RESEARCH PAPER

Effect of Mandibular Advancement On Airway Dimension In Patients With Skeletal Class II Malocclusion: A Systematic Review.

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ABSTRACT

Background: Skeletal Class II malocclusion associated with mandibular retrognathism has frequently been linked to reduced upper airway dimensions. Mandibular advancement through functional appliances, clear aligner mandibular advancement systems, or orthognathic surgery may induce favorable changes in airway morphology; however, the magnitude and consistency of these adaptations remain unclear.

Materials and Methods: Systematic review was conducted according to PRISMA guidelines. Electronic searches were performed in PubMed/MEDLINE, Scopus, Web of Science, Embase, Google Scholar, and the Cochrane Library from inception to January 2026. Clinical studies evaluating three-dimensional airway changes following mandibular advancement were included. Data regarding airway volume, minimum cross-sectional area (MCA), and hyoid bone position were extracted. Risk of bias was assessed using the ROBINS-I tool.

Results: Of 410 identified records, 12 studies met the eligibility criteria for qualitative synthesis. Mandibular advancement was associated with increased upper airway dimensions, particularly within the oropharyngeal region. Consistent increases in oropharyngeal airway volume and MCA were reported across most studies, with the greatest MCA increase (71%) observed following mandibular advancement surgery. Several studies also demonstrated anterior displacement of the hyoid bone after treatment. Changes in nasopharyngeal dimensions were less consistent. Two studies were judged to have a low risk of bias, whereas ten studies demonstrated a moderate risk of bias.

Conclusions: Mandibular advancement appears to be associated with favorable three-dimensional changes in upper airway morphology in patients with skeletal Class II malocclusion. The most consistent findings were increases in oropharyngeal airway volume, enlargement of MCA, and anterior repositioning of the hyoid bone.

PROSPERO Registration Number: CRD4202564241

Keywords: Skeletal class II malocclusion, Mandibular advancement, Airway volume, Cone- beam computed tomography.

How to site this article: Dr. Ridham Doshi,Dr. Aakash Shah,Dr. Bhagyashree Desai, Dr. Ahuti G Shah,Dr. Rutvi Shah ,Dr. Manisha Tripathi,Dr. Neel Shah, “Effect of Mandibular Advancement On Airway Dimension In Patients With Skeletal Class II Malocclusion: A Systematic Review.”Int J Drug Deliv Technol. 2026;16(79s):415-425. DOI: 10.25258/ijddt.16.79s.44

1. INTRODUCTION

A class II malocclusion usually has its dental, skeletal, and/or functional components present. Although most of these features are discussed as if they tend to occur individually, it must be remembered that they often coexist and are often present in varying degrees [1]. Skeletal Class II malocclusion is a prevalent and multifaceted sagittal discrepancy where the upper and lower jaws do not meet properly [2]. Typically manifesting as a convex facial profile, lip incompetency and large overjet this condition is not a single clinical entity but a complex morphological outcome of divergent growth patterns involving the entire craniofacial complex. Consequently, a comprehensive diagnosis must evaluate the position of the maxilla relative to the cranial base before attributing the deformity solely to mandibular deficiency. In terms of global prevalence, this malocclusion affects approximately 30% of the population seeking orthodontic treatment [1].

Several etiological factors contribute to a deficient mandible, ranging from genetic predisposition and hormonal imbalances to environmental influences and functional habits during early childhood. In many instances, the mandible fails to reach its full genetic growth potential, resulting in a skeletal configuration that predisposes the patient to a narrowed pharyngeal airway space [3]. This anatomical deficiency is particularly concerning in growing children, as a retrusive mandible can lead to increased airway resistance and potential respiratory complications [4].

To address these skeletal discrepancies, clinicians employ various treatment modalities tailored specifically to the patient's age and skeletal maturity. For growing patients, functional appliances (FAs) serve as the primary tool for growth modification, ranging from removable options like the Twin Block and Activator to fixed versions like the Herbst, Forsus, MARA etc. These devices work by repositioning the mandible anteriorly to stimulate remodelling at the condyle and the glenoid fossa while simultaneously stretching the associated soft tissues to enhance airway dimensions [5]. In cases where traditional orthopedic growth modification is insufficient or the patient has reached skeletal maturity, more invasive surgical interventions may be required. Surgical advancement of the mandible can be performed in patients in whom the growth has been completed. This modality is particularly useful for severe micrognathia or craniofacial syndromes, as it allows for large-scale skeletal movements and concurrent expansion of the surrounding soft tissue envelope, which significantly increases airway volume.

Despite the extensive body of literature regarding Class II malocclusion, much of the historical data concerning airway changes has been limited by the inherent constraints of two-dimensional cephalometry [6]. These 2D methods fail to capture critical volumetric shifts and transverse expansions that occur during treatment. Consequently, the primary objective of this systematic review is to evaluate the three-dimensional (3D) changes of the upper airway in patients with skeletal Class II malocclusion following mandibular advancement therapy. By synthesizing high-fidelity data from Cone-Beam Computed Tomography (CBCT) studies, this review aims to provide a definitive assessment of changes in oropharyngeal and nasopharyngeal volumes, the minimum cross-sectional area (MCA), and the stability of the hyoid bone position.

This paper serves a conclusive purpose by expanding upon previous meta-analyses and incorporating the most recent clinical trials and surgical data. It offers a comprehensive comparison of treatment outcomes across both growing children and adult populations, bridging the gap between pediatric growth modification and adult surgical interventions (such as BSSO). Ultimately, this systematic review seeks to establish a clear, evidence-based understanding of how different advancement modalities impact long-term respiratory health and airway patency, providing clinicians with a robust framework for managing the craniofacial complex in Class II patients.

2. MATERIAL AND METHOD

2.1 Protocol and Registration

This systematic review was conducted and reported in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 guidelines. The review protocol was prospectively registered with the International Prospective Register of Systematic Reviews (PROSPERO) under registration number CRD42025642412 prior to the commencement of the literature search.

2.2 Data Sources and Search Method

A comprehensive electronic search was performed across PubMed/MEDLINE, Scopus, Web of Science, Embase, Ovid, Nature, Google Scholar, and the Cochrane Library from the date of inception to January 2026. Manual searches were also conducted in relevant orthodontic journals. Search strategies were developed in accordance with the PICOS framework, utilizing Boolean operators and MeSH terms: ("mandibular advancement" OR "functional appliance" OR "BSSO") AND ("airway volume" OR "pharyngeal airway" OR "CBCT"). Studies included in the reference lists of retrieved articles were also screened for relevancy.

2.3 Eligibility Criteria

The inclusion and exclusion criteria were established to prioritize high-fidelity 3D data and capture all relevant modalities of mandibular advancement:

Inclusion criteria (Table 1) are as follow:

Table 1: Inclusion Criteria

Component	Description
Population (P)	Patients of any age with skeletal class II malocclusion (ANB > 4° or equivalent) and mandibular retrognathism, with no prior history of airway abnormalities or significant ENT interventions.
Intervention (I)	All clinical modalities achieving mandibular advancement: Functional Appliances: Removable (Twin Block) and Fixed (Herbst, Forsus, MARA) functional appliances. Modern Modalities: Clear aligner mandibular advancement systems. Surgical Advancement: Bilateral Sagittal Split Osteotomy (BSSO).
Comparison (C)	Pre-treatment baseline measurements or untreated Class II control groups matched for chronological age, skeletal age, sex, and time interval to eliminate natural growth factors.
Outcomes (O)	Primary: 3D volumetric changes in the upper airway (OAV, NAV) and the Minimum Cross-Sectional Area (MCA). Secondary: 2D/3D linear changes in the hyoid bone (HB) position.

Exclusion Criteria (Table 2): To minimize confounding variables and ensure high-fidelity data, the following were excluded:

Table 2: Exclusion Criteria

Imaging Limitations:	Studies utilizing 2D lateral cephalometry as the primary modality for airway assessment due to dimensional reduction and landmark superimposition.
Medical Comorbidities:	Patients with craniofacial anomalies (e.g., Cleft Lip and Palate) or prior significant ENT interventions (e.g., tonsillectomy or adenoidectomy).
Concurrent Therapy:	Cases involving maxillary expansion before or during the mandibular advancement treatment.
Data Integrity:	Case reports, editorials, animal studies, and studies failing to provide quantitative raw mean values and standard deviations.

2.4 Data Extraction

Two independent reviewers performed the initial screening of titles and abstracts; any disagreements were resolved through consensus or consultation with a third senior reviewer. Data extraction was performed using a standardized spreadsheet capturing: author/year, country, study design, participant characteristics (sample size, age, sex), intervention details (appliance type, duration), imaging methodology, and primary 3D volumetric outcomes.

2.5 Risk of Bias Assessment

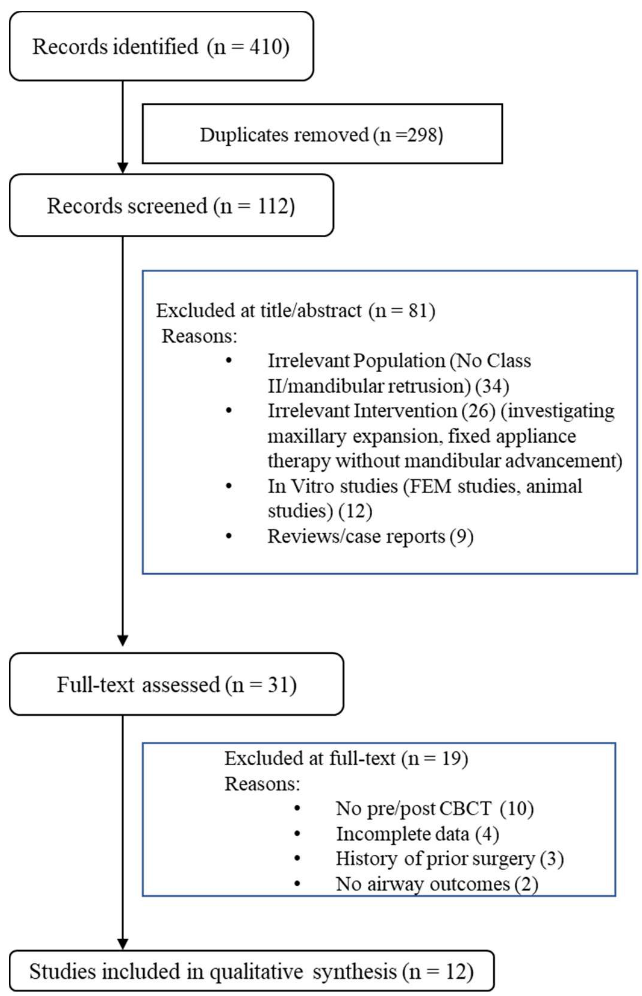
The methodological quality of the included studies was assessed using the Cochrane Risk of Bias in Non-randomized Studies of Interventions (ROBINS-I) tool. Seven domains were evaluated: bias due to confounding, selection of participants, classification of interventions, deviations from intended interventions, missing data, measurement of outcomes, and selection of the reported result. An overall assessment of risk of bias (low, moderate, high, or critical) was made for each included study.

3. RESULTS

3.1 Search Results

A total of 410 records were identified through the primary electronic search of databases and manual screening. Following the removal of 298 duplicate records, 112 unique studies remained for screening. The initial screening of titles and abstracts resulted in the exclusion of 81 articles. A total of 31 full-text articles were assessed for eligibility, of which 19 studies were excluded based on the established inclusion and exclusion criteria. Ultimately, 12 studies were included in the qualitative synthesis. (Figure 1)

Figure 1: PRISMA Flow Diagram



The characteristics of these studies, including study design, participant demographics, interventions, observation periods, and primary outcomes, are detailed in Table 3.

Table 3: The characteristics of the included studies in the systematic review.

Author and Year	Design	Characteristics of participants	Characteristics of control group	Sample (M/F)	Intervention	Observation period	Primary 3D Findings
Iwasaki (2014)7	Retrospective	Class II division 1 malocclusion, with greater than half-step Class II molar and canine relationships, Class II skeletal relationship, and growing children (ages, 9–14 years)	Class I malocclusion, Class I skeletal relationship, and growing children (9–14 years)	24 (11/13)	Herbst	12.3 +/- 4.2 months	Significant oropharyngeal, laryngopharyngeal airway volume increase. And forward positioning of hyoid bone
Li et al. (2014)8	Comparative	The overjet was at least 7 mm with an Angle Class II molar relationship, SNA angle was within the normal range between 78.4° and 85°, SNB angle was less than 75°, and the patients had a clinically retrognathic mandible, ANB angle was greater than 4°, and no other potential airway abnormalities	The overjet was at least 7 mm with an Angle Class II molar relationship, SNA angle was within the normal range between 78.4° and 85°, SNB angle was less than 75°, and the patients had a clinically retrognathic mandible, ANB angle was greater than 4°, and no other potential airway abnormalities	30 (13/17)	Twin Block	13.67 +/- 1.51 months	Volume of nasopharynx, oropharynx, and hypopharynx, were increased, anterior position of hyoid bone, and mean cross-sectional area increased
Elfeky (2015)9	Prospective	Aged 10–12 years with CS3-4, skeletal Class II malocclusion with mandibular deficiency, Class II molar and/or canine relationship, and no potential airway problems or abnormalities	Aged 10–12 years with CS3-4, skeletal Class II malocclusion with mandibular deficiency, Class II molar and/or canine relationship, and no potential airway problems or abnormalities	18	Twin Block	8 months	increased Oropharyngeal airway, nasopharyngeal airway, and minimal constricted area
Rizk (2016)10	Retrospective	Class II white patients	Skeletal Class II white subjects, SN–GoGn 27°–37°, SNB no more than 77°, ANB ≥4.5°, and CVMS to match the experimental group	20 (7/13)	MARA	16.8 months	increase Oropharyngeal airway volume and airway dimension; anterior positioning of hyoid bone.

Iwasaki (2017)11	Retrospective	Class II division 1 malocclusion, Class II skeletal relationship, age 9–14 years	Class I malocclusion, Class I skeletal relationship, age 9–14 years, matched for sex, age, and FMA angle with the Herbst group	21 (10/11)	Herbst	12.3 +/- 4.2 months	Improved maxillofacial form and ventilation of both the oropharyngeal and laryngopharyngeal airways.
Isidor (2018)12	Retrospective	Overjet equal to or greater than 6 mm	Less than 6 mm overjet and a Class I molar relationship	20 (8/12)	TB/Activator	12.7 +/- 8.4 months	Increase in oropharyngeal volume.
Alhammadi (2019)13	Prospective	Females in Stages CS3–CS4, mandibular deficiency, normal, or protruded maxilla, overjet: ≥5 mm, ≥½ unit Class II molar and canine relationship	Females in Stages CS3–CS4, mandibular deficiency, normal, or protruded maxilla, overjet: ≥5 mm, ≥½ unit Class II molar and canine relationship	44	TB/Forsus	not mentioned	Oropharyngeal and Nasopharyngeal airway volume increase and increase in minimal cross-section area.
Abdalla (2020)5	Retrospective	Full-unit Angle's Class II molar relationship, Class II skeletal base, between the ages of 8 and 15 year	Angle's Class I molar relationship, matched the FA group for chronological age, skeletal age, sex, and time interval	73 (35/38)	Fixed FA	1 year 11 months	Increase in Upper airway volume and minimum cross-section area
Oliveira (2020)14	Retrospective	Class II malocclusion with an ANB angle more than 4°, facial appearance of mandibular retrusion, and cervical stage from CS2 to CS5	Class II malocclusion with an ANB angle more than 4°, facial appearance of mandibular retrusion, and cervical stage from CS2 to CS5, with marsupialization of cysts, traction of impacted permanent canines, or restorative dentistry	24 (12/12)	Herbst	8.9 ± 0.8 months	increase in total airway volume
Yıldırım (2021)15	Prospective	Class II malocclusion with ANB more than 4 degrees, class II molar and canine relation bilaterally with at least 5 mm of overjet, stage 3-4 CVMI.	No control group were present in the study.	30 (14/16)	Twin Block	7.4 months	Increase in superior and inferior compartment of airway and total airway volume is also increased.
Sohaib Shujaat (2022)16	Retrospective	Mandibular advancement surgery without genioplasty	No control group were present in the study.	120 (40/80)	Surg. BSSO	12 +/- 2.6 months	MCA increased by 71%; Total airway volume increased 38%.
Yue et al. (2023)17	Retrospective	Skeletal class II with ANB more than 4 degrees, hypodivergent or normal growth	No control group were present in the study.	32 (15/17)	Twin Block and Mandibular Advancement	12.11 +/- 1.3 months	Increase in Oropharynx volume and oropharynx minimal cross section area, and Hypopharynx volume and minimal cross section

		pattern, cervical maturation stage between CS2 and CS3.			with clear aligners.		area. Hyoid bone moved downward and forward

3.2 Risk of Bias Assessment

The risk of bias assessment using the ROBINS-I tool is shown in Table 4. Overall, two studies (Elfeky 2015, Alhammadi 2019) were assessed as having a low risk of bias due to their prospective designs and well-defined control groups. Ten studies were assessed to be at moderate risk of bias, primarily due to the retrospective nature of archival data and the inherent challenges in controlling for natural growth as a confounding factor in adolescent subjects. Bias in the measurement of outcomes was consistently low across all studies, attributed to the objective nature of 3D CBCT volumetric segmentation.

3.3 Airway Volume Changes

3.3.1 Oropharyngeal Airway Volume

Oropharyngeal airway volume was the most frequently evaluated parameter and demonstrated consistent improvement following mandibular advancement therapy. Iwasaki et al. reported significant increases in both oropharyngeal and laryngopharyngeal airway volumes following Herbst treatment. Similarly, Li et al., Elfeky and Fayed, Rizk et al., Isidor et al., Alhammadi et al., Yıldırım and Karaçay, Oliveira et al., and Yue et al. demonstrated significant enlargement of the oropharyngeal airway after functional appliance therapy. Shujaat et al. reported substantial increases in pharyngeal airway volume following bilateral sagittal split osteotomy (BSSO), indicating that both orthopedic and surgical mandibular advancement positively influence the oropharyngeal airway.

3.3.2 Nasopharyngeal Airway Volume

Nasopharyngeal volume was evaluated in studies employing Twin Block and Herbst appliances. Li et al., Elfeky and Fayed, Alhammadi et al., Yıldırım and Karaçay, and Oliveira et al. reported significant increases in nasopharyngeal volume following treatment. Oliveira et al. demonstrated an 11.7% increase in nasopharyngeal volume after Herbst therapy. In contrast, Isidor et al. found no statistically significant difference in lower nasopharyngeal volume between treated and untreated subjects.

3.3.3 Hypopharyngeal and Laryngopharyngeal Airway Volume

Li et al. reported significant enlargement of the hypopharyngeal airway following Twin Block therapy. Yue et al. similarly demonstrated significant increases in hypopharyngeal volume after both Twin Block and clear aligner mandibular advancement therapy. Iwasaki et al. reported significant increases in laryngopharyngeal airway volume following Herbst treatment.

3.4 Total Airway Volume

Total airway volume was evaluated in several studies. Oliveira et al. demonstrated significant increases in total upper airway volume following Herbst therapy, while Yıldırım and Karaçay reported increases in total airway volume after Twin Block treatment. The largest volumetric increase was observed by Shujaat et al., who reported a 38% increase in total airway volume one year after isolated mandibular advancement surgery.

3.5 Minimum Cross-Sectional Area

Minimum cross-sectional area (MCA) was assessed in six studies and consistently increased following treatment. Elfeky and Fayed reported significant enlargement of the minimal constricted area after Twin Block therapy. Alhammadi et al. demonstrated significant increases in MCA following both Twin Block and Forsus treatment. Abdalla et al. reported enlargement of the upper airway MCA after fixed functional appliance therapy. Yue et al. observed significant increases in both oropharyngeal MCA and hypopharyngeal MCA following Twin Block and clear aligner mandibular advancement treatment. The greatest increase was reported by Shujaat et al., who found a 71% increase in MCA following mandibular advancement surgery.

3.6 Hyoid Bone Position

Five studies evaluated changes in hyoid bone position. Li et al. demonstrated anterior displacement of the hyoid bone following Twin Block therapy. Rizk et al. reported a mean anterior hyoid movement of 4.3 mm following MARA treatment. Iwasaki et al. observed anterosuperior displacement of the hyoid bone after Herbst therapy. Yue et al. reported a forward and downward displacement of the hyoid bone following both Twin Block and clear aligner mandibular advancement therapy. Shujaat et al. demonstrated significant anterior and superior repositioning of the hyoid bone following mandibular advancement surgery.

3.7 Airway Morphology and Shape Changes

Beyond volumetric changes, several studies reported alterations in airway morphology. Li et al. demonstrated a significant increase in the left-right to anteroposterior (LR/AP) ratio of the oropharyngeal airway, indicating a transition toward a more elliptical airway configuration. Rizk et al. reported significant increases in both transverse and anteroposterior airway dimensions. Isidor et al. observed a significant increase in palatal width following functional appliance therapy, whereas Oliveira et al. reported a 5.5% increase in nasal cavity volume after Herbst treatment.

3.8 Airflow Characteristics

Only one study assessed functional airflow parameters. Using computational fluid dynamics, Iwasaki et al. demonstrated improved airflow ventilation and reduced airway resistance within the oropharyngeal and laryngopharyngeal regions following Herbst therapy.

4. DISCUSSION

The present systematic review evaluated the effects of mandibular advancement on upper airway morphology in patients with skeletal Class II malocclusion using three-dimensional imaging modalities. Overall, mandibular advancement, whether achieved through functional appliances or orthognathic surgery, was associated with favourable changes in upper airway dimensions. The most consistent findings across the included studies were increases in airway volume, enlargement of the minimum cross-sectional area (MCA), and anterior displacement of the hyoid bone, with the most pronounced changes occurring in the oropharyngeal region.

These findings are consistent with the established anatomical relationship between the mandible, tongue, hyoid bone, and pharyngeal airway. Mandibular retrognathism has been associated with posterior tongue posture and reduced pharyngeal dimensions [18,19,20,21]. Advancement of the mandible repositions the tongue-hyoid complex anteriorly through muscular attachments, thereby increasing the available airway space [18,19,20,21]. This mechanism likely explains the consistent enlargement of the oropharyngeal airway observed across the included studies.

Airway volume was the most frequently reported outcome. Although the magnitude of change varied among studies, nearly all investigations demonstrated enlargement of upper airway dimensions following treatment. Oropharyngeal changes were consistently greater than nasopharyngeal changes, suggesting that airway segments anatomically related to mandibular position are most responsive to mandibular advancement. Similar observations have been reported in previous systematic reviews and meta-analyses [22,23,24].

A major strength of the present review is the inclusion of MCA as a primary outcome measure. Unlike total airway volume, MCA identifies the narrowest airway segment and may better reflect the site of greatest airflow limitation [25,26]. Several studies reported significant increases in MCA following mandibular advancement, indicating that treatment not only enlarges airway dimensions but may also reduce localized constrictions [9,16,17]. Because airway resistance is highly dependent on the smallest airway dimension, increases in MCA may have important functional implications [25,26].

Differences were observed between functional and surgical mandibular advancement. Functional appliances, including Twin Block, Herbst, MARA, Forsus, and clear-aligner mandibular advancement systems, generally produced favourable airway changes in growing patients. However, interpretation should be cautious because airway dimensions naturally increase during growth [27,28]. Although several studies included untreated controls, distinguishing treatment effects from normal developmental changes remains challenging [5,7,8,9,10,11,12,13,14].

In contrast, isolated mandibular advancement surgery produced larger and more immediate airway changes [16]. Greater skeletal advancement results in more substantial displacement of the tongue-hyoid complex and correspondingly larger increases in airway volume and MCA. These findings support previous reports demonstrating significant airway enlargement following orthognathic mandibular advancement [19,21].

The present findings are broadly consistent with previous systematic reviews. Li et al. [22] and Xiang et al. [23] reported significant enlargement of upper airway dimensions following functional appliance therapy, particularly within the oropharyngeal region. Katyal et al. [24] similarly highlighted the relationship between craniofacial morphology and airway dimensions. The present review extends previous evidence by incorporating recent CBCT-based studies evaluating clear-aligner mandibular advancement systems, surgical mandibular advancement, and MCA-related outcomes.

Changes in hyoid bone position were also frequently reported. Most studies demonstrated anterior displacement of the hyoid bone, although vertical changes were less consistent [7,10,17]. Because the hyoid bone serves as an important attachment point for the tongue and suprahyoid musculature, its anterior repositioning likely reflects adaptive changes accompanying mandibular advancement.

Several limitations should be considered. Considerable methodological heterogeneity existed among studies, including differences in patient positioning, image acquisition, airway segmentation protocols, and airway boundary definitions. Most investigations were observational in design, had relatively small sample sizes, and provided limited long-term follow-up. Consequently, the overall certainty of evidence remains moderate.

From a clinical perspective, the findings suggest that mandibular advancement may provide benefits beyond correction of sagittal skeletal discrepancies by promoting favourable upper airway adaptations. Nevertheless, enlargement of airway dimensions should not be assumed to directly translate into improvements in respiratory function, sleep quality, or long-term airway health. Future studies should incorporate standardized CBCT protocols and objective functional outcomes, such as airflow analysis and polysomnography, to better establish the clinical significance of treatment-induced airway changes.

5. CONCLUSION

This systematic review suggests that mandibular advancement, achieved through functional appliances, clear aligner mandibular advancement systems, or orthognathic surgery, is associated with favourable three-dimensional changes in the upper airway morphology of patients with skeletal Class II malocclusion. The most consistent findings were increases in oropharyngeal airway volume, enlargement of the minimum cross-sectional area, and anterior repositioning of the hyoid bone. Although both orthopedic and surgical interventions demonstrated positive airway adaptations, greater changes were generally observed following mandibular advancement surgery.

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