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Systematic Review

Mouth Breathing and Obstructive Sleep Apnea in Children: An Umbrella Review

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Abstract

Background: Mouth breathing and obstructive sleep apnea (OSA) in children are interrelated conditions that can negatively impact neurocognitive development and overall quality of life. This study aimed to critically analyze the available evidence regarding the relationship between these conditions, highlighting their prevalence, clinical consequences, and therapeutic approaches. Methods: To this end, an umbrella review was conducted, including systematic reviews and meta-analyses retrieved from scientific databases, following rigorous inclusion criteria. Results: A total of six systematic reviews met the inclusion and exclusion criteria and were included in the final analysis. These studies explored various aspects of the topic and underwent a thorough assessment of methodological quality. Conclusions: The findings indicated that mouth breathing may act as both a predisposing and aggravating factor for OSA, while OSA itself may contribute to the persistence of this breathing pattern. However, the methodological heterogeneity among the included studies posed a challenge to synthesizing the findings, underscoring the need for more standardized research. It is concluded that early interventions and multidisciplinary approaches are essential for the effective management of these conditions. Furthermore, this review provides a foundation for future research in this area.

Keywords: obstructive sleep apnea; mouth breathing; umbrella review; pediatrics; sleep disorders

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1. Introduction

Sleep plays an indispensable role in neurological, somatic, and psychosocial development during childhood and adolescence [1]. The architectural integrity of sleep is fundamental for memory consolidation, emotional regulation, and endocrine and immune function [2,3]. However, this vital process can be profoundly disrupted by sleep-disordered breathing (SDB), of which obstructive sleep apnea (OSA) represents the most prevalent and clinically significant manifestation in the pediatric population, with prevalence estimates ranging from 1% to 5% [4]. OSA is characterized by recurrent episodes of partial or complete collapse of the upper airway during sleep. This obstruction results in interruptions of airflow that trigger a pathophysiological cascade of intermittent hypoxemia, hypercapnia, frequent arousals, and sleep fragmentation [5]. The primary anatomical cause in children is adenotonsillar hypertrophy, although factors such as obesity and craniofacial anomalies are also significant contributors [6].

The consequences of untreated pediatric OSA are multisystemic and can lead to long-term morbidities. In the neurocognitive domain, sleep fragmentation and chronic hypoxemia are associated with deficits in executive functions, attentional difficulties, impaired

academic performance, and symptoms that mimic attention-deficit/hyperactivity disorder (ADHD) [7,8]. Furthermore, growing evidence points to cardiovascular repercussions, including endothelial dysfunction, elevated blood pressure, and cardiac remodeling, as well as metabolic disturbances, such as insulin resistance [9,10]. Such adverse outcomes compromise a child's quality of life and underscore the urgency of the early identification and intervention.

Within the spectrum of risk factors for pediatric OSA, mouth breathing has emerged as a central element, not merely as a symptom but as a potential causal agent in the development and perpetuation of airway obstruction. Chronic mouth breathing, often a compensatory adaptation to nasal obstruction from conditions like allergic rhinitis or adenoid hypertrophy, disrupts the functional equilibrium of the stomatognathic system [11]. The absence of physiological nasal airflow and the abnormally low posture of the tongue alter the forces that shape the growth and development of maxillomandibular structures. This can result in an anomalous craniofacial growth pattern, classically described as "adenoid facies", which includes a high-arched palate, mandibular retrognathia, and increased anterior lower facial height [12–17].

These morphological and postural changes are not merely cosmetic; they hold direct implications for upper airway patency. The atresic maxilla and retropositioned mandible contribute to the narrowing of the pharyngeal airway space, predisposing the individual to a greater risk of collapse during sleep and, consequently, aggravating the severity of OSA [18–22]. A vicious cycle is thus formed: nasal obstruction leads to mouth breathing, which promotes craniofacial changes that, in turn, exacerbate airway obstruction and perpetuate the dependence on mouth breathing throughout life [3,23–26].

The multifactorial nature and bidirectional relationship between mouth breathing and pediatric OSA have generated a vast and heterogeneous body of research, spanning various specialties such as otolaryngology, orthodontics, pediatrics, and sleep medicine. Despite the clinical recognition of this association, the literature lacks a systematic synthesis that integrates the evidence on prevalence, risk factors, dysmorphic consequences, and therapeutic strategies [10,27–32]. The breadth of these approaches necessitates a comprehensive and critical evaluation of the scientific knowledge produced to date. Therefore, the objective of this study is to conduct an umbrella review of the current evidence on the role of mouth breathing in the context of pediatric OSA, with the aim of critically analyzing trends, identifying knowledge gaps, and delineating the clinical implications of this complex association to optimize clinical practice and direct future investigations.

This study is justified by the need for an umbrella review that synthesizes the available evidence, providing a global and reliable perspective on the topic. In addition to offering essential information for healthcare professionals, educators, and policymakers, this research may guide future studies and contribute to the development of preventive and therapeutic strategies aimed at minimizing the impacts of OSA in children.

2. Objectives

This study aims to conduct an umbrella review on the topic Mouth Breathing and Obstructive Sleep Apnea (OSA) in Children. The umbrella review represents a robust methodology for synthesizing complex research, enabling a comprehensive and reliable analysis of the scientific knowledge on a specific subject.

Specific Objectives

- To synthesize the results of different systematic reviews on the relationship between mouth breathing and OSA in children.
- To assess the methodological quality of the included systematic reviews.

- To analyze different perspectives on the topic.
- To identify inconsistencies and knowledge gaps regarding the subject, guiding future research.
- To provide theoretical and practical implications for healthcare professionals, educators, and policymakers regarding the importance of assessing and managing mouth breathing in children.

3. Methodology

This umbrella review was conducted and reported in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 statement [4] (Figure S2). The study exclusively selected systematic reviews and meta-analyses centered on mouth breathing and obstructive sleep apnea (OSA) within a pediatric population, defined as individuals aged 0 to 18 years. This paper is not registered in a public registry. PRIOR checklist was performed (Supplementary Materials Figure S1).

The selection process was rigorous and systematic. Two reviewers independently screened titles and abstracts for eligibility. The full texts of potentially relevant studies were subsequently assessed against the inclusion criteria. Any disagreements at either stage were resolved through discussion or, if necessary, consultation with a third reviewer to reach a consensus. Following selection, a formal data extraction was performed by one reviewer using a predefined, standardized form; a second reviewer then meticulously verified the extracted data to ensure accuracy and completeness.

To ensure the methodological robustness of the included literature, a critical appraisal was conducted using the A MeaSurement Tool to Assess systematic Reviews 2 (AMSTAR 2.0). This assessment was performed independently by two reviewers, with any discrepancies in ratings resolved through consensus or adjudication by a third party. Finally, due to the anticipated high degree of clinical and methodological heterogeneity among the included reviews and the qualitative nature of the evidence synthesis, a formal assessment of publication bias was not performed. ChatGPT (version 3.5) was used for linguistic editing in English.

3.1. Study Eligibility Criteria

Eligibility for inclusion in this review was predicated on a defined set of criteria. The review only considered systematic reviews and meta-analyses that investigated the relationship between OSA and mouth breathing. The target population was strictly pediatric, encompassing studies focused exclusively on children and adolescents (0–18 years). Studies were excluded if their scope was narrowed to specific subpopulations with distinct anatomical malformations, genetic syndromes, or other significant comorbidities that could confound the results and thereby limit the generalizability of the findings to the broader pediatric population.

3.2. Information Sources

A comprehensive and systematic literature search was conducted across several major electronic databases renowned for their extensive coverage in health sciences. The platforms utilized were PubMed, Scopus (Elsevier), Web of Science, SciELO, and EMBASE. This multi-database approach was designed to ensure the thorough and up-to-date retrieval of all relevant literature.

3.3. Search Strategy

The search strategy was meticulously developed utilizing a combination of Medical Subject Headings (MeSH) and free-text keywords in English. Core search concepts included “mouth breathing,” “oral breathing,” “obstructive sleep apnea,” “children,” and

"pediatrics," along with their relevant variations. Boolean operators (AND, OR) were strategically employed to combine these terms. The search encompassed all literature published up to August 2024 and was filtered within each database to retrieve only articles classified as systematic reviews or meta-analyses.

4. Results

4.1. Methodological Quality Assessment

The methodological quality of each included review was systematically evaluated using the 16-item AMSTAR 2.0 checklist. This instrument facilitates a critical appraisal of the conduct and reporting of systematic reviews. Two reviewers independently assigned ratings across each domain, culminating in an overall confidence rating for each review: high, moderate, low, or critically low. This process involved a detailed assessment of critical domains, including the a priori registration of a protocol, the adequacy of the literature search, and the consideration of risk of bias in the primary studies. The final ratings provided a structured framework for interpreting the robustness of the evidence presented in each review and for contextualizing the overall synthesis of findings.

The studies included in this umbrella review investigated different aspects of the relationship between mouth breathing and OSA in children. While some reviews focused on prevalence and risk factors, others analyzed the effectiveness of specific interventions. Although there is consensus on the negative impact of mouth breathing on sleep quality, diagnostic methods and study populations varied, making direct comparisons challenging (Table 1).

Table 1. Results of the AMSTAR 2.0 Assessment.

Study Reference	Protocol Registered	Included Studies Quality	Clear Inclusion/Exclusion Criteria	Adequate Database Search	Risk of Bias Assessment	Discussion on Bias Impact	Final Rating
Barbosa et al. (2023) [9]	Yes	Moderate	Yes	Yes	Yes	Yes	High confidence
Ji et al. (2021) [10]	No	Moderate	Yes	Yes	Yes	Yes	Moderate confidence
Lumeng & Chervin (2008) [5]	No	High	Yes	Yes	Yes	Yes	High confidence
Mohammed et al. (2021) [6]	No	Low	Yes	Yes	Yes	No	Low confidence
Neiva et al. (2018) [7]	No	Low	Yes	Yes	Yes	No	Low confidence
Zhao et al. (2021) [21]	Yes	Moderate	Yes	Yes	Yes	Yes	Moderate confidence

Given the broad scope of the topic Mouth Breathing and Obstructive Sleep Apnea in Children, the analysis of the included studies was structured into thematic categories, allowing for clearer organization of the findings and facilitating comparison among systematic reviews and meta-analyses (Figure 1).

Categorization was based on the main focuses of the studies, resulting in the following areas of analysis: prevalence, risk factors and pathophysiological mechanisms, impact on child health and development, and therapeutic interventions (Table 2). Each study was classified according to its primary approach, and the results were synthesized within each category.

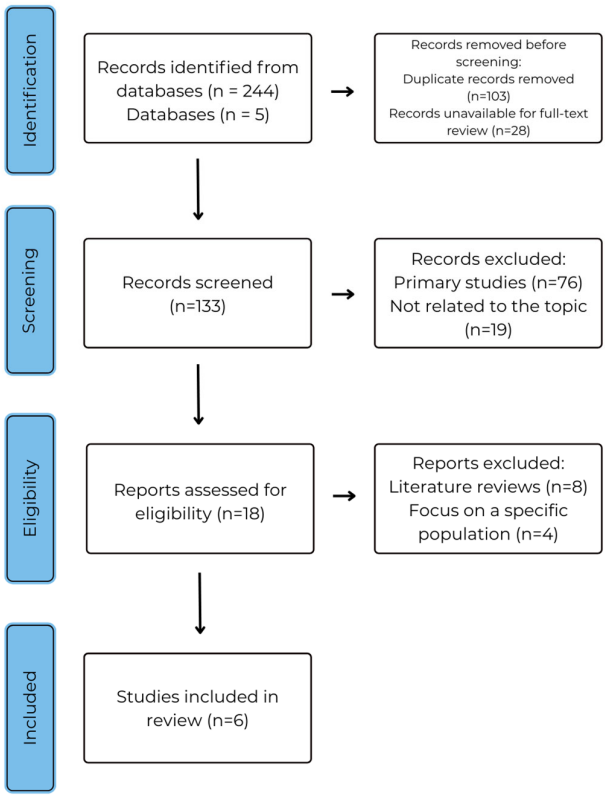

Figure 1. PRISMA Flow Diagram.

Table 2. Categorization of the Studies.

Category	Key Findings	References	Limitations
Epidemiology and Diagnosis	OSA prevalence ranges from 0.1% to 13%; lack of standardized diagnostic criteria	Lumeng & Chervin (2008) [5]	Inconsistent diagnostic methods
Child Development	Craniofacial alterations, postural changes, and speech/language impairments associated with mouth breathing	Zhao et al. (2021) [21]; Neiva et al. (2018) [7]; Mohammed et al. (2021) [6]	Small sample sizes, selection bias
Therapeutic Interventions	RME and montelukast show promising results, but evidence remains limited	Barbosa et al. (2023) [9]; Ji et al. (2021) [10]	High heterogeneity, potential adverse effects

This categorization enabled the identification of convergences and divergences among studies, highlighting methodological aspects that may influence findings. Furthermore, it revealed gaps in the literature, underscoring the need for more integrative studies that address the relationship among the different factors analyzed.

4.2. Findings from Individual Studies

4.2.1. Epidemiology and Diagnosis of OSA

The review conducted by Lumeng and Chervin (2008) [5] provides a comprehensive overview of the epidemiology of pediatric OSA, with particular emphasis on the challenges associated with defining, diagnosing, and estimating the prevalence of this condition. The wide variability in methods prevented comparisons across studies and hindered

the generalization of findings. Consequently, the study highlighted the need for more standardized diagnostic criteria.

The authors emphasized diagnostic challenges in pediatric OSA in the context of growing recognition of the disorder, noting that few studies have established direct correlations between OSA severity levels and adverse clinical outcomes. One of the main inconsistencies lies in the heterogeneity of the Apnea-Hypopnea Index (AHI) criteria, ranging from 1 to 5 events per hour, with no clear consensus on the optimal cut-off.

Other patient assessment methods were also discussed, including home audio and video recordings, as well as pulse oximetry, which, although promising, still requires extensive validation against polysomnography (PSG), the gold standard for OSA diagnosis. Additional aspects reviewed included the reliability of questionnaires for screening snoring and sleep disorders, and the lack of standardized definitions of clinical entities across populations, which limits reproducibility.

Regarding prevalence, pediatric OSA has been estimated to range from 0.1% to 13%, depending on methodology, sampling, and population, with most studies reporting between 1% and 4%. The authors also observed demographic variations and suggested that differences in the perception of snoring between community and clinical populations may influence prevalence estimates.

In conclusion, the study underscored the need for further research employing increasingly standardized diagnostic criteria and sampling strategies to facilitate early diagnosis and intervention in pediatric OSA. These findings highlight the importance of systematic and rigorous approaches to understanding the condition and its impact on child health (Table 3).

Table 3. Summary of Findings.

Study Reference:	Total Studies Included:	Population (Sample):	Metrics:	Main Findings:
Barbosa, D. et al., 2023 [9]	8	0–18 years	AHI; SaO2; LSAT; AI;	The studies presented high heterogeneity, compromising the uniformity of results. Despite some improvements in sleep after RME, the evidence is limited for definitive recommendations. The study highlights the importance of assessing the disease phenotype prior to intervention and reinforces the need for preventive strategies for childhood respiratory disorders.
Ji, T. et al., 2021 [10]	4	0–18 years	AHI; ODI; AI; SpO2; PSQ; OSA-18;	Montelukast, when combined with conventional treatments, showed improvements in sleep parameters, such as apnea-hypopnea index and oxygen saturation. However, concerns remain regarding serious side effects reported by the FDA. The quality of evidence was considered moderate due to methodological limitations and inconsistencies across studies.

Table 3. *Cont.*

Study Reference:	Total Studies Included:	Population (Sample):	Metrics:	Main Findings:
Lumeng et al., 2008 [5]	48	0–18 years	AHI; ODI; SDB Score;	The study highlights the lack of standardization in diagnostic criteria for pediatric OSA, resulting in wide variability in prevalence (0.1% to 13%). It points out the limitations of alternative methods, such as questionnaires and home recordings, and reinforces the need for standardized diagnoses to improve identification and intervention in at-risk children.
Mohammed, D. et al., 2021 [6]	6	2–13 years	PSG; Behavior Rating Inventory of Executive Function–Preschool Version (BRIEF-P); Child Behavior Checklist (CBCL 1.5–5); Caregiver-Teacher Report Form (C-TRF 1.5–5); Behavior Assessment System for Children, 2nd Ed. (BASC-II) Parent/Primary; Psychological tests, such as the Token Test (TT); Physical examinations to assess adenotonsillar hypertrophy and malocclusion.	It was concluded that speech and language difficulties are common in these children, with an impact associated with low oxygen saturation during sleep, affecting neurocognitive and neurobehavioral functions. However, the quality of evidence was considered very low due to methodological limitations and small sample sizes.
Neiva, P. D. et al., 2018 [7]	10	5–14 years	New York Postural Assessment Scale; Photography; Motion capture; Postural Analysis Software (SAPO); Goniometer; ALC image; MATLAB (version 2.1) program routines.	The review indicates a possible association between mouth breathing and postural changes in children, such as forward head posture and body misalignment. However, all studies analyzed presented low methodological quality, with shortcomings in participant description and in the standardization of assessment methods. Thus, no conclusive evidence exists, underscoring the need for more rigorous research to validate this relationship.

Table 3. *Cont.*

Study Reference:	Total Studies Included:	Population (Sample):	Metrics:	Main Findings:
Zhao, Z. et al., 2021 [21]	10	2–14 years	SNA (Sella–Nasion–A); SNB (Sella–Nasion–B); ANB; SN-OP (Sella–Nasion–Occlusal Plane); SN-PP (Sella–Nasion–Palatal Plane); PP-MP (Palatal Plane–Mandibular Plane); SNGoGn (Sella–Nasion–Gonion); 1-NA (Tooth 1–Nasion); 1-NB (Tooth 1–B); Overjet; Overbite; SPAS; PAS; C3-H;	The findings showed that children with mouth breathing had unique facial characteristics, such as posterior mandibular rotation, steeper occlusal plane, and limited upper arch width, commonly referred to as an "adenoid face." Additionally, this group presented higher frequencies of malocclusion, especially Class II and crossbite. The study also demonstrated that nasal stenosis exacerbates these changes. Comparisons were made using control groups, and statistically significant differences in facial growth were identified, emphasizing the need for early diagnosis and timely intervention in pediatric patients.

4.2.2. Impacts of OSA on Child Health and Development

a. Postural Disorders

The review by Neiva et al. (2018) [7] examined the association between mouth breathing and postural alterations in children, assessing the methodological quality of existing studies on this topic. Studies published up to March 2016 were retrieved from MEDLINE, CINAHL, PEDro, LILACS, EMBASE, and the Cochrane Central databases, resulting in the selection of ten studies including 417 children aged 5 to 14 years. Postural assessment methods varied, ranging from photographs to specific software, and methodological quality was evaluated using the Downs and Black checklist (external validity, bias control, and confounding variable control).

The average methodological quality scores of the included studies were low. Key limitations identified included the lack of participant descriptions and methodological details regarding posture assessment, as well as failure to control for variables such as age and type of mouth breathing. Despite these limitations, limited evidence supported the hypothesis that mouth-breathing children present with forward head posture, body misalignment, and scapular changes, although further confirmation is needed.

The review concluded that current evidence is limited and emphasized the importance of rigorous and standardized methods for evaluating posture in mouth-breathing children in future studies. These findings underline the need for cautious approaches among healthcare professionals, such as physiotherapists and pediatric respiratory and developmental specialists, to verify potential postural effects of mouth breathing and to promote timely interventions.

b. Craniofacial Development

The review by Zhao et al. (2021) [21] examined how mouth breathing affects the craniofacial skeletal system and dental occlusion in children up to 18 years of age. The review included clinical trials and cohort studies assessing maxillofacial deformities associated with this breathing pattern, applying cephalometric markers to measure structural variations.

The findings revealed that mouth-breathing children exhibited distinctive facial characteristics, such as posterior mandibular rotation, a steeper occlusal plane, and reduced maxillary arch width, commonly described as the "adenoid face." Additionally, this group showed a higher prevalence of malocclusions, particularly Class II malocclusion and crossbite. The study also noted that nasal stenosis exacerbates these changes. Comparisons with control groups revealed statistically significant differences in facial growth, highlighting the importance of early diagnosis and timely intervention in pediatric patients.

Despite methodological heterogeneity among the included studies, this systematic review underscores the relevance of addressing mouth breathing to mitigate its effects on craniofacial development in children.

c. Speech Development

The review "The Impact of Childhood Obstructive Sleep Apnea on Speech and Oral Language Development: A Systematic Review", conducted by Dania Mohammed et al., analyzed the relationship between sleep-disordered breathing and communication difficulties in children. The review included studies published between 2000 and 2020, focusing on children aged 2 to 13 years diagnosed with OSA or sleep-disordered breathing. After rigorous screening, only six articles were selected, and methodological quality was assessed using the PEDro-P tool.

The results indicated that speech and language difficulties are common in these children, with one study addressing speech specifically and five others investigating receptive and expressive language. Associations were also identified between lower oxygen saturation levels during sleep and language performance, suggesting that the impact of OSA extends beyond communication, affecting neurocognitive and neurobehavioral functions. However, the quality of evidence was deemed very low due to methodological limitations and small sample sizes.

The review concluded that significant gaps remain in the literature and reinforced the need for more robust studies to clarify how these disorders affect speech and language development. It also highlighted the importance of involving speech–language pathologists in early assessment and intervention, recommending a multidisciplinary approach to minimize the impact of OSA on child communication.

4.2.3. Therapeutic Interventions for OSA

a. Rapid Maxillary Expansion (RME)

The review by Barbosa et al. (2023) [9] investigated the effectiveness of Rapid Maxillary Expansion (RME) as a treatment for pediatric OSA. The main objective was to compare polysomnographic parameters across studies to determine whether RME is a viable alternative in managing pediatric OSA. To this end, the authors conducted a systematic review of eight meta-analytic reviews, analyzing outcomes such as the Apnea-Hypopnea Index (AHI) and oxygen desaturation levels.

The results revealed substantial heterogeneity among studies, with methodological differences compromising consistency. Although some studies demonstrated improvements in sleep parameters following RME, the authors emphasized that the overall quality of available evidence remains limited and insufficient to support definitive recommendations. The study further stressed the importance of evaluating disease phenotype before selecting interventions and highlighted the role of preventive strategies for childhood sleep-disordered breathing.

In conclusion, the authors suggested that although RME is a widely used orthopedic procedure, current evidence is insufficient to confirm its efficacy in treating pediatric OSA. Further high-quality research is required to guide clinical practice more accurately.

b. Montelukast

The review by Ji et al. (2021) [10] investigated the use of montelukast as a therapeutic option for children with mild to moderate OSA. The study aimed to evaluate the drug's efficacy and safety through randomized controlled trials. Four studies were included, involving a total of 305 children, and findings indicated that montelukast, when combined with conventional treatments, significantly improved sleep parameters such as AHI and oxygen saturation.

However, the review also warned of potential severe side effects associated with the drug, as reported by the FDA, raising concerns about its safety. The overall quality of evidence was rated as moderate due to methodological limitations and inconsistencies across studies.

Montelukast functions by blocking the action of leukotrienes, inflammatory mediators that can cause airway constriction and increased mucus production. Its mechanism involves binding to leukotriene receptors, thereby reducing inflammation, improving airway morphology, and alleviating OSA symptoms such as snoring. The drug is administered orally and is typically used as part of a broader treatment strategy, particularly in children with mild to moderate OSA.

The authors concluded that although benefits were observed, further rigorous studies are needed to confirm montelukast's efficacy and clarify its associated risks in pediatric OSA management.

4.3. Results of Syntheses

The presentation of results was conducted using comparative tables and descriptive syntheses, which facilitated data visualization and enabled critical discussion of the limitations and implications of the findings for clinical practice and future research.

5. Discussion

The findings of this review corroborate the existing literature by demonstrating that Obstructive Sleep Apnea (OSA) in childhood can significantly impact anatomical, neurocognitive, behavioral, and language development, highlighting the need for early interventions. Based on the results, it was possible to identify the multifaceted nature of the topic and, in particular, the cyclical relationship between OSA and mouth breathing, since mouth breathing may predispose to apnea, while apnea may, in turn, reinforce the habit of mouth breathing. This interrelationship underscores the importance of multidisciplinary approaches in diagnosis and treatment, involving dentists, otorhinolaryngologists, speech–language pathologists, and pediatricians.

At a broader level, a recurring pattern was observed across several of the studies evaluated: the presence of significant methodological shortcomings. These limitations introduced complexity in the synthesis of results, as many of the findings were considered inconsistent due to the low quality of the primary studies included. Methodological heterogeneity compromised the validity of the findings and hindered data comparability, rendering the application of more advanced statistical analyses, such as meta-analysis, unfeasible.

Beyond methodological issues, the lack of standardization in diagnostic criteria and outcome measures also undermines the reliability of the studies. The absence of uniform parameters for assessing pediatric OSA may lead to variability in results and impede evidence synthesis. This reinforces the need for the adoption of more standardized and rigorous methodological criteria to establish comparable metrics and generate more robust findings in systematic and umbrella reviews.

From a clinical standpoint, the findings of this review highlight the importance of therapeutic strategies such as Rapid Maxillary Expansion (RME) and the use of montelukast.

While some evidence suggests that RME may improve polysomnographic parameters, the quality of studies remains variable, preventing definitive conclusions about its efficacy in managing pediatric OSA. Montelukast, in turn, demonstrated potential in reducing symptoms associated with mild to moderate OSA; however, its long-term safety continues to raise concerns, particularly due to FDA warnings regarding possible neuropsychiatric side effects.

Therefore, the results of this review point to the need for further high-quality research, especially randomized clinical trials and longitudinal studies, to evaluate the impact of different therapeutic approaches on the neurocognitive and anatomical development of children with OSA. In addition, health policies directed at the early screening and continuous follow-up of these children are essential to minimize the impacts of OSA and improve patients' quality of life. Thus, this study reinforces the relevance of a multidisciplinary approach and the implementation of evidence-based strategies for the management of pediatric OSA.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/ijom51020013/s1, Figure S1: PRIOR Checklist [33]; Figure S2: PRISMA Checklist [4].

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