



Review the Impact of Mandibular Setback Surgery for the Correction of Class III Malocclusion on the Upper Airway Space

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Abstract

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AIM: This study aimed to review the scientific evidence related to the effect of mandibular setback surgery for the correction of Class III malocclusion on the changes in volume and anatomical structures' positions of the upper airway within at least 1 year follow-up.

METHODS: An electronic research was conducted on PubMed, Google scholar, and Elsevier up to April 20, 2021, the inclusion criteria were prospective or retrospective studies aiming to compare the changes in upper airway space following isolated mandibular setback through at least 1 year of follow-up.

RESULTS: A total of 84 studies were retrieved, only 12 studies met the eligibility criteria. Their methods of measurement were using lateral cephalometry, CT, or Cone-beam computed tomography. Most of them showed narrowing in the Pharyngeal airway space, with some variability within the follow-up periods. Impact on the possibility of obstructive sleep apnea (OSA) was discussed in most of the included studies.

CONCLUSION: Narrowing of upper airway volume is associated with isolated mandibular setback surgeries within 1 year of follow-up. However, OSA was not necessarily a consequence. Any predisposing factors for OSA should be considered before isolated mandibular setback surgery.

Introduction

Mandibular setback surgery, most commonly done by Bilateral Sagittal Split Osteotomy, has frequently been used in the surgical phase of correcting skeletal Class III malocclusion [1]. Combining it with orthodontics can improve masticatory functions, occlusion, and esthetics. However, numerous studies showed its influence on the soft- and hard-tissue components of the orofacial complex, particularly the positions of tongue, hyoid bone, and consequent narrowing of pharyngeal airway space (PAS).

These changes, which occur also in cases of bimaxillary surgeries done for the same purpose, bring numerous concerns in possibility of obstructive sleep apnea (OSA) that can affect the patient's quality of life [2]. Numerous studies have been conducted to measure the changes in the soft and hard tissues' positions, including soft palate, tongue and hyoid bone, as well as volumetric changes in nasopharyngeal, oropharyngeal and hypopharyngeal spaces, following both mandibular and bimaxillary surgeries, or one of them.

These studies initially used lateral cephalometric radiographs for analysis, which is limited by its lateral viewing angle in two dimensions. But later, the

widespread usage of computed tomography (CT) and its three-dimensional (3D) reconstructive imaging technique allowed more researches to use these techniques.

Not only immediate post-surgical measurements have importance, but also long-term follow-up; which have shown in some studies a sort of postural adaptation and long-term changes of tongue and pharyngeal airway morphology, and this adaptation influences the structures' positions, volumetric changes and the surgical stability of the operation [3], [4], [5], [6].

Therefore, this article reviews the previous human studies discussing the effect of mandibular setback orthognathic surgery on pharyngeal airway, hyoid bone, and craniocervical posture using lateral cephalometric radiographs and CT or Cone-beam CT (CBCT) techniques, in both short term and over at least 1 year period of follow-up.

Methods

Inclusion criteria

The inclusion criteria were developed according to the PICOS criteria (Table 1). Exclusion

criteria were as follow: Animal studies, case reports, no follow-up, or post-treatment records, follow-up period less than 1 year.

Table 1: PICOS criteria for the systematic review

Population (P)	Patients with a prognathic mandible and Class III malocclusion who had undergone mandible setback; age 18–60 years
Intervention (I)	Mandibular setback surgery (IVRO or BSSO) with or without other surgeries, such as genioplasty, and maxillary advancement
Comparison (C)	Comparison between: Pre-surgery, immediate post-surgery, and minimum 1 year post-surgery of upper airway space dimensions
Outcome (O)	Changes of the upper airway (three CSA parameters: PNS-CSA, SP-CSA and EP-CSA; volume parameters such as: Nasopharynx volume, oropharynx volume, hypopharynx volume, and upper airway total volume)
Study design (S)	Prospective or retrospective studies with the aim of comparing upper airway space changes pre-surgery and post-surgery parameters for the prognathic mandible
Question	What are the short and long terms results and values of mandibular orthognathic surgery on pharyngeal airway, hyoid bone, and craniocervical posture in Class III patients

IVRO: Intraoral vertical ramus osteotomy; BSSO: Bilateral sagittal split osteotomy.

An electronic search was conducted on PubMed, Google scholar, and Elsevier up to April 20, 2021 as research sources, an additional manual search of references in the included studies was also conducted. We used the search terms combination (“Orthognathic Surgery” OR “airway space” OR “mandible” OR AND [“Skeletal Class III” OR “Class III Malocclusion” OR “Hypopharynx” OR “Oropharynx”]).

An initial screening through titles and abstracts was conducted independently by two reviewers, who then reviewed and cross-checked the text in full to decide their eligibility. Disagreements were resolved through discussion, when necessary, by seeking the opinion of a third reviewer.

The quality of the papers was assessed using the adaptation of the bias analysis used by Haas *et al.* [7]. The criteria based on sample selection, blinding of the authors, comparison between treatments, statistical analysis and outcome validation measured the degree of bias, definition of inclusion and exclusion criteria, and post-operative follow-up. They were classified as low risk if all the criteria were met, uncertain risk when only one criterion was missing, and high risk if two or more criteria were missing.

Results

We found 84 studies about the effect of orthognathic surgery on the airway space, we excluded 35 because it was about maxillary or combined maxillarymandibular setback then we excluded 14 because it was case report, then we excluded 23 because there was no follow-up, or follow-up period less than 1 year. Finally, we end up with 12 studies discuss the effect of orthognathic surgery on the airway space in a Class III malocclusion with mandibular setback with follow-up period 1 year or more (Table 2).

Discussion

Numerous studies studied the direct changes in the upper airways following mandibular setback surgeries, other studies went further and studied their relation with OSA [2], [9], [16]. Although most of the studies analyzed data from two dimensional cephalograms, other studies used 3D CT scan, which can measure accurately the upper airways indicators both horizontally and vertically.

Lateral cephalograms have the advantages of being widely available, simple, exposing the patient to comparatively low-radiation dose, and easy to compare with previous studies. Moreover, studies have shown a significant correlation between volume obtained on CT scans and PAS measurements obtained on cephalometric radiographs [17].

Chen *et al.* [4] measured the changes in positions of hyoid bone, highest point of the tongue and the fourth vertebrae throughout the post-operative follow-up period. They emphasized the care that should be given to the patient in the first nights of the surgery due to the post-operative edema, muscle relaxation effect of the anesthesia during the first night, bleeding and edema due to trans-nasal intubation and inability of the patient to open their mouth due to maxillary and mandibular fixation. They concluded that oropharyngeal airway space is significantly decreased and correlated with a change in the head posture after mandibular setback surgery. The study suggests to evaluate patient airway space before commencing the surgery to avoid OSA. Moreover, the study confirms that Class III patients have different anatomical positions of the tongue and hyoid bone which favors the surgery. Finally, the study reports some adaptations following surgery in the form of increase in the craniocervical angle correlated with the decreases in both the laryngeal airway space and the upper and lower segments of the oropharyngeal airway space.

Cho *et al.* [10] studied the changes of PAS and position of hyoid bone on the basis of Frankfurt Horizontal (F-H) plane. Diameters of nasopharynx, oropharynx, and hypopharynx were measured in 13 patients who undergone split sagittal ramus osteotomy (SSRO), the average amount of mandible setback was 7.5 ± 3.8 mm. a significant reduction was observed within 2 months from the operation in both the nasopharynx and oropharynx (2.8 ± 2.5 , 1.7 ± 2.4 respectively) at $p < 0.01$ mm, with non-significant change from 2 months point to > 6 months postoperatively. While the hypopharynx showed significant reduction only after more than 6 months. Pearson’s correlation coefficient showed high correlation between the positions of tongue, soft palate, decrease in the airway size and the amount of mandibular setback with observations through follow-up period of mean value 13.3 months postoperatively.

Table 2: Detailed data of the included studies

Author and year of publication	Study design	Sample (m, males; f, females; age in parentheses)	Intervention	Method and timing of results' data collection	Conclusion
Irani <i>et al.</i> [8] (2018)	Case series	28 patients (17 M, 11 F) Mean age 23.88 6	Isolated mandibular setback surgery	Cone-beam computed tomography scans were obtained at 3 time points: Before surgery, average of 6 months after surgery, and average of 1 year after surgery	After mandibular setback surgery the airway dimensions will decrease but no strong correlation exists between them
Chen <i>et al.</i> [4] (2015)	Case series	37 patients (26 F and 11 M; mean age, 20.8 years	Mandibular setback surgery	Lateral cephalograms were obtained before (T1), immediately postoperatively (T2), 6 weeks to 3 months (T3), and 1 year (T4) after surgery	The oropharyngeal airway space significantly decreased and correlated with a change in the head posture after mandibular setback surgery
Cho <i>et al.</i> [9] (2014)	Retrospective study	13 patients (7 M, 6 F) Median age 22.4 years (range 18–29	Sagittal Split Ramus Osteotomy (SSRO)	Lateral cephalometric radiographs were obtained: preoperatively (T1), postoperatively within 2 months (T2), after 6 months or more from the operation (T3). The mean term of follow-up was 13.3 months	A significant reduction in the oropharynx and nasopharynx was observed within 2 months from the operation with non-significant change from 2 months point to >6 months postoperatively
Choi <i>et al.</i> [10] (2014)	Case series	50 patients (21M, 29 F) 20~33 years mean age 24.1	Bilateral sagittal split ramus osteotomy	Cephalometric radiography taken preoperatively, immediately after surgery, 8 weeks after surgery, 6 months after surgery, and 1 year after surgery	The amount of mandibular set back was significantly associated with post-operative reduction of airway space
Park <i>et al.</i> [11] (2012)	Retrospective study	36 patients (23 M, 13 F; mean age 22.97 years; range 19–29 years)	Mandibular setback sagittal split ramus osteotomy (SSRO with rigid fixation), -LeFort I osteotomy with advancement and mandibular setback SSRO	CBCCT examination within a month prior to surgery, 4.6 months after surgery and 1.4 years after surgery	The volumes of the oropharyngeal and hypopharyngeal airways decreased 4.6 months post-surgery in the mandibular setback group and these diminished airways had not recovered 1.4 years after surgery
Abdelrahman <i>et al.</i> [12] (2011)	Retrospective study	30 patients (12 M, 18 F) Mean age 24.4 years	Mandibular setback surgery using sagittal split ramus osteotomy (SSRO) or Bimaxillary surgery, 4 cases who received Le Fort I and bilateral SSRO, and 3 cases who received Le Fort I and bilateral IVRO or bilateral intraoral vertical ramus osteotomy (IVRO)	Lateral cephalometric radiographs were taken and analyzed n preoperatively (T1), about 3 months postoperatively (T2), and more than 1 year postoperatively (T3)	PAS was significantly decreased after corrective jaw surgery for skeletal class III jaw deformity Less PAS narrowing after bimaxillary surgery compared with mandibular setback surgery alone
Filho <i>et al.</i> [13] (2011)	Retrospective study	45 patients	-Bimaxillary surgery (23 patients). -Maxillary advancement surgery (15 patients). Mandibular setback surgery (7 patients)	Lateral cephalograms were obtained preoperatively (T0), 1 week postoperatively (T1), and at least 1 year postoperatively (T2)	Maxillary advancement should be preferred to mandibular setback Bimaxillary surgery can neutralize or minimize the effects of the setback on narrowing in the PAS Limiting the magnitude of mandibular setback is recommended to minimize risk of reducing the airway space.
Chen <i>et al.</i> [5] (2007)	Retrospective study	35 F patients	Bilateral Sagittal Split Ramus Osteotomies (SSRO)	Lateral cephalograms before surgery, 3-6 months, and at least 2 years after the surgery	Significant reduction at the oropharyngeal and hypopharyngeal levels over the short and long terms
Saitoh [6] (2004)	Case series	10 female patients, (mean age, 23.3)	Mandibular setback surgery by bilateral sagittal split ramus osteotomy (SSRO)	Lateral cephalometric radiographs before treatment (T1), 3-6 months after SSRO (T2), and 2 or more years after SSRO (T3)	Marked changes of the lower facial morphology and the pharyngeal airway morphology after SSRO, followed by gradual physiologic readaptation in the pharyngeal airway morphology
Gu <i>et al.</i> [14] (2000)	Retrospective study	62 patients (12 M, 50 F) average age of 21.4 years	Bilateral Sagittal Split Ramus Osteotomy (SSRO)	Lateral cephalograms before the surgery, immediately after the surgery, 1 month after the surgery, 3 months, 6 months, 1 year, 2 years and 3 years after the surgery	The changes in the relationship between hyoid position, pharyngeal airway and head posture after the surgery is followed by long-term adaptation of the tongue, infrahyoid and all of the neck muscles
Kawamata <i>et al.</i> [15] (2000)	Case series	30 patients (10 M, 20 F) age 17 to 37 years	-Sagittal Split Ramus Osteotomy (SSRO) -Intraoral Vertical Ramus Osteotomy (IVRO)	CT and 3DCT before operation, and at 3, 6 and 12 months postoperatively	Narrowing of the lateral and frontal widths of the pharyngeal airway after mandibular setback surgery
Tselnik <i>et al.</i> [3] (2000)	Retrospective study	14 patients (15-36 years)	-Sagittal Split Ramus Osteotomy (SSRO)	Lateral cephalometric radiographs taken preoperatively, 2 weeks postoperatively, and after 6 months–2 years post operatively	Mandibular setback surgery causes a long-term decrease in pharyngeal airway space area. It could develop OSA in patients who have other risk factors for developing OSA

Regarding the pre-operative oropharyngeal airway space, this study mentioned that patients with skeletal Class III malocclusion showed already increased pharyngeal airway compared to those of skeletal Class II. Hence, any reduction in the PAS dimensions will not necessary be accompanied with OSA.

Abdelrahman *et al.* [12] studied the effects of both SSRO and IVRO with mean amount of mandibular setback 6.7 and 4.3 mm, respectively, on PAS. Results showed significant PAS narrowing on short- and

long-term follow-up. In spite of the lower mean amount of setback in IVRO than bimaxillary surgery conducted for some patients in the same study, the advancement of the velum and velopharyngeal muscle due to Le Fort osteotomy partly reduced the narrowing effect of the associated mandibular setback [18]. However, no patient developed snoring or any manifestation of OSA after surgery.

Filho *et al.* [13] showed that mandibular setback did not result in changes at the nasopharynx

and oropharynx at 1 week postoperatively and at least 1 year postoperatively. While the hypopharynx showed a slight non-significant reduction in the anteroposterior dimension.

This result was differing from most investigators, which may be due to low magnitude of mandibular posterior repositioning (average 3.2 mm). Moreover, the limited number of patients in this study is considered another limitation.

This study also suggested that this small decrease in the airway volume may not have a clinical relevance, because many patients with skeletal Class III deformity already present an enlarged PAS preoperatively [19].

However, after comparing the results of the mandibular setback alone with those of the maxillary advancement and bimaxillary surgery group, the authors preferred maxillary advancement or bimaxillary surgery to mandibular setback surgery.

Choi *et al.* [10] showed posterior and inferior movement of the hyoid bone following mandibular setback surgery, but through the one year follow-up period, the hyoid bone moved anteriorly and superiorly toward its original position. These changes can occur because of the physiologic reflex mechanism for maintaining the airway space. However, these movements could not return the hyoid bone to its original position. Regarding the airway space; it changed from a value of 18.55 ± 4.17 mm immediately after the surgery to 14.38 ± 4.08 mm after 2 months, showing the greatest reduction in airway space. Mainly due to resolution of post-operative inflammatory phase, this reduction recovered gradually to 16.58 ± 3.60 after 1 year, but complete recovery compared to the pre-operative airway space was not observed, and a reduction of about 11% measurement was still present. This study also assessed the risk factors associated with changes in the airway space; age, gender, BMI, amount of mandibular set back, and genioplasty were statistically analyzed. The amount of setback only was identified as a significant factor affecting the airway space changes ($p < 0.05$).

Chen *et al.* [5] evaluated the effects of bimaxillary surgery and mandibular setback surgery on pharyngeal airway measurements in Class III patients using cephalometric radiograph. The study confirmed less narrowing in the oropharyngeal and hypopharyngeal area after bimaxillary surgery rather than mandibular setback surgery alone. Moreover, they advocate bimaxillary surgery for Class III patients especially if the patient has other predisposing factors for the development of OSA.

Saitoh [6] showed that PAS has narrowed significantly at 3–6 months after SSRO. However, after 2 years, significant relapse in tongue position, soft palate length and PAS occurred, and it was not accompanied by relapse in lower facial morphology which may be

due to adaptation of the pharyngeal airway to function, hard tissues, or occlusion.

However, it should be noticed that the limited sample size (10 patients) remains as a limitation to the findings of this study.

Tselnik *et al.* [3] evaluated the changes in the PAS area and antro-posterior dimensions following mandibular setback surgery. Unlike other studies, the author's measurements showed increase in the immediate post-operative PAS dimensions, which were attributed to the anterior movement of hyoid bone due to post-operative inflammation and swelling.

With long-term follow-up, there was significant reduction in both PAS area (1.52 ± 1.4 cm², equivalent to 12.78% mean change from pre-operative values) the antro-posterior dimension of the pharyngeal airway (4.77 ± 3.86 mm, equivalent to 28.19% mean change from pre-operative values). Moreover, there was strong positive correlation between the amount of mandibular setback and the reduction in the PAS (which were 14.75% and 12.78%, respectively). Therefore, the surgeon can predict the amount of post-operative reduction in the PAS area. If it fell below the values of OSA patients (especially if the patient has other OSA predisposing factors such as macroglossia and short neck), the surgeon should consider other surgical options.

Gu *et al.* [14] correlated the hyoid position, pharyngeal airway, and head posture in relation to mandibular relapse over a follow-up period of 3 years following SSRO surgery, which showed pronounced backward and downward movement of hyoid bone after the surgery; however, it tends to return to its preoperative position over time but it never regains its original location. Interestingly, in this study, the nasopharyngeal and hypopharyngeal airway sizes increased by 0.6 mm and 1.0 mm, respectively, after the surgery. But their changes through the follow-up period were negligible. Long-term follow-up showed changes in the correlation between head posture and nasopharyngeal airway which was found to be negative immediately after surgery, but positively with hypopharyngeal airway as a long-term effect. Regarding the hyoid position, it suggests that its change is related to the mandibular morphology, rather than the dental position. The study concluded that Mandibular setback has altered the relationship of the pharyngeal airway, hyoid position, and head posture. This resulted in a long-term biomechanical adaptation of the tongue, supra- and infrahyoid, and all of the neck muscles, to balance the stomatognathic system.

Numerous studies used CT and CBCT for evaluation of the pharyngeal air way spaces and changes after mandibular or combined setback surgeries to overcome some limitations of lateral cephalometric radiographs. Most importantly that the airway is 3D space surrounded by soft tissues,

therefore, 3D image analysis is required to obtain more accurate information, and to avoid image distortion that may occur with lateral cephalometry [20]. CBCT can at least distinguish the boundaries between soft tissues and the airway space, even if it cannot discriminate the various soft tissues.

Irani *et al.* [8] evaluated the pharyngeal airway volume change, and lateral surface and anteroposterior dimensional changes using CBCT before mandibular setback surgery, 6 months and 1 year after surgery. Results showed reduction in oropharyngeal, hypopharyngeal and total volumes. Significant changes occurred postoperatively at 6 months and 1 year compared to preoperative measurements, while the changes between 1 year and 6 months postoperatively were non-significant. It is worth to mention that this study - unlike other studies - did not find correlation between the amount of setback and the changes in pharyngeal airway volumes and dimensions.

Park *et al.* [11] measured both linear and volumetric changes in PAS by both lateral cephalometry and CT, after (a) bilateral SSRO and (b) LeFort I osteotomy with advancement and mandibular setback SSRO.

Results of cephalometric analysis showed posterior movement of the oral structures (hyoid bone, soft palate and tongue) as well as linear reduction in all measurements, especially middle and inferior pharyngeal depths only in group (a). However, the volumetric analysis in the airway obtained by CT showed no significant volumetric reduction in nasopharynx, oropharynx, and pharynx in both groups. This suggests that the airway volume can be maintained with some deformation anteroposteriorly (constriction) and laterally (expansion) to preserve the airway capacity. The informative results mentioned in this study were worthy to mention although the follow-up period was 6 months.

Kawamata *et al.* [15] found significant reduction after mandibular setback by SSRO and IVRO in both lateral pharyngeal (23.6%) and frontal pharyngeal (11.4%) widths, which was identified 3 months after surgery with no significant tendency to recover at either 6 months or 1 year after surgery except in five cases with visible recovery of pharyngeal width, which may be related to the mandibular prognathism relapse. There was a positive correlation between the amount mandibular setback and the reduction in the lateral width of the pharyngeal airway and hyoid bone displacement. Because of this correlation, the size of the post-operative pharyngeal airway may be predictable at the time of treatment planning. Therefore, maxillomandibular advancement, rather than isolated mandibular setback, would be indicated in patients with OSA and a posterior airway space of less than 10 mm on lateral cephalometric X-ray [21].

Conclusion

This review indicated that the upper airway volume showed significant reduction after long-term (12 months or more) follow-up following isolated mandibular setback surgery. However, some studies showed sort of physiological adaptation in the long-term follow-up to maintain PAS.

Although Narrowing of the PAS is not necessarily accompanied by OSA - especially with skeletal Class III patients who already have wider preoperative PAS - the surgeon should properly measure and assess the preoperative PAS and its expected post-operative change according to the amount of the mandibular setback.

In cases of pre-operative OSA, narrowed PAS, OSA predisposing factors such as short neck, obesity, macroglossia, a large uvula, or excessive soft tissue around the nasopharyngeal area, Maxillary advancement or bimaxillary surgery should be preferred, to minimize the effects of the setback on PAS and avoid any possibility of future OSA.

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