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REVIEW ARTICLE

Facial growth direction after surgical intervention to relieve mouth breathing: a systematic review and meta-analysis

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Abstract

Objectives A systematic review was performed to assess the prognosis for facial growth direction documented by mandibular plane inclination and anterior face height in growing subjects who had undergone surgical intervention to relieve mouth breathing (PROSPERO database, registration no. CRD 42013005707).

Methods PubMed, Scopus, Web of Science, the Cochrane Library and LILACS were searched based on the guidelines of the PRISMA statement. Included were longitudinal studies with mouth-breathing patients who had undergone surgical interventions to relieve their respiratory pattern, with a minimum follow-up of one year.

Results A total of 1555 studies were identified, whereby only three nonrandomized clinical trials comprising 155 participants met the inclusion criteria. Primary outcome was change between the initial and final measurements of the mandibular plane-SN angle (95% confidence interval [CI] –2.13° [–3.08, –1.18]). Secondary outcomes included changes in total anterior face height (AFH; 95% CI –0.76 mm [–1.91, 0.38]), upper AFH (95% CI 0.09 mm [–0.57, 0.74]), and lower AFH (95% CI 0.06 mm [–0.87, 0.99]). Risk of bias was low for most of bias domains and the quality of evidence across the studies was considered to be very low. The design, the small number of participants, and the absence of blinding generated imprecision.

Conclusions There is very low evidence that the mandibular growth direction became more horizontal during the first year after surgery to treat mouth breathing. The total anterior facial height decreased, although not always significantly.

Keywords Respiration disorders · Nasal surgical procedures · Maxillofacial development · Adenoidectomy · Tonsillectomy

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Richtung des Gesichtswachstums nach chirurgischen Eingriffen zur Verbesserung der Mundatmung: systematisches Review und Metaanalyse

Zusammenfassung

Zielsetzung Durchgeführt wurde ein systematisches Review zur prognostischen Beurteilung der Richtung des Gesichtswachstums bei wachsenden Patienten, die sich einem chirurgischen Eingriff zur Verbesserung der Mundatmung unterzogen hatten (PROSPERO-Datenbank, Registernummer CRD 42013005707). Analysiert wurden die Neigung der Unterkieferebene und die vordere Gesichtshöhe.

Methoden Basierend auf den Leitlinien des PRISMA-Statements wurde in den Datenbanken PubMed, Scopus, Web of Science, Cochrane Library und LILACS gesucht. Eingeschlossen wurden Längsschnittstudien mit Patienten, die sich chirurgischen Behandlungen wie Tonsillektomie oder Adenoidektomie unterzogen hatten, um ihre Atmungsstörungen zu beheben. Der Beobachtungszeitraum betrug mindestens ein Jahr.

Ergebnisse Insgesamt wurden 1555 Studien identifiziert, wobei nur drei nicht randomisierte klinische Studien mit 155 Probanden die Einschlusskriterien erfüllten. Primäres Ergebnis war die Veränderung des Unterkieferebenen-SN-Winkels (95%-Konfidenzintervall -2,13° [-3,08, -1,18]) initial und nach der Behandlung. Zu den sekundären Ergebnissen zählten Veränderungen der gesamten vorderen Gesichtshöhe (AFH; 95%-Konfidenzintervall -0,76 mm [-1,91, 0,38]), obere AFH (95%-Konfidenzintervall 0,09 mm [-0,57, 0,74]) und untere AFH (95%-Konfidenzintervall 0,06 mm [-0,87, 0,99]). Das Bias-Risiko war für die meisten Bias-Bereiche gering, die Qualität der Evidenz wurde als sehr gering eingestuft. Ungenauigkeiten waren bedingt durch Studiendesign Studien, geringe Kollektivgrößen und fehlende Verblindung.

Schlussfolgerungen Die Evidenz dafür, dass die Richtung des Unterkieferwachstums im ersten Jahr nach einem chirurgischen Eingriff zur Verbesserung der Mundatmung horizontaler wurde, ist sehr gering. Die anteriore Gesichtshöhe verringerte sich insgesamt, wenn auch nicht in jedem Fall signifikant.

Schlüsselwörter Atmungsstörungen · Operative Interventionen an der Nase · Maxillofaziale Entwicklung · Adenoidektomie · Tonsillektomie

Introduction

Respiratory needs determine the posture of the head and tongue. By establishing an altered breathing pattern, the position of these structures can generate changes in the balance between teeth, bones and facial soft tissues, affecting both the growth of the jaws and the positioning of teeth [2, 5, 18, 24]. Some studies suggest that habitual oral breathing in childhood, associated with nasal obstruction, may lead to facial deformities [7, 13, 36]. Normalization of the breathing pattern in growing individuals may play an important role in the orthodontic prognosis and encourages cooperation between various medical and dental specialties. According to some authors, however, it is still necessary to prove whether the mode of breathing results in dentofacial changes,or if these differences are predisposing or supporting factors in the establishment of an altered breathing pattern.

A typical facial expression, named adenoid face, has been related to individuals diagnosed as oral-breathing patients. In these cases, an altered relationship can be observed between the maxilla and the mandible, characterized by an increase in the anterior facial height (AFH) and in the mandibular plane inclination, reflecting a vertical facial growth pattern. Intraoral changes accompany this facial feature, with upper incisor protrusion, narrow upper arch in a 'V' shape and high palate [23]. By four years of age, the craniofacial skeleton has reached 60% of its adult size [2]. The establishment of a correct mode of breathing may prevent the development of an unwanted facial growth pattern, such as long-face syndrome, or adenoid face [2, 14, 42].

Several studies have identified significant differences between cephalometric values of nasal and mouth breathers [2, 4, 6, 8–12, 17, 20, 28, 29, 31, 32, 39, 44]. According to some authors, however, the causal relationship between breathing mode and the development of growth disharmonies has not been proven yet [2, 6, 10, 19, 28, 29, 31, 34, 36, 40, 41], and that more evidence must be gathered before recommending intervention [6, 7, 36, 37, 44].

Therefore, in light of the controversies found in the literature, this systematic review was performed to answer the following question: what is the prognosis for the facial growth direction (FGD), documented by mandibular plane inclination and anterior face height (AFH) in growing individuals that underwent adenoidectomy, tonsillectomy, adenotonsillectomy, or surgical correction of nasal stenosis surgical intervention to relieve mouth breathing?

Methods

The format for this review was based on the guidelines of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement [21]. The inclusion criteria and methods of analysis were previously specified and documented in a protocol at the PROSPERO database (crd-register@york.ac.uk; registration number CRD 42013005707).

The search strategy, the question for research and the null hypothesis were defined according to the PICO format:

1. Population (P): Individuals who underwent surgical interventions to correct nasal obstruction during growth, aiming to restore nasal breathing;
2. Intervention (I): Adenoidectomy, tonsillectomy, adenotonsillectomy, or surgical correction of nasal stenosis, aiming to relieve mouth breathing;
3. Comparison (C): Comparison of the facial growth direction in patients with restored nasal-breathing pattern compared to that in untreated nasal-breathing subjects;
4. Outcome (O): Evaluation of, at least, one of the following cephalometric variables, before and after the intervention: (1) mandibular plane inclination in relation to the cranial base; (2) anterior facial height;
5. Null hypothesis: Surgical interventions to correct nasal obstruction during growth, aiming to relieve the breathing pattern, do not influence facial growth direction;
6. Question: What is the prognosis for the facial growth direction in growing individuals who underwent surgical intervention to relieve mouth breathing?

An experienced librarian in the health research area (DM) helped to develop search strategies for each electronic database, as it is shown in Table 1. Additionally, the references of the articles obtained were screened in order to identify articles that were not found in the electronic databases. Experts were contacted in an attempt to identify potentially relevant studies, published and unpublished.

During the selection process, no restrictions were made on the publication year or language of the studies. Considering that only longitudinal research designs provide acceptable prognostic evidence, the following inclusion criteria were adopted to select articles: randomized clinical trials (RCTs), controlled clinical trials, case–control studies and cohort studies involving mouth-breathing patients who had undergone interventions to relieve their respiratory pattern; evaluation of facial growth direction using cephalometric radiographs or computed tomography; follow-up equal to or greater than one year. Laboratory studies, animal studies, case series, case reports, narrative reviews, author's opinions, patients undergoing orthodontic treatment or orthognathic surgery, patients with syndromes, palate and cleft lip were excluded. The research of databases was held from inception up to December 2017. The probability of bias of each selected article was independently evaluated by two authors (RRN and OVV).

An initial selection was performed by the first author (RRN), identifying the studies related to the topic by considering titles and abstracts. Duplicated studies were excluded. An additional analysis by a second reviewer (OVV) excluded studies that did not fully meet the criteria. Articles that met all criteria were obtained in full text, and two

Table 1 Electronic search strategy, according to each database
Tab. 1 Elektronische Suchstrategie bei der jeweiligen Datenbank

MEDLINE via PubMed
http://www.ncbi.nlm.nih.gov/pubmed
#1 AND #2 AND #3

#1	*#2*	*#3*
(head[MeSH Terms] OR head[tiab] OR ″head posture″[tiab] OR ″maxillofacial development″[MeSH Terms] OR ″maxillofacial development″[tiab] OR face[tiab] OR ″facial growth″[tiab] OR ″facial development″[tiab] OR ″facial pattern″[tiab] OR ″facial patterns″[tiab] OR ″facial morphology″[tiab] OR ″craniofacial growth″[tiab] OR ″facial growth direction″[tiab] OR ″vertical dimension″[MeSH Terms] OR ″vertical dimension″[tiab] OR ″lower face height″[tiab] OR ″dentition″[MeSh Terms] OR ″dentition″[tiab] OR ″dental occlusion″[MeSH Terms] OR ″dental occlusion″[tiab] OR ″malocclusion″[MeSH Terms] OR ″malocclusion″[tiab] OR ″mandible″[MeSH Terms] OR ″mandible″[tiab] OR chin[MeSH Terms] OR chin[tiab] OR ″maxilla″[MeSH Terms] OR ″maxilla″[tiab] OR ″jaw″[MeSH Terms] OR ″jaw″[tiab])	(″respiration″[MeSH Terms] OR ″respiration″[tiab] OR ″mouth breathing″[MeSH Terms] OR ″mouth breathing″[tiab] OR respiratory mechanics[tiab] OR respiratory pattern[tiab] OR respiratory patterns[tiab] OR oral breathing[tiab] OR oral breathers[tiab] OR buccal breathing[tiab] OR buccal breathers[tiab] OR mouth respiration[tiab] OR mouth breather[tiab] OR upper airways[tiab] OR ″nasopharynx″[MeSH Terms] OR nasopharynx[tiab] OR nasal airflow[tiab] OR nasopharyngeal airways[tiab] OR ″adenoids″[MeSH] OR adenoids[tiab])	(″cephalometry″ [Mesh Terms] OR cephalometry[tiab] OR ″teleradiology″[Mesh Terms] OR teleradiology[tiab] OR radiographic analysis[tiab] OR ″lateral cephalogram″ [tiab] OR ″lateral cephalograms″[tiab] OR ″lateral radiographs″[tiab] OR ″cone-beam computed tomography″[Mesh Terms] OR ″cone-beam computed tomography″[tiab] OR ″cone beam CT″[tiab] OR ″cone beam″[tiab] OR ″computerized tomography″[tiab])

Table 1 (Continued)
Tab. 1 (Fortsetzung)

Scopus http://www.scopus.com #1 AND #2 AND #3		
#1	*#2*	*#3*
(head OR ″head posture″ OR ″maxillofacial development″ OR face OR ″facial growth″ OR ″facial development″ OR ″facial pattern″ OR ″facial patterns″ OR ″facial morphology″ OR ″craniofacial growth″ OR ″facial growth direction″ OR ″vertical dimension″) *OR* (″lower face height″ OR dentition OR ″dental occlusion″ OR malocclusion OR mandible OR chin OR maxilla OR jaw)	(respiration OR ″mouth breathing″ OR ″respiratory mechanic″ OR ″respiratory mechanics″ OR ″respiratory pattern″ OR ″respiratory patterns″ OR ″oral breathing″ OR ″oral breathers″ OR ″buccal breathing″ OR ″buccal breather″ OR ″buccal breathers″) *OR* (″mouth respiration″ OR ″mouth breather″ OR ″mouth breathers″ OR ″upper airways″ OR nasopharynx OR ″nasal airflow″ OR ″nasopharyngeal airway″ OR ″nasopharyngeal airways″ OR adenoids)	(cephalometry OR teleradiology OR ″radiographic analysis″ OR ″lateral cephalogram″ OR ″lateral cephalograms″ OR ″lateral radiograph″ OR ″lateral radiographs″ OR ″cone-beam computed tomography″ OR ″cone beam CT″ OR ″cone beam″ OR ″computerized tomography″)
Web of Science http://www.webofknowledge.com #1 AND #2 AND #3		
#1	*#2*	*#3*
TS=(head OR ″head posture″ OR ″maxillofacial development″ OR face OR ″facial growth″ OR ″facial development″ OR ″facial pattern″ OR ″facial patterns″ OR ″facial morphology″ OR ″craniofacial growth″ OR ″facial growth direction″ OR ″vertical dimension″ OR ″lower face height″ OR dentition OR ″dental occlusion″ OR malocclusion OR mandible OR chin OR maxilla OR jaw)	TS=(respiration OR ″mouth breathing″ OR ″respiratory mechanic″ OR ″respiratory mechanics″ OR ″respiratory pattern″ OR ″respiratory patterns″ OR ″oral breathing″ OR ″oral breathers″ OR ″buccal breathing″ OR ″buccal breather″ ″buccal breathers″ OR ″mouth respiration″ OR ″mouth breather″ OR ″mouth breather″ OR ″upper airways″ OR nasopharynx OR ″nasal airflow″ OR ″nasopharyngeal airway″ ″nasopharyngeal airways″ OR adenoids)	TS=(″cephalometry″ OR ″teleradiology″ OR ″radiographic analysis″ OR ″lateral cephalogram″ OR ″lateral cephalograms″ OR ″lateral radiograph″ OR ″lateral radiographs″ OR ″cone-beam computed tomography″ OR ″cone beam CT″ OR ″cone beam″ OR ″computerized tomography″)
LILACS **(Latin American and Caribbean Center on Health Sciences Information)** http://www.bireme.br #1 AND #2 AND 3#		
#1	*#2*	*#3*
(tw:(MH:″cabeça″ OR MH:″dimensão vertical″ OR MH:″dentição″ OR MH:″oclusão dentária″ OR MH: ″má oclusão″ OR MH: ″mandibular″ OR MH: ″queixo″ OR MH: ″maxilla″)) OR (head OR cabeça OR cabeza OR maxillofacial development OR desenvolvimento maxilofacial OR desarollo maxilofacial OR face OR cara OR facial growth OR crescimento facial OR crecimiento facial OR facial development OR desenvolvimento facial OR desarollo facial OR facial pattern OR padrão facial OR patrón facial OR craniofacial growth OR crescimento craniofacial OR crecimiento craneofacial OR vertical dimension OR dimensão vertical OR dimensión vertical OR dentition OR dentição OR dentición OR dental occlusion OR oclusão dentária OR oclusión dental OR malocclusion OR máoclusão OR maloclusión OR mandible OR mandíbula OR chin OR queixo OR mentón OR maxilla OR maxila OR maxilar OR jaw)	(tw:(MH: ″respiração″ OR MH: ″respiração bucal″ OR MH: ″nasofaringe″ OR MH: ″tonsil faríngea″)) OR (respiration OR respiração OR respiración OR mouth breathing OR respiração bucal OR respiración por la boca OR oral breathing OR oral breathers OR buccal breathing OR respiración bucal OR buccal breathers OR respiradores bucais OR respiradores bucales OR upper airways OR vias aéreas superiores OR vías respiratorias superiores OR nasopharynx OR nasofaringe OR nasopharyngeal airways OR vias aéreas nasofaríngeas OR vías respiratorias nasofaríngeas OR adenoids OR adenóides OR adenoides)	(tw:(MH:″telerradiologia″ MH: ″tomografia computadorizada de feixe cônico″)) OR (cephalometry OR cefalometria OR cefalometría OR teleradiology OR telerradiologia OR telerradiología OR lateral cephalogram OR cefalograma lateral OR lateral cephalograms OR cefalogramas laterais OR cefalogramas laterales OR cone-beam computed tomography OR tomografia computadorizada de feixe cônico OR tomografia computarizada de haz cónico OR cone-beam computed tomography OR tomografia computadorizada volumétrica OR tomografia computarizada OR cone beam CT OR TC de feixe cônico OR TC de haz cónico)

Table 1 (Continued)

Tab. 1 (Fortsetzung)

The Cochrane Library

http://www.thecochranelibrary.com/view/0/index.html

#42 AND # 67 AND #85

#42

#1″head″:ti,ab,kw (Word variations have been searched)
#2MeSH descriptor: [Head] explode all trees
#3#1 or #2
#4maxillofacial development:ti,ab,kw (Word variations have been searched)
#5MeSH descriptor: [Maxillofacial Development] explode all trees
#6: #4 or #5
#7″vertical dimension″:ti,ab,kw (Word variations have been searched)
#8MeSH descriptor: [Vertical Dimension] explode all trees
#9: #7 or #8
#10″dentition″:ti,ab,kw (Word variations have been searched)
#11MeSH descriptor: [Dentition] explode all trees
#12: #10 or #11
#13″dental occlusion″:ti,ab,kw (Word variations have been searched)
#14MeSH descriptor: [Dental Occlusion] explode all trees
#15: #13 or #14
#16″malocclusion″:ti,ab,kw (Word variations have been searched)
#17MeSH descriptor: [Malocclusion] explode all trees
#18: #16 or #17
#19″mandible″:ti,ab,kw (Word variations have been searched)
#20MeSH descriptor: [Mandible] explode all trees
#21: #19 or #20
#22″chin″:ti,ab,kw (Word variations have been searched)
#23MeSH descriptor: [Chin] explode all trees
#24: #22 or #23
#25″maxilla″:ti,ab,kw (Word variations have been searched)
#26MeSH descriptor: [Maxilla] explode all trees
#27: #25 or #26
#28″jaw″:ti,ab,kw (Word variations have been searched)
#29MeSH descriptor: [Jaw] explode all trees
#30: #28 or #29
#31: #3 or #6 or #9 or #12 or #15 or #18 or #21 or #24 or #27 or #30
#32″head posture″:ti,ab,kw (Word variations have been searched)
#33″face″:ti,ab,kw (Word variations have been searched)
#34″facial growth″:ti,ab,kw (Word variations have been searched)
#35″facial development″:ti,ab,kw (Word variations have been searched)
#36″facial pattern″:ti,ab,kw (Word variations have been searched)
#37″facial morphology″:ti,ab,kw (Word variations have been searched)
#38″craniofacial growth″:ti,ab,kw (Word variations have been searched)
#39″facial growth direction″:ti,ab,kw (Word variations have been searched)
#40″lower face height″:ti,ab,kw (Word variations have been searched)
#41: #32 or #33 or #34 or #35 or #36 or #37 or #38 or #39 or #40
#42: #31 or #41

#67

#43″respiration″:ti,ab,kw (Word variations have been searched)
#44MeSH descriptor: [Respiration] explode all trees
#45:#43 or #44
#46″mouth breathing″:ti,ab,kw (Word variations have been searched)
#47MeSH descriptor: [Mouth Breathing] explode all trees
#48: #46 or #47
#49″nasopharynx″:ti,ab,kw (Word variations have been searched)
#50MeSH descriptor: [Nasopharynx] explode all trees
#51: #49 or #50
#52adenoid:ti,ab,kw (Word variations have been searched)
#53MeSH descriptor: [Adenoids] explode all trees
#54: #52 or #53
#55″respiratory mechanics″:ti,ab,kw (Word variations have been searched)
#56″respiratory pattern″:ti,ab,kw (Word variations have been searched)
#57″oral breathing″:ti,ab,kw (Word variations have been searched)
#58″oral breathers″:ti,ab,kw (Word variations have been searched)
#59″buccal breathing″:ti,ab,kw (Word variations have been searched)
#60″mouth respiration″:ti,ab,kw (Word variations have been searched)
#61″mouth breather″:ti,ab,kw (Word variations have been searched)
#62″upper airways″:ti,ab,kw (Word variations have been searched)
#63″nasal airflow″:ti,ab,kw (Word variations have been searched)
#64″nasopharyngeal airways″:ti,ab,kw (Word variations have been searched)
#65: #45 or #48 or #51
#66: #55 or #56 or #57 or #58 or #59 or #60 or #61 or #62 or #63 or #64
#67: #65 or #66

#85

#68″cephalometry″:ti,ab,kw (Word variations have been searched)
#69MeSH descriptor: [Cephalometry] explode all trees
#70: #68 or #69
#71″teleradiology″:ti,ab,kw (Word variations have been searched)
#72MeSH descriptor: [Teleradiology] explode all trees
#73: #71 or #72
#74″cone-beam computed tomography″:ti,ab,kw (Word variations have been searched)
#75MeSH descriptor: [Cone-Beam Computed Tomography] explode all trees
#76: #74 or #75
#77″radiographic analysis″:ti,ab,kw (Word variations have been searched)
#78″lateral cephalogram″:ti,ab,kw (Word variations have been searched)
#79″lateral radiograph″:ti,ab,kw (Word variations have been searched)
#80″cone beam CT″:ti,ab,kw (Word variations have been searched)
#81″cone beam″:ti,ab,kw (Word variations have been searched)
#82″computerized tomography″:ti,ab,kw (Word variations have been searched)
#83: #77 or #78 or #79 or #80 or #81 or #82
#84: #70 or #73 or #76
#85: #83 or #84

ti title, *ab* abstract, *kw* keywords, *tiab* title and abstract, *MeSH* Medical Subject Headings

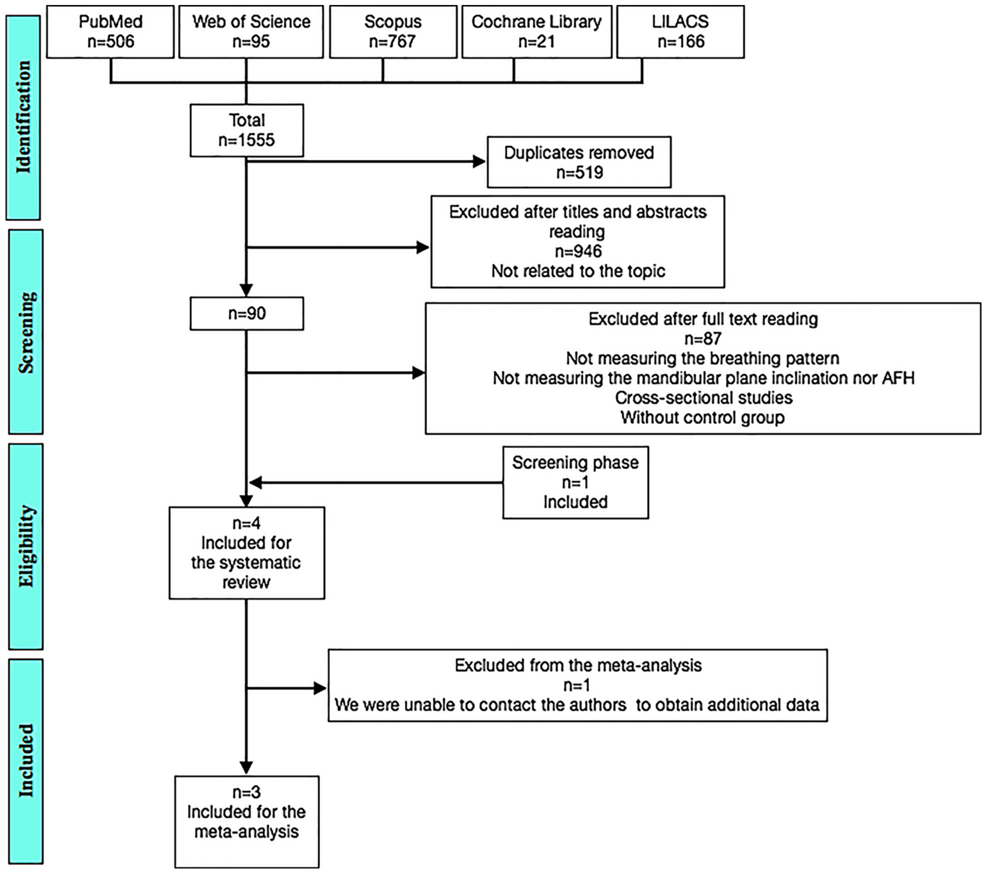

Fig. 1 PRISMA flow diagram of the selected studies. *AFH* anterior face height
Abb. 1 PRISMA-Flussdiagramm der ausgewählten Studien. *AFH* vordere Gesichtshöhe

authors (RRN and OVV) read the selected texts. Interexaminer conflicts were solved by a third author (CTM) in a consensus meeting. The studies were assessed according to the Quality In Prognosis Studies (the QUIPS tool), a checklist developed to evaluate prognosis studies [15], available at www.annals.org.

The data extraction from the studies was carried out by two authors (RRN and CTM). The main outcomes evaluated were differences between initial (T1) and final (T2) values in mandibular plane-SN angle, and in AFH measurements (total, upper, lower and the ratio between these measures). The data of the selected studies were extracted, and a meta-analysis was performed by the third reviewer (CTM) utilizing Review Manager (RevMan5) of The Cochrane Collaboration (ims.cochrane.org/RevMan). Because of only a few studies were comparable, a fixed-effects model was used for the analysis. Heterogeneity among studies was checked, and forest plots were created to show comparisons.

Results

The research of the electronic databases identified 1555 titles and abstracts. Duplicated articles (519) were removed. A flow diagram of the search process is shown in Fig. 1. All remaining titles and abstracts (1036) were analyzed, and 946 were considered not related to the topic and subsequently excluded.

The full texts of 90 studies were evaluated. A rigorous search identified four longitudinal nonrandomized clinical trials [18, 27, 30, 43] that met all criteria. The follow-up time ranged from two [30] to five years [18, 27, 43], and the mean age of the participants at the initial and final measurements revealed that the samples comprised growing individuals. The characteristics of the selected studies are shown in Table 2.

Primary outcome was the change between the initial (T1) and final (T2) measurements of mandibular plane-SN angle. Secondary outcomes were the AFH measurements (total, upper, lower and the ratio between these measures) between T1 and T2. In the four studies, the control group (CG) was composed of nasal breathers, and the experimental group (EG) consisted of individuals who had undergone adenoidectomy, tonsillectomy or adenotonsillectomy, due to extreme respiratory obstruction.

Evaluation of the breathing pattern started with recording the medical history of individuals, followed by tests to assess the mode of breathing. In two studies [18, 27], posterior rhinomanometry was performed before treatment and repeated at the 1-, 3- and 5-year follow-up. One arti-

Table 2 Characteristics of the included studies. The experimental group is comprised of mouth breathers and the control group is comprised of nasal breathers

Tab. 2 Charakteristika der eingeschlossenen Studien. Experimentelle Gruppe: Mundatmer, Kontrollgruppe: Nasenatmer

Author/year	Study design	Clinical setting Period of recruitment	Experimental Group (MB) *N*/Gender Mean age (years)	Control Group (NB) *N*/Gender Mean age (years)	Intervention	Follow-up (months)
Mattar et al. (2011) [30]	COHORT PS NR	Rhinosinusology Outpatient Clinics/Pedodontics Clinic, Schools of Medicine and Dentistry University of São Paulo, Ribeirão Preto Brazil nr	33/nr 4.8 (T1) 7.2 (T2)	22/nr 5.1—T1 7.4—T2	Adenoidectomy/adenotonsillectomy	28
Zettergren et al. (2006) [43]	COHORT RS NR	Department of Otorhinolaryngology, Söder Hospital, Stockholm, Sweden nr	17/10 M, 7 F 5.6 ± 1.34—T1 10.9 ± 1.37—T2	17/10 M, 7 F 5.8 ± 1.40—T1 10.7 ± 1.43—T2 HCG	Adenoidectomy/adenotonsillectomy/tonsillectomy	60
Mahony et al. (2004) [27]	COHORT RS NR	Otorhinolaryngologic Department of Örebro University Hospital, Sweden October 1966–September 1967	45—T1* 36—T2/nr 7.5 ± 1.7—T1 nr—T2	35—T1* 30—T2/nr 7.9 ± 1.7—T1 nr—T2	Adenoidectomy	60
Kerr et al. (1989) [18]	COHORT RS NR	Otorhinolaryngologic Department of Örebro University Hospital, Sweden October 1966–September 1967	26/17 M, 9 F 8.2 ± 1.6,—T1 13.6 ± 1.6—T2	26/17 M, 9 F 8.4 ± 1.6—T1 13.0 ± 1.7—T2	Adenoidectomy	60

PS prospective study, *RS* retrospective study, *MB* mouth breathers, *NB* nasal breathers, *NR* nonrandomized, *HCG* historical control group, *T1* initial, *T2* final, *nr* not reported

cle [43] reported that breathing pattern reassessments were carried out in the experimental group, and the polysomnography registered a reduced overnight sleep one year after surgery. Another study [30] reported that oroscopy and anterior rhinoscopy were performed in the experimental group at 1, 6, 12, and 24 months postoperatively. According to the authors, the tests generally confirmed a change in the respiratory pattern in the experimental group, from oral to nasal breathing. The studies do not report the exact standards that were used to define the breathing pattern in the experimental groups.

Linear measurements in the AFH were assessed in three studies [18, 27, 43], and the mandibular plane inclination was investigated using SN/ML angle in three papers [18, 30, 43]. Additionally, Mattar et al. [30] used superimpositions on the SN line and the Gn point to assess mandibular growth direction expressed at the chin, and the gonial angle (Ar-Go/Go-Me) to investigate mandibular morphology. Kerr et al. [18] evaluated mandibular body length (Xi-pm) and also assessed mandibular morphology using the mandibular arc (cd-Xi/Xi-pm angle). Three authors were contacted to obtain additional data [27, 30, 43]. Table 3 shows the assessments at T1 and T2 for each selected study.

The risk of bias in individual studies was assessed by two authors (RRN and OVV) according to the QUIPS tool [15], and the results are shown in Table 4. Within each domain, assessments were made for one or more items, covering different aspects of the domains or outcomes. The selected studies do not cite sample size calculation or blinding in their articles, and the method error of the measurements is described only in two studies [18, 43]. For one article [43], the small number of participants was considered a source of increased risk of bias in the study participation domain. Additionally, this article [43] used the experimental group from another study [1] and included a historical control group [3]. Two independent articles published in different journals [18, 27] used the same sample from a previous prospective cohort study [23]. This fact was considered to mean low risk of bias in the selection process. Therefore, we scored these studies as having low risk in this domain, too. All four studies reported their results adequately, thus, presenting low risk for most of bias domains, according to the QUIPS tool. Thus, all of the selected studies were classified as having low risk of bias.

The Grading of Recommendations Assessment, Development and Evaluation (GRADE) [16] table for systematic reviews of prognostic studies was also used to evaluate the quality of evidence of the selected studies (Table 5). According to this, the studies were judged as presenting very low quality of evidence. Four articles [18, 27, 30, 43] presented their measurements in a way that could be compared. Three authors [27, 30, 43] were contacted to obtain additional data, including the differences within each group (EG and CG) between T2 and T1. One article was excluded

Table 3 Comparison of the initial (T1) and final (T2) variables of the selected studies for the experimental group (EG) and the control group (CG). *SD* standard deviation

Tab. 3 Vergleich der Variablen in den eingeschlossenen Studien initial (T1) und bei Abschluss (T2) für die experimentelle Gruppe (EG) und die Kontrollgruppe (CG). *SD* Standardabweichung

Mattar et al. [30]	**Initial comparison of the variables (T1)—means (SD)**						
	Variables	**EG (T1)**		**CG (T1)**		***P***	
	SN-GoGn (°)	41.2 (4.8)		36.6 (4.8)		<0.001	
	ArGo-GoMe (°)	136.9 (3.6)		131.3 (3.2)		<0.001	
	SN.Gn (°)	70.8 (3.5)		69.2 (4.8)		ns	
	BaN.PtGn (°)	84.2 ± 3.9		88.2 ± 3.2		<0.0001	
	N-Me (mm)	100.1 (5.2)		99.2 (4.8)		ns	
	N-ANS (mm)	43.1 (2.9)		43.1 (2.8)		ns	
	ANS-Me (mm)	60.1 (3.8)		59.2 (3.5)		ns	
	Comparison of measurements between T1 and T2 for each group						
	Variables	**EG**		**CG**			
		T1	**T2**	***P***	**T1**	**T2**	***P***
	SN-GoGn (°)	41.2 (4.8)	38.8 (5.1)	<0.0001	36.6 (4.8)	36.6 (5.3)	ns
	ArGo-GoMe (°)	136.9 (3.6)	133.4 (3.6)	<0.0001	131.3 (3.2)	134.2 (5.4)	0.02
	SN.Gn (°)	70.8 (3.5)	69.6 (3.5)	<0.0031	69.2 (4.8)	69.1 (5.2)	ns
	BaN.PtGn (°)	84.2 ± 3.9	86.0 ± 3.9	<0.0001	88.2 ± 3.2	89.0 ± 3.0	ns
	N-Me (mm)	100.1 (5.2)	105.6 (5.1)	<0.0001	99.0 (4.8)	105.5 ()	<0.0001
	N-ANS (mm)	43.1 (2.9)	46.4 (3.1)	<0.0001	43.1 (2.8)	46.7 (2.7)	<0.0001
	ANS-Me (mm)	60.1 (3.8)	62.2 (3.3)	<0.0001	59.2 (3.5)	61.4 (4.1)	<0.0004
	Comparison of the variation of the measures within each group between T2 and T1						
	Variables	**EG T2–T1**		**CG T2–T1**		***P***	
	SN-GoGn (°)	–2.3 (2.6)		0.0 (3.0)		0.004	
	ArGo-GoMe (°)	–3.5 (2.6)		2.9 (5.4)		<0.0001	
	SN.Gn (°)	–1.2 (2.1)		–0.1 (1.9)		ns	
	BaN.PtGn (°)	1.9 ± 2.3		0.8 ± 2.1		ns	
	N-Me (mm)	5.5 (2.8)		6.5 (3.6)		ns	
	N-ANS (mm)	3.3 (1.6)		3.5 (2.0)		ns	
	ANS-Me (mm)	2.1 (2.1)		2.2 (2.4)		ns	
	Comparison of cephalometric measurements of EG and CG in T2 (means)						
	Variables	**EG**		**CG**		***P***	
	SN-GoGn (°)	38.8 (5.1)		36.6 (5.3)		ns	
	ArGo-GoMe (°)	133.4 (3.6)		134.2 (5.4)		ns	
	SN.Gn	69.6 (3.5)		69.1 (5.2)		ns	
	BaN.PtGn (°)	86.6 ± 3.9		89.0 ± 3.0		0.004	
	N-Me (mm)	105.6 (5.1)		105.5 (5.5)		ns	
	N-ANS (mm)	46.4 (3.1)		46.7 (2.7)		ns	
	ANS-Me (mm)	62.2 (3.3)		61.4 (4.1)		ns	

SN-GoGn mandibular plane inclination, *ArGo-GoMe* gonial angle, *SN.Gn* face growth direction, *BaN-PtGn* variation in anterior face height and face depth, *N-Me* total anterior face height, *N-ANS* upper anterior face height, *ANS-Me* lower anterior face height, *ns* not significant

[18] from the meta-analysis as we were unable to contact the authors. However, as these authors reported their results adequately, we included their work in the discussion. Table 6 shows the differences in the EG and CG means at the initial (T1) and final (T2) evaluations. The studies reported significant differences between the two time points. To perform the meta-analysis, they were selected according to the units for mandibular plane inclination (°) and for total, upper and lower AFH (mm).

Our meta-analysis demonstrated nonsignificant heterogeneity for the studies included in the analysis of mandibular plane (Fig. 2). For total AFH the analysis presented a tendency towards an overall but low effect (Fig. 3). Although heterogeneity was also low between studies for the analysis of upper (Fig. 4) and lower AFH (Fig. 5), the over-

Table 3 (Continued)
Tab. 3 (Fortsetzung)

Zettergren et al. [43]

Cephalometric differences angular (°), linear (mm) variables, means (SD) and proportions (%) at baseline values between EG and CG

Variables	**EG**	**CG**	**Mean differences**	***P***
ML/NSL (°)	38.0 (4.41)	33.5 (4.42)	4.5 (6.50)	<0.05
sp′-gn′ (mm)	53.4 (3.57)	50.9 (3.12)	2.5 (4.68)	<0.05
n′-gn′(mm)	92.0 (5.49)	90.7 (4.98)	1.3 (5.56)	ns
s′-p′/n′-gn′ (%)	58 (1.95)	56.2 (2.25)	1.8 (2.87)	<0.05

Cephalometric differences angular (°), linear (mm) variables, means (SD) and proportions (%) at 5 years follow-up

Variables	**EG**	**CG**	**Mean differences**	***P***
ML/NSL (°)	34.4 (4.91)	31.9 (4.97)	2.5 (7.62)	0.184 ns
sp′-gn′ (mm)	58.7 (4.36)	56.3 (3.47)	2.4 (6.44)	0.139 ns
n′-gn′ (mm)	103.9 (5.37)	102.4 (4.77)	1.5 (6.53)	0.343 ns
sp′-gn′/n′-gn′ (%)	56.5 (2.54)	55 (2.04)	1.5 (3.69)	0.113 ns

ML/NSL mandibular plane inclination, *n′-gn′* total anterior face height, *sp′-gn″* lower anterior face height, *sp′-gn′/n′-gn′* ratio of lower anterior face height to total anterior face height, *ns* not significant

Mahony et al. [27]

Comparison of means between the experimental group (EG) and control (CG)

Variables	**EG T1–CG T1** ***n*** **= 45–*n*** **= 35**	***P***	**EG T2–CG T2** ***n*** **= 36–*n*** **= 30**	***P***
N-ANS (mm)	46.3 (3.09)–45.3(3.57)	ns	52.4 (3.24)–51.2 (3.75)	ns
ANS-Me (mm)	62.7 (4.79)–58.7 (3.70)	<0.001	68.4 (6.48)–63.8 (4.68)	<0.01
N-ANS/ANS-Me (%)	0.72 (0.06)–0.78 (0.07)	<0.001	0.78 (0.07)–0.8 (0.06)	ns

Association between changes in the variables and the nasal breathing pattern in both groups (T2)

Variables	***N***	***P***
N-ANS (mm)	65	ns
ANS-Me (mm)	66	ns
N-ANS/ANS-Me (%)	65	<0.01

N-ANS upper anterior face height, *ANS-Me* lower anterior face height, *N-ANS/ANS-Me* ratio of upper anterior face height to lower anterior face height, *N* individuals showing nasal breathing pattern in T2, *ns* not significant

Kerr et al. [18]

Comparisons between the mean differences in variables of the experimental group (EG) and control (CG)

Variables	**(T1)**	***P***	**1 year**	***P***	**5 years (T2)**	***P***
ML/SNL (°)	3.27 (6.88)	<0.5	2.40 (7.12)	ns	2.30 (8.51)	ns
sn.me (mm)	2.77 (5.99)	<0.05	3.09 (5.70)	<0.01	3.34 (7.62)	<0.5
n.me (mm)	4.47 (7.02)	<0.01	4.22 (7.44)	<0.01	5.04 (9.54)	<0.01
cd-Xi/Xi-pm (°)	0.48 (6.43)	ns	0.98 (7.07)	ns	1.94 (6.15)	ns
Xi-pm (mm)	0.73 (3.25)	ns	1.14 (3.51)	ns	2.53 (4.27)	<0.01

ML/SNL mandibular plane inclination, *sn.me* lower anterior face height, *n.me* total anterior face height, *Xi-pm* mandibular body length, *cd-Xi/Xi-pm* mandibular arch, *ns* not significant

Table 4 The risk of bias in individual studies according to the QUIPS tool

Tab. 4 Bias-Risiko in den einzelnen Studien entsprechend dem QUIPS-Tool

	Mattar et al. [30]	Zettergren et al. [43]	Mahony et al. [27]	Kerr et al. [18]
Domains				
1. Study Participation	++	+++	+	+
2. Study Attrition	++	+	+	+
3. Prognostic Factor Measurement	+	+	+	+
4. Outcome Measurement	+	+	+	+
5. Study Confounding	+	+	+	+
6. Statistical Analysis and Reporting	+	+	+	+
Rattings	*Moderate*	*Low*	*Low*	*Low*

QUIPS Quality in Prognosis Studies

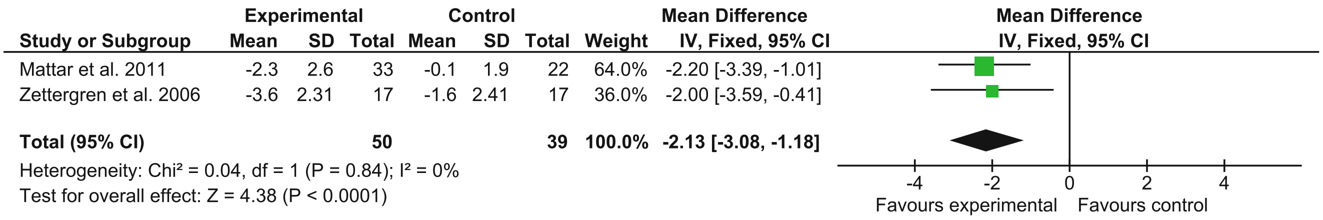

Fig. 2 Forest plot of the changes in the mandibular plane angle between initial (T1) and final (T2) measurements

Abb. 2 Forest-Plot der Veränderungen des Winkels der Unterkieferebene Studien, Messungen initial (T1) und bei Abschluss (T2)

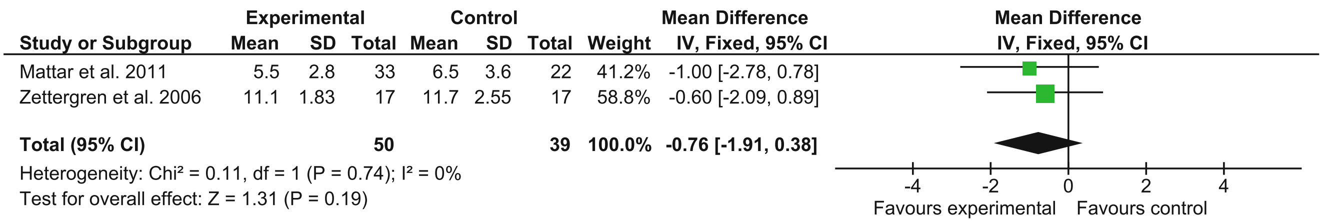

Fig. 3 Forest plot of the changes in the total anterior face height (AFH) between initial (T1) and final (T2) measurements

Abb. 3 Forest-Plot der Veränderungen der gesamten vorderen Gesichtshöhe (AFH), Messungen initial (T1) und bei Abschluss (T2)

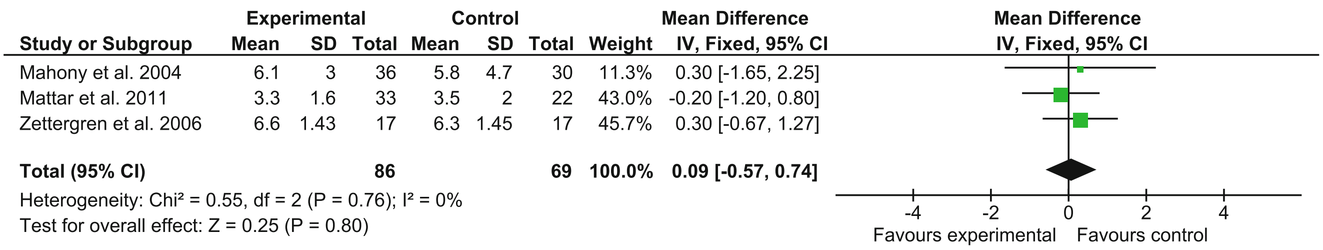

Fig. 4 Forest plot of the changes in the upper anterior face height (AFH) between initial (T1) and final (T2) measurements

Abb. 4 Forest-Plot der Veränderungen der oberen vorderen Gesichtshöhe (AFH), Messungen initial (T1) und bei Abschluss (T2)

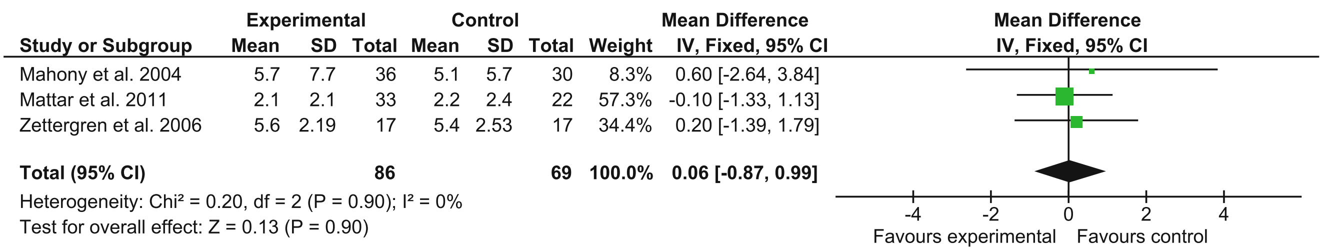

Fig. 5 Forest plot of the changes in the lower anterior face height (AFH) between initial (T1) and final (T2) measurements

Abb. 5 Forest-Plot der Veränderungen der unteren vorderen Gesichtshöhe (AFH), Messungen initial (T1) und bei Abschluss (T2)

Table 5 Quality of evidence of the selected studies according to an adapted Grading of Recommendations Assessment, Development and Evaluation (GRADE) for systematic reviews and meta-analysis

Tab. 5 Qualität der Evidenz der eingeschlossenen Studien entsprechend einer adaptierten Fassung des GRADE (Grading of Recommendations Assessment, Development and Evaluation) für systematische Reviews und Metaanalysen

Outcome: mandibular growth direction

Prognostic factors	Number of participants	Number of studies	Number of cohorts	Estimated effect size (95% CI)	GRADE factors: Phase	Study limitation	Inconsistency	Indirectness	Imprecision	Publication bias	Moderate/Large effect size	Overall quality
Mandibular plane inclination	89	2 [30, 43]	1	−2.13 [−3.08, −1.18]	2	X	✓	✓	UNCLEAR	✓	X	+
Total AFH	89	2 [30, 43]	2	−0.76 [−1.91, 0.38]	2	X	✓	✓	UNCLEAR	✓	X	+
Upper AFH	155	3 [27, 30, 43]	3	0.09 [−0.57, 0.74]	2	X	✓	✓	UNCLEAR	✓	X	+
Lower AFH	155	3 [27, 30, 43]	3	0.06 [−0.87, 0.99]	2	X	✓	✓	UNCLEAR	✓	X	+

AFH anterior facial height, *Phase* phase of investigation, *95% CI* 95% confidence interval

For GRADE factors: ✓ no serious limitations, *X* serious limitations (or not present for moderate/large effect size), *XX* very serious limitations, *UNCLEAR* unable to rate item based on available information

For overall quality of evidence: + very low, ++ low, +++ moderate, ++++ high

all effect for both analyses was nonsignificant. The article of Mahony et al. [27] was not included in the analysis for mandibular plane and total AFH, since their study did not evaluate these variables.

Discussion

RCTs are considered the optimal research design for being considered for systematic reviews. When assessing effects of surgical interventions, however, ethical reasons limit the use of this type of study design, since the patients have to be submitted to the best treatment available, and the interventions cannot be randomized in most of the cases. The present review focused on the prognosis for the facial growth direction (FGD) documented by changes of mandibular plane inclination and AFH in growing individuals who underwent surgical intervention to relieve mouth breathing. Only longitudinal studies provide acceptable prognostic evidence. Therefore, this review selected only longitudinal nonrandomized studies.

We followed a strict protocol to develop search strategies in accordance with the tutorial for each electronic database. The references of the articles obtained were screened, in order to identify articles that were not found in the databases, and experts were contacted. Only four longitudinal studies with significant samples were identified in the literature [18, 27, 30, 43], which is considered a limitation of this review. Three studies [18, 27, 43] were retrospective and one [30] was prospective. The follow-up time ranged from two [30] to five years [18, 27, 43]. Two independent studies [18, 27] used the same sample from a previous study [23]. As the authors searched different variables in each study, this review considered them as different studies. The small number of studies with significant samples and adequate follow-up time indicates the need for more well-designed research addressing the subject.

Three studies recruited participants to the experimental group from representative nose and mouth breathing individuals in the population [18, 27, 43]. Zettergren et al. [43] reported that the sample used in their study contained 17 subjects in the experimental group from a previous study [1], and the experimental and control groups were matched according to gender and chronological and dental age. According to the authors, it was impracticable to obtain a sufficient number of longitudinal cephalometric records of nasal-breathing Swedish children between 3 and 6 years of age, making it necessary to complete the control group with six records from a British longitudinal study [3]. This fact was a source of increased risk of bias in the study participation domain for this article [43]. Historical controls should be avoided, whenever possible, because this can lead to bias due to time–trend effects, e.g., baseline differences. The use

Table 6 Comparisons of mean differences between the initial (T1) and final (T2) measurements in the experimental group (EG) and control group (CG) for each prognostic factor

Tab. 6 Vergleich der durchschnittlichen Unterschiede der Messwerte für jeden Prognosefaktor initial (T1) und bei Abschluss (T2) für die experimentelle Gruppe (EG) und die Kontrollgruppe (CG)

	Author	Reference points	EG			CG		
			T1	T2	T2–T1	T1	T2	T2–T1
Mandibular plane	Mattar et al. [30]	SN.GoGn	41.2 (4.8)	38.8 (5.1)	–2.3 (2.6)	36.6 (4.8)	36.6 (5.3)	–0.1 (1.9)
	Zettergren et al. [43]	ML/NSL	38.0 (4.41)	34.4 (4.91)	–3.6 (2.31)	33.5 (4.42)	31.9 (4.97)	–1.6 (2.41)
Total AFH	Mattar et al. [30]	N-Me	100.1 (5.2)	105.6 (5.1)	5.5 (2.8)	99.0 (4.8)	105.5 (5.5)	6.5 (3.6)
	Zettergren et al. [43]	n′-gn′	92.0 (5.49)	103.9 (5.37)	11.1 (1.83)	90.7 (4.98)	102.4 (4.77)	11.7 (2.55)
Upper AFH	Mahony et al. [27]	N-ANS	46.3 (3.09)	52.4 (3.24)	6.1 (3.0)	45.3 (3.09)	51.2 (3.75)	5.8 (4.7)
	Mattar et al. [30]	N-ANS	43.1 (2.9)	46.4 (3.1)	3.3 (1.6)	43.1 (2.8)	46.7 (2.7)	3.5 (2.0)
	Zettergren et al. [43]	n′-sp′	38.6 (2.95)	45.2 (3.20)	6.6 (1.43)	39.7 (3.25)	46.1 (2.87)	6.3 (1.45)
Lower AFH	Mahony et al. [27]	ANS-Me	62.7 (4.79)	68.4 (6.48)	5.7 (7.7)	58.7 (3.70)	63.8 (4.68)	5.1 (5.7)
	Mattar et al. [30]	ANS-Me	60.1 (3.8)	62.2 (3.3)	2.1 (2.1)	59.2 (3.5)	61.4 (4.1)	2.2 (2.4)
	Zettergren et al. [43]	sp′-gn′	53.4 (3.57)	58.7 (4.36)	5.6 (2.19)	50.9 (3.12)	56.3 (3.47)	5.4 (2.53)

AFH anterior facial height

of concurrent controls allows fair comparisons between the groups, and more valid results. Nonetheless, for the most bias domains, this study [43] presented low risk of bias.

The results and measurements across the studies were consistent for all four selected articles. The included articles were considered to be phase 2 explanatory research aimed to confirm associations between prognostic factors and the outcome, according to the Grading of Recommendations Assessment, Development and Evaluation (GRADE) [16]. The mandibular plane inclination [18, 30, 43] and the AFH [18, 27, 30, 43] were assessed as prognostic factors to evaluate the FGD after relief of mouth breathing in growing individuals. According to the tools to assess the risk of bias and the quality of evidence, the selected studies evaluating changes in these variables as prognostic factors for changes in the FGD were judged to involve no serious limitations. This evidence comes from two studies [18, 27] that presented low risk for all six items, one study [43] that showed low risk of bias for five items, and one study [30] presenting low risk of bias for four items according to the QUIPS tool. However, according to GRADE [16], the selected studies were judged as showing very low evidence related to the analysis of AFH [27, 30, 43] and of mandibular plane inclination [30, 43]. For the meta-analysis, we excluded one article [18], since we could not contact the authors to obtain data related to the mean differences between the initial and final measurements in the EG and CG for the prognostic factors.

The meta-analysis showed a significant overall effect for the studies included that measured changes in mandibular plane inclination (95% confidence interval [CI], –2.13° [–3.08, –1.18]). Thus, we concluded that there is a relationship between this variable and FGD. At T1, these studies [30, 43] reported significant differences in mandibular plane inclination between the experimental and control groups. Zettergren et al. [43] found a mean difference of 4.5° between the two groups ($P<0.05$), while Mattar et al. [30] reported 4.6° ($P<0.001$). At the 5-year follow-up, Zettergren et al. [43] reported a difference of 2.5° [41], and Mattar et al. [30] found a mean difference of 2.2° at the 28-month follow-up. It can be inferred that the differences, detected at T1 between the EG and CG, were no longer existent after the EG interventions and did not to differ significantly at T2. In addition, the study of Kerr et al. [18], which was not included in the meta-analysis, also reported a decrease in the mandibular plane inclination in relation to the SN line in the EG at 5 years after surgery. According to these authors, this angular variable ceased to differ significantly at T2 between the EG and CG, suggesting that an establishment of a nasal breathing pattern has a favourable effect, producing an anterior rotation of the mandibular plane. Although cross-sectional studies are not appropriate to assess causes and consequences, the results of the present meta-analysis related to changes of mandibular plane angle are in agreement with several previous research [2, 4, 6, 8–12, 17, 20, 28, 29, 31, 32, 39, 44].

For the total, upper and lower AFH, the heterogeneity between the studies was considered nonsignificant ($\chi^2 = 0.11$; $P = 0.74$). Two studies were included in the analysis of total AFH [30, 43]. Mattar et al. [30] compared the values for AFH for the EG (100.1) and for the CG (99.0) at T1 and found no significant difference. At T2, the two groups remained without statistical difference (105.6 and 105.5, respectively), although both groups had presented a significant increase for this variable ($P < 0.0001$). According to Zettergren et al. [43], in their patients AFH in the EG was greater when compared to the CG at T1 (92.0 and 90.7), although this difference was not significant. Five-years after surgery, this variable increased proportionally for both groups (103.9 and 102.4) which was also not significantly difference. For total AFH, despite the meta-analysis presenting only a small overall effect (Z = 1.31; $P = 0.19$), it showed a tendency towards an improvement for this variable (95% CI –0.76 [–1.91, 0.38]) after treatment in the EG.

Heterogeneity was also low between studies when analyzing upper and lower AFH, but the overall effect for both analyses was nonsignificant (Z = 0.25, $P = 0.80$ and Z = 0.13, $P = 0.90$, respectively). Mattar et al. [30] reported nonsignificant differences for lower AFH between the EG and CG at T1 and T2. Mahony et al. [27] observed significant differences for the lower AFH between the EG and CG at T1 (62.7 and 58.7, $P < 0.001$) and at T2 (68.4 and 63.8, $p < 0.01$), which was higher for the EG at both times. During the follow-up period, the EG and the CG demonstrated significant increases of this variable. This difference between the two groups remained significant at T2, but it did not increase. Zettergren et al. [43] found a significant, but smaller, difference between the groups for lower AFH at T1 (2.5, $P < 0.05$), with the EG presenting higher values. At T2, the authors reported that this difference had decreased to a nonsignificant statistic value (2.4, $P = 0.139$).

When assessing the ratio between lower and total AFH, Zettergren et al. [43] observed that this value was significantly greater in the EG (1.8, $P < 0.05$) at T1. According to these authors, initially, the mean difference for mandibular plane inclination between the EG and CG (4.5, $P < 0.05$) was paralleled by a significantly higher lower AFH and lower AFH ratio in the experimental group. At the 5-year follow-up, mandibular plane inclination showed a reduced difference between the two groups (2.5, $P = 0.184$), and both groups also showed smaller differences for lower AFH and AFH (2.4, $P = 0.139$ and 1.5, $P = 0.113$, respectively). The difference for total AFH between the two groups remained nonsignificant at the 5-year follow-up (1.5, $P = 0.343$). Mahony et al. [27] reported that the proportion of upper and lower AFH (N-ANS/ANS-Me) at T1 was significantly larger in the CG (0.78) compared to the EG (0.72, $P < 0.001$), but no significant difference was found after the follow-up period. According to these authors, the lower AFH (the denominator in the ratio) which was increased at the EG in T1 was the main cause of this finding. This difference disappeared during the follow-up period, as a consequence of changing the mode of breathing from oral to nasal.

Kerr et al. [18] reported initial significant differences for total (4.47, $P < 0.01$) and lower AFH (2.77, $P < 0.05$) between the EG and the CG. According to their study, these differences between the groups remained significant until the end of the follow-up period (5.04, $P < 0.01$ and 3.34, $P < 0.05$, respectively). These results showed that the differences between the groups for lower and total AFH at T1 continued to exist at T2. Interestingly, by analyzing the BaN-PtGn angle, Mattar et al. [30] observed that, at T1, the EG was diagnosed to present a predominantly dolichofacial pattern when compared to the CG (84.2 and 88.2, $P < 0.0001$). At T2, this variable remained significantly different between the two groups (86.0 and 89.0, $P < 0.04$), demonstrating the persistence of a dolichofacial pattern in the patients, even after relief of the breathing pattern. However, a comparison between T1 and T2 in the EG demonstrated a significant decrease of this variable (84.2 and 86, $P < 0.0001$). These findings suggest that the relief of mouth breathing had a favorable effect both on a reduction of facial angle and in preventing a more pronounced increase of the AFH. This fact is supported by a trend to normalization of total AFH observed in the meta-analysis, although this result did not show a high overall effect. For this review, there is moderate evidence for the existence of a relationship between total AFH and FGD. Therefore, we upgraded the evidence to moderate effect sizes for this variable.

It is important to highlight that in a cohort study not included in this review, Linder-Aronson [25] demonstrated that some children may experience some spontaneous recovery from adverse skeletal characteristics, such as increased mandibular plane angles. According to his work, these changes were more evident during the first year after normalization of the breathing pattern. The changes continued for the 5 years of follow-up but did not reach the results of the control group. His findings are in agreement with other longitudinal studies [18, 22, 43], where in the experimental groups a comparison of cephalometric records showed that the largest changes in FGD occurred in the first postoperative year. In the following years, despite continuing to be favorable, these changes were less expressive.

Another important aspect is related to the age ranges of the studied samples. The individuals of the included studies in this meta-analysis ranged from 4.8 to 7.5 years at T1, and 7.2 to 10.7 years at T2. Older individuals typically present more significant and visible changes in facial growth than young children. This also may explain the low or nonsignificant overall effects for the total, upper and lower AFH in the present meta-analysis.

In summary, we agree with Vargervik et al. [38] and Tomer and Harvold [35] who stated that an altered breathing pattern may be, at least, a predisposing factor for the development of differences in facial growth, due to an influence on tongue, jaw and head posture during the development phase.

- *Implications for practice:*
  The estimated impact of the breathing pattern on facial growth direction and its magnitude has varied from one study to another. The cost-effectiveness of interventions to normalize the breathing pattern in growing individuals has also been controversially discussed. The three studies selected in this meta-analysis confirm a low, but existent association between the normalization of the breathing pattern and an establishment of a more favorable facial growth direction.
- *Implications for research:*
  According to GRADE, inclusion of nonrandomized controlled trials, without blinding, downgraded the overall quality of the selected studies in the present review. Moreover, only a few studies—mostly with a small number of participants—exist. In addition, sample size calculation was not performed in most of the included articles. This implies that imprecision may play an important role and may decrease the quality level of evidence. However, we established that an exposure–response gradient existed between the studies. The studies used the same measures to assess the variables and outcomes, which made a meta-analysis possible. Due to the small number of studies with significant samples found in the literature, this systematic review recommends further trials. These studies should focus on prospective larger controlled trials using samples with concurrent controls. Precalculation of the sample size is recommended, aimed at answering the proposed questions for habitual clinical practice with adequate statistical power. Another limitation is related to the produced radiographs. One study [27] mentioned that the image enlargement was 6.5%, but the data were not corrected for that magnification. Another one [43] cited that the radiographs were performed at three different centers, showing 6.4, 6.5 and 7.8% of magnification, respectively, and that all linear measurements were adjusted according to this enlargement. However, the authors did not report the method used for this adjustment. The image magnification was cited in two more articles, but the authors did not offer information about the extent of distortion [18, 30]. Future authors are encouraged to standardize their study protocols, such as calibration and blinding, when feasible. Finally, the statistical analysis should not interpret trials results based solely on P values, but should quote confidence intervals to report the range of treatment effects.

Conclusions

- The present review and meta-analysis concluded that there is evidence, although very low, to infer that when the breathing pattern changes from oral to nasal in developing individuals, mandibular plane inclination decreases significantly. With regard to total AFH, the relief of mouth breathing had a favorable effect by preventing more pronounced increases of this variable.
- Positive effects on mandibular plane inclination were observed primarily during the first postoperative year after interventions to normalize the breathing pattern. Thus, our paper points out that medical and dental specialties should recognize that early diagnosis and treatment creating normalization of the breathing pattern play an important role in facial development in growing individuals.

Conflict of interest R.R. do Nascimento, D. Masterson, C. Trindade Mattos and O. de Vasconcellos Vilella declare that they have no competing interests.

References

1. Agren K, Nordlander B, Linder-Aronson S, Zettergren-Wijk L, Svanborg E (1998) Children with nocturnal upper airway obstruction: postoperative orthodontic and respiratory improvement. Acta Otolaryngol 118:581–587
2. Arun T, Isik F, Sayiunsu K (2003) Vertical growth changes after adenoidectomy. Angle Orthod 73:146–150
3. Bathia SN, Leighton BC (1993) A manual of facial growth: a computer analysis of longitudinal cephalometric growth data. Oxford University Press, Oxford
4. Baumann I, Plinkert PK (1996) The influences of breathing modes and nasal ventilation in craniofacial development. HNO 44:229–234
5. Behlfelt K, Linder-Aronson S, Neander P (1990) Posture of the head, the hyoid bone, and the tongue in children with and without enlarged tonsils. Eur J Orthod 12:458–467
6. Bresolin D, Shapiro GG, Shapiro PA, Dassel SW, Furukawa CT, Pierson WE, Chapko M, Bierman CW (1984) Facial characteristics of children who breathe through the mouth. Pediatrics 73:622–625
7. Bresolin D, Shapiro PA, Shapiro GG, Chapko MK, Dassel S (1983) Mouth breathing in allergic children: its relationship to dentofacial development. Am J Orthod 83:334–340
8. Brunelli V, Lione R, Franchi L, Cozza P, Becker HM, Franco LP, Souki BQ (2016) Maxillary dentoskeletal changes 1-year after adenotonsillectomy. Int J Pediatr Otorhinolaryngol 86:135–141
9. Caprioglio A, Zucconi M, Calori G, Troiani V (1999) Habitual snoring, OSA and craniofacial modification. Orthodontic clinical and diagnostic aspects in a case control study. Minerva Stomatol 48(4):125–137
10. Cheng MC, Enlow DH, Papsidero M, Broadbent BH Jr., Oyen O, Sabat M (1988) Developmental effects of impaired breathing in the face of the growing child. Angle Orthod 58:309–320

11. Chung Leng Muñoz I, Beltri Orta P (2014) Comparison of cephalometric patterns in mouth breathing and nose breathing children. Int J Pediatr Otorhinolaryngol 78:1167–1172
12. Deng J, Gao X (2012) A case-control study of craniofacial features of children with obstructed sleep apnea. Sleep Breath 16:1219–1227
13. Dunn GF, Green LJ, Cunat JJ (1973) Relationships between variation of mandibular morphology and variation of nasopharyngeal airway size in monozygotic twins. Angle Orthod 43:129–135
14. Faria PT, de Oliveira Ruellas AC, Matsumoto MA, Anselmo Lima WT, Pereira FC (2002) Dentofacial morphology of mouth breathing children. Braz Dent J 13:129–132
15. Hayden JA, van der Windt DA, Cartwright JL, Côté P, Bombardier C (2013) Assessing bias in studies of prognostic factors. Ann Intern Med 158:280–286
16. Huguet A, Hayden JA, Stinson J, McGrath PJ, Chambers CT, Tougas ME, Wozney L (2013) Judging the quality of evidence in reviews of prognostic factor research: adapting the GRADE framework. Syst Rev 2(1):71. https://doi.org/10.1186/2046-4053-2-71
17. Kawashima S, Peltomäki T, Sakata H, Mori K, Happonen RP, Rönning O (2002) Craniofacial morphology in preschool children with sleep-related breathing disorder and hypertrophy of tonsils. Acta Pediatr 91(1):71–77. https://doi.org/10.1080/080352502753457996
18. Kerr WJS, McWilliam JS, Linder-Aronson S (1989) Mandibular form and position related to changed mode of breathing—A five-year longitudinal study. Angle Orthod 2:91–96
19. Kluemper GT, Vig PS, Vig KW (1995) Nasorespiratory characteristics and craniofacial morphology. Eur J Orthod 17:491–495
20. Lessa FC, Enoki C, Feres MF, Valera FC, Lima WT, Matsumoto MA (2005) Breathing mode influence in craniofacial development. Braz J Otorhinolaryngol 71:156–160
21. Liberati A, Altman DG, Tetzlaff J, Mulrow C, Gotzsche PC, Ioannidis JPA, Clarke M, Devereaux PJ, Kleijnen J, Moher D (2009) The PRISMA statement for reporting systematic reviews and Meta-analysis of studies that evaluate health care interventions: explanation and elaboration. PLoS Med 6(7):1–28. https://doi.org/10.1371/journal.pmed.1000100
22. Linder-Aronson S, Woodside DG, Lundströn A (1986) Mandibular growth direction following adenoidectomy. Am J Orthod 89:273–284
23. Linder-Aronson S (1970) Adenoids. Their effect on mode of breathing and nasal airflow and their relationship to characteristics of the facial skeleton and the dentition. A biometric, rhino-manometric and cephalometro-radiographic study on children with and without adenoids. Acta Otolaryingol Suppl 265:1–132
24. Linder-Aronson S (1974) Effects of adenoidectomy on dentition and nasopharynx. Am J Orthod 65:1–15
25. Linder-Aronson S (1975) Effects of adenoidectomy on the deviation and facial skeleton over a period of five years. In: Cook JT (ed) Transactions of the Third International Orthodontic Congress. Crosby Lockwood Staples, London, pp 85–100
26. Lundström A, Woodside DG (1980) Individual variation in growth directions expressed at the chin and the midface. Eur J Orthod 2:65–79
27. Mahony D, Karsten A, Linder-Aronson S (2004) Effects of adenoidectomy and changed mode of breathing on incisor and molar dentoalveolar heights and anterior face heights. Aust Orthod J 20:93–98
28. Malhotra S, Pandey RK, Nagar A, Agarwal SP, Gupta VK (2012) The effect of mouth breathing on dentofacial morphology of growing child. J Indian Soc Pedod Prev Dent 30:27–31
29. Mattar SEM, Anselmo-Lima WT, Valera FCP, Matsumoto MA (2004) Skeletal and occlusal characteristics in mouth-breathing pre-school children. J Clin Pediatr Dent 28:315–318
30. Mattar SEM, Valera FCP, Faria G, Matsumoto MAN, Anselmo-Lima WT (2011) Changes in facial morphology after adenotonsillectomy in mouth breathing children. Int J Paediatr Dent 21:389–396
31. Özdemir H, Altin R, Sögüt A, Cinar F, Mahmutyazicioglu K, Kart L, Uzun L, Davsanci H, Gungogdu S, Tomac N (2004) Craniofacial differences according to AHI scores of children with obstructive sleep apnoea syndrome: cephalometric study in 39 patients. Pediatr Radiol 34:393–399
32. Rossi RC, Rossi NJ, Rossi NJ, Yamashita HK, Pignatari SS (2015) Dentofacial characteristics of oral breathers in different ages: a retrospective case-control study. Prog Orthod 16:23
33. Schardt C, Adams MB, Owens T, Keitz S, Fontelo P (2007) Utilization of the PICO framework to improve searching PubMed for clinical questions. Bmc Med Inform Decis Mak 7:16. http://www.biomedcentral.com/1472-6947/7/16
34. Shanker S, Fields HW, Beck FM, Vig PS, Vig KW (2004) A longitudinal assessment of upper respiratory function and dentofacial morphology in 8- to 12-year-old children. Semin Orthod 10:45–53
35. Tomer BS, Harvold EP (1982) Primate experiments on mandibular growth direction. Am J Orthod 82:114–119
36. Trask GM, Shapiro GG, Shapiro PA (1987) The effects of perennial allergic rhinitis on dental and skeletal development: A comparison of sibling pairs. Am J Orthod Dentofacial Orthop 92:286–293
37. Ung N, Koenig J, Shapiro PA, Shapiro G, Trask G (1990) A quantitative assessment of respiration patterns and their effects on dentofacial development. Am J Orthod Dentofacial Orthop 98:523–532
38. Vargevik K, Miller AJ, Chierici G, Harvold E, Tomer BS (1985) Morphologic response to changes in neuromuscular patterns experimentally induced by altered mode of respiration. Am J Orthod 85:115–124
39. Vieira BB, Itikawa CE, de Almeida LA, Sander HS, Fernandes RMF, Anselmo-Lima WT, Valera FCP (2011) Cephalometric evaluation of facial pattern and hyoid bone position in children with obstructive sleep apnea syndrome. Int J Pediatr Otorhinolaryngol 75:383–386
40. Vig KWL (1988) Nasal obstruction and facial growth: the strength of evidence for clinical assumptions. Am J Orthod Dentofacial Orthop 113:603–611
41. Watson RM, Warren DW, Fischer ND (1968) Nasal resistance, skeletal classification and mouth breathing in orthodontic patients. Am J Orthod 54:367–379
42. Woodside DG, Linder-Aronson S, Lundströn A, McWilliam J (1991) Mandibular and maxillary growth after changed mode of breathing. Am J Orthod Dentofacial Orthop 100:1–18
43. Zettergren-Wijk L, Forsberg CM, Linder-Aronson S (2006) Changes in dentofacial morphology after adeno-tonsilectomy in young children with obstructive sleep apnea—a 5-year follow-up study. Eur J Orthod 28:319–326
44. Zucconi M, Caprioglio A, Ferini-Strambi L, Oldani A, Castronovo C, Smirne S (1999) Craniofacial modifications in children with habitual snoring and obstructive sleep apnea: a case-control study. Eur Respir J 13:411–417