

# development and malocclusion in children: A systematic review and meta-analysis.

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## **ABSTRACT**

**BACKGROUND:** Mouth breathing is closely related to the facial skeletal development and malocclusion.

The purpose of this systematic review and meta-analysis was to assess the effect of mouth breathing on facial skeletal development and malocclusion in children.

**METHODS:** An electronic search in PubMed, the Cochrane Library, Medline, Web of Science, EMBASE and Sigle through February 23rd, 2020, was conducted. Methodological quality assessments of the selected articles were performed using the Newcastle-Ottawa Scale. Review Manager 5.3, was used to synthesize various parameters associated with the impact of mouth breathing on facial skeletal development and malocclusion.

**RESULTS:** Following full-text evaluations for eligibility, 7 studies (387 mouth-breathing subjects and 433 nasal-breathing controls) were included in the final quantitative synthesis; they were all high-quality. The included indicators were SNA ( $p > 0.050$ ), ANS-PNS ( $p > 0.050$ ), 1.NB ( $p > 0.050$ ), MP-H ( $p > 0.050$ ), FMA ( $p > 0.050$ ), SNB (MD: -1.99,  $P < 0.0001$ ), ANB (MD: 0.95,  $P = 0.0005$ ), SN-OP (MD: 3.20,  $P < 0.0001$ ), SNGoGn (MD: 4.34,  $P < 0.0001$ ), 1-NA (MD: 0.72,  $P = 0.004$ ), 1. NA (MD: 1.98,  $P = 0.020$ ), 1-NB (MD: 1.06,  $P < 0.0001$ ), SPAS (MD: -5.23,  $P < 0.0001$ ), PAS (MD: -2.11,  $P < 0.0001$ ), and C3-H (MD: -1.34,  $P < 0.0001$ ).

**CONCLUSIONS:** The results showed that mouth breathing can cause underdevelopment of the mandible. The mandible rotated backward and downward, and the occlusal plane was steep. However, there was little effect on the maxilla. In addition, mouth breathing presented a tendency of lip inclination of the upper and lower anterior teeth. Airway stenosis was common in mouth-breathing children.

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**KEYWORDS:** Mouth breathing; Facial skeletal development; Children; Systematic review, Meta-analysis.

## 1. Background

Mouth breathing is a form of breathing that replaces nasal breathing and its aetiology is complex. Mouth breathing may be due to genetic factors, poor oral habits, or nasal obstruction, including but not limited to adenoid/tonsil hypertrophy, nasal polyps, nasal septum deviation, turbinate hypertrophy, or sinusitis. [1-6]. In addition, mouth breathing may be related to respiratory allergies, climatic conditions, a poor sleeping position, breastfeeding [7].

Currently, the influence of mouth breathing on the development of oral maxillofacial bone is still controversial. Children with mouth breathing often have "adenoid faces"[8], which are characterized as having upper lip incompetence, a retropositioned hyoid bone, a narrow upper dental arch, retropositioned mandibular incisors, an increased anterior face height, a narrow or "V"-shaped maxillary arch, an increased mandibular plane angle, and a posterior-rotated mandible in comparison with healthy controls[9, 10]. With respect to the occlusal relationship, most of the children with mouth breathing presented with Class II malocclusion, and a cross-bite is more frequent than that in those with normal nasal breathing[11]. However, different scholars have reported different research results on the effects of mouth breathing on the maxilla and mandible and the position of the maxilla relative to the skull base[12, 13]. A growing number of scholars believe that facial skeletal development is greatly improved after the aetiology of mouth breathing is removed by surgery or other means[14-16]. To date, systematic reviews about the effect of mouth breathing on maxillofacial development and malocclusion

have been mainly divided into two categories: reviews on the effects of adenoid/tonsil hypertrophy on oral and maxillofacial development before and after oral respiratory surgery and qualitative analyses of the effects of mouth breathing on the occlusal relationship in children. To the best of our knowledge, our study is the first quantitative analysis to explore the effects of mouth breathing on facial bone development and malocclusion in children.

The purpose of this study was to elucidate, through a systematic review and meta-analysis, the changes in facial skeletal development and malocclusion in mouth-breathing children.

## **2. Materials and methods**

The format for this systematic review and meta-analysis was based on the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement [17]. The inclusion criteria and methods of analysis have been previously specified and documented in a protocol in the PROSPERO database (crd-register@york.ac.uk; registration number CRD42019129198).

### **2.1 Search strategy**

Electronic searches in the PubMed, Cochrane Library, Medline, Web of Science, EMBASE and Sigle databases through February 23rd, 2020, were conducted. There were no language restrictions. The following MeSH terms and texts in various combinations were used: malocclusion, mouth breathing, mandible, maxilla, dentofacial growth, and facial growth. In addition, the references of relevant studies were also searched manually. Two authors (Ziyi Zhao and Leilei Zheng) were trained on the inclusion

and exclusion criteria before screening, and pre-screening was conducted to unify the standards in controversial areas. After completing the relevant training, the two authors (Ziyi Zhao and Leilei Zheng) independently screened the study titles and abstracts to identify any potentially eligible studies; then, full-texts were strictly screened according to the inclusion and exclusion criteria. If there was any discrepancy regarding the eligibility of an article, consensus was reached with the guidance of the senior author (Yun Hu).

## 2.2 Study selection

### 2.2.1 Inclusion criteria

The search strategy was defined according to the patient, intervention, comparison, outcome, and study design (PICOS) format: (1) Population: children under the age of 18 with mouth breathing habits; (2) Exposure: Upper airway obstruction, including but not limited to tonsil and adenoid hypertrophy, polyps, allergies, recurrent infections and nasal deformities, interventions[18]; (3) Comparison: facial growth direction and malocclusion in children with mouth breathing compared to those in children with normal nasal breathing without related diseases; (4) Outcome: at least one of the following cephalometric indicators: SNA, SNB, ANB, PP-MP, SN-MP, SN-PP, SN-OP, OP-MP, FMA, N-Me, SN-Gn, SNGoGn, GoGn, ArGoMe, ArGo, N-ANS, ANS-Me, S-Go, MP-H, 1-NA, 1. NA, 1. NB, 1-NB, SPAS, PAS, C3-H, overbite, and overjet; and (5) Study design: Clinical controlled trials, randomized controlled trials, and cohort studies.

### 2.2.2 Exclusion criteria

The exclusion criteria were as follows: studies that were opinion articles, letters, news reports, editorials, bibliographies, conference summaries, project presentations, data compilation, reviews (although the reviews were not included in this study, related reviews were tracked the original studies according to references); studies that included children with systemic diseases, lip or palate cleft, oral or maxillofacial trauma or surgical history, orthodontic treatment history and children aged over 18 years.

### 2.3 Data extraction

The data extracted from the included studies were as follows: the first author's name, year of publication, interventions, sample size, characteristics of the subjects, age of the subjects, and cephalometric outcomes. The cephalometric value data of different groups in the same study were extracted. However, only the original data of the oral and nasal breathing groups before the change in respiratory patterns without treatment or by other means were considered. Unless the same parameters originated from at least two of the selected studies, the relevant data could be described but not synthesized.

### 2.4 Quality assessment

Two authors (Ziyi Zhao and Leilei Zheng) independently assessed the methodological quality of the

included studies using the Newcastle-Ottawa Scale[19]. This scale is mainly composed of 8 items and three parts: selection, comparability and exposure. A study can be awarded a maximum of one star for each numbered item within the selection and exposure categories. A maximum of two stars can be awarded for comparability. Studies with more than five stars were included. The risk of bias in nonrandomized studies of interventions (ROBINS-I) tool was used for controlled clinical trials (CCTs)[20]. When the two authors (Ziyi Zhao and Leilei Zheng) disagreed, a third investigator (Yun Hu) was consulted for discussion to arrive at a reasonable conclusion.

## 2.5 Statistical analysis

The data were analysed using Review Manager 5.3, provided by the Cochrane Collaboration, according to the methods in the Cochrane Handbook for Systematic Reviews of Interventions (version 5.1.0). All the evaluated cephalometric parameters extracted from the included studies were continuous variables. The mean difference (MDs) with 95% confidence intervals (CIs) were used to construct forest plots for the continuous data. The significance level for the hypothesis test was set at  $P < 0.050$ . The Cochrane Q test was used to assess the heterogeneity between studies, and Cochrane's test (statistic) was used to evaluate the magnitude of heterogeneity. If heterogeneity was low ( $P > 0.100$ ,  $I^2 < 50\%$ ), we presented results with fixed-effects model; Otherwise, the random-effects model was adopted for the meta-analysis. If the result was statistically significant ( $P < 0.050$ ) and heterogeneity was high ( $I^2 > 75\%$ ), sensitivity analyses were conducted by removing each study individually to confirm the effect of the relevant study on the overall mean difference. Funnel plots were used to examine publication bias if the number of included studies exceeded 10.

### **3. Result**

#### 3.1 Eligible studies and study characteristics

A total of 1178 records were found by keyword searching in the PubMed (n=312), Cochrane Library (n= 34), EMBASE (n= 618), Medline (n=9), Web of Science (n=200) and Sigle (n=5) databases. Subsequently, 558 duplicates were removed from the pooled database, and 620 unrelated studies were excluded by screening the titles and abstracts. Following full-text assessments, 25 articles were excluded: 5 articles had no control groups; 14 publications had low quality; 2 studies did not present metrics of interest; 2 studies were meta-analyses (although we excluded these articles, we included all the original studies); and one study's subjects were older than the target age range. Finally, a total of 7 studies met the inclusion criteria for meta-analysis[21-27]. Among them, three studies contained subgroups. In one study, the subgroup was divided into two different age groups. One article was grouped by sex, and in another study, a second cephalometric analysis was performed a year later in the same population without any intervention. The flow diagram of the literature search and review process based on the PRISMA statement is shown in Appendix A. The publication time of the included studies ranged from 2009 to 2018. The characteristics of the included studies are displayed in Table 1, the quality assessment is shown in Table 2, and the bias assessment is shown in Table 3.

#### 3.2 Meta-analysis

In this review, there were a total of 820 subjects; 387 children with mouth breathing were included in the experimental group and 433 children with normal nasal breathing were included in the control group. The age range included in these studies was 3 to 16 years old. Of the 7 articles included, 6 mentioned the cause of mouth breathing. Among them, mouth breathing due to adenoid/tonsil hypertrophy was studied in 4 articles, obstructive sleep apnoea syndrome (OSAS) was studied in 2 articles, and the last paper simply stated that the cause was severe airway or nasal obstruction, without specifying. The cephalometric analysis indicators in all the included studies were statistically analysed, and the indicators that appeared 2 times or more were selected for consolidation. The included indicators were SNA, SNB, ANB, SN-OP, FMA, SNGoGn, ANS-PNS, MP-H, 1-NA, 1. NA, 1. NB, 1-NB, SPAS, PAS, and C3-H.

After the meta-analysis with Review Manager 5.3, SNA, 1. NB, FMA, MP-H, ANS-PNS were not statistically significant (fixed: MD, random, 95% CI,  $P > 0.050$ ). All the indicators with statistical significance ( $P < 0.050$ ) were divided into three parts: sagittal direction, vertical direction and airway. As illustrated in Fig. 1, the indicators of sagittal direction are as follows. Only one indicator in mouth-breathing children was lower than that in nasal-breathing children: SNB (MD: -1.99, 95% CI: -2.86 to -1.12,  $P < 0.0001$ ). However, four parameters showed higher values in children with mouth breathing than in children with nasal breathing: ANB (MD: 0.95, 95% CI: 0.42 to 1.49,  $P = 0.0005$ ), 1. NA (MD: 1.98, 95% CI: 0.30 to 3.66,  $P = 0.020$ ), 1-NA (MD: 0.72, 95% CI: 0.23 to 1.20,  $P = 0.004$ ), and 1-NB (MD: 1.06, 95% CI: 0.55 to 1.57,  $P < 0.0001$ ). The vertical indicators are shown in Fig. 2. The following indexes were higher in mouth-breathing individuals than in nasal-breathing individuals: SN-OP (MD: 3.20, 95% CI: 2.44 to 3.97,  $P < 0.0001$ ), and SNGoGn (MD: 4.34, 95% CI: 3.54 to 5.14,  $P < 0.0001$ ). As shown in Fig. 3, the airway data of children in the experimental group were lower than those in the control group: SPAS

(MD: -5.23, 95% CI: -5.95 to -4.51,  $P < 0.0001$ ), PAS (MD: -2.11, 95% CI: -2.90 to -1.32,  $P < 0.0001$ ), and C3-H (MD: -1.34, 95% CI: -1.96 to -0.72,  $P < 0.0001$ ). The heterogeneity of the other outcomes mentioned above was acceptable. Since there were less than 10 studies included in the meta-analysis, we did not conduct funnel plots or Begg's rank correlation tests.

#### **4. Discussion**

This systematic review showed that mouth breathing can cause underdevelopment of the jaw in children and adolescents. The maxilla had no obvious rotation tendency according to the position of the skull, but the mandible's rotation tendency included downward rotation. At the same time, the mandibular plane angle in mouth-breathing children increased, which caused the occlusal plane to steepen and was not conducive to the growth of the temporomandibular joint. Other scholars have also proposed that posterior rotation of the mandible and an increase in the mandibular angle exist in children with mouth breathing, consistent with our results [28, 29] [30] [31]. Juliana pointed out that the maxilla also tends to rotate backward, in contrast with our conclusion [28]. In terms of the development of the maxilla and mandible, mouth breathing had little influence on the maxilla, and the mandible showed obvious underdevelopment. Mouth breathing had no significant effect on the maxilla palatal length. Contrary to the conclusion of this study, Kim proposed that children with mouth breathing may also present maxillary shortening [29]. In addition, there are some reports of palatal stenosis in children with nasal obstruction [29, 31, 32]. The upper and lower anterior teeth all showed a tendency for lip inclination. Anterior lip inclination may be caused by an imbalance in the internal and external muscle force due to the lips opening and teeth showing. Although the lower anterior teeth

resulted in compensatory lip inclination, the compensation of the lower jaw was still not enough. From the point of view of the airway, it was obviously narrowed, which may be related to the posterior rotation of the mandible. Posterior inferior rotation of the mandible may compensate for airway stenosis. This conclusion was similar to the results of several studies[28, 30, 31, 33, 34]. In addition, combined with the indexes that were not included, we believed that the ascending ramus of the lower jaw was also underdeveloped in children with mouth breathing. Moreover, Juliana's study indicated compensatory growth of the jaw in children with airway obstruction[28]. According to the conclusion of this paper, orthodontists should pay more attention to inducing the normal growth of mandible in children with mouth breathing habits.

The relationship between respiratory method and facial skeletal development has long been a topic of interest to paediatricians, otorhinolaryngologists, orthodontists, and other professionals[18, 35-37]. Rizomar and Bibi conducted a systematic review and meta-analysis of the effects of adenoid/tonsil hypertrophy on oral and maxillofacial development before and after oral respiratory surgery[15, 16]. Moreover, Wanderson conducted a systematic review and qualitative analysis on the effects of mouth breathing on the occlusal relationship in children[34]. They proposed that before surgery, compared with children with nasal breathing, children with mouth breathing tended to have an increased mandibular plane angle and posterior inferior rotation of the mandible, and most of them had Class II malocclusion. By correcting poor breathing patterns, children's facial development can be improved to a large extent.

According to literature, mouth breathing occurs in 12%–55% of children[38-42]. The prevalence of adenoid hypertrophy was 49.70%[43]. The high prevalence of adenoid hypertrophy and mouth breathing reminds us to pay more attention to its prevention. Surgical intervention to remove the cause,

and early orthodontic treatment for malocclusion can provide children and adolescents with a higher quality of life. Timely attention to mouth breathing caused by adenoid hypertrophy and other causes can promote the physical and mental health of children.

To the best of our knowledge, this is the first meta-analysis to explore the effects of mouth breathing on facial skeletal development and malocclusion in children. Through a strict and thorough screening process, 7 high-quality studies were included. The total sample size of our study was large. The heterogeneity of the results was mostly acceptable. The mouth-breathing group and nasal-breathing group had the same indexes for analysis. Additionally, three authors included all the indicators appearing two times or more in the literature for meta-analysis and reached a conclusion by referring to the indicators not included in the analysis to ensure the reliability of the conclusions. Altogether, the results of this meta-analysis are credible.

Nevertheless, certain limitations exist. Considering that children's facial skeletal development is closely related to age and sex, heterogeneity may be derived from the age and sex of the research subjects. We tried to conduct subgroup analyses considering age and sex but found that the included literature in this study included overlapping ages and did not stratify data by sex, so this condition was not met. Although there was an age range in the included literature, only a few studies conducted cephalometric analyses by age group, so subgroup analysis was not feasible in this meta-analysis. Therefore, the effects of facial skeletal development at various stages of growth and development could not be determined. Additionally, the growth and development peaks of the sexes differ. Considering the low heterogeneity of the included indicators in this paper, it was confirmed that age and gender had little influence on this study. So, the data are still reliable. Nevertheless, we are willing to conduct a long-term literature review and relevant clinical studies to explore this issue.

## **5. Conclusion**

The results showed that mouth breathing can cause underdevelopment of the mandible. The mandible rotated backward and downward, and the occlusal plane was steep. However, there was little effect on the maxilla. In addition, mouth breathing presented a tendency of lip inclination of the upper and lower anterior teeth. Airway stenosis was common in mouth-breathing children.

## **Declarations**

### **Ethics approval and consent to participate**

Not applicable

### **Consent for publication**

Not applicable

### **Availability of data and materials**

All data generated or analysed during this study are included in this published article and its supplementary information files.

### **Competing interests**

The authors declare that they have no competing interests.

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## Author Contributions

The authors declare that they have no conflicts of interest. Ziyi Zhao and Leilei Zheng designed the study, analysed the data, and drafted the manuscript. Xiaoya Huang and Caiyu Li searched the articles and collected the data. Jing Li prepared all the figures and tables. Yun Hu participated in the literature selection and quality evaluation and revised the article. All authors approved the final version of the manuscript.

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Not applicable

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## Figure legends

Figure 1. Study selection flow diagram (PRISMA).

Figure 2. Forest plot of sagittal measurement changes comparing the mouth-breathing groups with the nasal-breathing groups. SNB, ANB, 1. NA, 1-NA, 1-NB.

Figure 3. Forest plot of vertical measurement changes comparing the mouth-breathing groups with the nasal-breathing groups. SN-OP, SNGoGn

Figure 4. Forest plot of airway changes comparing the mouth-breathing groups with the nasal-breathing groups. SPAS, PAS, C3-H