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Review Article

Effects of orthognathic surgery on pharyngeal/oropharyngeal airway in adults: A systematic review of systematic reviews

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Abstract

Introduction: Orthognathic surgery is a commonly employed surgical intervention for the correction of dentofacial deformities, and its impact on the upper airway is of clinical significance. Such surgeries can also alter tongue position which can further alter the upper airway. This review synthesizes findings from multiple systematic reviews to provide a comprehensive overview of the current knowledge base.

Aim and Objectives: To study the effects of maxillary advancement or setback, mandibular advancement or setback or combination of above surgeries on pharyngeal/oropharyngeal airway in adults pharyngeal airway dimension and tongue position.

Materials and Methods: A systematic search was conducted in major databases, including Ovid, PubMed and Embase. The inclusion criteria encompassed systematic reviews that evaluated the impact of orthognathic surgery on pharyngeal or oropharyngeal airway dimensions, with a focus on adult populations. The quality of the included reviews was assessed using the R-AMSTAR tool. Data extraction was done only for medium and high-quality reviews.

Results: The search yielded a total of 8 reviews meeting the inclusion criteria and satisfied the quality appraisal. The reviews collectively examined a diverse range of orthognathic surgical procedures and their effects on the airway. Our review showed that there is an increase in airway dimensions post maxillomandibular advancement (MMA), and a decrease post mandibular setback surgery and a decrease in airway to a lesser extent when mandibular setback was combined with maxillary advancement.

Conclusion: Although clinical evidence indicates a potential augmentation in airway dimensions following MMA, and decrease after setback, there is an imperative need for further research employing controlled methodologies. Additionally, there is a necessity for studies that standardize both follow-up periods and imaging techniques to ensure more robust and comparable findings across investigations.

Keywords: Airway, Orthognathic surgery, Systematic review, Obstructive sleep apnea, Tongue position

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1. Introduction

In orthodontics, severe skeletal dysplasia such as Class II and Class III in a non-growing individual are corrected with orthognathic surgery-to achieve the best possible esthetics and functional efficiency. Such surgeries have an impact on functions such as speech, respiration and mastication.

After orthognathic surgery, the efficiency of the airway may be altered due to the surgical corrections. Decrease in the posterior airway space can consequently lead to development of snoring and/or OSA, which is a common disorder associated with oxyhemoglobin desaturation and increased effort to breathe that is characterized by intermittent, partial or total cessation of air flow leading to sleep fragmentation.[1] On the other hand, patients with severe OSA have been suggested bi-maxillary advancement to alleviate or even treat the problem. Thus, it is firmly believed that it is essential to review the changes in airway that can ensue due to orthognathic surgeries.[2]

The pharyngeal airway evaluation has become an integral part of planning in orthognathic surgery due to its impact on the overall health and quality of life.[3]

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This evaluation of airway can be done using cephalometric measurements, computed tomography (CT) and cone bean computed tomography (CBCT). However, a 2D measurement neglects much of the information regarding the complex 3D structure of the upper airway so the most accurate changes are measured either in CT and CBCT.[4] Many authors suggest that a mandibular setback can cause a significant decrease in the pharyngeal airway[5,6] whereas mandibular advancement or bimaxillary advancement can increase the pharyngeal airway.[7,8] However, there are also studies that have not been able to show any significant changes in the airway following orthognathic surgeries.[9,10]

Additionally, tongue is the most dynamic component of the oropharyngeal system and is highly influenced by changes in the oral and dental environment, particularly the mandible. In mandibular setback surgery, the tongue is repositioned backward, altering its position. This leads to a reduction in the pharyngeal airway space (PAS), potentially increasing the risk of obstructive sleep apnea (OSA). Thus, it is imperative to assess tongue position after surgery.[11]

The aim of this systematic review is to ascertain the changes in airway and tongue position following different orthognathic surgeries by studying previous systematic reviews.

2. Aim

The aim of this systematic review is to study the effects of maxillary advancement or setback, mandibular advancement or setback or combination of above surgeries on pharyngeal/ oropharyngeal airway in adults

1. Pharyngeal airway dimension
2. Tongue position

3. Objective

To conduct a systematic review and collect evidence from published SRs on effect of various orthognathic surgeries on pharyngeal airway and tongue position in adults.

4. Methodology and Protocal Registration

This research employed the Arksey and O'Malley method[12] and adhered to the Preferred Reporting Items for Systematic Reviews (PRISMA) guidelines[13] and was previously registered with PROSPERO under registration number CRD42024420812. The effectiveness of the included reviews was evaluated using the Revised Assessment of Multiple Systematic Reviews (R-AMSTAR) tool.[14]

5. Eligibility Criteria

We included SRs with or without meta-analyses of human clinical trials with either a prospective or retrospective study design to evaluate the effect of maxillary or mandibular advancement or setback on pharyngeal airway and tongue position.

We included studies as a SR if:

1. An independently verifiable search strategy was present,
2. Information about our outcomes of interest was mentioned, Studies written in languages other than English and without full text were excluded.

The PICOs listed below outlined our eligibility requirements.

1. **Population:** Adults admitted to orthognathic surgery.
2. **Intervention:** Surgical correction using mandibular or maxillary advancement or setback, either isolated or in combination.
3. **Comparator:** Pre/post-surgery and comparisons between different orthognathic surgeries.
4. **Outcomes:** Primary outcome focused on pharyngeal airway dimension, and secondary outcome on tongue position.

6. Search Strategy

A comprehensive search strategy encompassed three electronic databases—OVID, Embase, and PubMed—from their inception to July 2020. No restrictions were placed on date or language. To ensure a nuanced approach, a sensitive search filter was employed, eliminating solely animal reviews while incorporating both human and animal reviews [15]. The ovid search was conducted with the following entry terms for indexing articles: (("Orthognathic surgery" OR "orthognathic surgeries" OR "jaw surgery" OR "orthognathic surgical procedures" OR "mandibular advancement" OR "mandibular setback" OR "maxillary advancement" OR "maxillary setback" OR "bimaxillary surgery" OR "bijaw surgery" OR "bi jaw surgery" OR "two jaw surgery" OR "maxillofacial surgery" OR "oral and maxillofacial orthognathic surgeries" OR "maxillomandibular surgery" OR "maxillomandibular surgeries" OR "maxillomandibular advancement") AND ("airway space" OR "oropharyngeal airway" OR "pharyngeal airway" OR "airway volume" OR "oropharyngeal volume" OR "pharyngeal airway volume" OR "cross sectional area" OR "CSA" OR "airway dimension" OR ["dimensions" AND "pharyngeal" OR "oropharyngeal"]) OR ("tongue space OR "tongue position" OR ("cephalometric OR "cephalometry OR "cephalometric image" OR "images" OR "MRI" OR "magnetic resonance imaging" OR "CT scan" OR "imaging" OR "2D imaging" OR "2 dimensional imaging" OR "3D imaging" OR "3 dimensional imaging"))

6.1. Selection of sources of evidence

Retrieved studies underwent deduplication using EndNote as the initial reference manager, followed by secondary deduplication in Rayyan. References displaying over 95% duplication were excluded, and those with less than 50% duplication were included in the screening process. Duplicates were organized in a separate folder for further review. For the remaining studies, a decision was taken after reading their abstracts and the updated versions were included for our screening.

Primary screening involved the examination of titles and abstracts by two reviewers (J.M and A.C), with secondary screening focusing on full-text studies to determine eligibility. Articles were included based on consensus agreement on predefined criteria, involving the reviewers (R.K.M and R.M) in case of any disagreements.

Table 1: Quality appraisal using R-AMSTAR

	Criteria/SR	Giralt-Hernando M[16]	Safi M[17]	Mattos CT[18]	Christovam IO[19]	Louro RS[20]	He J [21]	Fernández-Ferrer L [22]	Daluz ADJ[23]	Al-Moraissi EA[24]	Rosaria B[25]	AlZayer MA[26]	Aljehani D[27]	Steegman R[28]	Rosário HD[3]	Rojo-Sanchis C[29]	He L[30]
1	Was a priori design provided?	3	3	2	4	4	3	2	3	3	2	1	3	2	4	3	2
2	Was there duplicate study selection and data extraction?	4	2	4	4	4	4	4	4	1	3	1	1	3	3	3	2
3	Was a comprehensive literature search performed?	3	2	4	4	4	4	3	3	4	4	4	3	3	4	4	3
4	Was the status of publication bias used as an inclusion criteria?	3	1	2	2	2	1	2	2	1	1	1	1	2	1	1	1
5	Was a list of all studies (excluded and included) provided?	3	1	3	2	1	1	1	1	2	1	2	3	2	2	2	1
6	Were the characteristics of all included studies provided?	2	2	4	4	4	3	3	2	3	3	2	4	1	3	2	2
7	Was the scientific quality of included studies assessed and documented?	3	1	2	3	3	2	2	1	2	3	1	2	2	2	1	2
8	Was the scientific quality of included studies used appropriately in formulating conclusion?	1	1	1	1	2	1	1	1	1	2	1	1	1	1	1	1
9	Were the methods used to combine the findings were appropriate?	4	1	2	2	3	2	1	1	2	3	1	1	1	1	2	2
10	Was the likelihood of publication bias assessed?	4	1	3	1	1	3	1	1	1	2	1	1	1	1	3	2
11	Was the conflict of interest included?	3	3	2	2	3	2	2	3	2	3	2	1	3	2	2	2
	R-AMSTAR Score	33	18	29	29	31	26	22	22	22	27	17	21	21	24	24	20

7. Quality Appraisal

The quality assessment of the included reviews was carried out independently using the R-AMSTAR tool. **(Table 1)** This tool comprises 11 questions, each answered with a yes or no response. Scores ranging from 1 to 4 were assigned based on a set of criteria in response to each question. After completing all questions, the total score was calculated and translated into low (11-22), medium (23-33), and high (34-44) quality ratings.[14] Studies with low quality were excluded at this stage and were not included for data extraction.

Table 2: Data extraction sheet of the selected studies

Author and year of study	Population	Intervention	Outcome	Follow up	Measurement of Outcome	Key characteristics	Conclusive results
Giralt-Hernando M, 2019[16]	Patients with OSA, no gender differences, however overall male population was higher	MMA	Final PA dimensions	6 months	CBCT		MMA significantly increases PA dimensions
Mattos CT 2011[18]	adults submitted to orthognathic surgery	orthognathic surgery (mand. adv, mand. set, mx adv + mand. set, mx adv)	linear, area or volumetric measurement of oropharyngeal dimensions.	1 week-6 years	cephalometric/ CT	results were reported at different anatomical levels	Mand set surgery leads to decrease in oropharyngeal airway, mx adv + mand set followed by a milder decrease in oropharyngeal airway and no difference in axial section areas. and MMA may lead to an increase in the airway
Christovam IO 2015[19]	patients > 15 years, submitted to orthognathic surgery (max or mand adv or set, isolated or in combination)	orthognathic surgery (Mx or Md Adv or Set, isolated or in combintion)	upper airway volume and/ or minimum cross-sectional area (CSA)	Upto 1 year	CT/ MRI		upper airway minimum CSA and the total volume increases significantly after MMA, and the total volume decreases significantly after mx adv + mand set and isolated mand set.
Louro RS 2017[20]	adult patients undergoing orthognathic surgery with Counterclockwise rotation and MMA	orthognathic surgery with CCR and MMA	upper airway	3 days to 12 months	CT/CBCT/PSG (helical CT scan for one study)	counterclockwise rotation of occlusal plane, which has been used widely to improve aesthetic profile	MMA increases the total airway volume and also improves the volume of the retropalatal and retrolingual regions
He J 2016[21]	patients with prognathic mandible and class 3 malocclusion who had undergone mandible setback or MMA; age-15-50 years	Mand set surgery (IVRO or BSSO) or MMA	Changes of the upper airway (three CSA parametes-PNS-CSA, SP-CSA and EP-CSA; four volume parameters-naspharynx volume, oropharynx volume, hypopharynx volume and upper airway total volume	NR**	CT		Mand set + Mx adv caused smaller changes in the CSA of PNS and EP.
Rosaria B 2020[25]	Adults with skeletal class II	BSSO	volume and area measurements of changes in the airway	NA/NR**	Lateral cephalogram, CBCT, Acoustic pharyngometry		
Rosário HD 2016[3]	adult patients with obstructive sleep apnea	MMA	volumetric changes in the upper airway seen through CT	Within 1 year	CBCT or CT		Statistically significant increase in upper airway post MMA observed
Rojo-Sanchis C 2018[29]	adult patients with obstructive sleep apnea who had three-dimensional CBCT or CT and oximetric measurement records and a follow-up period of at least six weeks	MMA	airway dimensions in both vertical and supine position	NR	CBCT or CT		MMA has been shown to be beneficial in increasing upper airway size

*Comparator for all studies were pre and post surgical measurements

** NR- Not reported NA- not applicable

8. Data Extraction

The same reviewers extracted data independently, using a template created iteratively and modified as required to fit the data into categories that complemented the breadth of our review. **(Table 2)** Two studies were excluded at this stage from our review. Any discrepancies among reviewers were resolved through discussion, and consultation with a third reviewer (R.M) was sought if needed.

9. Synthesis

The results of the systematic reviews (SRs) were synthesized utilizing a narrative approach. This involved the presentation of summary paragraphs conveying the key findings of the SRs, which were subjected to further scrutiny.

10. Results

10.1. Study selection

The research process involved an initial identification of 14,380 studies from electronic databases. Subsequent to the removal of duplicates, the dataset was refined to 12,044 titles and abstracts, which underwent thorough screening. During this screening process, 11,857 items were excluded based on a review of their titles and abstracts. Following this initial exclusion, 187 studies were deemed eligible for further assessment, involving a comprehensive reading of the full text. 16 studies met the inclusion criteria for our systematic review. **(Figure 1)**

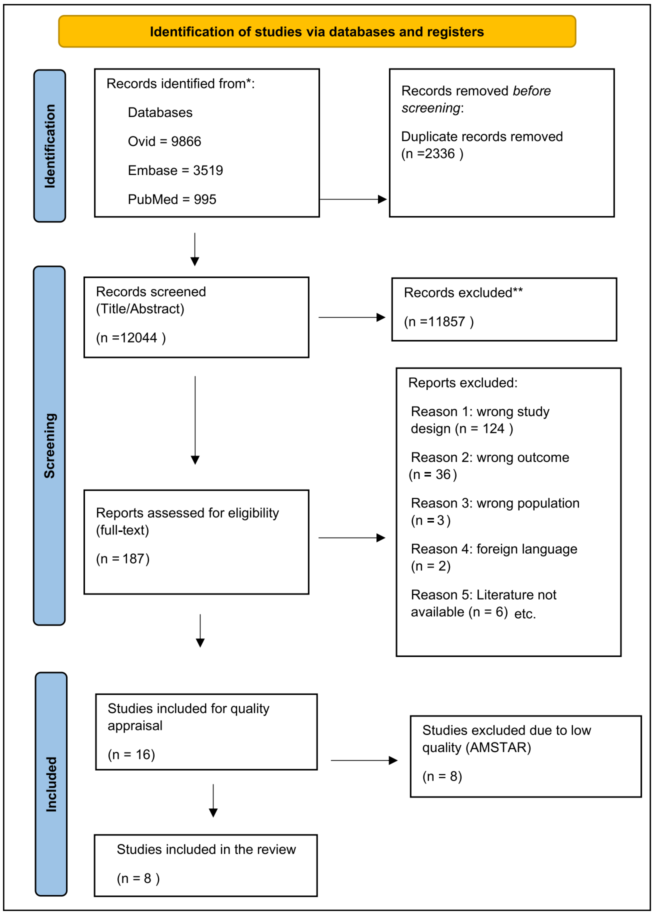

Figure 1: Preferred reporting items for systematic reviews and meta-analyses flowchart.

However, after doing a quality assessment of the selected papers, 8 were removed due to poor quality with R-AMSTAR Score between 11-22, leaving us only 8 studies for our systematic review, thus, providing a strong foundation for our evidence synthesis.

In terms of study design, all included studies were systematic reviews.

10.2. Study characteristics

Our evidence synthesis is based on eight systematic reviews, spanning publications from 2011-2020. These reviews collectively encompassed retrospective, prospective and before-after studies, investigating the impact of orthognathic surgeries on airway dimensions. The orthognathic surgeries studied in these reviews included bimaxillary advancement, mandibular setback, mandibular advancement, and a combination of mandibular setback and maxillary advancement. The primary objective across all systematic reviews was to assess changes in the airway post-surgery. Of particular note, the interventions most frequently examined were bimaxillary advancement and mandibular setback.

10.3. Quality appraisal

The eight studies that were included in our systematic review were of medium quality.

10.4. Primary outcome

Seven studies on maxillomandibular advancement consistently showed increased airway dimensions. Three studies on mandibular setback found a reduction in airway space. Two studies on combined maxillary advancement and mandibular setback also showed a decrease, though less pronounced than with setback alone. One study on mandibular advancement indicated increased airway space, but its low-quality evidence calls for further research. In conclusion, maxillomandibular advancement generally improves airway dimensions, while mandibular setback consistently reduces airway space. The impact of mandibular advancement requires further investigation.

10.5. Secondary outcome

The secondary outcome of interest was tongue position following orthognathic surgery. It has been noted that with mandibular setback, there is an alteration in tongue position which can ultimately hamper airway space as well [11]. We were unable to locate any results for our secondary outcome. The absence of relevant data underscores a significant gap in the current understanding of how orthognathic surgery influences tongue position. Additional research is crucial for a comprehensive assessment of the broader consequences of orthognathic surgeries. Table for summary of results. **(Table 2)**

Table 3: Summary of results of the selected studies

Study	Surgery	Results	R-AMSTAR Score
Giralt-Hernando M[16]	MMA	Increase	33
Mattos CT[18]	MMA	Increase	29
	MdS	decrease	
	MdS + MA	Decrease (less prominent compared to MdS)	
Christovam IO[19]	MMA	Increase	29
	MdS	Decrease	
	MdS + MA	Decrease (less prominent compared to MdS)	
Louro RS[20]	MMA	Increase	31
He J[21]	MMA	Increase	26
	MdS	Decrease	
Rosaria B[25]	MdA	Increase	27
Rosário HD[3]	MMA	Increase	24
Rojo-Sanchis C[29]	MMA	Increase	24

*Results for upper airway space; units and reference planes not specified in the **(Table 3)**.

11. Discussion

Surgeons and orthodontists have displayed an increasing interest in the upper airways, recognizing their significance in impacting individuals' health and overall quality of life. Changes in the upper airway are still disputed with some authors claiming increase in airway after certain surgeries and some stating no changes have occurred.[9,10] This systematic review aimed to assess the changes in the pharyngeal/oropharyngeal airway after different orthognathic surgeries. Eight medium-quality studies meeting inclusion criteria were included, while low-quality studies were excluded to enhance result reliability.

Our review revealed interesting insights into the effects on the oropharyngeal airway space. Specifically, MMA surgery demonstrates a consistent trend of increasing the airway space, particularly at the level of the soft palate[18] and in retropalatal and retrolingual areas.[20] An additional intriguing facet of MMA pertains to the incorporation of Counterclockwise (CCW) rotation. This rotational aspect holds the potential to further enhance the increase in airway space. The repositioning of both bony and soft tissue components in a specific rotational manner underscores the importance of considering not only linear advancements but also rotational adjustments in MMA. One of the studies[21] emphasize a significant increase in upper airway space following MMA, particularly in the horizontal plane defined by anatomical landmarks C1 and C4. This augmentation in the upper airway dimensions signifies a positive impact on the oropharyngeal airway at specific cervical levels. These positive changes in airflow caused by MMA are of importance when treating patients with OSA who fail to respond to positional and appliance therapy.[31] The improvement of upper airway space in OSA patients who undergo MMA is confirmed by an improvement in the Apnea Hypopnea Index (AHI) scores, which describes the severity of OSA. The MMA surgery lead to reduction of AHI below the threshold of 20 but does not claim to fully cure OSA (AHI less than 5). The gold standard for positive impact on airway is a 10 mm MMA advancement.[15] Cephalometric data analysis on 40 patients revealed that the successful group exhibited average advancements of 7.25 ± 1.2 mm in the maxilla, 10.9 ± 2.5 mm in the mandible, and 13.3 ± 1.8 mm in the genioglossus.[32]

On the contrary, MdS exhibits a tendency to decrease the oropharyngeal airway space. Interestingly, when these surgical approaches are combined—utilizing both Maxillary Advancement (Mx Adv) and Mandibular Setback (MdS)—one of the studies pointed towards the decrease in oropharyngeal space, however, the decrease being less pronounced compared to that seen after MdS,[19] and the outcomes of another study[18] exhibit differences at various anatomical levels. The oropharyngeal airway space experiences a milder decrease at certain sites, including the soft palate, base of the tongue, and vallecula. Simultaneously, an increase in airway space is noted at the level of the posterior nasal spine. These results can be attributed to the fact that mandibular setback will lead to posterior positioning of the mandible thus causing a posterior position of the base of the tongue (which is attached to mandible by muscles such as the genioglossus muscle, geniohyoid muscle, and mylohyoid muscle) leading to decrease in airway at this level whereas advancement of the maxilla will lead to anterior repositioning of the posterior nasal spine producing an increase in that specific anatomical area. Hence, the lesser decrease [19] of airway in combined surgery as compared to mandibular setback alone can be credited to the increase in airway due to maxillary advancement. This finding is crucial for patients with a reduced airway requiring orthognathic surgery. Combining maxillary and mandibular surgery can prevent severe airway collapse and reduce the risk of OSA.

Additionally, some studies noted an increase in airway space after mandibular advancement.

However, a correlation between amount of advancement and quantity of increase in the upper airway has not been established. Despite the inclusion of five primary studies (from two systematic reviews[17,18]) in which isolated mandibular advancement osteotomies (BSSO) were performed, the findings and results were not extensively discussed. This lack of elaboration is likely attributed to the limited number and heterogeneity of the primary studies.

Furthermore, the secondary outcome which was the alteration of tongue position post orthognathic surgery was not discussed in the included systematic reviews. After mandibular setback osteotomy, the dorsal surface of the tongue tends to move upward towards the palatal side, while the tip of the tongue moves backward. This is correlated with the posterior and upright positioning of the tongue, which occurs as a result of narrowing of the oral cavity. It has been theorized that the posterior and inferior displacement of the hyoid bone serves as an adaptation mechanism to prevent tongue encroachment into the pharyngeal space.[33] Many studies in the individual SRs used lateral cephalograms, which have limitations in predicting 3D structures with 2D measurements. To improve accuracy, we included studies using CBCT or CT for more precise airway measurements. While MRI (magnetic resonance imaging) provides high-quality airway images, it is more expensive and less accessible than CT.[34,35] Also, another drawback of using MRI is that patient is placed in supine position and centric relation is difficult to establish in such a position which is important to formulate a treatment plan for the patient requiring orthognathic surgery.[19]

It is essential to recognize that the observed variations in airway space alterations are contingent upon differences in reference planes utilized for assessment. This highlights the importance of employing comprehensive and standardized methodologies for evaluating postoperative changes. There is future scope to standardize the levels of airway on CBCT using a universally accepted classification.[18] Additionally, individual patient characteristics and anatomical variations may contribute to the divergent outcomes seen after MMA, MdS, and their combined approach.

Ideally, all systematic reviews that we have assessed must use RCT studies to assess the results of the procedure. However, there lies an ethical dilemma in such a topic to conduct an RCT as all patients need the best treatment and surgeries cannot be interchanged between patients.[14,19,20]

The studies assessed did not have a uniform follow up in all studies. Follow-up period varies across primary studies between 5 weeks to as much as 12 years. A minimum of one year follow up is required to study the relapse of an orthognathic surgery and longer follow ups are needed to verify the outcomes. Future studies with longer follow up are required to produce a reliable outcome.

In conclusion, while our investigation provides valuable insights into the varied effects of orthognathic surgeries on the oropharyngeal airway, it is essential to acknowledge the need for continued research endeavors as these interventions are compounded by factors like rotation and variations in reference planes. Furthermore, our discussion draws attention towards the importance of extended and uniform follow-up periods in future studies. A collaborative effort between researchers, clinicians, and surgeons is imperative to design studies with standardized methodologies and extended follow-up durations.

12. Conclusion

The current body of literature indicates that MMA procedures are linked to an augmentation of airway dimensions, whereas mandibular setback interventions are associated with a reduction in airway dimensions. However, it is crucial to note the limitations of existing studies, as they lack consistent follow-up periods and employ disparate methods for analysing the upper airway, often referencing different anatomical planes. Therefore, to establish more robust and conclusive evidence, further research is warranted with standardized follow-up durations, reference planes, and methods of analysing the airway. This will contribute to a more comprehensive understanding of the impact of maxillofacial procedures on airway dimensions.

13. Source of Funding

Our systematic review did not require any external funding.

14. Conflict of Interest

The authors declare they have no conflict of interest.

15. Acknowledgment

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