Comparing Outcomes of Airway Changes and Risk of Sleep Apnea after Bimaxillary Orthognathic Surgery and Mandibular Setback Surgery in Patients with Skeletal Class III Malocclusion: A Systematic Review and Meta-Analysis

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ABSTRACT

Objective: To compare the airway changes and risks of sleep apnea after the bimaxillary orthognathic surgery and mandibular setback surgery in the growing patients with skeletal Class III malocclusion.

Material and Methods: MEDLINE, PubMed, Cochrane Library, Embase, ISI, Google scholar have been utilized as the electronic databases for performing systematic literature between 2010 to August 2020. The quality of the included studies has been assessed using MINORS. Meta-analysis was performed using Stata 16 software.

Results: In electronic searches, a total of 218 potentially relevant abstracts and topics have been found. Finally, 23 papers met the criteria defined for inclusion in this systematic review. The mean difference of upper airway total volume changes between before and after surgery was (MD = 1.86 cm³ 95% CI 0.61 cm³–3.11 cm³; p= 0.00) among 14 studies. This result showed that after Mandibular Setback Surgery, there was a statistically significant decrease in the upper airway volume.

Conclusions: Class III Patients who undergo bimaxillary surgery show no other significant difference in airways volume after surgery than patients in Class III who undergo mandibular setback alone.

Keywords: Malocclusion, Angle Class III; Orthognathic Surgery; Sleep Apnea Syndromes.
Introduction

Class III malocclusion could be characterized as a skeletal facial deformity joint in the clinical cases described by forwarding the mandibular position about the cranial base and maxilla [1]. Moreover, malocclusion may cause trouble in eating, breathing, and talking. A few children may have gum disease and jaw joint issues, too [2].

The Le Fort I maxillary osteotomy is the foremost common surgical method to redress the dentofacial deformities, including the maxilla, and it was more successful than that of mandibular [3]. Over the 1970s, orthodontic treatment was combined with orthognathic surgery for malocclusion redress because malocclusion issues may reoccur after following a surgical operation because of the traction of the soft tissues and the muscle forces created in the course of its function. This method also led to stable and desirable impacts [4], and thus it has been proved that it is a tool with the most significant effect to treat the skeletal Class III malocclusion [5]. Also, probable postsurgical changes can modify the location and traction of the around soft tissues, muscles, hyoid bone, soft palate, and tongue, location as well as the traction of the around Soft tissues, tongue, soft palate, muscles, and hyoid bone, and may alter the airway volumes and an estimate of the oral and nasal cavity [6,7].

Dynamic changes in airway anatomy may also contribute to obstructive sleep apnea [8]. The mandibular setback surgery (MdS) effect on the association of the soft tissue and skeletal tissue has been also demonstrated that could result in a relative reduction of the pharyngeal airway space [9,10].

Bimaxillary orthognathic surgery is essentially the combination of armamentaria for maxillary and mandibular, so that adjustment of the Class III malocclusion expanded the total airway volume [10]. Hence, modification in the upper airway space through diverse orthognathic surgery is questionable [4,9-11]. Therefore, it is of particular significance to investigate the correlations between the risk of sleep apnea and changes in patients with Class III skeletal malocclusion in the upper airway.

Given the importance of this issue and the feeling of the need to research this area, the purpose of this systematic review and meta-analysis is to compare the results of changes in the airway and risk of sleep apnea after the bi-maxillary orthognathic surgery and mandibular setback surgery in with skeletal Class III malocclusion.

Material and Methods

Search Strategy

Between 2010 and August 2020, MEDLINE, PubMed, Cochrane Library, Embase, ISI, Google Scholar were used as electronic databases for systematic literature results. Then, Endnote x8 software has been employed for electronically managing the titles. The search has been done with the keywords "mandibular setback, MdS, mandibular setback (MdS) surgery", "Class III malocclusion, malocclusion, or Angle Class III", "maxillary, mandibular", "sleep apnea, apnea-hypopnea, the obstructive sleep apnea, sleep apnea treatment, OSA, SA", "Bimaxillary Orthognathic, Bimaxillary Orthognathic Surgery, bimaxillary osteotomies", "cross-sectional area OR CSA, cross-sectional area (CSA)", "upper airway, upper respiratory OR airways, respiratory", "Orthognathic Surgery, orthodontic treatment", "Cone-beam computed tomography, CBCT", and "Computer tomography or CT". The current systematic review was carried out based on the key considerations of the PRISMA Statement Preferred Reporting Items for the Systematic Review and Meta-analysis [12] as well as by the PICO strategy (Table 1).
Table 1. PICO OR PECO Strategy.

| PICO or PECO | Description |
|--------------|-------------|
| **P** | Population/Patient: Patients with Class III Malocclusion |
| **E** | Exposure/Intervention: Bimaxillary Orthognathic Surgery or Mandibular Setback Surgery |
| **C** | Comparison: Pre-Surgery and Post-Surgery Parameters/Mandibular Setback vs. Maxillary Advancement |
| **O** | Outcome: Upper Airway Total Volume and Sleep Apnea |

Selection Criteria

The following inclusion criteria were established: a) Randomized controlled trials studies, controlled clinical trial, prospective as well as retrospective cohort studies; b) Patients with Class III malocclusion; c) Changes of the upper airways; d) Evaluation sleep apnea before and after surgery; e) Conducted in the humans; f) CT and CBCT outcome; and g) Written in English. The following exclusion criteria were adopted: a) Case studies, clinical reports, case reports, and reviews; b) Incomplete data; and c) Animal studies.

Data Extraction and Method of Analysis

The following data were extracted from the research, including study, years, study design, sex, sample size, range, and mean age. The quality of the studies covered was evaluated using MINORS [13]. This methodological index had 12 items so that each case ranged between 0 and 2, and the total score equaled 24 (0-12 = high risk of bias, 13 to 18 = moderate risk of bias, and 19-24 = low risk). Two reviewers blinded and independently extracted data from the included studies for Data extraction. Moreover, mean differences with 95% confidence interval (CI), the fixed-effect and inverse-variance methods were calculated. Random effects were used to resolve potential heterogeneity, and heterogeneity was demonstrated in I². Meta-analysis was performed using Stata 16 Software (StataCorp LLC, Texas, USA).

Results

In the initial search with keywords, 584 articles were found. In the first step of the selection studies, 523 studies were selected to review the abstracts, and then 451 papers were excluded. In the second stage, the remaining 72 studies' full-text publications have been completely assessed. After that, 49 articles were excluded due to non-compliance with the inclusion criteria in this study and not report complete data. In the end, 23 papers met these crucial criteria to do a systematic review and meta-analysis (Figure 1). Thus 23 studies were included (Table 2).

Figure 1. Study Attrition Diagram.
Table 2. Studies selected for systematic review & meta-analysis.

| Study/Year   | Study Design | Sample Size | Age (Years) | Sort of Surgery                     | Measurements                                      | Quality Score by MINORS |
|--------------|--------------|-------------|-------------|-------------------------------------|---------------------------------------------------|--------------------------|
| Agarwal et al. (2019) | Retrospective | 5 5         | NA          | Mandibular Setback                 | Upper Airway Total Volume                          | Parameters of Post-Surgery |
| On et al. (2019) | Prospective  | 29 21       | 21.86       | Mandibular Setback                 | Upper Airway Total Volume Apnea-hypopnea index (AHI) | Parameters of Post-Surgery |
| Havron et al. (2019) | Retrospective | 14 NA       |             | Mandibular Setback                 | Upper Airway Total Volume                          | Parameters of Post-Surgery |
| Cosmin Ioan et al. (2019) | Retrospective | 9 27        |             | BOS                                | Upper Airway Total Volume                          | Parameters of Post-Surgery |
| Jeong et al. (2018) | Retrospective | 10 8        | 22.7        | Mandibular Setback                 | Upper Airway Total Volume                          | Parameters of Post-Surgery |
| Tepecik et al. (2018) | Retrospective | 7 14 NA     |             | BOS                                | Upper Airway Total Volume Apnea-Hypopnea Index (AHI) | Parameters of Post-Surgery |
| Jang et al. (2018) | Prospective  | 13 >18      |             | BOS                                | Upper Airway Total Volume Apnea-Hypopnea Index (AHI) | Parameters of Post-Surgery |
| Vaezi et al. (2017) | Prospective  | 4 6         | 20.4        | BOS                                | Upper Airway Total Volume                          | Parameters of Post-Surgery |
| Lee et al. (2017) | Prospective  | 5 17        | 22.1        | BOS                                | Upper Airway Total Volume                          | Parameters of Post-Surgery |
| Kim et al. (2016) | Prospective  | 16 22       | 23.84       | Mandibular Setback                 | Upper Airway Total Volume                          | Parameters of Post-Surgery |
| Canellas et al. (2016) | Prospective | 11 22       | 24.5        | BOS                                | Upper Airway Total Volume Apnea-Hypopnea Index (AHI) | Parameters of Post-Surgery |
| Azevèdo et al. (2016) | Retrospective | 9 5         | 17-40       | Mandibular Setback Maxillary Advancement | Upper Airway Total Volume                          | Parameters of Post-Surgery |
| Hatab et al. (2015) | Prospective  | 9 11        | 21.7        | Mandibular Setback                 | Upper Airway Total Volume Maxillary Advancement    | Parameters of Post-Surgery |
| Hsieh et al. (2015) | Prospective  | 18 54       | 24.0        | Mandibular Setback                 | Upper Airway Total Volume                          | Parameters of Post-Surgery |
| Wang et al. (2015) | Prospective  | 13 15       | 19          | Mandibular Setback                 | Upper Airway Total Volume                          | Parameters of Post-Surgery |
| Hart et al. (2015) | Prospective  | 31 40       | 19          | Mandibular Setback + Maxillary Advancement | Upper Airway Total Volume                          | Parameters of Post-Surgery |
| Burkhard et al. (2014) | Retrospective | 3 8         | 26          | Mandibular setback + Maxillary Advancement | Upper Airway Total Volume                          | Parameters of Post-Surgery |
| Li et al. (2014) | Prospective  | 0 29        | 23          | Mandibular Setback + Maxillary Advancement | Upper Airway Total Volume                          | Parameters of Post-Surgery |
| Uesugi et al. (2014) | Prospective  | 21 19       | 23          | Mandibular Setback                 | Upper Airway Total Volume Maxillary Advancement    | Parameters of Post-Surgery |
| Park et al. (2012) | Retrospective | 23 13       | 23          | Mandibular Setback + Maxillary Advancement | Upper Airway Total Volume                          | Parameters of Post-Surgery |
| Hong et al. (2011) | Retrospective | 14 7        | 27          | Mandibular Setback                 | Upper Airway Total Volume                          | Parameters of Post-Surgery |
| Park et al. (2010) | Retrospective | 5 7         | 26          | Mandibular Setback                 | Upper Airway Total Volume                          | Parameters of Post-Surgery |
| Jakobsone et al. (2010) | Retrospective | 8 6         | 20          | Mandibular Setback + Maxillary Advancement | Upper Airway Total Volume                          | Parameters of Post-Surgery |

ROS = Bimaxillary Orthognathic Surgery; Quality score by MINORS: 0-12 demonstrated the increased risks of bias, 15-18 for the moderate risks of bias, and 19 to 24 for lower risks of bias.
The number of patients a total was 606, with 23.1 years mean of age. Mean difference of upper airway total volume changes between before and after mandibular setback was (MD = 2.26 cm³, 95% CI = 0.36 cm³-4.16 cm³; p=0.02) among six studies and heterogeneity found (I² = 64.27%; p=0.02). This result showed that after mandibular setback surgery, there was a statistically significant decrease in the upper airway volume (Figure 2). Also Figure 3 showed mean difference of upper airway total volume changes between before and after Bimaxillary orthognathic surgery was (MD = 1.90 cm³, 95% CI = 0.34 cm³-3.45 cm³; p=0.02) among ten studies and heterogeneity found (I² = 37.94%; p=0.011). Comparing this result, it turns out that bimaxillary surgery promotes less decrease than mandibular setback.

![Figure 2. Forest plots showed upper airway total volume changes between before and after mandibular setback.](image_url)

![Figure 3. Forest plots showed upper airway total volume changes between before and after Bimaxillary orthognathic surgery.](image_url)

Mean difference of upper airway total volume changes between 1-jaw and 2-jaw surgery was (MD = 0.95 cm³, 95% CI = -1.37 cm³-3.28 cm³; p=0.42) among 5 studies and heterogeneity found (I² = 61.80%, p=0.03). This result showed no statistically significant decrease in the upper airway volume between 1-jaw and 2-jaw (Figure 4).
Figure 4. Forest plots showed upper airway total volume changes between 1-jaw and 2-jaw.

Mean difference of apnea-hypopnea index (AHI) between before and after orthognathic surgery was (MD = 0.01, 95% CI = -0.51-0.54, p=0.96) among 5 studies and heterogeneity found (I² = 48.37%; p=0.10). This result showed no statistically significant results difference in sleep apnea after orthognathic surgery (Figure 5).

Figure 5. Forest plots showed apnea-hypopnea index (AHI) changes between before and after surgery.

Bias Assessment

According to the MINORS tool, none studies had a high risk of bias, 14 studies had a moderate risk of bias, and nine studies had low risk (Table1).

Discussion

Due to their anatomical structures, the upper airways were considered by surgeons and orthodontists because they can affect the health and quality of life of patients. An association has also been observed between the upper airways and obstructive sleep apnea syndrome. The purpose of this systematic review and meta-analysis was a comparison of the outcomes of the airway changes and risk of sleep apnea after the bimaxillary orthognathic surgery and mandibular setback surgery in the growing patients with a severe, developing skeletal Class III malocclusion. The meta-analysis result showed the upper airway changes
following the mandibular setback surgery equal to 1.86 cm³. It showed a statistically significant decrease in the upper airway volume before and after Mandibular Setback Surgery. Also, 0.95 cm³ upper airway changes showed between 1-jaw and 2-jaw surgery. As a result, there was no statistically significant decrease in the upper airway volume between 1-jaw and 2-jaw. The apnea-hypopnea index's mean difference showed 0.01 changes and no statistically significant difference in sleep apnea after orthognathic surgery.

Some studies did not report this change, while others indicated the upper airway [37–39]. Some studies also have shown that any significant difference changes have not been found between the upper airway [24] or lower volume significantly decreased [25–29, 40, 41]. The three-dimensional (3D) results showed that bi-maxillary orthognathic surgery considerably changed the soft palate and hyoid bone location. The pharyngeal airway space was significantly reduced in the correction of the skeletal Class III malocclusion [30]. The operation of the 2-jaws should be investigated in the skeletal Class III patients with the above risks because it reduces the amounts of the pharyngeal airway spaces due to the mandibular setback surgery [31]. A result of a systematic review and meta-analysis which has been done by He et al. [10] demonstrated a 3.24 cm³ [95%CI (-5.25, -1.23; p=0.85] mean decrease in the upper airway volume following the MdS surgery; the almost the same as the results of the present study. This study also showed statistically significant differences between 2-jaw and 1-jaw, contrary to the present study results.

According to this meta-analysis, there has been no statistically significant increase in sleep apnea risk before and after surgery. A three-dimensional (3D) PAS volume showed a significant decrease in the oropharyngeal airway, and no significant change has been observed in the sleep symptoms [8]. Reports indicated that bimaxillary orthognathic surgery to reduce PAS played a role, but it does not increase AHI, one of the important determinants of sleep apnea [18, 19, 21, 23]. As a result of a significant decrease in the airway space, it did not influence the AHI-values or cause OSA. In a systematic review conducted by Vancan et al. [42], 17 articles have been included, which reflected the role of orthognathic surgery in obstructive sleep apnea syndrome. However, this study did not mention the statistical dimensions and values of changes. Also, Faria et al. [43] compared the cephalometric radiographs and found a 0.76 mm increment within the retro-palatal region and a 1.2 mm increment in a retro-lingual region in each millimeter (mm) of the maxillo-mandibular progression.

Nonetheless, skeletal relapse and airway compromise in the mandibular setback surgery cases and bimaxillary orthognathic surgery (as observed in this study) required a clinician to analyze and arrange the treatment in these cases fastidiously. Thus a more extensive Bi-jaw surgery may be considered at the cost of avoiding airway compromise in these patients. According to the existing studies, it is felt that longitudinal studies with high quality and larger sample size with a longer follow-up period would be necessary for the future.

**Conclusion**

In Class III patients undergoing mandibular setback surgery alone, a statistically significant decrease in total volume changes at the upper airway. Patients undergoing orthognathic surgery in Class III showed no significant difference in the apnea-hypopnea index after surgery compared to before surgery. Section III Patients undergoing bimaxillary surgery do not show any other significant difference in airways volume after surgery compared to patients undergoing mandibular setback alone. It is also possible that these two surgeries significantly narrowed the airway dimensions but did not cause an increase in the apnea-hypopnea index.
The data used to support the findings of this study can be made available upon request to the corresponding author.

The authors declare no conflicts of interest.

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Conflict of Interest
The authors declare no conflicts of interest.

Data Availability
The data used to support the findings of this study can be made available upon request to the corresponding author.

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