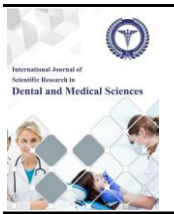

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Effects of Rapid Maxillary Expansion on Upper Airway Airflow Characteristics: A Systematic Review and Meta-analysis

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ABSTRACT

Background and aim: After rapid maxillary expansion, there is evidence that nasal airflow resistance is reduced. In the developmental age, it is unclear how RME affects upper airway airflow characteristics. Therefore, the aim pf present study was to evaluate the effects of rapid maxillary expansion on upper airway airflow characteristics.

Material and methods: The present systematic review and meta-analysis included three randomized clinical trials and sixteen cohort studies international databases, PubMed, Scopus, Web of Science, and Embase, from January 1, 2015 to May 10, 2025, using keywords aligned with the study objective. Data extracted included numbers of participants, mean age, gender, Midpalatal suture maturation stage, nasal septum deviation, Intervention, and upper airway assessment. For each study that included, the mean value of airway pressure, nasal cavity volume, nasopharyngeal volume, and oropharyngeal volume was calculated between before and after rapid maxillary expansion. The statistical analysis was performed with Stata/MP.v17 as fixed effect models.

Results: A significant reduction of airway pressure was found after RME (MD = -152.25; 95%CI -154.59 Pa to -149.92 Pa; p<0.001). there was a significant increase in nasal cavity volume after RME compared before RME (MD = 1.88; 95%CI 1.82 to 1.95; p<0.001), mean differences of oropharyngeal volume was 0.87 (MD = 0.87; 95%CI 0.75 to 0.99; p<0.001), and mean differences of nasopharyngeal volume was 0.80 (MD = 0.80; 95%CI 0.73 to 0.88; p<0.001).

Conclusions: In children of growing age, rapid maxillary expansion can be an effective method on upper airway airflow characteristics.

1. Introduction

In the treatment of transverse maxillary deficiency in growing ages, the Rapid Maxillary Expansion (RME) method is used, in which orthopedic forces are applied with a maxillary expander to induce mid-palatal suture (MPS) distraction.[1] Lateral enlargement of the nasal cavity (NC) usually occurs following MPS opening.[2] Therefore, RME can improve airway resistance by increasing the volume of the nasal airway cavity and also affect the dimensions of the nasopharyngeal airway.[3] Studies have shown that RME can play a crucial role in enhancing nasal breathing patterns. By reducing UA obstruction, airflow is better transported through the airway, which in turn leads to a decrease in inspiratory pressure. Based on the available evidence, RME may be a suitable treatment for obstructive sleep apnea (OSA) in children of developing age; however, there is no definitive evidence.[4-7] The results of studies indicate that the effects of RME treatment do not have long-term effects.[8] A systematic review reported that changes in the natural growth of the skull and jaw can affect the effects of treatment and cause spontaneous improvement or closure of UA over time.[9] Age plays an important role in the treatment of OSA because the stages of craniofacial development influence airway obstruction.[10] Children of developing ages also need to be exposed to ionizing radiation, which makes treatment challenging.[11, 12] Although many studies have been conducted on the effect of RME on the volume of the upper airway, there is a lack of strong evidence on its role in improving upper airway airflow. Therefore, a comprehensive study is needed that can provide good evidence by reviewing previous studies and integrating their findings. Therefore, the present study was conducted to

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determine the Effects of rapid maxillary expansion on upper airway airflow characteristics.

2. Material and methods

Search and study selection

A systematic search was conducted in international databases, including PubMed, Scopus, Web of Science, and Embase, from January 1, 2015, to May 10, 2025, using keywords aligned with the study's objective. All retrieved articles were entered into End. Note: X8 software. The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines were followed at each stage.

PubMed search strategy: ((("Palatal Expansion Technique"[Mesh]) AND "Sleep Apnea Syndromes"[Mesh]) OR "Sleep Apnea, Obstructive"[Mesh]) OR "Nasal Cavity"[Mesh].

"Palatal Expansion Technique"[Mesh]; Entry Terms: Technique, Palatal Expansion OR Technic, Palatal Expansion OR Maxillary Expansion OR Expansion, Maxillary.

"Sleep Apnea Syndromes"[Mesh] OR "Sleep Apnea, Obstructive"[Mesh]; Entry Terms: Apneas, Obstructive Sleep OR Obstructive Sleep Apneas OR Sleep Apneas, Obstructive OR Apnea, Obstructive Sleep OR Sleep Apnea Hypopnea Syndrome OR Obstructive Sleep Apnea Syndrome OR Obstructive Sleep Apnea OR Syndrome, Obstructive Sleep Apnea OR Syndrome, Sleep Apnea, Obstructive OR Sleep Apnea Syndrome, Obstructive OR OSAHS OR Upper Airway Resistance Sleep Apnea Syndrome OR Syndrome, Upper Airway Resistance, Sleep Apnea.

"Nasal Cavity"[Mesh]; Entry Terms: Cavities, Nasal OR Cavity, Nasal OR Nasal Cavities

Searches were also conducted in other databases using keywords similar to MeSH keywords. Google Scholar was searched for additional studies using the keywords "Maxillary expansion", "upper airway airflow", "rapid maxillary expansion", "Nasal Cavity", "Sleep Apnea Syndromes", and "upper airway".

Eligibility criteria

Inclusion Criteria: Inclusion criteria were based on the PICO strategy (Table 1). All human studies were included, provided they were written in the English language, participants were of reproductive age, and there was no history of adenoidectomy or tonsillectomy, as well as the absence of obstructive adenoid hypertrophy. The included studies also assessed prospective and retrospective clinical studies, Randomized controlled trials, cross-sectional studies, and those with a control group, as well as pre- and post-operative assessments.

Exclusion Criteria: Number of participants less than ten, case studies of specific syndromes, case reports, studies investigating other treatment options, incomplete or atypical data reporting, review studies, case report studies, laboratory studies, animal studies, letters to the editor, conference papers, studies without full text.

Table 1. PICO process in selecting studies

PICO Strategy	
Patient/population (P)	Growing patients who underwent RME
Intervention (I)	RME
Comparison (C)	Before RME (T0) and after RME (T1).
Outcomes (O)	Airway Pressure, Nasal cavity volume, nasopharyngeal volume, oropharyngeal volume

Data extraction

Two independent, blinded authors extracted the data from the studies using a pre-designed table. Any disagreements were resolved through discussion and review by the third author, and a consensus was reached on recording the data.

The columns of the table were: study name (first author), year of publication, study design, number of participants, mean age, gender of participants, midpalatal suture maturation stage, nasal septum deviation, Intervention, and upper airway assessment.

Quality assessment

Using the Newcastle-Ottawa scale (NOS),[13] quality evaluation was conducted in three areas: outcome, comparability, and selection. "High quality" was defined as scores greater than seven according to the NOS tool. For evaluating the risk of bias in randomized trials that are part of Cochrane Reviews, the recommended tool is RoB 2 (Version 2 of the Cochrane risk-of-bias tool for randomized trials).

Statistical analysis

The statistical analysis was performed using Stata/MP v17 as fixed-effects models. The mean value of each study in the desired groups was included in the meta-analysis, and the mean difference was calculated with 95% CI and the inverse-variance method.

3. Results

A systematic literature review identified 1070 articles that matched the search strategy. Twenty-seven duplicates, 123 case reports, and 43 studies evaluating patients with other syndromes were excluded, and 431 articles were excluded based on titles relevant to the exclusion criteria. A total of 877 articles were screened, and articles that did not meet the inclusion criteria were excluded (n=796). The full texts of 81 articles were reviewed by two independent, blinded authors and assessed for inclusion and exclusion criteria. Only 19 articles met the inclusion criteria, which were selected for review in the present study (Fig. 1).

Characteristics of included studies

In the nineteen articles (three RCTs, nine retrospective studies, and seven prospective studies) assessed, the participants belonged to the age group of 9–18 years. The characteristics of other studies were summarized in Table 2.

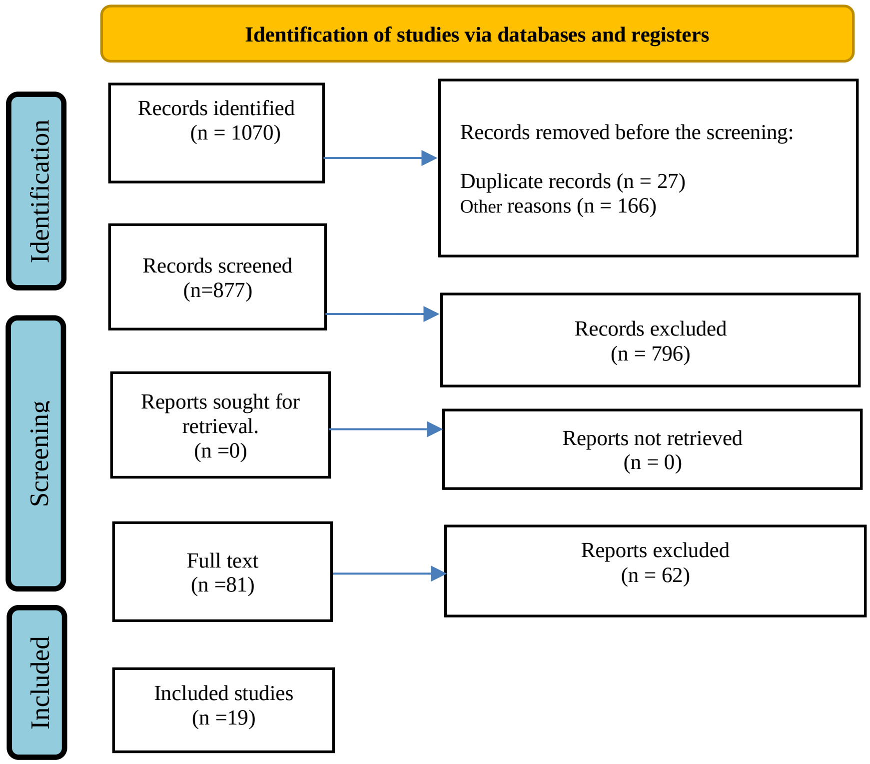


Fig. 1. Flowchart of PRISMA 2020 and selection of studies.

Table 2. Main characteristics of the included studies.

No.	Study	Study Design	Number of Participants	Mean/range Age	Gender		Intervention	Upper airway Assessment	MPS Stage		NSD	
					Female	Male			A	B	Yes	No
2	Lo Giudice et al., 2025[2]	Retrospective	48	10.5	28	20	RME	CBCT	39	9	11	37
1	Palazzo et al., 2025[14]	Retrospective	67	10.9	39	28	RME	CBCT	35	32	21	46
3	Stjepan et al., 2025[15]	RCT	99	9	39	138	RME and facemask	Cephalograms	NR	NR	NR	NR
4	Satto et al., 2025[16]	Prospective	28	10.7	NR	NR	RME	CT	NR	NR	NR	NR
5	Maraabeh et al., 2025[17]	Prospective	26	11.8	16	10	RME	CBCT	NR	NR	NR	NR
6	Crnković et al., 2025[18]	Retrospective	38	10.3	23	15	RME	Lateral cephalograms	NR	NR	NR	NR
7	Bastos et al., 2024[19]	Retrospective	37	11.4	NR	NR	RME	Computed tomography scans	NR	NR	NR	NR
8	Zreaqat et al., 2024[20]	Prospective	34	8–12	NR	NR	RME	CBCT	NR	NR	NR	NR
9	Pirelli et al., 2024[21]	Prospective	23	10.5	11	12	RME	CBCT	NR	NR	NR	NR
10	Ronsivalle et al., 2024[22]	Retrospective	48	10.4	27	21	RME	CBCT	39	9	NR	NR
11	Korayem et al., 2023[23]	Retrospective	52	8-15	NR	NR	RME	CBCT	NR	NR	NR	NR
12	Julián et al.,2023[24]	Retrospective	37	>18	18	19	RME	CBCT	NR	NR	NR	NR
13	Gokce et al., 2022[25]	RCT	46	12.8	30	16	RME	CBCT	NR	NR	NR	NR
14	Shetty et al., 2022[26]	Prospective	8	8-14	4	4	RME	CBCT	NR	NR	NR	NR

15	Almuzian et al., 2018[27]	Retrospective	16	12.4	8	8	RME	None	NR	NR	NR	NR
16	Giudice et al., 2017[28]	RCT	20	10.4	10	10	RME	SME	NR	NR	NR	NR
17	Cappellette et al., 2017[29]	Prospective	38	9.6	11	12	RME	Not receive RME	NR	NR	NR	NR
18	Almuzian et al., 2016[30]	Prospective	17	12.6	9	8	RME	None	NR	NR	NR	NR
19	Izuka et al.,2015[31]	Retrospective	25	10.5	14	11	RME	None	NR	NR	NR	NR

Bias assessment

All RCT studies that were included showed high quality (low risk of bias) (Table 3), and ten non-RCT studies received a score of 7-8/9 (low risk of bias), and six non-RCT studies had moderate risk of bias (Table 4).

Table 3. Cochrane risk-of-bias tool for randomized trials (RoB 2).

	D1	D2	D3	D4	D5	Overall
Stjepan et al., 2025[15]	+	?	+	+	+	+
Gokce et al., 2022[25]	+	+	+	×	+	+
Giudice et al., 2017[28]	+	?	+	+	+	+

D1: randomization process.
D2: deviations from intended intervention.
D3: missing outcome data.
D4: measurement of the outcome.
D5: selection reported result.

High risk: × Low risk: + No information: ?

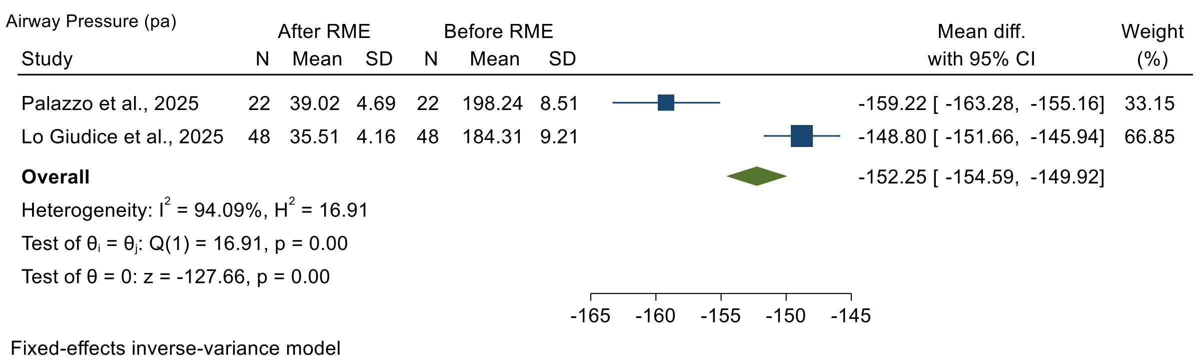
Table 4. The Newcastle-Ottawa Scale assessment was applied to the cohort included in the studies.

	Selection				Comparability	Outcome		Total
	Representativeness of the Exposed Cohort	Selection of a Nonexposed Cohort	Ascertainment of Exposure	Outcome Not Present at the Start of the Study		Assessment Outcome	Length of Follow-up	
Lo Giudice et al., 2025[2]	*	*	*	*	**	*	-	7
Palazzo et al., 2025[14]	*	*	*	*	**	*	-	7
Satto et al., 2025[16]	*	*	*	*	**	*	-	7
Maraabeh et al., 2025[17]	*	*	*	*	**	*	-	7
Crnković et al., 2025[18]	*	*	*	*	*	*	-	6
Bastos et al., 2024[19]	*	*	*	*	*	*	-	6
Zreaqat et al., 2024[20]	*	*	**	*	**	*	-	8
Pirelli et al., 2024[21]	*	*	*	*	**	*	-	7
Ronsivalle et al., 2024[22]	*	*	*	*	*	*	-	6

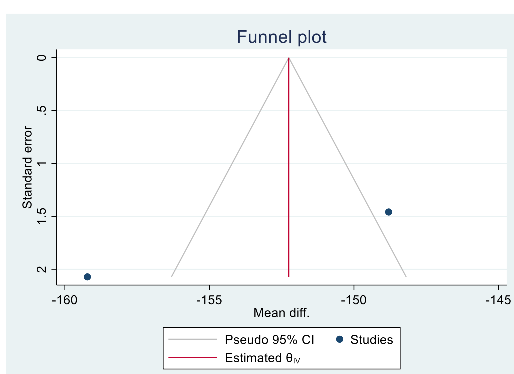
Korayem et al., 2023[23]	*	*	*	*	**	*	-	7
Julián et al.,2023[24]	*	*	*	*	*	*	-	6
Shetty et al., 2022[26]	*	*	*	**	**	*	-	8
Almuzian et al., 2018[27]	*	*	*	*	*	*	-	6
Cappellette et al., 2017[29]	*	*	*	*	**	*	-	7
Almuzian et al., 2016[30]	*	*	*	*	**	*	-	7
Izuka et al.,2015[31]	*	*	*	*	*	*	-	6

Airway pressure

Only two reported airway pressures were eligible for inclusion in the meta-analysis. According to meta-analysis (Fig. 2A), the mean differences of airway pressure between after RME and before RME were -152.25 Pa (MD = -152.25; 95%CI -154.59 Pa to -149.92 Pa; p<0.001); a significant reduction of airway pressure was found after RME (p<0.001). The I^2 coefficient (94.09%) indicates high heterogeneity between the two studies (p < 0.001). The funnel plot showed publication bias between two studies (Fig. 2B).



A.

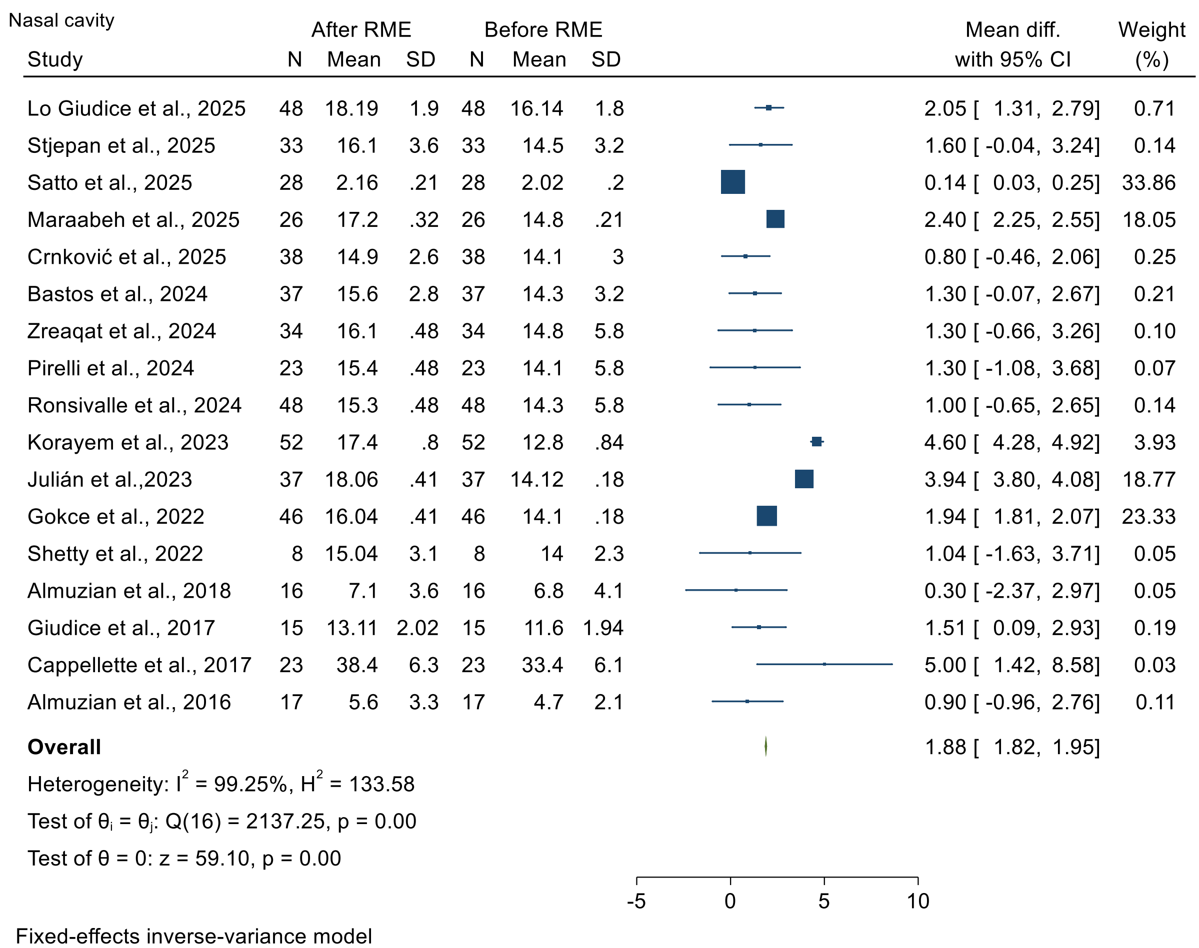


B.

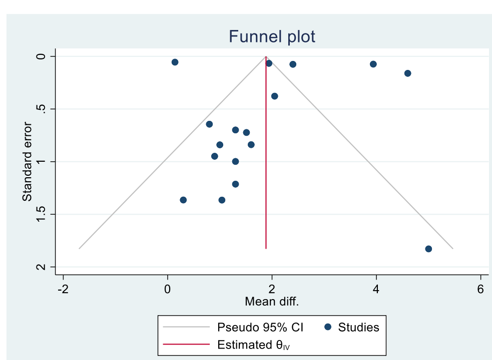
Figure 2. A: forest plot showed mean differences of airway pressure between after RME and before RME; B. funnel plot of publication bias between the two studies.

Nasal cavity volume

According to mean differences of nasal cavity volume (MD = 1.88; 95%CI 1.82 to 1.95; p<0.001), there was a significant increase in nasal cavity volume after RME compared to before RME (p<0.001) (Fig. 3A). The I^2 coefficient (99.25%) indicates high heterogeneity between studies (p < 0.001). The funnel plot revealed publication bias among the included studies that reported nasal cavity volume (Fig. 3B).



A.

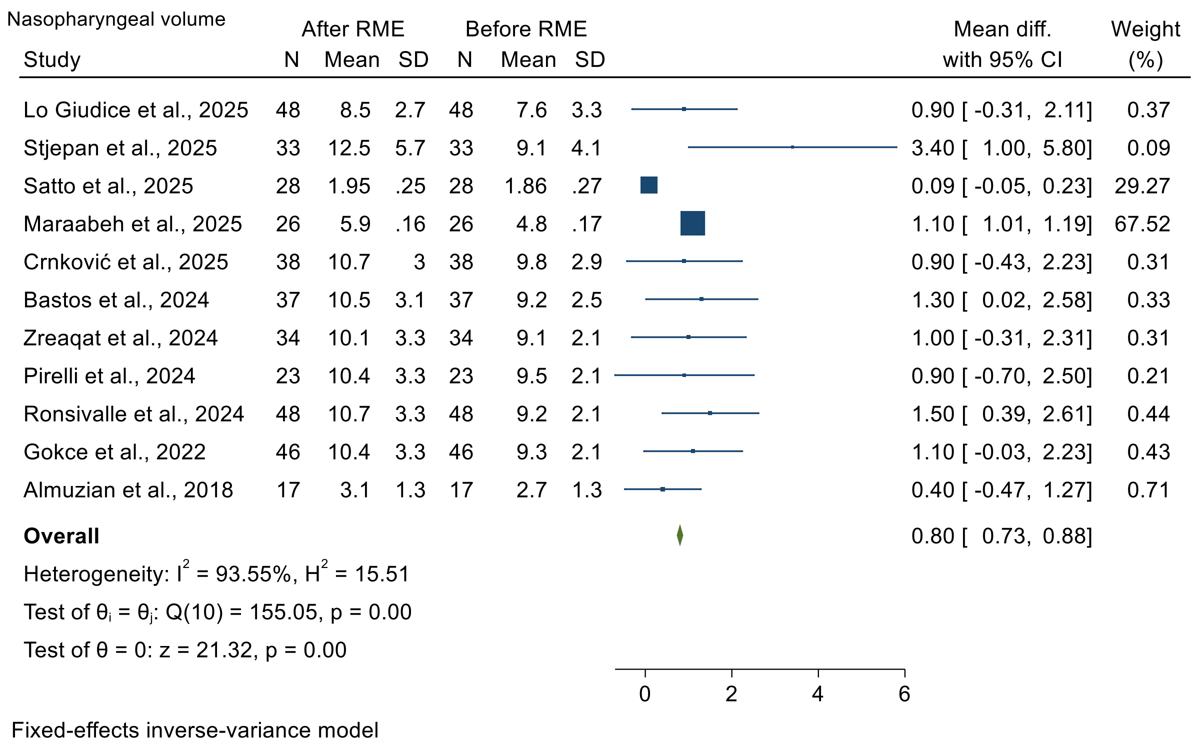


B.

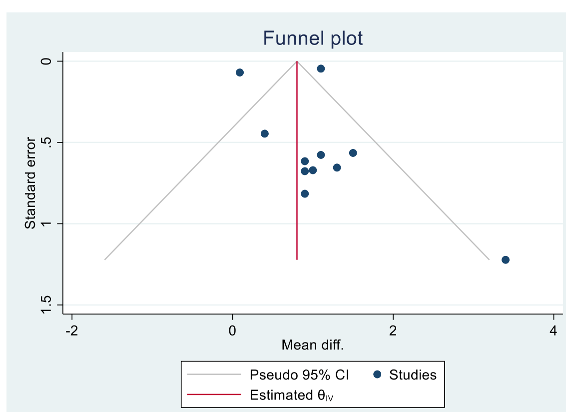
Fig. 3. A. forest plot showed mean differences of nasal cavity volume between after RME and before RME; B. funnel plot of publication bias between seventeen studies.

Nasopharyngeal Volume

According to mean differences of nasopharyngeal volume (MD = 0.80; 95% CI 0.73 to 0.88; p<0.001), there was a significant increase in nasopharyngeal volume after RME compared to before RME (p<0.001) (Fig. 4A). The I^2 coefficient (93.55%) indicates high heterogeneity between studies ($p < 0.001$). The funnel plot showed publication bias between included studies that reported nasopharyngeal volume (Fig. 4B).



A.

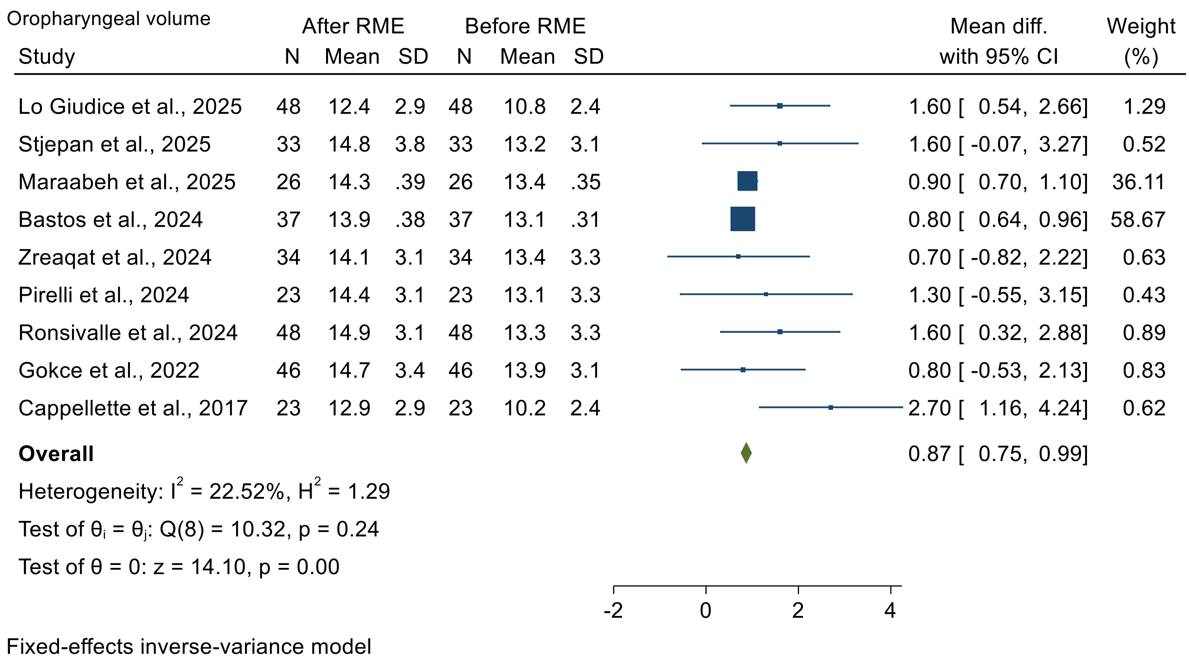


B.

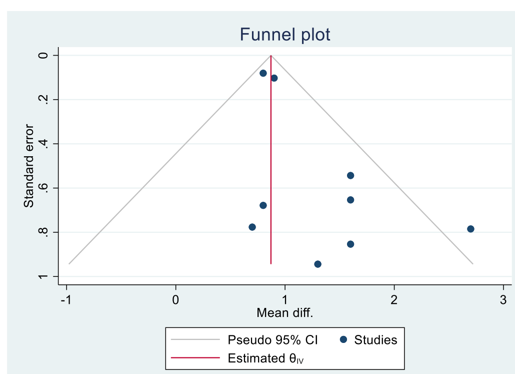
Fig. 4A. forest plot showed mean differences of nasopharyngeal volume between after RME and before RME; B. funnel plot of publication bias between eleven studies.

Oropharyngeal Volume

According to mean differences of oropharyngeal volume (MD = 0.87; 95% CI 0.75 to 0.99; p<0.001), there was a significant increase in oropharyngeal volume after RME compared to before RME (p<0.001) (Fig. 5A). The I^2 coefficient (22.52%) indicates low heterogeneity between studies (p = 0.24). The funnel plot showed publication bias between included studies that reported oropharyngeal volume (Fig. 5B).



A.



B.

Fig. 5A. forest plot showed mean differences of oropharyngeal volume between after RME and before RME; B. funnel plot of publication bias between nine studies.

4. Discussion

RME has been reported to improve both nasal and oral breathing, as evidenced by a one-year follow-up.[32] However, given the lack of long-term data, caution should be exercised when considering RME as a preventive approach to enhance respiratory function in growing children. For this reason, a recent consensus statement from the American Association of Orthodontists emphasized that the primary goal of RME is to correct maxillary transverse deficiency and improve occlusion, rather than being considered a respiratory treatment. Furthermore, individual variations are often not sufficiently taken into account when evaluating the effect of RME on nasal and oral airway obstruction.[33] Regarding age-related developmental changes, previous research has demonstrated that adenotonsillar hypertrophy typically regresses spontaneously before improving in children aged 7 to 8 years.[34] The adenoids continue to grow until approximately 5 to 7 years of age(34). Adenotonsillar hypertrophy is also common in elementary school-aged children.[35-37] RME is a common procedure for treating maxillary transverse deficiency in growing patients. Evidence has shown that RME improves airway function. The improvement rate when using RME is reported to be around 82%.[3, 38] According to the results of RME studies, it reduces nasal resistance, increases the geometry of the nasal cavity, and strengthens it.[3, 39] The long-term effects of RME on breathing and airway dimensions are evaluated in a systematic review.[32] To assess the long-term effects of RME on airway volume and breathing, studies have shown that changes in airway volume and function may improve nasal breathing conditions; however, this cannot be taken solely to indicate effects on breathing.[38] According to the present meta-analysis, RME reduces airway pressure and increases nasal cavity, nasopharyngeal, and oropharyngeal volumes. RME improves the nasal dimensions both horizontally and vertically, which helps to increase the overall volume of the nasal cavity. The horizontal dimension is achieved by widening the nasal cavity and increasing the distance between the nasal wall and the nasal septum. The vertical dimension is achieved by rotating the palate.[39] High heterogeneity was observed between the methodological approaches and findings of the studies, which could be attributed to the fact that children were examined in different age groups and the time point of airway volume assessment varied, with a small number of studies assessing airway volume immediately after RME. In contrast, others assessed it after a follow-up period. Growth assessment is a crucial parameter that must be carefully evaluated. Additionally, studies employed various methods to assess airways, which may have increased the heterogeneity of the studies. Most studies used CBCT; however, there is an inconsistency in defining the airway regions, which should be considered. Also, the timing of treatment initiation can affect the results of RME. Since the heterogeneity in the present study was high, the interpretation of the present findings should be done with caution. It is suggested that more RCTs with larger sample sizes and a control group should be designed to reduce heterogeneity between studies and provide stronger evidence. Studies could compare the effects of RM on oral and nasal breathing. It can also be used to assess the effect of RM in children across various age groups. Growth should also be considered an important factor. The time point for airway assessment should be standardized, and CBCT should be used for this purpose.

5. Conclusion

According to the present meta-analysis, rapid maxillary expansion is effective in improving upper airway airflow characteristics and leads to enhanced ventilation conditions by reducing airway pressure. The increase in volume of the nasal cavity, nasopharynx, and oropharynx after rapid maxillary expansion was significantly greater than before the procedure.

Conflict of Interest

The authors declared that there is no conflict of interest.

Acknowledgments

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