Submitted: 25 February, 2023 Accepted: 12 May, 2023 Published: 03 November, 2024 DOI:10.22514/jocpd.2024.124

Journal of Clinical Pediatric Dentistry

SYSTEMATIC REVIEW

Meta-analysis: effects of adenoidectomy/tonsillectomy on pediatric maxillary growth development

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Abstract

Quantitative analysis of adenoid size plays a pivotal role in experimental research, and imaging examinations are extensively employed for this purpose. This study aims to investigate the impact of adenoidectomy/tonsillectomy on the maxillary growth and respiratory outcomes of children. A comprehensive systematic search was conducted across multiple databases, including PubMed, Web of Science and Scopus, utilizing the following keywords: "gland resection", "tonsillectomy", "mouth breathing", "airway obstruction", "low ventilation", "obstructive sleep apnea (OSA) syndrome" and "dental maxillary growth" in articles published between January 2000 and April 2022. The eligibility criteria encompassed studies with a well-defined research question, appropriate sample size and reporting of pertinent cephalometric indices. The risk of bias was assessed using the Cochrane Risk of Bias tool. Heterogeneity between studies was evaluated using the Q test and I^2 statistics. Based on the meta-analysis of six studies, the odds ratio (OR) values for the influence of adenoidectomy/tonsillectomy on nasal line-nasion-sella line (NL-NSL) and mandibular line-nasion-sella line (ML-NSL) in children's maxillary growth were −0.84 and 0.58, respectively, with 95% confidence intervals (CI) of (−1.08, −0.61) and (0.34, 0.81). No heterogeneity was observed between studies (I^2 = 0.00% for both). In five studies, the OR values for the influence of adenoidectomy/tonsillectomy on children's maxillary growth angle formed by the sella-nasion line and line N-point A (SNA), and angle formed by the sella-nasion line and line N-point B (SNB) were −0.30 and −0.31, respectively, with 95% CI of (−0.55, −0.06) and (−0.56, −0.07). No heterogeneity was observed among studies (I^2 = 0.00% for both). The study indicated that adenoidectomy/tonsillectomy has a positive impact on the maxillary growth and respiratory issues in children.

Keywords

Gland resection; Tonsillectomy; Children; Dental surgery; Meta-analysis

1. Introduction

1.1 Background

The growth and development of the dental maxillary growth region in children is a multifaceted, coordinated and ongoing process. The maxilla possesses significant growth potential, which can be influenced by genetic factors, behavioral patterns and environmental factors. Adenoids and tonsils, located in the nasopharynx and palatopharynx, respectively, are integral constituents of the Waldeyer's ring, serving as peripheral lymphoid tissues [1, 2]. As physiological defense mechanisms of the body, adenoids and tonsils have a significant role in immune responses against inhaled allergens and microorganisms. Prolonged and recurrent infections, as well as chronic inflammatory stimulation in the nasopharynx, can result in pathological hyperplasia and persistent hypertrophy of the adenoids and tonsils [3]. Long-term adenotonsillar hypertrophy (ATH) results in changes in children's maxillary growth development, respiratory pattern and natural head position (NHP). In severe cases, "adenoid face" and distinct malocclusion occur [4]. At present, there is no consensus on the influences of adenotonsillar hypertrophy on maxillary growth development. Relevant studies show that adenoid hypertrophy (AH) and tonsil hypertrophy (TH) lead to different forms of facial deformity. Tonsil hypertrophy is not obvious among patients with adenoid hypertrophy. Mandibular bony narrowing is more likely to occur in class II malocclusion deformities [5]. Mandibular bony narrowing and Class III malocclusion deformity often occur in patients with tonsil hypertrophy but without adenoid hypertrophy. Class II malocclusion deformity is more prevalent in these two groups. Adenotonsillar hypertrophy does not have an impact on the opposite type when compared to adenoid hypertrophy alone. The severity of obstructive sleep apnea-hypopnea syndrome (OSAHS) shows a positive correlation with the craniocervical angle [6–8].

At present, there are various examination and diagnosis methods for AH. The most common clinical examination methods include the nasal endoscopic examination and nasal fiberscope examination. Nonetheless, the adenoid size can't be quantitatively analyzed because the examination result is often based on subjunctive judgment. Hence, they can only be applied in clinical examination. In experimental research, the measurement of the size of the adenoids needs to be analyzed quantitatively. Therefore, the imaging examination is applied more widely for the detection of the size of the adenoids [9]. The imaging examination methods used to assess adenoid size included X-ray lateral cranium examination, computed tomography (CT) examination, nuclear magnetic inspection and ultrasonography. Several studies compared the results of adenoid size detection using spiral CT and X-ray lateral cranium examination. These comparative analyses revealed a consistent agreement of 92% in the detection results [10]. According to other studies, there was no remarkable difference in the detection rate of adenoid hypertrophy between ultrasonography and X-ray lateral cranium examination [11]. The results of previous studies revealed the detection rate of adenoid hypertrophy by lateral X-ray view of cephalic shadow with low costs and radiotherapy costs and high operability as well as acceptance of patients [12]. Hence, X-ray cephalic lateral film was used to detect the adenoid size in the research. It was suggested in some studies that the normal adenoid size of Chinese children should be A/N $\leq$0.60, 0.60 $<$ A/N $\leq$ 0.66 indicated mild hypertrophy, 0.66 $<$ A/N $<$ 0.71 demonstrated moderate hypertrophy, and A/N $\geq$0.71 represented severe hypertrophy [13].

Adenotonsillar hypertrophy is a prevalent and frequently observed condition in children during their growth and development. This condition exerts significant effects on various aspects, including maxillary growth and development, neck posture, body shape, sleep quality, intelligence development and immune function [14, 15]. There is currently no consensus regarding the specific impacts of adenoid hypertrophy and tonsil hypertrophy on the growth and development of the maxillary growth region in children. Several studies have examined the maxillary growth morphology in children with adenoid hypertrophy, tonsil hypertrophy, and adenotonsillar hypertrophy. These studies have observed notable differences in the mandible position relative to the skull in children with adenoid hypertrophy and tonsil hypertrophy. Additionally, the SNB angle (mandibular position relative to the skull base) was significantly greater in children with tonsil hypertrophy compared to those with adenoid hypertrophy [16]. In simpler terms, the findings suggest that in children with adenoid hypertrophy, the mandible tends to protrude further forward than the cranial base. Children with tonsil hypertrophy exhibit a smaller forward projection of the mandible compared to those with adenoid hypertrophy. Interestingly, in cases of adenotonsillar hypertrophy, where both adenoid and tonsil tissues are enlarged, the SNB angle falls between those observed in tonsil hypertrophy and adenoid hypertrophy cases. This suggests that the effects of adenoid hypertrophy and tonsil hypertrophy on mandibular growth and development may counterbalance each other to some extent in patients with adenotonsillar hypertrophy. Additionally, there may not be a noticeable difference in maxillary growth morphology between patients with adenotonsillar hypertrophy and those without this condition [17]. In many studies, it was found that mandibular protrusion was very likely to occur among patients with tonsil hypertrophy, while patients with adenoid hypertrophy were inclined to suffer from mandibular retrusion [18, 19]. However, Huang *et al.* [20] conducted research and analysis on the mandibular morphology of children with mouth breathing. Their findings indicated that there were no significant differences in the measured values related to mandibular development between children with adenotonsillar hypertrophy and those with adenoid hypertrophy, aged 3 to 6 and 7 to 10, respectively. Therefore, it was inferred that maxillary growth developmental deformities resulting from various causes leading to mouth breathing in children were primarily associated with mandibular retrusion deformities. The most common facial growth pattern observed in children with compromised upper respiratory tract ventilation was the intermediate type. No significant difference in facial growth was observed between children with reduced upper respiratory tract ventilation and those with normal ventilation. Additionally, patients with decreased nasopharyngeal ventilation tended to exhibit a more horizontal facial growth pattern, while those with reduced oropharyngeal permeability tended to display a more vertical growth pattern [21, 22].

1.2 Purpose and significance

The objective of this study was to comprehensively investigate the effects of gland resection/tonsillectomy on children's dental maxillary growth, encompassing changes in maxillary growth and development, respiratory function and the amelioration of nasal airway obstruction. The primary aim was to provide evidence-based recommendations for clinical practice guidance. To accomplish this, a meta-analysis was conducted, incorporating both domestic and foreign articles that focused on the treatment of adenoid hypertrophy or tonsil hypertrophy using gland resection/tonsillectomy. The study design entailed statistical data pooling and systematic evaluation of the effectiveness of gland resection/tonsillectomy. The findings of this study aim to contribute to the development of effective treatment strategies for children afflicted with adenoid hypertrophy or tonsil hypertrophy.

2. Data and methods

2.1 Article retrieval

This protocol was developed based on the Preferred Reporting Items for Systematic Review and Meta-Analysis Protocols (PRISMA-P) and registered in PROSPERO (Registration number: CRD42024545684). This study was conducted following the Cochrane Handbook guidelines and PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines. In designing the search strategy, we referred to the PRISMA 2020 requirements and screened relevant literature databases to ensure comprehensive coverage. The databases searched in this study included the Cochrane Library, PubMed, MEDLINE, EMBASE, Web of Science, Chinese Biomedical Literature Database (CBM), China National Knowledge Infrastructure (CNKI), Wanfang Data and VIP databases. The rationale for searching PubMed and Medline simultaneously is that although PubMed contains literature from Medline, it also includes other sources, such as biomedical journals and online books, thus improving the comprehensiveness of the search. The literature search was confined to the period between January 2000 and May 2022. This limitation was imposed because research methods and techniques in the relevant fields have undergone significant advancements since 2000, rendering earlier studies potentially outdated in relation to current practices. Specific search strategies were devised for each database, employing a combination of subject terms (MeSH terms or Emtree terms) and free-text terms. As an example, the search strategy employed for PubMed is outlined below:

("Gland resection" (Title/Abstract) OR "tonsillectomy" (Title/Abstract) OR "Mouth breathing" (Title/Abstract) OR "Airway obstruction" (Title/Abstract) OR "Low ventilation" (Title/Abstract) OR "OSA syndrome" (Title/Abstract) OR "Dental maxillary growth" (Title/Abstract)) AND ("pediatric" (Title/Abstract) OR "children" (Title/Abstract)) AND ("2000/01/01" (PDAT): "2022/05/31" (PDAT)).

The search strategy for other databases was adjusted to comply with their specific search rules and requirements. Subsequently, a considerable number of potentially relevant articles were retrieved using the aforementioned search strategies. These articles underwent further screening, and only those that met the predetermined inclusion criteria were included in the final meta-analysis.

2.2 Inclusion and exclusion criteria

(A) Inclusion criteria: (1) Study types include randomized controlled trials (RCTs), prospective cohort studies, or retrospective cohort studies; (2) Study population consists of children ages 18 or under with adenoid or tonsillar hypertrophy; (3) Patients are under the age of 18; (4) Interventions involve children undergoing adenoidectomy/tonsillectomy; (5) Studies must include at least one therapeutic efficacy or safety outcome, such as overall response (OR), complete response (CR), partial response (PR) or adverse events (AE); (6) Articles must be in English.

(B) Exclusion criteria: (1) Study types include conference abstracts, case reports, reviews, correspondence articles, clinical experience reports, animal or cell experiments or other nonoriginal research; (2) Studies with a sample size of fewer than five patients; (3) Duplicate publications or overlapping data from the same study; (4) Insufficient information in the literature to assess study quality, or data that cannot be extracted and the authors cannot provide supplementary information; (5) Interventions other than adenoidectomy/tonsillectomy.

2.3 Data extraction

Two reviewers independently extracted data from the included studies using a standardized Microsoft Excel 2019 (Microsoft, Redmond, WA, USA) spreadsheet. Any discrepancies were resolved through discussion. The extracted data included the following: (1) general information of the included studies: title, first author, publication year, *etc.*; (2) basic characteristics of the study population: number of cases, age, gender, *etc.*; (3) key indicators: lateral skull radiograph data, the severity of the condition, *etc.*; (4) elements for risk of bias assessment: randomization methods, blinding, allocation concealment, *etc.*; and (5) primary and secondary outcome measures, such as OR, CR, PR, mean differences (MD), standardized mean differences (SMD), complete response (CR), partial response (PR) and safety outcomes (adverse events, AEs).

Primary outcomes in a meta-analysis refer to the key results directly associated with the specific research question or objective. These outcomes play a central role in the quantitative synthesis of the data and are crucial in addressing the main research objective. On the other hand, secondary outcomes encompass additional findings that can provide supplementary insights into the intervention under investigation. These outcomes may be included in the qualitative analysis or subgroup analyses, providing further context and understanding of the research topic. Examples of secondary outcomes include CR, PR and AEs.

2.4 Article assessment criteria

The assessment of study quality was conducted utilizing the Cochrane Risk of Bias tool (RoB 2), which is specifically designed for evaluating randomized controlled trials (RCTs). As this study involved a systematic review and meta-analysis focusing on RCTs investigating treatments or interventions, the RoB 2 tool was deemed appropriate. The RoB 2 tool evaluates the risk of bias across five domains, namely randomization process, deviations from intended interventions, missing outcome data, outcome measurement and selection of reported results. Each individual study underwent assessment to determine whether it presented a "low risk", "some concerns" or "high risk" of bias within each domain.

2.5 Statistical methods

Rev Man 5.3 (Cochrane, Oxford, UK) and Stata 17.0 (Stata Corp, College Station, TX, USA) were used. The odds ratio was set as the effect index of the binary variable, and the mean difference (MD) was set as the effect index of the continuous variable. Point-estimated values and 95% confidence intervals (CIs) of both effect indexes were calculated. The heterogeneity between the results of the included articles was analyzed with the χ^2 test (test level $\alpha = 0.1$). I^2 was combined to determine the size of heterogeneity. If there was no significant heterogeneity between study results ($I^2 < 50\%$ and $p > 0.1$), a fixed-effect model was adopted for meta-analysis. If significant heterogeneity was present ($I^2 \geq 50\%$ or $p \leq 0.1$), a random-effect model was employed, and the potential sources of heterogeneity were explored through subgroup analysis. The test level for meta-analysis was set at $\alpha = 0.05$. Forest plots were generated to present the results visually and facilitate the assessment of the effect sizes and their confidence intervals across different studies. Funnel plots, on the other hand, were employed to evaluate potential publication bias by examining the symmetry of data distribution. To further explore the possibility of publication bias, Egger's test was conducted to quantitatively assess the asymmetry of the funnel plot. To ensure the reliability and transparency of the evidence, the certainty of the findings was evaluated according to the PRISMA 2020 guidelines and the Grading of Recommendations Assessment, Development and Evaluation (GRADE) approach. This assessment considered several factors, including study limitations, inconsistency of results, imprecision of estimates, indirectness of evidence and potential publication bias. Based on these considerations, the results were categorized into levels of certainty, ranging from high to very low, providing a comprehensive evaluation of the strength of the evidence supporting the conclusions.

3. Results

3.1 Retrieval results and basic information about articles

A total of 147 articles were identified through database retrieval. After the initial screening process, 31 duplicate publications and 25 articles that did not meet the eligibility criteria were excluded. An additional 26 articles were removed due to reasons such as language restrictions, unavailability of full text or not being original studies. This resulted in a pool of 65 articles for preliminary selection. Further evaluation based on abstracts and titles led to the exclusion of 27 articles, while 38 articles remained. Among these, 16 research reports and review articles were eliminated, leaving 22 articles for further consideration. Subsequently, the full texts of these 22 articles were carefully reviewed, resulting in the exclusion of 9 articles that did not correspond to the correct research types. Six articles were also excluded due to incomplete or unavailable treatment results. Additionally, one article that did not involve human subjects was eliminated. Ultimately, a total of six articles were included in the final meta-analysis. The process of article retrieval and selection is visually depicted in Fig. 1.

The basic information about the included articles was as follows.

The relevant information from the six included articles [23–28] was extracted by carefully reviewing their contents. These articles collectively involved a total of 190 patients with mouth breathing associated with rhinitis lesions, 110 patients with airway obstruction (TH) and 61 patients with OSA syndrome. All of these patients underwent gland resection/tonsillectomy, resulting in a total of 361 treated patients across the included studies. The sample sizes of the six articles ranged from 17 to 120 participants. Detailed descriptions of the treatment procedures for children undergoing gland resection/tonsillectomy were provided in these articles. Furthermore, the articles documented the changes in various indexes before and after treatment, as well as the effects of gland resection/tonsillectomy on children's dental maxillary growth. According to the results of the evaluation of the quality of the six included articles, five articles were rated as level A (66.67%), one article was rated as level B (16.67%) and one article was rated as level C (16.67%). The basic characteristics of the included articles are displayed in Table 1. The evaluation and summary diagrams of risk bias of references drawn with Rev Man 5.3 are presented in Figs. 2,3.

3.2 Results of heterogeneity evaluation

According to the results of the evaluation of the heterogeneity of treatment efficacy in the included articles, there was no heterogeneity among the six studies on the influences of gland resection/tonsillectomy on children's dental maxillary growth

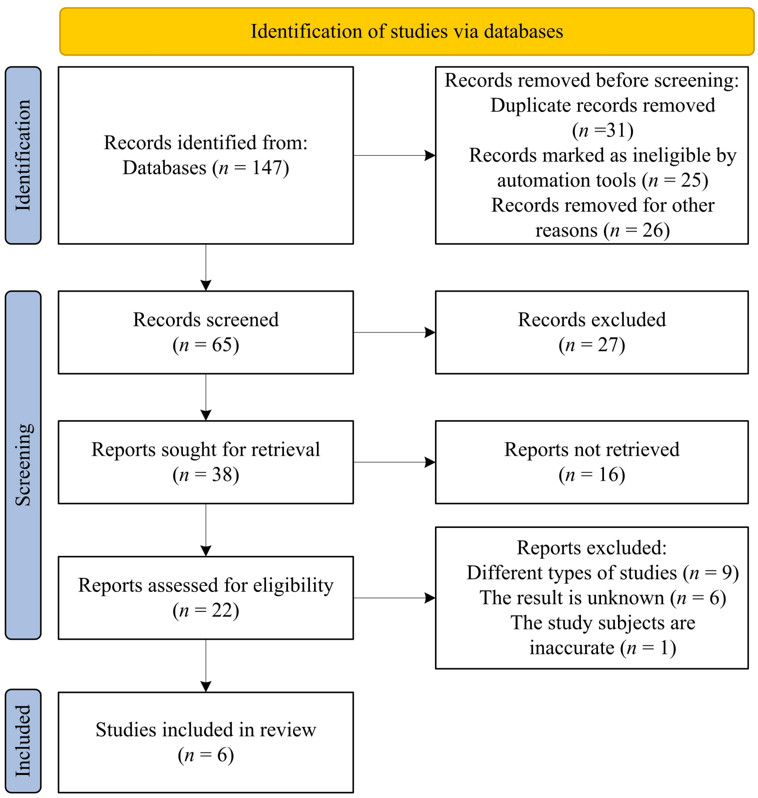


FIGURE 1. Flowchart of article retrieval process.

TABLE 1. Basic information about the included articles.

Author	Year	Case	Age (yr)	Types of diseases
Li [23]	2022	120	7–15	Mouth breathing (rhinitis lesions)
Mattar [24]	2011	72	3–6	Airway obstruction tonsil hypertrophy (TH)
Pereira [25]	2011	38	7–11	Airway obstruction (TH)
Pisacane [26]	2019	44	7–14	obstructive sleep apnea (OSA) syndrome
Souki [27]	2010	70	3–10	Mouth breathing (rhinitis lesions)
Zettergren [28]	2006	17	5–6	OSA syndrome

TH: tonsil hypertrophy; OSA: obstructive sleep apnea.

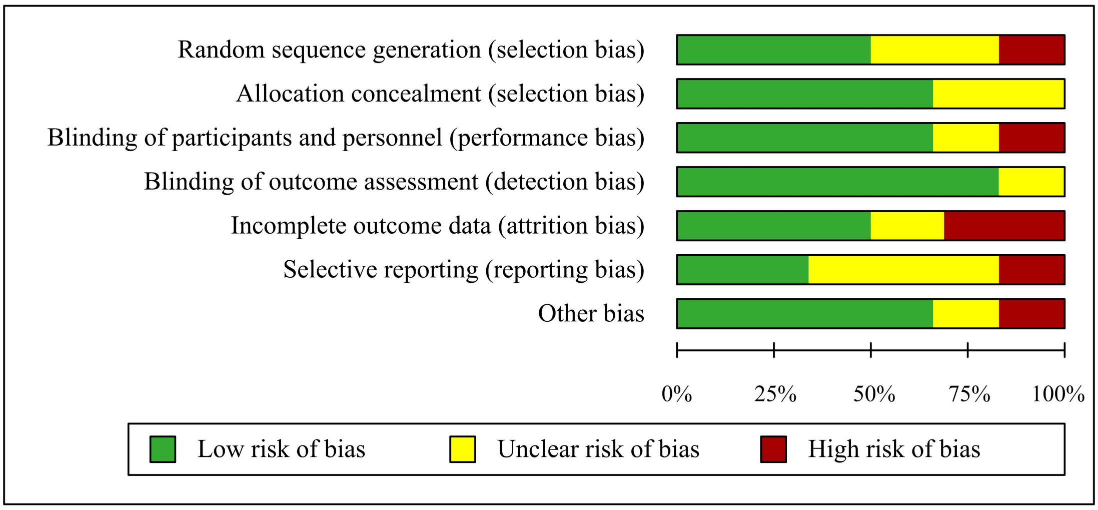


FIGURE 2. Evaluation of the risk bias of references drawn by Rev Man 5.3 software.

nasal line-nasion-sella line (NL-NSL) and mandibular line-nasion-sella line (ML-NSL) (I^2 = 0.00%, I^2 = 0.00%). In addition, there was no heterogeneity among the five included studies on the influences of gland resection/tonsillectomy on children's dental maxillary growth SNA and SNB (I^2 = 0.00% and I^2 = 0.00%). To further verify the heterogeneity between the data of the two examination methods and compare the differences between different treatment indexes, a random effect model was used for summary and analysis, and funnel plots were plotted.

3.3 Meta-analysis of the influences on NL-NSL

Lateral cranial annotation is shown in Figs. 4,5 [28–30]. OR was used as the clinical outcome index to analyze the influences of gland resection/tonsillectomy on children's maxillary growth, as shown in Fig. 6 below. The OR of the influence of gland resection/tonsillectomy on children's maxillary growth as represented by the NL-NSL values in six articles was −0.84, 95% CI was (−1.08, −0.61), I^2 = 0.00%, and p = 0.57. The OR value demonstrated that gland resection/tonsillectomy affected the children's maxillary growth as shown by the NL-NSL value. After surgical treatment, the NL-NSL value increased, and there was no heterogeneity between all articles. The lowest OR value was −1.21, and the 95% CI was (−1.78, −0.63), while the highest OR value reached −0.61, and the 95% CI was (−1.10, −0.12). To further observe therapeutic effects, the influences on children's NL-NSL values were comprehensively analyzed. The heterogeneity test of the influences of gland resection/tonsillectomy on children's maxillary growth, as shown by the NL-NSL value, is presented in Fig. 7. After evaluation of the heterogeneity and potential outlier values across all the included articles, it was observed that the heterogeneity among the studies was minimal, indicating a high level of accuracy. The funnel plot, displayed in Fig. 8, depicted the effects of gland resection/tonsillectomy on children's maxillary growth, specifically reflected by the NL-NSL value. The funnel plot indicated a low risk of bias across all the articles. Based on the findings, it was determined that gland resection/tonsillectomy led to an increase in NL-NSL values. This increase in the NL-NSL value, indicating anteversion of the maxilla, was associated with an improvement in respiratory issues among children.

3.4 Meta-analysis of the influences on ML-NSL

OR was used as the clinical outcome index for the analysis of the influences of gland resection/tonsillectomy on children's maxillary growth (Fig. 9). The OR of the influence of gland resection/tonsillectomy on children's maxillary growth as represented by the ML-NSL values in six articles was −0.58, 95% CI was (0.34, 0.81), I^2 = 0.00%, and p = 0.67. The OR value

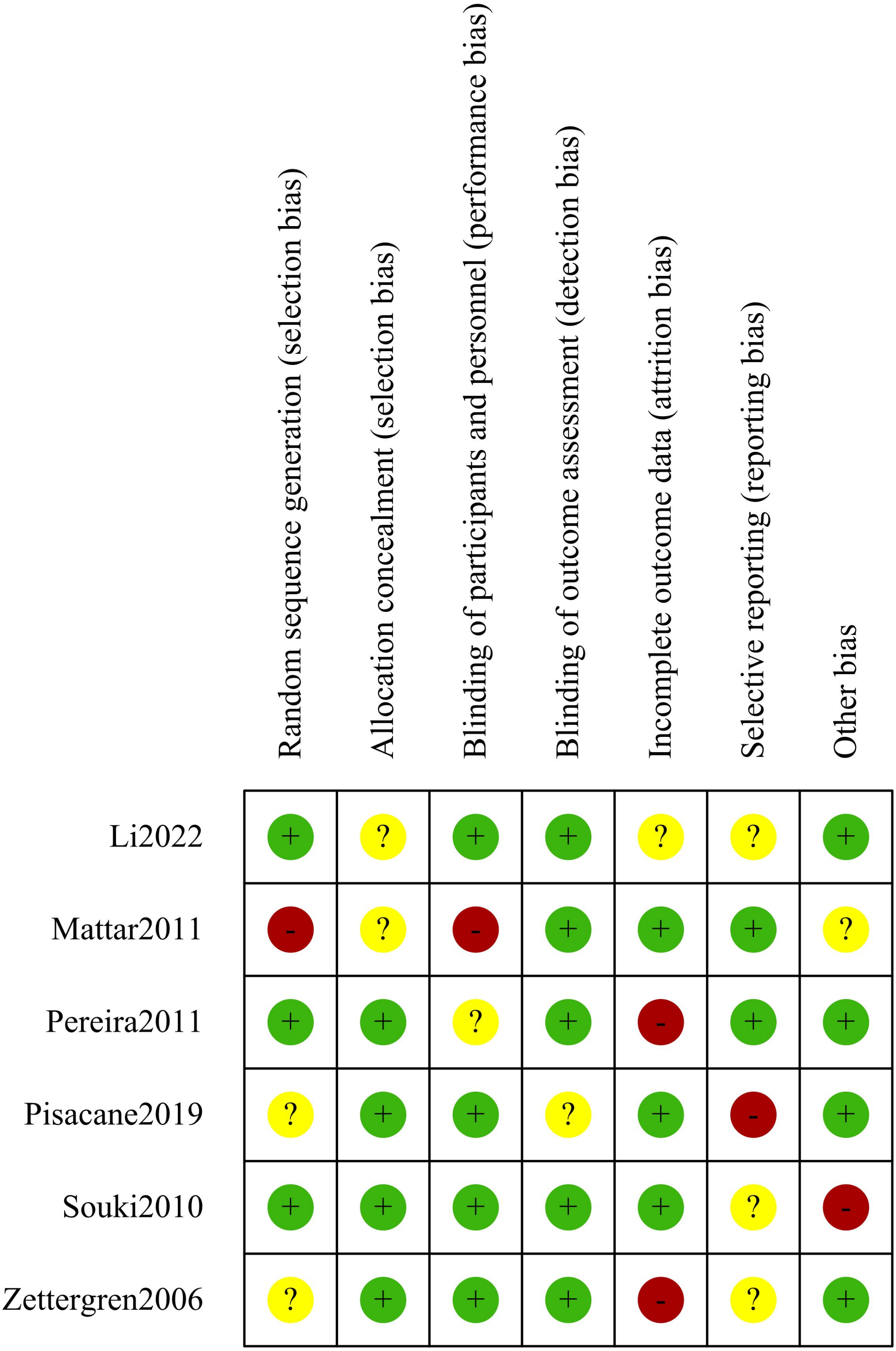


FIGURE 3. Summary of the risk bias of references. Note: "+" represents low risk, "–" refers to high risk and "?" indicates "unclear".

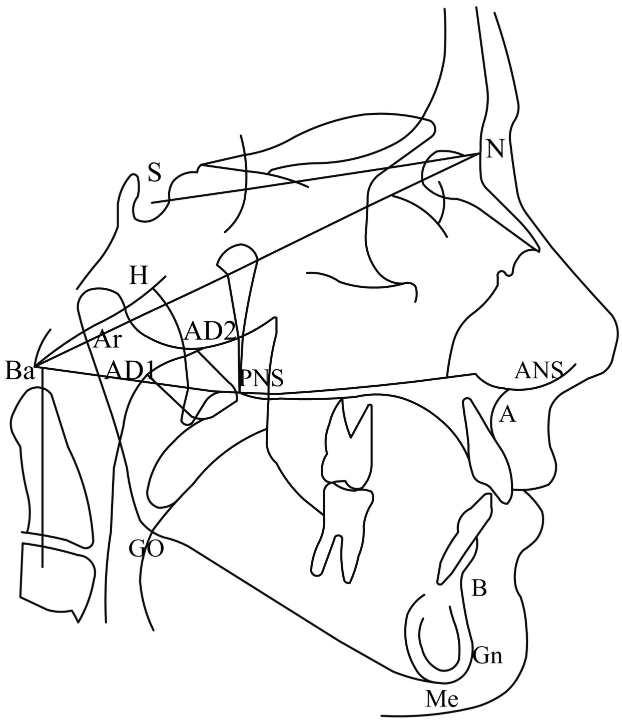


FIGURE 4. Traces of the anatomical structure of the tooth surface, soft tissues and cephalic measurement points. The head diagram illustrates the angular head measurement. The tooth surface structure and soft tissue were traced by hand, and the following angles and linear head measurements were obtained by head measurement tracking. S: sella; N: nasion; ANS: anterior nasal spine; PNS: posterior nasal spine; Ar: articulare; Go: gonion; Gn: gnathion; Me: menton; H: Hormion, point located at the intersection between the perpendicular line to Sella-Basion from posterior nasal spine and the cranial base; Ba: Basion; PNS-AD1: distance between the closest adenoid tissue and posterior nasal spine measured through the PNS-Ba line (AD1); PNS-AD2: distance between the closest adenoid tissue and the posterior nasal spine and measured through a perpendicular line to Sella-Basion from the posterior nasal spine (AD2); AD2-H: soft-tissue width at the posterior nasopharynx wall through the posterior nasal spine-Hormion line; AD1-Ba: soft-tissue width at the posterior nasopharynx wall through the posterior nasal spine-Basion line.

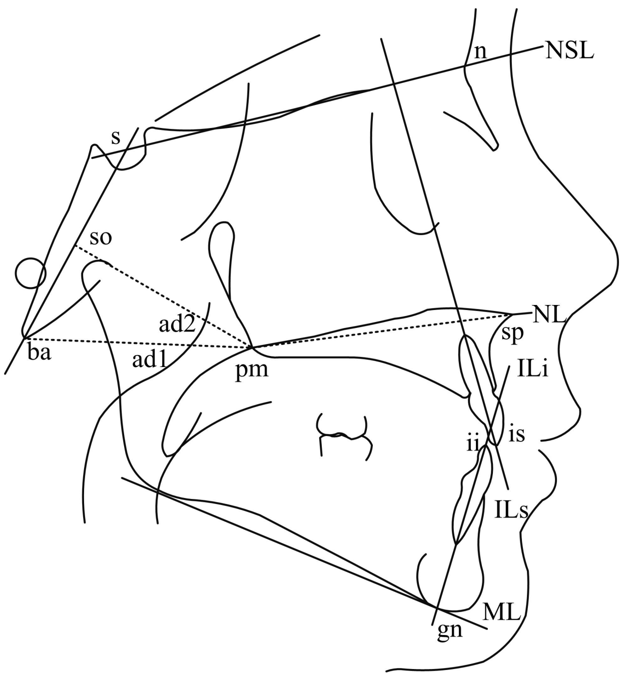
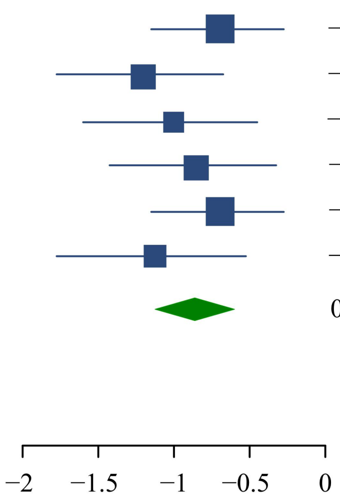


FIGURE 5. Reference points and lines in the head diagram. Dental and skeletal reference points and lines were defined by Bjork (1960) [29]. NSL: nasion-sella line; NL: nasal line; ML: mandibular line; ILs: the long axis of upper central cncisor; ILi: the long axis of low central incisor; ii: incision inferius; is: incision superius; pm: pterygomaxillare; Sp: spinal point.

Study	Treatment N	Treatment Mean	Treatment SD	Control N	Control Mean	Control SD	Hedges's *g* with 95% CI	Weight (%)
Study 1	45	3.73	2.91	21	5.53	2.77	−0.62[−1.14, −0.10]	20.50
Study 2	33	3.8	2	22	6.4	2.3	−1.21[−1.78, −0.63]	16.79
Study 3	20	2.7	1.7	18	4.6	2.2	−0.95[−1.61, −0.29]	12.89
Study 4	22	3.65	2.73	22	5.88	2.76	−0.80[−1.40, −0.19]	15.36
Study 5	26	3.41	2.02	44	4.75	2.27	−0.61[−1.10, −0.12]	23.34
Study 6	17	4.2	2.12	17	6.7	2.19	−1.13[−1.84, −0.42]	11.13
Overall							0.84[−1.08, −0.61]	



Heterogeneity: $\tau^2 = 0.00$, $I^2 = 0.00\%$, $H^2 = 1.00$
Test of $\theta^i = 0_j$: Q(5)= 3.88, $p = 0.57$
Test of $\theta = 0$: $z = -6.98$, $p < 0.001$

Random-effects REML model

FIGURE 6. Forest plot of the influences of gland resection/tonsillectomy on children's dental maxillary growth NL-NSL. CI: confidence interval; SD: standard deviation; REML: restricted maximum likelihood.

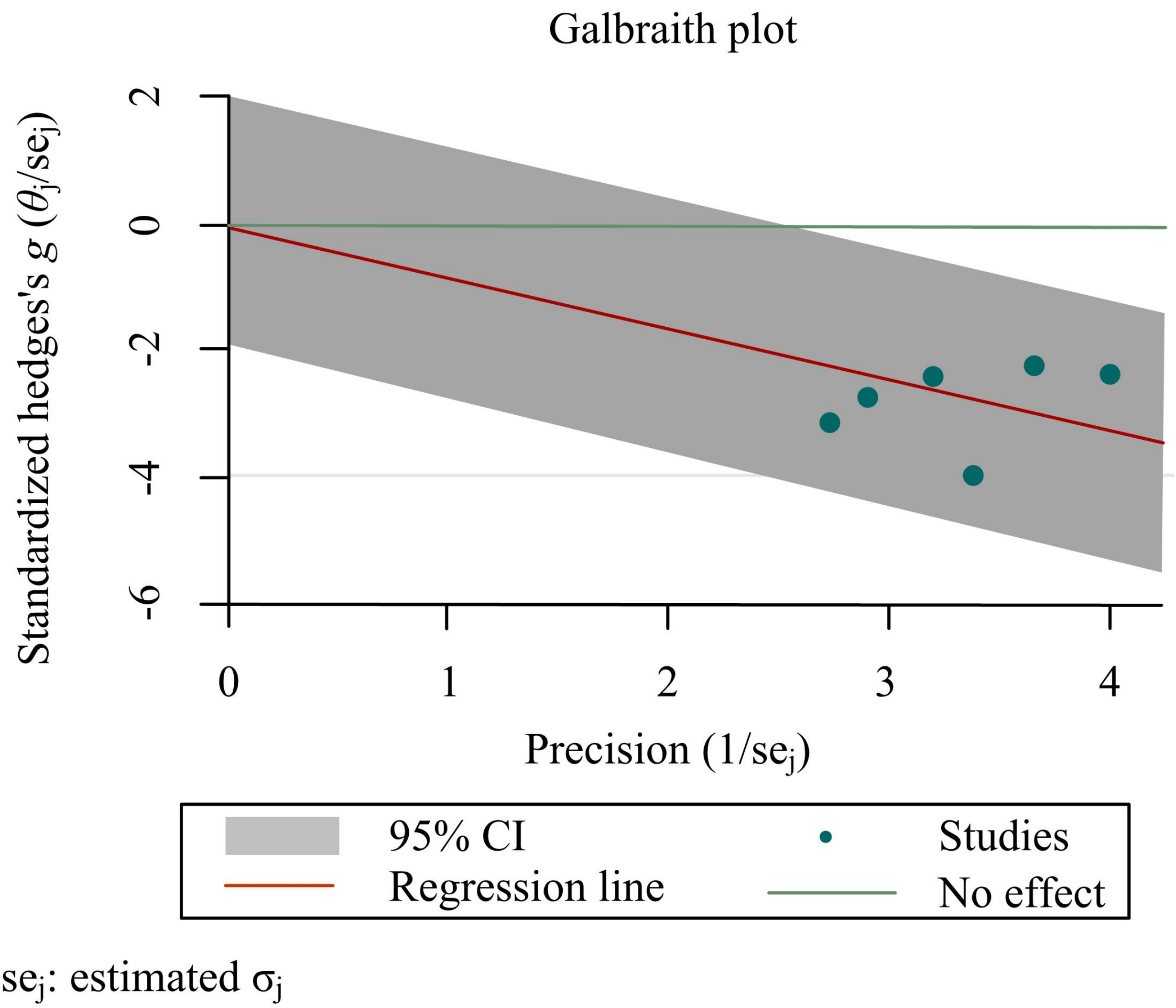


FIGURE 7. Galbraith heterogeneity test of the influences of gland resection/tonsillectomy on children's dental maxillary growth NL-NSL. CI: confidence interval.

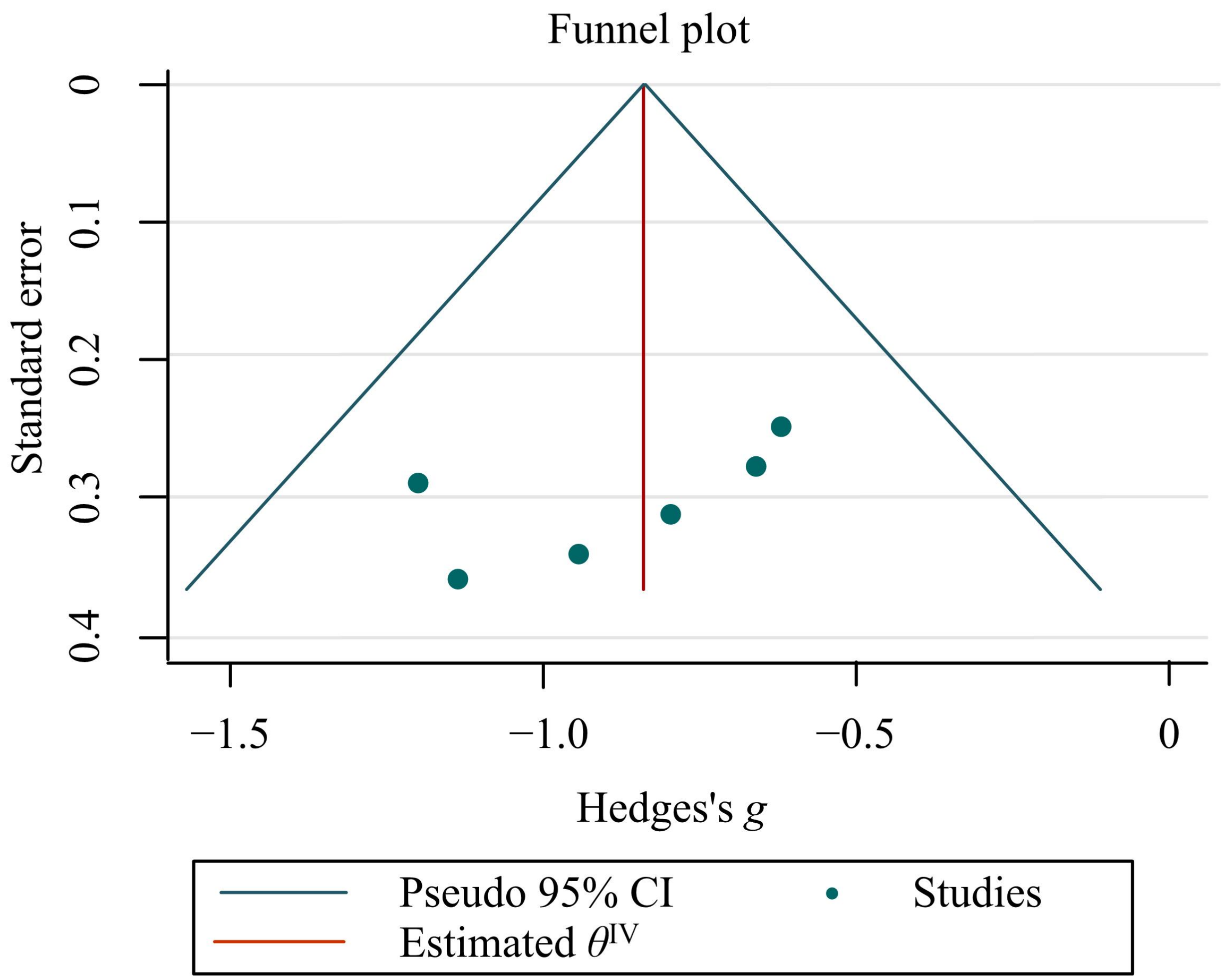
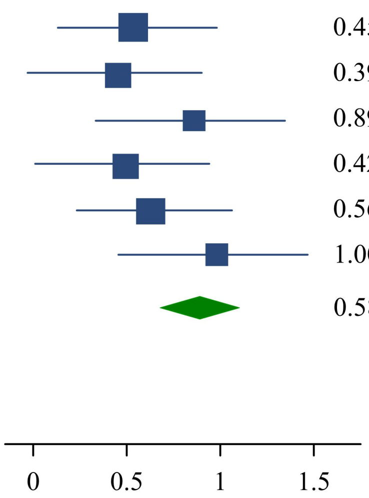


FIGURE 8. Funnel plot of the influences of gland resection/tonsillectomy on children's dental maxillary growth NL-NSL. CI: confidence interval.

Study	Treatment N	Treatment Mean	Treatment SD	Control N	Control Mean	Control SD	Hedges's g with 95% CI	Weight (%)
Li	45	36.25	4.75	21	34.23	3.47	0.45[−0.06, 0.97]	19.97
Mattar	33	37.5	4.6	22	35.9	3	0.39[−0.15, 0.93]	18.58
Percira	20	34.8	6.5	18	29.3	5.5	0.89[0.24, 1.55]	12.49
Pisacane	22	36.1	6.14	22	33.82	4.32	0.42[−0.17, 1.01]	15.53
Souki	26	36.11	4.03	44	33.75	4.21	0.56[0.07, 1.05]	22.44
Zettergren	17	38	4.41	17	33.5	4.42	1.00[0.30, 1.69]	11.00
Overall							0.58[0.34, 0.81]	



Heterogeneity: $\tau^2 = 0.00$, $I^2 = 0.00\%$, $H^2 = 1.00$
Test of $\theta^i = 0_j$: $Q(5) = 3.21$, $p = 0.67$
Test of $\theta = 0$: $z = 4.88$, $p < 0.001$

Random-effects REML model

FIGURE 9. Forest plot of the influences of gland resection/tonsillectomy on children's dental maxillary growth ML-NSL. CI: confidence interval; SD: standard deviation; REML: restricted maximum likelihood.

demonstrated that gland resection/tonsillectomy affected the children's maxillary growth as shown by the ML-NSL value. After surgical treatment, the ML-NSL value decreased, and there was no heterogeneity between all articles. The lowest OR value was 0.39, and the 95% CI was (−0.15, 0.93), while the highest OR value reached 1.00, and the 95% CI was (0.30, 1.69). To comprehensively assess the therapeutic effects, the influences of gland resection/tonsillectomy on children's maxillary growth, as indicated by the ML-NSL value, were further analyzed. The heterogeneity test of these influences is presented in Fig. 10, demonstrating minimal heterogeneity and high accuracy among the included articles. The funnel plot, depicted in Fig. 11, indicated a low risk of bias across all the articles. Based on the findings, it was determined that gland resection/tonsillectomy resulted in a reduction in ML-NSL values. This reduction in the ML-NSL value, indicating posterior inclination of the mandible, was associated with an improvement in respiratory issues among children.

3.5 Meta-analysis of the influences on SNA

OR was used as the clinical outcome index for the analysis of the influences of gland resection/tonsillectomy on children's maxillary growth (Fig. 12). The OR of the influence of gland resection/tonsillectomy on children's maxillary growth, as reflected in SNA values, in five articles was −0.30, 95% CI was (−0.55, −0.06), $I^2 = 0.00\%$, and $p = 0.49$. The OR value suggested that gland resection/tonsillectomy affected the children's maxillary growth as reflected in the SNA value. After surgical treatment, the SNA value rose, and there was no heterogeneity between all articles. The lowest OR value was −0.64, and the 95% CI was (−1.31, 0.03), while the highest OR value reached −0.03, and the 95% CI was (−0.62, 0.55). To comprehensively evaluate the therapeutic effects, the influences of gland resection/tonsillectomy on children's maxillary growth, as indicated by the SNA values, were further analyzed. The heterogeneity test of these influences is presented in Fig. 13, demonstrating minimal heterogeneity and high accuracy among the included articles. The funnel plot, depicted in Fig. 14, indicated a low risk of bias across all the articles. Based on the findings, it was determined that gland resection/tonsillectomy resulted in an increase in SNA values. This increase in the SNA value, indicating maxillary growth, was associated with an improvement in nasal airway obstruction among children.

3.6 Meta-analysis of the influences on SNB

OR was used as the clinical outcome index for the analysis of the influences of gland resection/tonsillectomy on children's maxillary growth (Fig. 15). The OR of the influence of gland resection/tonsillectomy on children's maxillary growth, as reflected in the SNB values, in five articles was −0.31, 95% CI was (−0.56, −0.07), $I^2 = 0.00\%$, and $p = 0.55$. The OR value suggested that gland resection/tonsillectomy affected the children's maxillary growth as reflected in the SNB value. After surgical treatment, the SNB value rose, and there was no heterogeneity between all articles. The lowest OR value was −0.66, and the 95% CI was (−1.34, −0.01), while the highest OR value reached 0.03, and the 95% CI was (−0.55, 0.61). To further examine the therapeutic effects, a comprehensive analysis was conducted on the influences of gland resection/tonsillectomy on children's maxillary growth, specifically reflected in the SNB values. The heterogeneity test of these influences is presented in Fig. 16, revealing minimal heterogeneity and high accuracy among the included articles. The funnel plot, depicted in Fig. 17, demonstrated a low risk of bias across all the articles. Based on the findings, it was determined that gland resection/tonsillectomy resulted in an increase in SNB values. This increase in the SNB value, indicating maxillary growth, was associated with an improvement in nasal airway obstruction among children.

3.7 Reliability analysis

Sensitivity analysis was conducted by altering the analysis models to evaluate the robustness of the results. The meta-analysis findings revealed that the summary results remained consistent across different analysis models, indicating the high stability of the included articles. Furthermore, model analysis, including funnel asymmetry and linear regression analysis, indicated good consistency in the research findings. These results provide additional support for the reliability and validity of the meta-analysis outcomes.

4. Discussion

In the research, the published clinical data were searched, sorted out, screened and subjected to meta-analysis. The heterogeneity of treatment was analyzed, and the OR index was investigated to evaluate therapeutic effects. In general, gland resection/tonsillectomy increased the NL-NSL value and NL-NSL value (anteversion of the maxilla) while reducing the ML-NSL value and ML-NSL value (posterior inclination of the mandible), which improved respiratory problems among children. In addition, gland resection/tonsillectomy affected the growth of the maxilla and mandible among children. After surgical treatment, the SNA value decreased, while the SNB value increased. The increase in SNA value (maxilla) and SNB value (mandible) improved nasal airway obstruction among children.

Regarding the NL-NSL indicator, our study revealed that after surgery, there was an increase in the NL-NSL value, indicating a forward inclination of the maxilla. Although there is limited research on the impact of adenoidectomy/tonsillectomy on the NL-NSL indicator, our findings provide a new perspective in this area. It is important for future studies to further explore potential influencing factors such as patient age, surgical techniques, and postoperative rehabilitation treatments [30, 31]. Furthermore, future research can also focus on investigating the long-term effects of surgery on the growth of children's maxillary bones and potential complications. In our meta-analysis, it was observed that after adenoidectomy/tonsillectomy, the ML-NSL value decreased. This suggests that the surgery may result in a posterior inclination of the mandible relative to the cranial base. These findings contribute to the understanding of the effects of surgery on the mandibular position and provide valuable insights for clinical practice. Our findings are in line with several previous stud-

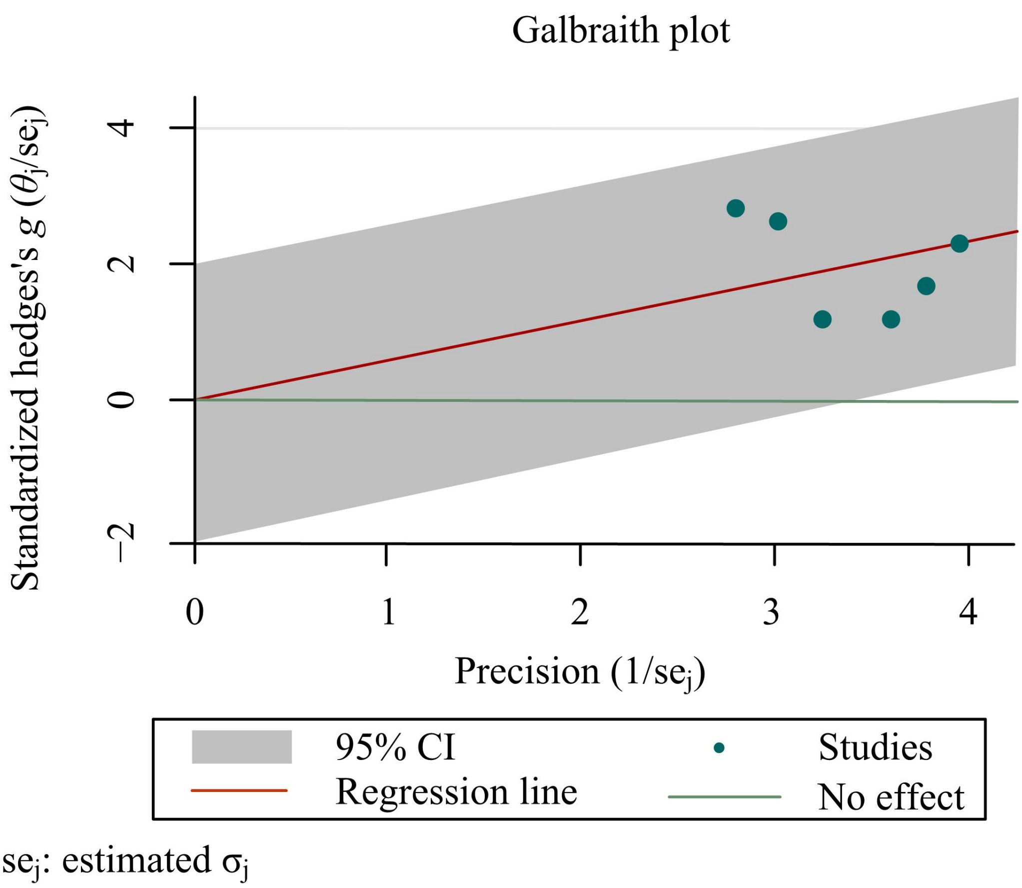


FIGURE 10. Galbraith heterogeneity test of the influences of gland resection/tonsillectomy on children's dental maxillary growth ML-NSL. CI: confidence interval.

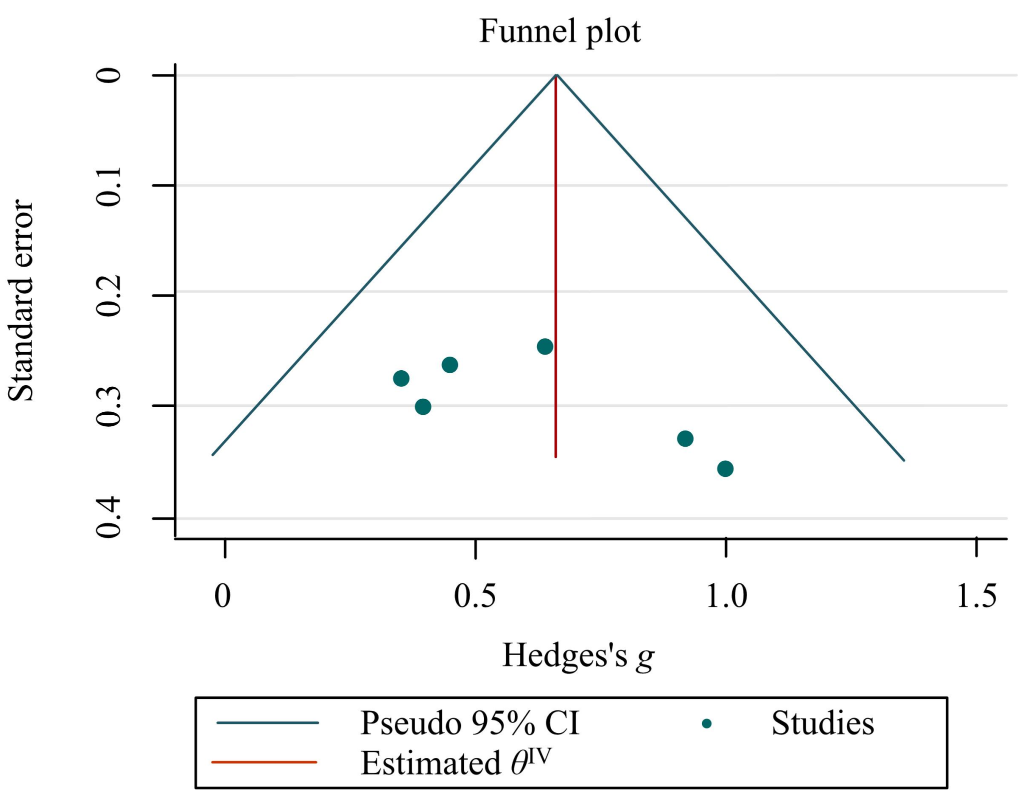


FIGURE 11. Funnel plot of the influences of gland resection/tonsillectomy on children's dental maxillary growth ML-NSL. CI: confidence interval.

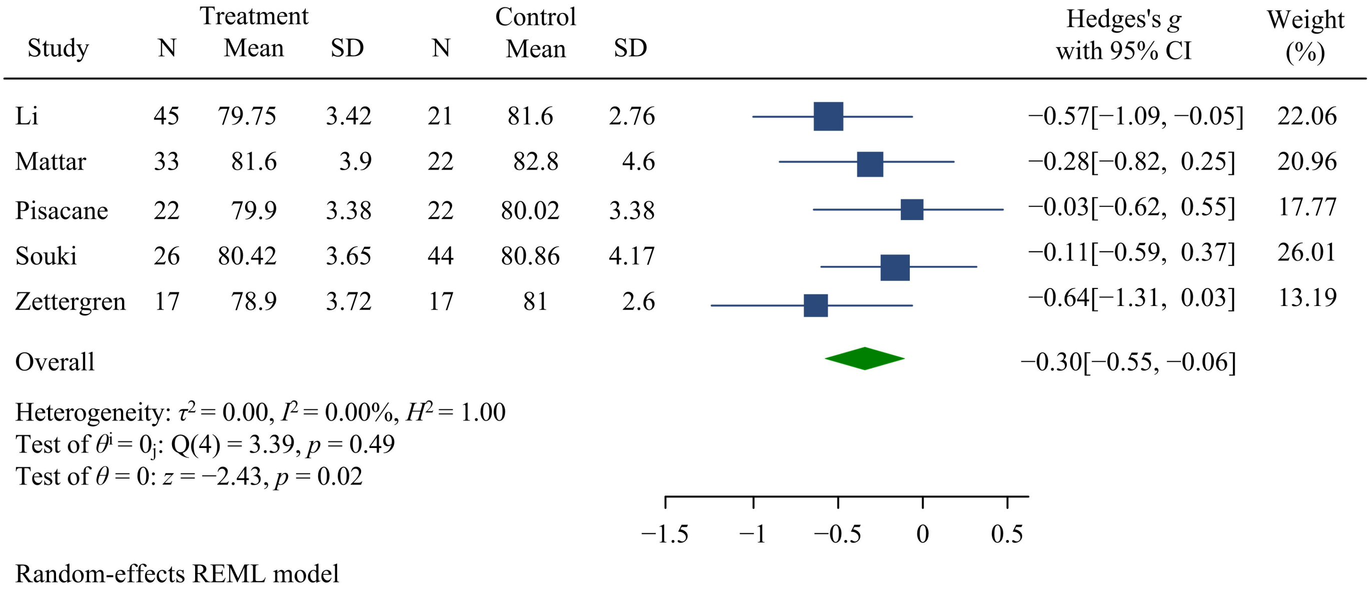


FIGURE 12. Forest plot of the influences of gland resection/tonsillectomy on children's dental maxillary growth SNA. CI: confidence interval; SD: standard deviation; REML: restricted maximum likelihood.

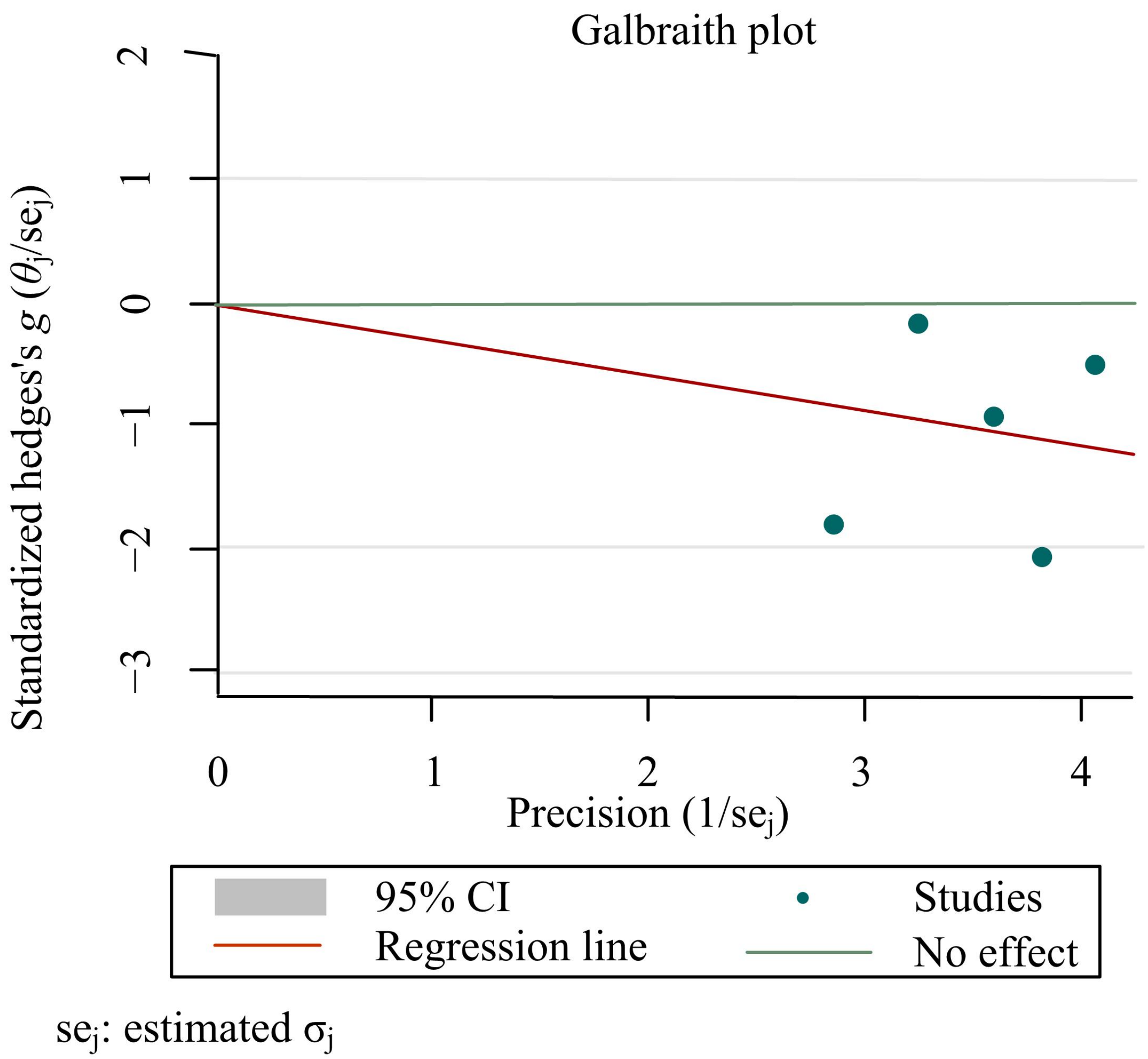


FIGURE 13. Galbraith heterogeneity test of the influences of gland resection/tonsillectomy on children's dental maxillary growth SNA. CI: confidence interval.

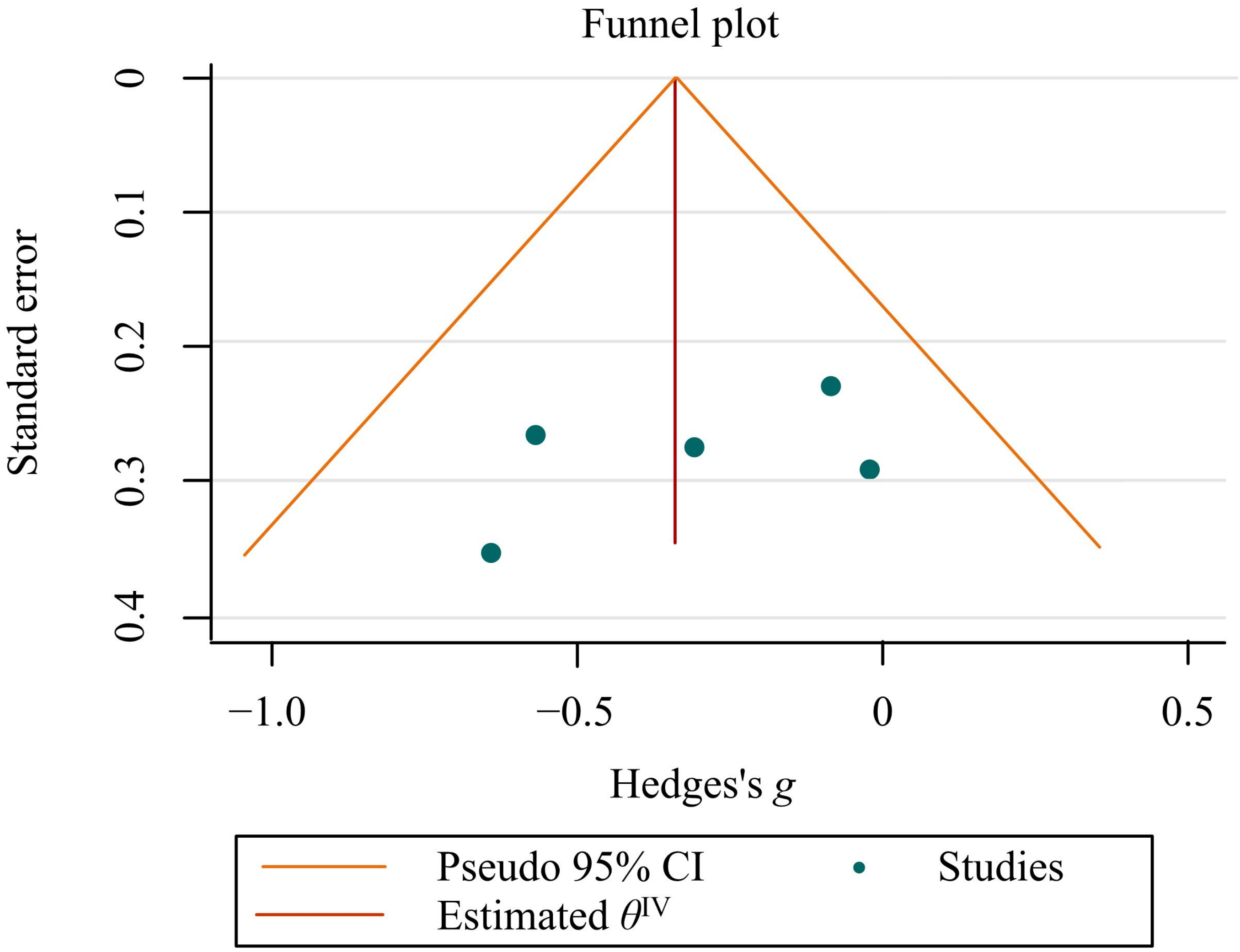
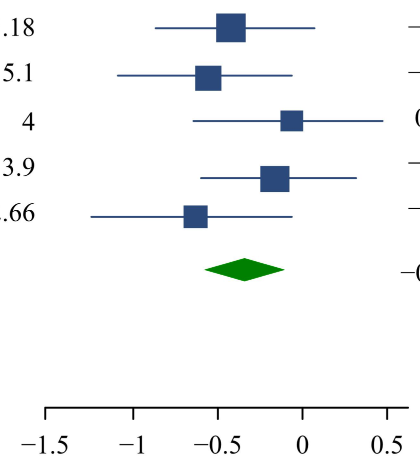


FIGURE 14. Funnel plot of the influences of gland resection/tonsillectomy on children's dental maxillary growth SNA. CI: confidence interval.

Study	Treatment N	Treatment Mean	Treatment SD	Control N	Control Mean	Control SD	Hedges's g with 95% CI	Weight (%)
Li	45	74.69	5.05	21	76.4	3.18	−0.37[−0.89, 0.14]	22.52
Mattar	33	75.8	2.8	22	77.7	5.1	−0.48[−1.02, 0.06]	20.59
Pisacane	22	76.25	3.32	22	76.14	4	0.03[−0.55, 0.61]	17.79
Souki	26	76.75	2.18	44	77.39	3.9	−0.19[−0.67, 0.29]	25.95
Zettergren	17	69.2	3.46	17	71.3	2.66	−0.66[−1.34, 0.01]	13.15
Overall							−0.31[−0.56, −0.07]	



Heterogeneity: $\tau^2 = 0.00$, $I^2 = 0.00\%$, $H^2 = 1.00$
Test of $\theta^i = 0_j$: Q(4) = 3.07, $p = 0.55$
Test of $\theta = 0$: $z = -2.51$, $p = 0.01$

Random-effects REML model

FIGURE 15. Forest plot of the influences of gland resection/tonsillectomy on children's dental maxillary growth SNB. CI: confidence interval; SD: standard deviation; REML: restricted maximum likelihood.

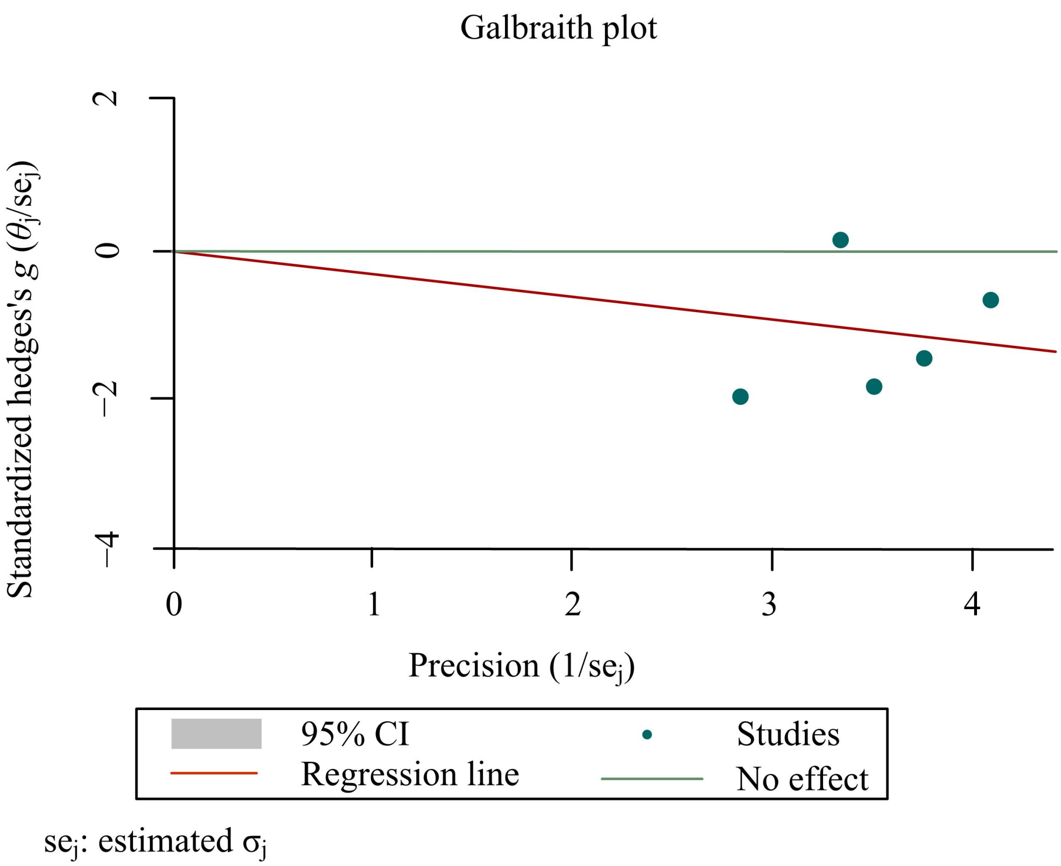


FIGURE 16. Galbraith heterogeneity test of the influences of gland resection/tonsillectomy on children's dental maxillary growth SNB. CI: confidence interval.

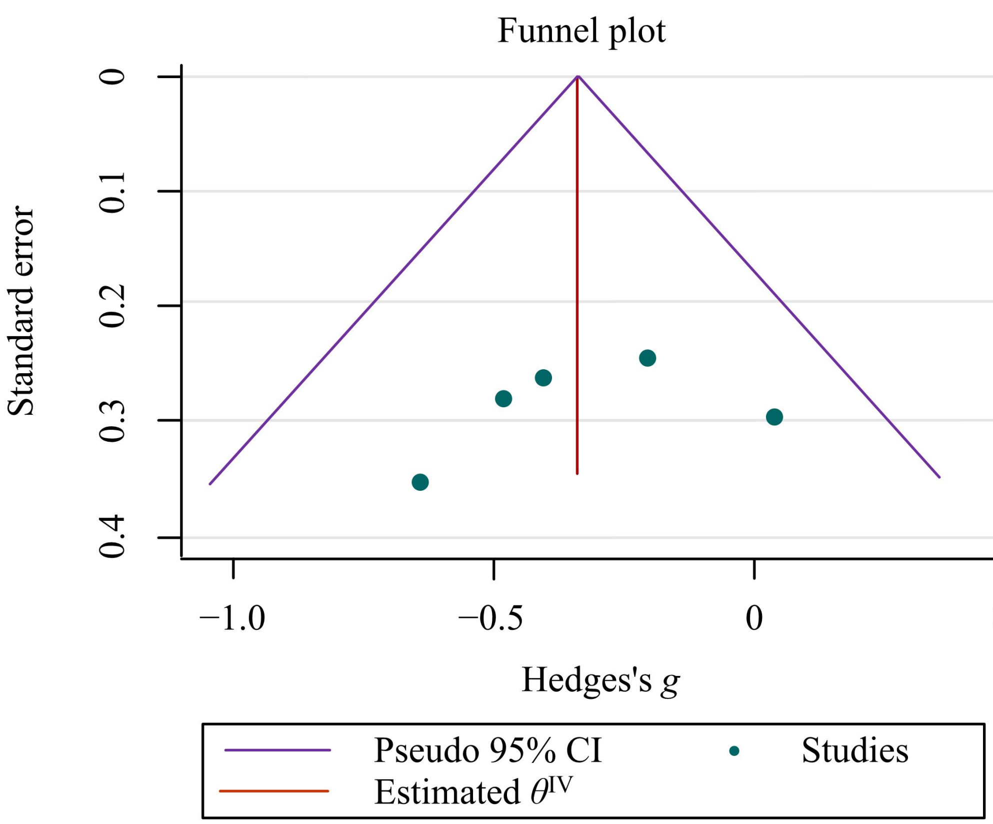


FIGURE 17. Funnel plot of the influences of gland resection/tonsillectomy on children's dental maxillary growth SNB. CI: confidence interval.

ies, which have reported a decrease in the ML-NSL value of children after surgery [32]. However, it is worth noting that other studies have found no significant impact of surgery on ML-NSL values [33]. These discrepancies may be attributed to variations in patients' baseline characteristics, study designs and surgical techniques employed. To gain a deeper understanding of the effects of surgery on the ML-NSL indicator, future research should consider exploring additional relevant factors, such as patient age and postoperative rehabilitation treatments. Furthermore, there is a need for further investigations focusing on the long-term effects of surgery on the growth of children's maxillary bones and the potential occurrence of complications. Such studies would contribute to advancing our knowledge in this field and inform clinical decision-making.

Regarding the SNA indicator, our meta-analysis showed that after adenoidectomy/tonsillectomy, the SNA value increased. This result is consistent with some existing studies. For example, some studies found that after surgical treatment, children's SNA values increased, suggesting an improvement in maxillary development [34]. In contrast, in other studies, the impact of surgery on SNA values was not evident. These differences may be due to different research methods, case selection criteria, and variations in patient age and surgical methods. More research is needed to further explore the impact of these factors on the SNA indicator [35]. Regarding the SNB indicator, according to our meta-analysis results, after adenoidectomy/tonsillectomy, the SNB value increased. This result is consistent with some studies that found that surgery can promote the development of mandibular protrusion in children, thereby increasing the SNB value [36]. However, this view is not universally agreed upon, as some studies argue that the impact of surgery on SNB values is not significant [37]. Factors that may influence these differences include patients' baseline data, research methods, surgical methods, *etc.* More research is needed to delve deeper into these factors.

In summary, this meta-analysis comprehensively evaluated the effects of gland resection/tonsillectomy on children's maxillary growth, aiming to provide evidence-based recommendations for clinical practice. It is crucial to conduct further clinical studies to reevaluate the therapeutic efficacy of these interventions in patients with different conditions. Future research should consider collecting additional indices and conducting detailed comparisons among patients with various conditions to provide a more precise reference for clinical treatment decision-making. By expanding the knowledge base and refining our understanding, we can enhance the quality of care for children with adenoid or tonsil hypertrophy.

5. Conclusion

In conclusion, our meta-analysis provides evidence that adenoidectomy/tonsillectomy has a significant impact on various maxillary growth indicators in children. Specifically, our findings indicate that following surgery, there is an increase in NL-NSL values, a decrease in ML-NSL values and an increase in both SNA and SNB values. These changes suggest improvements in maxillary and mandibular development and contribute valuable insights into the effects of adenoidectomy/tonsillectomy on children's maxillary growth.

However, it is important to acknowledge the inconsistencies observed in existing studies, highlighting the need for further investigation into factors such as patient age, surgical techniques and postoperative rehabilitation protocols. Future research endeavors should delve deeper into these aspects and explore the long-term effects of surgery on children's maxillary growth and the potential complications that may arise. By doing so, we can gain a more comprehensive understanding of the relationship between adenoidectomy/tonsillectomy and children's maxillary growth development. This knowledge will provide valuable guidance for clinical decision-making, ultimately leading to improved patient outcomes.

AVAILABILITY OF DATA AND MATERIALS

The data are contained within this article.

AUTHOR CONTRIBUTIONS

LX—performed the research. LX and YFZ—analyzed the data and wrote the manuscript. Both authors read and approved the final manuscript. Both authors designed the research study.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

Not applicable.

ACKNOWLEDGMENT

Not applicable.

FUNDING

This research received no external funding.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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How to cite this article: Ling Xu, Yingfei Zhang. Meta-analysis: effects of adenoidectomy/tonsillectomy on pediatric maxillary growth development. Journal of Clinical Pediatric Dentistry. 2024; 48(6): 29-44. doi: 10.22514/jocpd.2024.124.