Effects of orthognathic surgery on pharyngeal airway space: A literature review

Minh Truong Nguyen¹, Surakit Visuttiwattanakorn², Dung Manh Truong³, Natthamet Wongsirichat²

¹ Master of Science in Oral Maxillofacial Surgery (International Program), Faculty of Dentistry, Mahidol University.
² Faculty of Dentistry, Mahidol University.
³ Dean, School of Odonto Stomatology, Hanoi Medical University, Vietnam

Abstract

Pharyngeal airway changes after orthognathic surgery have been concerned because of the effects on breathing function of the patients. Moreover, sleep quality of patients can be improved or worsened by these changes. Obstructive sleep apnea is a disorder characterized by episode of pharyngeal airway collapse. It may be better following a maxillomandibular advancement surgery or may be worsened or developed after mandibular setback surgery. The purpose of this study is to review the changes of pharyngeal airway and its important related structure such as hyoid bone, the tongue and soft palate after orthognathic surgery in dentofacial deformity patients. The change of the head posture, the adaptation and the stability of the pharyngeal airway are also considered. Moderate evidence was found to support a significant decrease in the oropharyngeal airway after mandibular setback surgery. Bimaxillary surgery in class III patients has less unfavorable effects and should be considered when setback the mandible a large extent. Maxillomandibular advancement widens the airway in many levels and has high success rate in treatment of OSA.

Key words: orthognathic surgery, obstructive sleep apnea, pharyngeal airway, cephalometry, cone beam computed tomography, bilateral sagittal split tincus ostiotomy, maxillomandibular advancement


Correspondence author:
Surakit Visuttiwattanakorn
Department of Oral and Maxillofacial Surgery, Faculty of Dentistry, Mahidol University
6 Yothi Road, Rajthevi Bangkok 10400 Thailand.
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Introduction
Orthognathic surgery is a common method to treat dentofacial deformities. Orthognathic surgery by changing the position of facial skeletons has effects on the morphology of the pharynx. Since soft palate, tongue, hyoid bone and associated tissues are attached directly or indirectly to the mandible and maxilla, movement of the jaws by orthognathic surgery affects those tissues, causing changes in the pharyngeal area. Mandibular setback surgery can reduce the volume of pharyngeal airway space (PAS) and change the position of the hyoid bone and tongue. Moreover, mandibular setback has been reported to be associated with PAS decrease and in some patients can develop Obstructive sleep apnea (OSA). On the contrary, maxillomandibular advancement has been used successfully in the treatment of OSA due to the effect of PAS increase.

The pharyngeal airway is a complicated structure. It cooperates with surrounding structures to perform the physiologic processes of swallowing, speech, and respiration. The pharyngeal airway is subdivided into 3 regions: nasopharynx, oropharynx which contains retropalatal region and retrolingual region, and hypopharynx. The walls of pharyngeal airway consist only of soft tissue so the mechanism that maintains the patent airway results from tension and contraction of the surrounding muscles.

OSA is a condition characterized by recurring episodes of pharyngeal airway obstruction during sleep that results from collapse of the surrounding soft tissues. Prevalence of OSA is approximately 3 to 7 percent for adult men and 2 to 5 percent for adult women in the general population. Therefore, OSA is not infrequent in the age range that the patients commonly seek orthognathic procedures. Especially for class II patients who may already have snoring or OSA, as this deformity has been shown to be related to the clinical appearance of OSA patients. The symptoms of OSA include loud snoring, choking sensation, sudden awakening and especially daytime sleepiness. Other consequences are also significant: cardio metabolic disorder, cognitive dysfunction, anxiety, and increased risk of automobile accidents.

Airway analysis
Cephalometric is still used widely in many studies. Cephalometric can provide a linear or area measurement in sagittal plane of pharyngeal airway. Common methods are used to measure the pharyngeal airway using cephalometric:

1) Linear measurements across the airway at defined points. Several studies have used the method popularized by Riley et al in which the PAS is measured by a line through B-point and Gonion, with the linear measurement from the base of the tongue to the posterior pharyngeal wall. (Figure 1)

However, this linear measurement does not provide consistent anatomic segmentation of the airway that represents 3 regions i.e. nasopharynx, oropharynx and hypopharynx.

Fig. 1 PAS measurement by Riley
2) Linear measurement across the point of greatest constriction of the airway. Some authors stated that the two sites which are most reported to be narrowed in OSA patients are the retrolingual and retropalatal airway.\(^8\) (Figure 2)

Five different anteroposterior airway measurements were found to be common amongst studies. These measurements were: posterior nasal spine to pharyngeal wall; uvula to pharyngeal wall; base of tongue to pharyngeal wall; vallecula to pharyngeal wall; and minimal pharyngeal airway space. (Figure 3)

However, pharyngeal airway is 3D structure so cephalometric give no information about the lateral width, the cross sectional area and the volume of the airway. Therefore, recently, some authors have used Cone beam computed tomography (CBCT) to analyze the pharyngeal airway. CBCT can provide measurement of axial section area at different plane and volumetric analysis.

Orthognathic Surgery and Airway

One issue of orthognathic surgery, which has gained notice recently, is the effect of jaw movements on the pharyngeal airway. Many researches have showed the correlation between the PAS and OSA. Riley et al.\(^{22}\) found that a PAS less than 11 mm was a risk of OSA. Literature has shown the possibility of potential airway changes after orthognathic surgery and the development of OSA.

**Class III deformity surgery**

Class III skeletal deformity is the result of mandibular prognathism or maxillary deficiency.\(^{23}\) Class III malocclusion is more common in Asia than in Caucasian.\(^{24}\) The class III malocclusion affects around 22.4% of Asia population.\(^{25}\) Accordingly, class III malocclusions is one of the main cause of seeking orthodontic treatment in these countries, for example, 33% of orthodontic patients in Japan and 20% in China.\(^{26}\) The orthognathic surgeries commonly used to treat the deformity are mandibular setback osteotomy and Lefort I maxillary advancement osteotomy.

**Mandibular Setback**

Bilateral sagittal split ramus osteotomy (BSSRO) is the most common procedure. It is due to the versatility in treating mandibular deformities.
The comparison of anteroposterior changes after mandibular setback surgery showed a significant decrease in oropharyngeal airway in retropalatal dimension (mean -2.57 mm)\textsuperscript{9, 27-30} and in retrolingual (mean -2.99 mm).\textsuperscript{6, 9, 12, 28-32} The lateral width of the oropharyngeal airway also decreased after surgery (mean -2.37 mm).\textsuperscript{6, 28} Comparison of studies on mandibular setback surgery in CBCT showed a significant decrease in the axial section area of oropharyngeal airway at the level of the base of tongue (mean -46.23 mm\textsuperscript{2}).\textsuperscript{28, 30} However, Park et al.\textsuperscript{30} found no significant changes in the volume of the oropharyngeal airway.

The hyoid bone may be considered as the skeleton of the tongue. The hyoid bone serves as an indicator of the position of the tongue. Studies also showed downward and backward displacement of the hyoid bone post operation, which moved the tongue in the similar direction.\textsuperscript{3, 6, 33} The posteriorly displaced tongue narrows the retrolingual dimension of the airway and decreases the PAS.\textsuperscript{5-7, 9} Tongue’s displacement also causes the palatoglossus muscle to become less upright, increases the length of the soft palate and pushes the soft palate posteriorly and narrows the PAS.\textsuperscript{29} Liukkonen et al.\textsuperscript{9} noted that the degree of clockwise rotation of the mandible during the BSSRO is associated with the degree of airway narrowing. Another observation was the adaptive increased craniocevical inclination or counter clockwise rotation of the face after BSSRO setback.\textsuperscript{13, 34} The extension of the head serves as a compensatory mechanism in pulling the hyoid bone away from the posterior pharyngeal wall and pulling the tongue and soft palate from interfering with the upper airway.\textsuperscript{35} Muto et al.\textsuperscript{34} reported that the PAS correlated with the head posture (inclination at the cervical vertebrae). They concluded that 10° rise in the inclination will result in an increase in PAS about 4 mm. Kawamata et al.\textsuperscript{6} using 3D CT, found a positive correlation between the extent of mandibular setback, reduction in the lateral width of the pharyngeal airway, and the extent of hyoid bone displacement. Muto et al.\textsuperscript{36} developed a formula to predict the change of PAS on the cephalometric after mandibular setback surgery. The postoperative anteroposterior PAS dimension was calculated from the change of C3-Me (distance between the anteroinferior point of the third cervical vertebra and Menton) using 2 cephalometric taken before and after surgery 1 year. The equation used was PAS = -21.105 + 0.402 C3-Me (r =0.854).

There are controversies about the degree and stability of the postoperative changes in the PAS. Some studies suggested that the changes are temporary as the tissues readapt, resulting in partial or total resolution.\textsuperscript{3, 14, 27, 33} However, most of the other studies showed that the changes of the airway are stable over the long time.\textsuperscript{2, 5-7, 11, 33}

Bimaxillary Surgery

Some studies stated that Lefort I advancement would not produce an increase in retro-palatal airway space. On the other hand, there was a significant decrease in retropalatal airway dimension.\textsuperscript{8, 14} This was may be due to 2 reasons. Firstly, after maxillary advancement, there is adaptation of the soft palate to maintain velopharyngeal seal and palatal function.\textsuperscript{37} Secondly, the tongue moved posteriorly and superiorly from the mandibular setback and come into contact and displaces the soft palate backwards and upwards.\textsuperscript{38} As a result, the soft palate will be longer and thinner and the palatal angle increases. Mattos et al.\textsuperscript{31} stated that there is a significant decrease in retropalatal dimension (mean -0.91 mm)\textsuperscript{16, 27, 28, 39, 40} and a highly significant decrease in retrolingual dimension (mean -2.83 mm)\textsuperscript{28, 40} but no significant change in the
minimal PAS. The axial section areas in retropalatal and retrolingual level show no significant change. Jakobsone et al observed a substantial increase in volume in the oropharyngeal and hypopharyngeal areas but no statistically significant changes in the total volume.

Class II Deformity Surgery

The prevalence of class II malocclusion in Asian population is about 29.5%. This is less than that of Caucasian population (35%). This deformity is due to mostly mandibular deficiency and less frequent maxillary protrusion. The patients in this group should be examined carefully as they may already have snoring or OSA. This is due to the fact that this deformity has been shown to be a potential clinical feature of an OSA patient.

Mandible advancement is the most popular treatment whereas maxillary setback is of lesser extent. Mandibular advancement improved the retropalatal and retrolingual dimensions of the airway significantly. Furthermore, there was increased intermaxillary space and decreased tongue proportion. As the tongue area remained unchanged after surgery, this indicates a more functional space for the tongue, which adopts a more anterior position.

Besides mandibular advancement, there are also other procedures that could benefit OSA patients, like genioglossus advancement (GGA), uvulopalatopharyngoplasty (UPPP) and maxillomandibular advancement (MMA). UPPP is a surgical procedure in which the tissues of the soft palate, including the uvula and possibly the tonsils, are removed to improve upper airway obstruction. UPPP is widely used as a first-step procedure for the surgical management of OSA but only at oropharynx level. GGA advances genioglossus muscle to reposition the tongue in a forward position away from the back of the airway. This procedure is a safe and rapid method for improving retrolingual obstruction in OSA. However, the most successful orthognathic procedure that has been documented is MMA.

Maxillomandibular advancement (MMA)

MMA is described as the advancement of the maxilla and mandible via the LeFort I and BSSRO. MMA is the most successful acceptable surgical treatment for OSA, with a therapeutic efficacy equal to that of CPAP. MMA have traditionally been considered when non-surgical therapies and single-site surgeries, such as UPPP, GGA have been unsuccessful. Some authors now recommend MMA as a first surgical option in patients who have been diagnosed with multiples levels of airway collapse and those with craniofacial skeletal abnormalities. MMA is able, in 80 percent of cases, to bring the AHI index to normal or close to normal value (surgical success outcome AHI <20 and 50% reduction of preoperative AHI).

MMA has been shown to be efficacious in the elimination of OSA because it enlarges the PAS and tightens the upper airway muscles and tendons, by advancement of their bony origin. The rationale for this treatment is the advancement of the skeletal attachment of the suprahoid and velopharyngeal muscles and tendons, so increase the volume of the nasopharynx, oropharynx and hypopharynx.

MMA is so successful because it actually increases the space of the upper airway at many levels. A statistically significant increase was found in all the airway dimensions in the linear, area, volumetric analysis performed after surgery. The average increases were 34% for PAS area, 56% for PAS volume and 112% for the PAS minimum axial area. Some studies showed that the airway gain after MMA is stable. Souza Carvalho stated that there is a partial relapse after 6 months and the airway gain after 6 months is only 80% that of immediate post operation.
Counterclockwise rotation of the maxillomandibular complex

Bimaxillary surgery with counterclockwise rotation of the maxillomandibular complex and mandibular advancement significantly increases the postsurgical PAS and velopharyngeal anatomy. Moreover, the genial tubercles advance further than the teeth, so maximizing the advancement of the hyoid bone, the base of the tongue and the genioglossus and geniohyoid muscles.

The esthetical important point is that the anteroposterior position of the maxilla stays almost the same in contrast to the MMA technique, where the maxilla has to be anteriorly repositioned up to 10 mm. This procedure resulted in resolution of the apneic condition in 93.9% of OSA patients, and all the patients were satisfied with their appearance.

Discussion

Most studies that examine changes in the pharyngeal airway by using lateral cephalometric radiograph. Although the fact that lateral cephalometric radiograph provides only two-dimensional information of the pharyngeal airway, it is still a popular method in the assessment of craniofacial structures and sleep apnea. The advantages of cephalometry consist of its availability, simplicity, low cost, easily comparison with other studies. Moreover, cephalometry is a routine diagnosis material for orthodontic and orthognathic surgery treatment. However, CBCT has significant advantages because it allows better delineation of soft tissue and air. Skeletal maxillary and mandibular changes may be described by the change in the sagittal dimension only, but soft tissue pharyngeal changes should be considered in all three dimensions. Some studies reported significant correlation between the PAS measured with cephalometric and the volume of the pharyngeal airway on CBCT, but cephalometric provides no information about the lateral structures and cross sectional area of the upper airway. Sears et al found a weak, but statistically significant, correlation between the linear and volumetric measurements in nasopharynx and oropharynx but not in hypopharynx.

The size and morphology of upper airway structures differs in men and women. Women have greater genioglossal muscle tone than men, suggesting greater defense of the upper airway. Furthermore, OSA is more common in men than in women, despite their smaller pharyngeal airway size. It is still controversy whether changes in pharyngeal airway are different for each gender. Some studies assessed only subjects of the same gender. Samman et al showed a reduction in the minimal airway dimension after mandibular setback surgery only in males. Whereas Degerliyurt et al did not observe any difference between the two genders.

Modern trend in orthognathic surgery is the increase in bimaxillary surgery in treatment of class III deformities. It is due to the refinement of Lefort I down fracture technique and the increased diagnostic awareness of maxillary hypoplasia. In mandibular setback surgery, the main finding is the significant decrease in pharyngeal airway in all dimensions. However, there are controversies about the PAS changes after bimaxillary surgery. Some studies reported a significant decrease in linear measurements and in the retrolingual axial section area, whereas Jakobsone observed a substantial increase in volume in the oropharyngeal and hypopharyngeal areas.

OSA is associated with the presence of a narrowed PAS, inferiorly positioned hyoid, long soft palate, and narrowed nasopharyngeal airway. Mandibular setback surgery changes oropharyngeal characteristics to morphology similar to OSA. However, OSA after mandibular
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setback was rare and almost the patients have sleep study result within normal range.\(^3\) But it maybe risk in the long term, especially when these patients get older and are more likely to have other risk factors for OSA.\(^8\) Therefore, it is recommended caution when planning mandibular setback of 10 mm or more, especially when the PAS was less than 10 mm. For these patients, it might be better to consider bimaxillary surgery.\(^14\)

The increase in the pharyngeal airway in all the measurement in individuals submitted to MMA surgery seems to confirm the indication of this type of surgery for patients with OSA.\(^31\) Analysis of the literature reveals that the increase in PAS after MMA is greater than that offered by other surgical techniques such as UPPP, GGA because they are only effective at one level of airway obstruction.\(^49\) However, Small proportion of patients (10-20%) failed to respond to MMA even if the anatomic goals of MMA have been achieved.\(^64\) According to recent advance of understanding of the pathophysiology of OSA, besides anatomic constriction of the airway, central nervous system regulation of breathing (ventilator control) is now recognized as a significant contributor to the pathogenesis of OSA.\(^65\)

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