathic pain are crucial[48].

4. Change of nasal morphology

Nasal morphology is likely to change following repositioning of the maxilla during surgery. Nose widening and nose deviation are commonly observed following corrective procedures such as bony segment repositioning and suturing. Patients should be informed about the possible need for rhinoplasty after orthognathic surgery before they undergo the surgery[49,50].

1) Nose widening

Nose widening is frequently observed after orthognathic surgery during which the nasal septum and alar cartilage are affected by superior impaction or advancement of the maxilla. Nose widening can be minimized by performing an alar cinch suture that tightly anchors the bilateral alar fibroareolar tissue in the medial direction. However, many studies have reported the lack of effectiveness of this suture technique and have claimed that it prevents the medial movement of the ala of the nose into which a nasotracheal intubation tube is inserted. A modified alar cinch suture technique, which is used to move bilateral alar fibroareolar tissues individually, has been introduced to overcome these shortcomings[51]. Scholars have claimed that although points are used during intraoral suturing of fibroareolar tissue, suturing performed outside of the oral cavity leads to more predictable and stable results because it covers a larger tissue surface area[52,53].

2) Nasal deviation

Causes of nasal deviation include displacement of maxillary segments, pressure created by nasotracheal intubation, and dislocation of the quadrangular cartilage by an incompletely deflated cuff during extubation. During superior repositioning of the maxilla, septum reduction of at least 3 mm must be made to prevent nasal deviation. Corrective procedures such as nasal reduction using forceps, septoplasty, and fixation of the septum caudal portion to the anterior nasal septum through figure-of-8 suturing have been introduced for cases in which nasal deviation does occur[54,55].

5. Temporomandibular disorder

There is much controversy regarding the correlation of craniofacial anomalies and malocclusion with TMDs. Some claim that mandibular setback surgery can treat TMDs while others claim the surgery aggravates them. Although numerous studies have investigated the correlation between mandibular setback surgery and TMD, large variations exist amongst the studies, and they have used different diagnostic systems and methods of classification. Therefore, it is necessary to develop a standardized diagnostic standard and classification method for TMD through systematic and well-designed research[56]. The following are the most mutually agreed upon opinions among scholars[57-103].

1) All types of orthognathic surgery can directly or indirectly affect temporomandibular joint symptoms. The diagnosis of temporomandibular joint symptoms or disorders prior to surgery and incorporation of this information in treatment planning are necessary. Postoperative monitoring and management must also be conducted[57,61-67].

2) Patients with temporomandibular joint symptoms are recommended to undergo procedures that stabilize the temporomandibular joints before undergoing orthognathic surgery (splint, pharmacotherapy, injection therapy, etc.)[85,86].

3) Orthognathic surgery can improve or worsen the existing temporomandibular joint symptoms, or may not result in any changes at all[89,99-103].

4) SSRO and IVRO for posterior displacement of the mandible can be applied to all patients with TMD. The following principles should be followed when performing SSRO[87-92].

(1) All bony interferences that exist between proximal and distal segments should be removed.

(2) Condylar heads should passively settle into the glenoid fossa during surgery.

(3) For fixation of bony segments, non-rigid fixation using monocortical plates and screws is recommended. Use of compression plates or lag screws should be avoided[22,56,58,87-92].

5) By avoiding long-term intermaxillary fixation, postoperative mandibular hypomobility can be minimized[102,103].

6) Counterclockwise maxillomandibular rotation and a large amount of mandibular advancement can increase the load and stress on the temporomandibular joints. Therefore, the procedure must be performed with care for patients with TMD. Counterclockwise maxillomandibular rotation and a large amount of mandibular advancement can worsen the existing temporomandibular joint symptoms. When the load on the temporomandibular joints exceeds adaptability, condylar resorption results[60,68-86].

7) Generally, the rate of TMD tends to be higher among patients who have mandibular retrusion with steep occlusal planes[67-76].

8) Unlike mandible setback, which improves masticatory functions (for instance, by increasing the bite force), mandibular advancement does not improve masticatory functions.

9) Procedures in which the maxilla and mandible are rotated clockwise or counterclockwise to change the occlusal plane are safe as long as the temporomandibular joint can withstand the occlusal load and stress after surgery. It is generally known that the counterclockwise rotation induces occlusal overload on the temporomandibular joint to a greater degree than the clockwise rotation.

10) In double jaw surgeries, the maxilla is moved relative to the mandible. However, for patients with temporomandibular joint disorders, for whom making precise treatment plans prior to surgery as well as securing a stable condyle location can be difficult, it may be more advantageous to start operating on the mandible first.

6. Necrosis of bony segment

Kim et al.[104] reported rare cases of necrosis of the proximal segments in patients who underwent transoral vertical ramus osteotomy. Although the causes of the necrosis were not clear, it was presumed that it was caused by local ischemia that developed as a result of excessive ablation of soft tissues and hematoma formation. Necrosis of bony segments was successfully treated through intravenous injection of third generation cephalosporin and metronidazole, followed by a resection of 15 mm of necrotic tissue inferior to the proximal segment through an intraoral approach.

7. Delayed union or nonunion of osteotomy site

Delayed union or nonunion of an osteotomy site may occur as a result of poor healing of hard and soft tissues. The risk of nonunion is high when inadequate fixation is performed after non-rigid fixation using materials such as wires, and when the anterior displacement of a bony segment is large, or when maxillary advancement of over 6 mm is performed. Postoperative occlusal prematurities and improperly constructed splints can interfere with the stabilization and healing of bony segments. Delayed union and nonunion can also occur in patients with systemic diseases who also have compromised wound healing[105].

8. Infection

Postoperative infections include cellulitis, abscess, maxillary sinusitis, and osteomyelitis. Rates of postoperative infections are low thanks to aseptic techniques, surgeons' excellent skills, antibiotics, and a good blood supply into the oral and maxillofacial area. Even when infections do occur, they can be fully cured through early diagnosis and management. Davis et al.[106] reported that the rate of infections was 8% among 2,521 patients who underwent orthognathic surgery, and that infections occurred mostly in the mandible. Posnick et al.[107] reported that the rate of infections was merely 1% when antibiotics such as cefazolin or cephalexin were administered.

9. Respiratory insufficiency

Complications related to the respiratory system include airway obstruction, atelectasis, pneumonia, pneumomediastinum, and pneumothorax. Causes of respiratory insufficiency that occur after orthognathic surgery are stimulation by a tube used in anesthesia, elevation or damage of the nasal mucous membrane, reduced nasal cavity, intermaxillary fixation, aspiration of blood, long operation time, and influx of air through the fascial plane of the neck[108,109]. Dyspnea caused by bleeding or accumulated secretions can be prevented by avoiding excessive ventilation during general anesthesia and minimizing intraoperative trauma. Aspiration pneumonia can occur when food, saliva, or nasal secretions enter the bronchial tree. The rate of aspiration pneumonia after orthognathic surgery is approximately 0.01% to 0.03%[110].

Choi et al.[111] claimed that one must be aware of the fact that the airway space can be significantly reduced because of posterior movement of the mandible during SSRO. Potential postoperative problems can be prevented by predicting the risk of respiratory failure and determining the appropriate amount of setback. For class III patients with high preoperative Mallampati scores, only a small amount of mandibular setback is advised[111-113].

10. Trigeminocardiac reflex

Cardiac complications such as asystole, bradycardia, and cardiac dysrhythmias can occur during ophthalmic or maxillofacial surgeries and can be lethal in rare cases. The rate of these complications during maxillofacial surgery has been reported to be 1.6%. Stimulation of the maxillary branch of trigeminal nerve, greater palatine nerve, or posterior superior alveolar nerve leads to vagus nerve stimulation, which activates the parasympathetic nerve system, and consequently leads to dysrhythmia. The risk of reflex bradycardia during maxillofacial surgery that involves stimulation of the trigeminal nerve should be considered. In most cases, heart rate and blood pressure return to normal while arrhythmia disappears upon temporary cessation of surgery. When bradycardia accompanied by refractory bradycardia, asystole, and hypotension persists, anticholinergic drugs (atropine 0.2-1.0 mg, glycopyrrolate 0.1-0.4 mg) are injected[114-117].

11. Pseudoaneurysm

Pseudoaneurysm (arteriovenous fistula) is defined as an abnormal focal dilation of an arterial wall. It is a type of false aneurysm that causes blood vessels to be composed of fibrous tissue. Pseudoaneurysm rarely develops after orthognathic surgery, and can cause symptoms such as facial swelling, delayed bleeding, and development of a pulsatile soft mass. Large blood vessels such as the maxillary artery in the region of the sigmoid notch, the facial artery in the posterior region of the mandibular body, and the inferior alveolar artery are at high risk of pseudoaneurysms. If bleeding cannot be successfully controlled through surgical exploration and vessel ligation, interventional radiographic treatment such as embolization must be performed[118-120].

12. Vomero-sphenoidal disarticulation

Vomero-sphenoidal disarticulation can result from improper use of septal osteotome or use of septal osteotome in the wrong direction during maxilla osteotomy. An osteotome should be used precisely along the nasal floor. Bone resistance can be felt when an osteotome is in contact with the vomer. If vomer mobility is observed following downward fracture of the maxilla, the maxilla is left in its current position. Excessive resection of the maxilla can increase the risk of laceration of the mucous membrane and bleeding. However, the maxilla does not have to be repositioned to its original location if the vomer has been completely separated. Severe loss of function does not occur even after the vomer is removed[121].

13. Lack of tearing

Le Fort I osteotomy with iliac bone graft was performed on a 24-year-old female patient with maxillary retrusion. Two days after the surgery, it was observed that liquids ingested through straws leaked out from the nose. Three days after the surgery, lack of tearing in the left eye was observed, but no visual or motor dysfunction was observed. Based on ophthalmic examination, the patient was diagnosed with damage to the parasympathetic fibers to the lacrimal gland. The patient was also told that tearing will recover over a few months, and was recommended to use artificial tears in the meantime. A possible cause of the damage was fracture of the pterygoid plate on the affected side, which subsequently damaged non-myelinated fibers to the lacrimal gland[122,123].

14. Tooth injury

Although maxillomandibular fixation screws are safe and useful, one must be careful not to damage the dental roots during implantation. The rate of contact between screws and dental roots during orthognathic surgery was 12%. However, pulp necrosis or pain was not observed during postoperative monitoring[124]. During an orthognathic procedure in which an approach is made near the root apex, or direct resection is made, pulp necrosis and discoloration, and pulp diseases can develop. Lee et al.[125] investigated cases of pulp diseases among 1,455 patients who underwent orthognathic surgery. Among 1,339 patients who underwent bimaxillary surgery, 49 required endodontic treatment for tooth discoloration and root canals. Tooth discoloration was not observed among 116 patients who underwent single-jaw surgery. The main risk factors for tooth discoloration are descending palatine artery ligation, genioplasty, and mandibular subapical osteotomy. It is especially important to protect the descending palatine artery during Le Fort I osteotomy.

15. Benign paroxysmal positional vertigo

This is one of the most commonly observed types of vertigo. It causes brief dizziness that lasts less than one minute and repeats upon positional changes. Although its pathogenesis and physiological mechanisms have not been identified, it is generally accepted that formation of degenerated tissue particles in the lymph fluid inside the semicircular canals of the internal ear induces severe dizziness upon positional changes. Benign paroxysmal positional vertigo commonly occurs as a complication of head injury, vestibular neuritis, Meniere's disease, and otolaryngologic surgery. It has been suggested that benign paroxysmal positional vertigo is induced by vibrational energy that arises during dentoalveolar surgery with a rotating bur for removal of impacted teeth and cysts, orthognathic surgery, and sinus floor elevation with an osteotome[126,127].

16. Venous thromboembolism

Venous thromboembolism (VTE) is a common complication that occurs at a rate of 90 million cases per year in the United States. In Van de Perre's research, VTE developed in three (0.15%) (two with venous thrombosis and one with pulmonary embolism) out of 2,049 patients who underwent orthognathic surgery. VTE develops as a result of vascular wall injuries due to long-term hospitalization, immobility, local hypoxia that induces blood clots, anesthetics, surgery, and trauma[128,129].

17. Otitis media

A 20-year-old female patient exhibited the symptom of unilateral fullness in the left ear after undergoing orthognathic surgery in a department of plastic surgery 8 months ago. After undergoing a thorough medical examination, the patient was diagnosed with otitis media with effusion caused by the presence of a foreign body in the opening of the left eustachian tube. It was confirmed during transnasal endoscopic removal that a part of surgical gauze used during the surgery had moved to the Eustachian tube[130].

18. Psychological changes and patient satisfaction

Patients with dentofacial deformities have an inferiority complex due to their appearance alongside functional problems such as masticatory dysfunction. Therefore, functional and aesthetic improvements must be incorporated simultaneously to ensure patient satisfaction and psychological stability. Lee and Lee[131] studied the level of satisfaction and psychological changes among 34 patients who underwent orthognathic surgery. The reason for undergoing surgery was aesthetic purposes in 62% of the patients, functional improvement in 18%, and both in 18%. Patient satisfaction increased from 81% within six months after the surgery to 92% after more than six months had passed after the surgery. The main reasons for dissatisfaction with the surgery were temporary sensory impairment and insufficient facial improvement. Difficulty in speaking and eating due to intermaxillary fixation was ranked the most painful experience after surgery, followed by respiratory failure, swelling, and pain. Seol et al.[132] observed positive changes in the physical self-concept after orthognathic surgery among patients who had skeletal class III occlusion. While patients showed high satisfaction with facial improvement after orthognathic surgery, they also showed increasing dissatisfaction with functional impairments such as masticatory and pronunciation problems and sensory impairment. By explaining to patients about various types of discomfort that they may experience after orthognathic surgery, surgeons can reduce patient anxiety and concerns regarding the surgery, and increase subjective patient satisfaction with surgery outcomes[133].

A pattern of improvement in the quality of life in psychological and social aspects was observed following orthognathic surgery. Since orthognathic surgery negatively contributes to the quality of life among patients with depression, patients should be examined for depression through systematic screening before undergoing surgery, and receive treatment for depression if necessary[134-137].

19. Nausea and vomiting

Nausea and vomiting are postoperative complications that frequently occur after general anesthesia. Intermaxillary fixation is necessary after orthognathic surgery or facial bone fracture surgery. Severe hemorrhage and edematous swelling are common after these surgeries, and nausea and vomiting can have lethal effects on patients. Phillips et al.[138] investigated 204 patients who underwent orthognathic surgery in the period from 2008 to 2012. In their study, the rate of postoperative nausea and vomiting was 67% and 27%, respectively. Risk factors for postoperative nausea were female, increased IV fluids, long operation time, and use of nitrous oxide. Risk factors for postoperative vomiting were race (the risk of vomiting among non-Caucasians was 2.49 times that among Caucasians), additional procedures, and use of morphine. Although updated consensus guidelines were introduced in 2007 to lower rates of vomiting and nausea, the rates have not decreased compared with the rates in the period from 2003 to 2004[138]. Lin et al.[10] claimed that postoperative nausea and vomiting can be significantly reduced by limiting the use of narcotics after surgery for pain control. Postoperative pain can be effectively controlled with non-steroidal anti-inflammatory drugs (NSAIDs) or COX-2 inhibitors.

20. Snoring or obstructive sleep apnea

Snoring or obstructive sleep apnea (OSA) may develop following orthognathic surgery as the hyoid bone position changes and the airway becomes narrower, and some cases have been reported[139,140]. Posterior movement of the mandible by a large distance can lead to development of OSA at an older age, and requires consistent postoperative monitoring. Furthermore, when the mandibular setback distance is large, double jaw surgery, in which anterior maxillary advancement is performed, can be considered[140,141]. However, numerous studies have reported that orthognathic surgery does not affect the airway significantly and that it does not induce snoring or OSA[142,143]. Oral and maxillofacial surgeons must have full understanding of the possibility of postoperative development of snoring or OSA, and their methods of treatment (conservative and/or surgical treatment).

21. Hearing problem

Maxillary osteotomy may induce muscle traction and edema, which can lead to paratubular muscle and auditory dysfunction. Yaghmaei et al.[144] reported that auditory system dysfunction which occurs during maxillary or bimaxillary osteotomies are mostly mild and temporary, and does not require special treatment. Bayram et al.[145] also claimed that while Le Fort I osteotomy induces changes in hearing sensitivity and middle ear pressure, these changes are not drastic and do not pose any clinical problems.

22. Death

Main causes of death during or after orthognathic surgery are accidents related to severe intraoperative hemorrhage, delayed secondary hemorrhage, airway obstruction, and general anesthesia. Fourteen cases of serious complications such as death and falling into a vegetative state after jaw bone surgery such as the orthognathic surgery (10 cases) and facial contouring surgery (4 cases) were reported in the period from 2000 to 2016. Causes of these complications were bleeding in two cases, respiratory problems in four cases, surgical errors in one case, and unknown in six cases. The procedures were performed by plastic surgeons in 12 cases, by dentists in one case, and in a university hospital in one case (Exact department is unknown). An underreporting of cases of death after orthognathic surgery is suggestive since only four cases of death have been reported in the last 16 years despite the fact that around 5,000 cases of orthognathic surgery are performed in Korea every year. Serious complications such as death rarely occurs when orthognathic surgery is performed by experienced surgeons with all the necessary equipment, and orthognathic surgery can be considered a safe procedure as long as these conditions are met[2,146,147].

IV. Conclusion

There is a wide variety of complications associated with orthognathic surgery, including unusual complications that are hard to predict. There should be a clear distinction between malpractice and complications. Oral and maxillofacial surgeons must have a full understanding of the types, causes, and treatment of complications, and should deliver this information to patients who develop these complications. Malpractice should never occur, and is best prevented by careful and meticulous performance by surgeons. We believe that oral and maxillofacial surgeons who can confidently and perfectly manage postoperative complications are truly competent.

Conflict of Interest

No potential conflict of interest relevant to this article was reported.

References

1. Jung JY, Park JH, Sin SH, Lee HK, Lee SW, Kim WH, et al. Postoperative complications of bilateral sagittal split ramus osteotomy of mandible. Korean J Hosp Dent 2006;4:67-81.
2. Kim JH, Kim SG, Oh JS. Complications related to orthognathic surgery. J Korean Assoc Maxillofac Plast Reconstr Surg 2010;32:416-21.
3. Ahn YS, Kim SG, Baik SM, Kim BO, Kim HK, Moon SY, et al. Comparative study between resorbable and nonresorbable plates in orthognathic surgery. J Oral Maxillofac Surg 2010;68:287-92.
4. Jędrzejewski M, Smektała T, Sporniak-Tutak K, Olszewski R. Preoperative, intraoperative, and postoperative complications in orthognathic surgery: a systematic review. Clin Oral Investig 2015;19:969-77.
5. Brons S, Becking AG, Tuinzing DB. Value of informed consent in surgical orthodontics. J Oral Maxillofac Surg 2009;67:1021-5.
6. Lanigan DT, Hey JH, West RA. Major vascular complications of orthognathic surgery: hemorrhage associated with Le Fort I osteotomies. J Oral Maxillofac Surg 1990;48:561-73.
7. Thastum M, Andersen K, Rude K, Nørholt SE, Blomlöf J. Factors influencing intraoperative blood loss in orthognathic surgery. Int J Oral Maxillofac Surg 2016;45:1070-3.
8. Lee HK, Shin SS, Kim HW, Cheon SH, Kim S, Park YH, et al. A case report: menstrual dysfunction and bleeding tendency caused by surgical stress. Korean J Hosp Dent 2006;4:59-66.
9. Basu HK. Fibrin degradation products in sera of women with normal menstruation and menorrhagia. Br Med J 1970;1:74-5.
10. Lin S, Chen C, Yao CF, Chen YA, Chen YR. Comparison of different hypotensive anaesthesia techniques in orthognathic surgery with regard to intraoperative blood loss, quality of the surgical field, and postoperative nausea and vomiting. Int J Oral Maxillofac Surg 2016;45:1526-30.
11. Steenen SA, Becking AG. Bad splits in bilateral sagittal split osteotomy: systematic review of fracture patterns. Int J Oral Maxillofac Surg 2016;45:887-97.
12. O'ryan F, Poor DB. Completing sagittal split osteotomy of the mandible after fracture of the buccal plate. J Oral Maxillofac Surg 2004;62:1175-6.
13. Patterson AL, Bagby SK. Posterior vertical body osteotomy (PVBO): a predictable rescue procedure for proximal segment fracture during sagittal split ramus osteotomy of the mandible. J Oral Maxillofac Surg 1999;57:475-7.
14. Precious DS, Lung KE, Pynn BR, Goodday RH. Presence of impacted teeth as a determining factor of unfavorable splits in 1256 sagittal-split osteotomies. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 1998;85:362-5.
15. Posnick JC, Choi E, Liu S. Occurrence of a 'bad' split and success of initial mandibular healing: a review of 524 sagittal ramus osteotomies in 262 patients. Int J Oral Maxillofac Surg 2016;45:1187-94.
16. Steenen SA, van Wijk AJ, Becking AG. Bad splits in bilateral sagittal split osteotomy: systematic review and meta-analysis of reported risk factors. Int J Oral Maxillofac Surg 2016;45:971-9.
17. Reyneke JP, Tsakiris P, Becker P. Age as a factor in the complication rate after removal of unerupted/impacted third molars at the time of mandibular sagittal split osteotomy. J Oral Maxillofac Surg 2002;60:654-9.
18. Van Sickels JE, Dolce C, Keeling S, Tiner BD, Clark GM, Rugh JD. Technical factors accounting for stability of a bilateral sagittal split osteotomy advancement: wire osteosynthesis versus rigid fixation. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2000;89:19-23.
19. Schwartz HC. Simultaneous removal of third molars during sagittal split osteotomies: the case against. J Oral Maxillofac Surg 2004;62:1147-9.
20. Lee JH, Lee IW, Seo BM. Clinical analysis of early reoperation cases after orthognathic surgery. J Korean Assoc Oral Maxillofac Surg 2010;36:28-38.
21. Moroi A, Yoshizawa K, Iguchi R, Kosaka A, Ikawa H, Saida Y, et al. Comparison of the computed tomography values of the bone fragment gap after sagittal split ramus osteotomy in mandibular prognathism with and without asymmetry. Int J Oral Maxillofac Surg 2016;45:1520-5.
22. Ellis E 3rd, Hinton RJ. Histologic examination of the temporomandibular joint after mandibular advancement with and without rigid fixation: an experimental investigation in adult Macaca mulatta. J Oral Maxillofac Surg 1991;49:1316-27.

23. Ueki K, Degerliyurt K, Hashiba Y, Marukawa K, Nakagawa K, Yamamoto E. Horizontal changes in the condylar head after sagittal split ramus osteotomy with bent plate fixation. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2008;106:656-61.
24. Baek SH, Kim TK, Kim MJ. Is there any difference in the condylar position and angulation after asymmetric mandibular setback? Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2006;101:155-63.
25. Yoshida K, Rivera RS, Kaneko M, Kurita K. Minimizing displacement of the proximal segment after bilateral sagittal split ramus osteotomy in asymmetric cases. J Oral Maxillofac Surg 2001;59:15-8.
26. Kang MG, Yun KI, Kim CH, Park JU. Postoperative condylar position by sagittal split ramus osteotomy with and without bone graft. J Oral Maxillofac Surg 2010;68:2058-64.
27. Ellis E 3rd. A method to passively align the sagittal ramus osteotomy segments. J Oral Maxillofac Surg 2007;65:2125-30.
28. Yang HJ, Hwang SJ. Evaluation of postoperative stability after BSSRO to correct facial asymmetry depending on the amount of bone contact between the proximal and distal segment. J Craniomaxillofac Surg 2014;42:e165-70.
29. Uckan S, Buchbinder D, Orhan M, Mutlu N. Management of early relapse after a sagittal split ramus osteotomy by gradual callus distraction: a case report. J Oral Maxillofac Surg 2000;58:220-3.
30. Chang HP, Tseng YC, Chang HF. Treatment of mandibular prognathism. J Formos Med Assoc 2006;105:781-90.
31. Kim JW, Jeon HR, Hong JR. The study on vertical stability of anterior open bite patients after bssro. J Korean Assoc Oral Maxillofac Surg 2005;31:422-6.
32. Han JJ, Park MW, Park JB, Park HS, Paek SJ, Sul H, et al. Evaluation of dominant influencing factor for postoperative relapse after BSSRO for mandibular prognathism. Recent Advances in Orthodontics and Orthognathic Surgery 2014;1:27-36.
33. Yang HJ, Hwang SJ. Contributing factors to intraoperative clockwise rotation of the proximal segment as a relapse factor after mandibular setback with sagittal split ramus osteotomy. J Craniomaxillofac Surg 2014;42:e57-63.
34. Proffit WR, Phillips C, Turvey TA. Stability after surgical-orthodontic corrective of skeletal Class III malocclusion. 3. Combined maxillary and mandibular procedures. Int J Adult Orthodon Orthognath Surg 1991;6:211-25.
35. Jakobsone G, Stenvik A, Sandvik L, Espeland L. Three-year follow-up of bimaxillary surgery to correct skeletal Class III malocclusion: stability and risk factors for relapse. Am J Orthod Dentofacial Orthop 2011;139:80-9.
36. Han JJ, Lee SY, Hwang SJ. Postoperative stability after SSRO in mandibular prognathism in relation to rotation of proximal segment. Recent Advances in Orthodontics and Orthognathic Surgery 2013;2:1-8.
37. Al-Din OF, Coghlan KM, Magennis P. Sensory nerve disturbance following Le Fort I osteotomy. Int J Oral Maxillofac Surg 1996;25:13-9.
38. Hasegawa T, Tateishi C, Asai M, Imai Y, Okamoto N, Shioyasono A, et al. Retrospective study of changes in the sensitivity of the oral mucosa: sagittal split ramus osteotomy (SSRO) versus intraoral vertical ramus osteotomy (IVRO). Int J Oral Maxillofac Surg 2015;44:349-55.
39. Verweij JP, Mensink G, Fiocco M, van Merkesteyn JP. Incidence and recovery of neurosensory disturbances after bilateral sagittal split osteotomy in different age groups: a retrospective study of 263 patients. Int J Oral Maxillofac Surg 2016;45:898-903.
40. Agbaje JO, Salem AS, Lambrichts I, Jacobs R, Politis C. Systematic review of the incidence of inferior alveolar nerve injury in bilateral sagittal split osteotomy and the assessment of neurosensory disturbances. Int J Oral Maxillofac Surg 2015;44:447-51.
41. de Vries K, Devriese PP, Hovinga J, van den Akker HP. Facial palsy after sagittal split osteotomies. A survey of 1747 sagittal split osteotomies. J Craniomaxillofac Surg 1993;21:50-3.
42. Consolo U, Salgarelli A. Transient facial nerve palsy following orthognathic surgery: a case report. J Oral Maxillofac Surg 1992;50:77-9.
43. Jones JK, Van Sickels JE. Facial nerve injuries associated with orthognathic surgery: a review of incidence and management. J Oral Maxillofac Surg 1991;49:740-4.
44. Koh KM, Yang JY, Leem DH, Baek JA, Ko SO, Shin HK. Facial nerve palsy after sagittal split ramus osteotomy: follow up with electrodiagnostic tests. J Korean Assoc Maxillofac Plast Reconstr Surg 2011;33:190-7.
45. Luo Y, Svensson P, Jensen JD, Jensen T, Neuman B, Arendt-Nielsen L, et al. Quantitative sensory testing in patients with or without ongoing pain one year after orthognathic surgery. J Oral Facial Pain Headache 2014;28:306-16.
46. Politis C, Lambrichts I, Agbaje JO. Neuropathic pain after orthognathic surgery. Oral Surg Oral Med Oral Pathol Oral Radiol 2014;117:e102-7.
47. Teerijoki-Oksa T, Jääskeläinen SK, Soukka T, Virtanen A, Forssell H. Subjective sensory symptoms associated with axonal and demyelinating nerve injuries after mandibular sagittal split osteotomy. J Oral Maxillofac Surg 2011;69:e208-13.
48. Agbaje JO, Van de Casteele E, Hiel M, Verbaanderd C, Lambrichts I, Politis C. Neuropathy of trigeminal nerve branches after oral and maxillofacial treatment. J Maxillofac Oral Surg 2016;15:321-7.
49. Chow LK, Singh B, Chiu WK, Samman N. Prevalence of postoperative complications after orthognathic surgery: a 15-year review. J Oral Maxillofac Surg 2007;65:984-92.
50. Kramer FJ, Baethge C, Swennen G, Teltzrow T, Schulze A, Berten J, et al. Intra- and perioperative complications of the LeFort I osteotomy: a prospective evaluation of 1000 patients. J Craniofac Surg 2004;15:971-7.
51. Yen CY, Kuo CL, Liu IH, Su WC, Jiang HR, Huang IG, et al. Modified alar base cinch suture fixation at the bilateral lower border of the piriform rim after a maxillary Le Fort I osteotomy. Int J Oral Maxillofac Surg 2016;45:1459-63.
52. Shams MG, Motamedi MH. A more effective alar cinch technique. J Oral Maxillofac Surg 2002;60:712-5.
53. Monnazzi MS, Mannarino FS, Gabrielli MFR. Extraoral alar base cinch. A modification for the technique. J Oral Maxillofac Surg Med Pathol 2014;26:142-4.
54. Shin YM, Lee ST, Kwon TG. Surgical correction of septal deviation after Le Fort I osteotomy. Maxillofac Plast Reconstr Surg 2016;38:21.
55. Ibrahim A, Balakrishnan R, Ebenezer V, Padmanabhan A, Muthlingam V. Combating nasal septum deviation in le fort 1 orthognathic surgery complications, with submental intubation. J Clin Diagn Res 2014;8:ZC46-8.
56. Al-Riyami S, Moles DR, Cunningham SJ. Orthognathic treatment and temporomandibular disorders: a systematic review. Part 1. A new quality-assessment technique and analysis of study characteristics and classifications. Am J Orthod Dentofacial Orthop 2009;136:624.e1-15; discussion 624-5.
57. Jung HD, Kim SY, Park HS, Jung YS. Orthognathic surgery and temporomandibular joint symptoms. Maxillofac Plast Reconstr Surg 2015;37:14.
58. Hackney FL, Van Sickels JE, Nummikoski PV. Condylar displacement and temporomandibular joint dysfunction following bilateral sagittal split osteotomy and rigid fixation. J Oral Maxillofac Surg 1989;47:223-7.
59. Spitzer W, Rettinger G, Sitzmann F. Computerized tomography examination for the detection of positional changes in the temporomandibular joint after ramus osteotomies with screw fixation. J Maxillofac Surg 1984;12:139-42.
60. Nadershah M, Mehra P. Orthognathic surgery in the presence of temporomandibular dysfunction: what happens next? Oral Maxil-

lofac Surg Clin North Am 2015;27:11-26.
61. De Clercq CA, Abeloos JS, Mommaerts MY, Neyt LF. Temporomandibular joint symptoms in an orthognathic surgery population. J Craniomaxillofac Surg 1995;23:195-9.
62. Panula K, Somppi M, Finne K, Oikarinen K. Effects of orthognathic surgery on temporomandibular joint dysfunction. A controlled prospective 4-year follow-up study. Int J Oral Maxillofac Surg 2000;29:183-7.
63. Hellsing G, Holmlund A. Development of anterior disk displacement in the temporomandibular joint: an autopsy study. J Prosthet Dent 1985;53:397-401.
64. Legrell PE, Isberg A. Mandibular length and midline asymmetry after experimentally induced temporomandibular joint disk displacement in rabbits. Am J Orthod Dentofacial Orthop 1999;115:247-53.
65. Schellhas KP, Pollei SR, Wilkes CH. Pediatric internal derangements of the temporomandibular joint: effect on facial development. Am J Orthod Dentofacial Orthop 1993;104:51-9.
66. Cascone P, Di Paolo C, Leonardi R, Pedullà E. Temporomandibular disorders and orthognathic surgery. J Craniofac Surg 2008;19:687-92.
67. Toll DE, Popović N, Drinkuth N. The use of MRI diagnostics in orthognathic surgery: prevalence of TMJ pathologies in Angle Class I, II, III patients. J Orofac Orthop 2010;71:68-80.
68. Celić R, Jerolimov V, Pandurić J. A study of the influence of occlusal factors and parafunctional habits on the prevalence of signs and symptoms of TMD. Int J Prosthodont 2002;15:43-8.
69. Miller JR, Burgess JA, Critchlow CW. Association between mandibular retrognathia and TMJ disorders in adult females. J Public Health Dent 2004;64:157-63.
70. Miller JR, Mancl L, Critchlow C. Severe retrognathia as a risk factor for recent onset painful TMJ disorders among adult females. J Orthod 2005;32:249-56.
71. Thilander B, Rubio G, Pena L, de Mayorga C. Prevalence of temporomandibular dysfunction and its association with malocclusion in children and adolescents: an epidemiologic study related to specified stages of dental development. Angle Orthod 2002;72:146-54.
72. Hwang CJ, Sung SJ, Kim SJ. Lateral cephalometric characteristics of malocclusion patients with temporomandibular joint disorder symptoms. Am J Orthod Dentofacial Orthop 2006;129:497-503.
73. Pahkala RH, Laine-Alava MT. Do early signs of orofacial dysfunctions and occlusal variables predict development of TMD in adolescence? J Oral Rehabil 2002;29:737-43.
74. Riolo ML, Brandt D, TenHave TR. Associations between occlusal characteristics and signs and symptoms of TMJ dysfunction in children and young adults. Am J Orthod Dentofacial Orthop 1987;92:467-77.
75. Jung WS, Kim H, Jeon DM, Mah SJ, Ahn SJ. Magnetic resonance imaging-verified temporomandibular joint disk displacement in relation to sagittal and vertical jaw deformities. Int J Oral Maxillofac Surg 2013;42:1108-15.
76. Abrahamsson C, Ekberg E, Henrikson T, Nilner M, Sunzel B, Bondemark L. TMD in consecutive patients referred for orthognathic surgery. Angle Orthod 2009;79:621-7.
77. Kobayashi T, Izumi N, Kojima T, Sakagami N, Saito I, Saito C. Progressive condylar resorption after mandibular advancement. Br J Oral Maxillofac Surg 2012;50:176-80.
78. Hatcher DC. Progressive condylar resorption: pathologic processes and imaging considerations. Semin Orthod 2013;19:97-105.
79. Hoppenreijs TJ, Stoelinga PJ, Grace KL, Robben CM. Long-term evaluation of patients with progressive condylar resorption following orthognathic surgery. Int J Oral Maxillofac Surg 1999;28:411-8.
80. Catherine Z, Breton P, Bouletreau P. Condylar resorption after orthognathic surgery: a systematic review. Rev Stomatol Chir Maxillofac Chir Orale 2016;117:3-10.
81. Merkx MA, Van Damme PA. Condylar resorption after orthognathic surgery. Evaluation of treatment in 8 patients. J Craniomaxillofac Surg 1994;22:53-8.
82. Arnett GW, Milam SB, Gottesman L. Progressive mandibular retrusion--idiopathic condylar resorption. Part I. Am J Orthod Dentofacial Orthop 1996;110:8-15.
83. Arnett GW, Milam SB, Gottesman L. Progressive mandibular retrusion-idiopathic condylar resorption. Part II. Am J Orthod Dentofacial Orthop 1996;110:117-27.
84. Joss CU, Vassalli IM. Stability after bilateral sagittal split osteotomy advancement surgery with rigid internal fixation: a systematic review. J Oral Maxillofac Surg 2009;67:301-13.
85. Gunson MJ, Arnett GW, Milam SB. Pathophysiology and pharmacologic control of osseous mandibular condylar resorption. J Oral Maxillofac Surg 2012;70:1918-34.
86. Handelman CS, Greene CS. Progressive/idiopathic condylar resorption: an orthodontic perspective. Semin Orthod 2013;19:55-70.
87. Joos U. An adjustable bone fixation system for sagittal split ramus osteotomy: preliminary report. Br J Oral Maxillofac Surg 1999;37:99-103.
88. Gerressen M, Zadeh MD, Stockbrink G, Riediger D, Ghassemi A. The functional long-term results after bilateral sagittal split osteotomy (BSSO) with and without a condylar positioning device. J Oral Maxillofac Surg 2006;64:1624-30.
89. Kim YK, Yun PY, Ahn JY, Kim JW, Kim SG. Changes in the temporomandibular joint disc position after orthognathic surgery. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2009;108:15-21.
90. Ueki K, Marukawa K, Nakagawa K, Yamamoto E. Condylar and temporomandibular joint disc positions after mandibular osteotomy for prognathism. J Oral Maxillofac Surg 2002;60:1424-32.
91. Hu J, Wang D, Zou S. Effects of mandibular setback on the temporomandibular joint: a comparison of oblique and sagittal split ramus osteotomy. J Oral Maxillofac Surg 2000;58:375-80.
92. White CS, Dolwick MF. Prevalence and variance of temporomandibular dysfunction in orthognathic surgery patients. Int J Adult Orthodon Orthognath Surg 1992;7:7-14.
93. Al-Riyami S, Cunningham SJ, Moles DR. Orthognathic treatment and temporomandibular disorders: a systematic review. Part 2. Signs and symptoms and meta-analyses. Am J Orthod Dentofacial Orthop 2009;136:626.e1-16.
94. Jang JH, Choi SK, Park SH, Kim JW, Kim SJ, Kim MR. Clinical evaluation of temporomandibular joint disorder after orthognathic surgery in skeletal class II malocclusion patients. J Korean Assoc Oral Maxillofac Surg 2012;38:139-44.
95. Ueki K, Marukawa K, Shimada M, Yoshida K, Hashiba Y, Shimizu C, et al. Condylar and disc positions after intraoral vertical ramus osteotomy with and without a Le Fort I osteotomy. Int J Oral Maxillofac Surg 2007;36:207-13.
96. Bell WH, Yamaguchi Y. Condyle position and mobility before and after intraoral vertical ramus osteotomies and neuromuscular rehabilitation. Int J Adult Orthodon Orthognath Surg 1991;6:97-104.
97. Egyedi P, Houwing M, Juten E. The oblique subcondylar osteotomy: report of results of 100 cases. J Oral Surg 1981;39:871-3.
98. Choi YS, Jung HD, Kim SY, Park HS, Jung YS. Remodelling pattern of the ramus on submentovertex cephalographs after intraoral vertical ramus osteotomy. Br J Oral Maxillofac Surg 2013;51:e259-62.
99. Jung HD, Jung YS, Park JH, Park HS. Recovery pattern of mandibular movement by active physical therapy after bilateral transoral vertical ramus osteotomy. J Oral Maxillofac Surg 2012;70:e431-7.
100. Ohba S, Tasaki H, Tobita T, Minamizato T, Kawasaki T, Motooka N, et al. Assessment of skeletal stability of intraoral vertical ramus osteotomy with one-day maxillary-mandibular fixation followed by early jaw exercise. J Craniomaxillofac Surg 2013;41:586-92.
101. Méndez-Manjón I, Guijarro-Martínez R, Valls-Ontañón A,

Hernández-Alfaro F. Early changes in condylar position after mandibular advancement: a three-dimensional analysis. Int J Oral Maxillofac Surg 2016;45:787-92.
102. Lindboe CF, Platou CS. Disuse atrophy of human skeletal muscle. An enzyme histochemical study. Acta Neuropathol 1982;56:241-4.
103. MacDougall JD, Ward GR, Sale DG, Sutton JR. Biochemical adaptation of human skeletal muscle to heavy resistance training and immobilization. J Appl Physiol Respir Environ Exerc Physiol 1977;43:700-3.
104. Kim S, Kim SY, Kim GJ, Jung HD, Jung YS. Partial necrosis of the mandibular proximal segment following transoral vertical ramus osteotomy. Maxillofac Plast Reconstr Surg 2014;36:131-4.
105. Van Sickels JE, Tucker MR. Management of delayed union and nonunion of maxillary osteotomies. J Oral Maxillofac Surg 1990;48:1039-44.
106. Davis CM, Gregoire CE, Steeves TW, Demsey A. Prevalence of surgical site infections following orthognathic surgery: a retrospective cohort analysis. J Oral Maxillofac Surg 2016;74:1199-206.
107. Posnick JC, Choi E, Chavda A. Surgical site infections following bimaxillary orthognathic, osseous genioplasty, and intranasal surgery: a retrospective cohort study. J Oral Maxillofac Surg 2016. doi: 10.1016/j.joms.2016.09.018. [Epub ahead of print]
108. Turvey TA, Hall DJ, Warren DW. Alterations in nasal airway resistance following superior repositioning of the maxilla. Am J Orthod 1984;85:109-14.
109. Virkkula P, Hurmerinta K, Löytönen M, Salmi T, Malmberg H, Maasilta P. Postural cephalometric analysis and nasal resistance in sleep-disordered breathing. Laryngoscope 2003;113:1166-74.
110. Kim T, Kim JY, Woo YC, Park SG, Baek CW, Kang H. Pneumomediastinum and pneumothorax after orthognathic surgery: a case report. Korean J Anesthesiol 2010;59(Suppl):S242-5.
111. Choi SK, Yoon JE, Cho JW, Kim JW, Kim SJ, Kim MR. Changes of the airway space and the position of hyoid bone after mandibular set back surgery using bilateral sagittal split ramus osteotomy technique. Maxillofac Plast Reconstr Surg 2014;36:185-91.
112. Soydan SS, Bayram B, Akdeniz BS, Kayhan Z, Uckan S. Changes in difficult airway predictors following mandibular setback surgery. Int J Oral Maxillofac Surg 2015;44:1351-4.
113. Samsoon GL, Young JR. Difficult tracheal intubation: a retrospective study. Anaesthesia 1987;42:487-90.
114. Stott DG. Reflex bradycardia in facial surgery. Br J Plast Surg 1989;42:595-7.
115. Precious DS, Skulsky FG. Cardiac dysrhythmias complicating maxillofacial surgery. Int J Oral Maxillofac Surg 1990;19:279-82.
116. Green JG, Wood JM, Davis LF. Asystole after inadvertent intubation of the orbit. J Oral Maxillofac Surg 1997;55:856-9.
117. Matarasso A. The oculocardiac reflex in blepharoplasty surgery. Plast Reconstr Surg 1989;83:243-50.
118. Pappa H, Richardson D, Niven S. False aneurysm of the facial artery as complication of sagittal split osteotomy. J Craniomaxillofac Surg 2008;36:180-2.
119. Dediol E. Pseudoaneurysm of the facial artery as a complication of the sagittal split osteotomy. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2010;110:683; author reply 683-4.
120. Madani M, Veznedaroglu E, Pazoki A, Danesh J, Matson SL. Pseudoaneurysm of the facial artery as a late complication of bilateral sagittal split osteotomy and facial trauma. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2010;110:579-84.
121. Smith KS, Heggie AA. Vomero-sphenoidal disarticulation during the Le Fort I maxillary osteotomy: report of case. J Oral Maxillofac Surg 1995;53:465-7.
122. Tomasetti BJ, Broutsas M, Gormley M, Jarrett W. Lack of tearing after Le Fort I osteotomy. J Oral Surg 1976;34:1095-7.
123. Lanigan DT, Romanchuk K, Olson CK. Ophthalmic complications associated with orthognathic surgery. J Oral Maxillofac Surg 1993;51:480-94.
124. Camargo IB, Van Sickels JE, Laureano Filho JR, Cunningham LL. Root contact with maxillomandibular fixation screws in orthognathic surgery: incidence and consequences. Int J Oral Maxillofac Surg 2016;45:980-4.
125. Lee UL, Lee EJ, Seo HY, Han SH, Choi WC, Choi YJ. Prevalence and risk factors of tooth discolouration after orthognathic surgery: a retrospective study of 1455 patients. Int J Oral Maxillofac Surg 2016;45:1464-70.
126. Beshkar M, Hasheminasab M, Mohammadi F. Benign paroxysmal positional vertigo as a complication of orthognathic surgery. J Craniomaxillofac Surg 2013;41:59-61.
127. Sammartino G, Mariniello M, Scaravilli MS. Benign paroxysmal positional vertigo following closed sinus floor elevation procedure: mallet osteotomes vs. screwable osteotomes. A triple blind randomized controlled trial. Clin Oral Implants Res 2011;22:669-72.
128. Williams B, Indresano AT, O'Ryan F. Venous thromboembolism in oral and maxillofacial surgery: a review of the literature. J Oral Maxillofac Surg 2011;69:840-4.
129. Forouzanfar T, Heymans MW, van Schuilenburg A, Zweegman S, Schulten EA. Incidence of venous thromboembolism in oral and maxillofacial surgery: a retrospective analysis. Int J Oral Maxillofac Surg 2010;39:256-9.
130. Park CM, Choi KY, Heo SJ, Kim JS. Unilateral otitis media with effusion caused by retained surgical gauze as an unintended iatrogenic complication of orthognathic surgery: case report. Br J Oral Maxillofac Surg 2014;52:e39-40.
131. Lee KH, Lee SH. A clinical study of orthognathic surgery patients' satisfaction and psychologic change. J Korean Assoc Oral Maxillofac Surg 1999;25:151-64.
132. Seol YS, Son WS, Park SB, Kim SS, Kim JR. Changes of self-concept by orthognathic surgery in the patients of skeletal class III malocclusion. J Korean Assoc Maxillofac Plast Reconstr Surg 2008;30:370-9.
133. Lee JY, Kim YK, Yun PY. Evaluation of the patients' subjective satisfaction about the orthognathic surgery. J Korean Assoc Oral Maxillofac Surg 2009;35:94-100.
134. Ryan FS, Moles DR, Shute JT, Clarke A, Cunningham SJ. Social anxiety in orthognathic patients. Int J Oral Maxillofac Surg 2016;45:19-25.
135. Brunault P, Battini J, Potard C, Jonas C, Zagala-Bouquillon B, Chabut A, et al. Orthognathic surgery improves quality of life and depression, but not anxiety, and patients with higher preoperative depression scores improve less. Int J Oral Maxillofac Surg 2016;45:26-34.
136. Baherimoghaddam T, Tabrizi R, Naseri N, Pouzesh A, Oshagh M, Torkan S. Assessment of the changes in quality of life of patients with class II and III deformities during and after orthodontic-surgical treatment. Int J Oral Maxillofac Surg 2016;45:476-85.
137. Kurabe K, Kojima T, Kato Y, Saito I, Kobayashi T. Impact of orthognathic surgery on oral health-related quality of life in patients with jaw deformities. Int J Oral Maxillofac Surg 2016;45:1513-9.
138. Phillips C, Brookes CD, Rich J, Arbon J, Turvey TA. Postoperative nausea and vomiting following orthognathic surgery. Int J Oral Maxillofac Surg 2015;44:745-51.
139. Ishiguro K, Kobayashi T, Kitamura N, Saito C. Relationship between severity of sleep-disordered breathing and craniofacial morphology in Japanese male patients. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2009;107:343-9.
140. Hasebe D, Kobayashi T, Hasegawa M, Iwamoto T, Kato K, Izumi N, et al. Changes in oropharyngeal airway and respiratory function during sleep after orthognathic surgery in patients with mandibular prognathism. Int J Oral Maxillofac Surg 2011;40:584-92.
141. Degerliyurt K, Ueki K, Hashiba Y, Marukawa K, Nakagawa K, Yamamoto E. A comparative CT evaluation of pharyngeal airway changes in class III patients receiving bimaxillary surgery or

mandibular setback surgery. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2008;105:495-502.
142. Gu G, Gu G, Nagata J, Suto M, Anraku Y, Nakamura K, et al. Hyoid position, pharyngeal airway and head posture in relation to relapse after the mandibular setback in skeletal Class III. Clin Orthod Res 2000;3:67-77.
143. Kitagawara K, Kobayashi T, Goto H, Yokobayashi T, Kitamura N, Saito C. Effects of mandibular setback surgery on oropharyngeal airway and arterial oxygen saturation. Int J Oral Maxillofac Surg 2008;37:328-33.
144. Yaghmaei M, Ghoujeghi A, Sadeghinejad A, Aberoumand D, Seifi M, Saffarshahroudi A. Auditory changes in patients undergoing orthognathic surgery. Int J Oral Maxillofac Surg 2009;38:1148-53.
145. Bayram B, Deniz K, Aydin E, Uckan S. Is auditory function affected after Le Fort I osteotomy? Int J Oral Maxillofac Surg 2012;41:709-12.
146. Panula K, Finne K, Oikarinen K. Incidence of complications and problems related to orthognathic surgery: a review of 655 patients. J Oral Maxillofac Surg 2001;59:1128-36.
147. Hwang JM, Min BM, Park SC, Oh SY, Sung NK. A randomized comparison of prism adaptation and augmented surgery in the surgical management of esotropia associated with hypermetropia: one-year surgical outcomes. J AAPOS 2001;5:31-4.