Universidad Católica de Valencia

"San Vicente Mártir"

The Role of Mouth Breathing in Growing Patients on the Sagittal Skeletal Malocclusion & Craniofacial Morphology

SYSTEMATIC REVIEW AND META-ANALYSIS

FINAL DEGREE THESIS DENTISTRY

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THESIS

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Abstract

Introduction: Skeletal Sagittal Malocclusions and Craniofacial deformities are conditions that are receiving raising awareness mainly due to enhanced consciousness and social media. The impact on the individual's life quality can range from mild to substantial depending on the severity of the disorders. Behaviour patterns that are believed to affect the integrity of the Craniofacial morphology are oral habits like Mouth breathing

Objectives: Investigate the effects of mouth breathing on sagittal skeletal malocclusion and craniofacial morphology in growing patients

Materials and Methods: A systematic literature search was conducted on PubMed, Cochrane Library, and SCOPUS. The PICO question was: "Does mouth breathing cause craniofacial deformities and sagittal skeletal malocclusions in growing patients?". The meta-analysis was performed using R 4.3.1 (R Core Team, 2018) software with the chosen studies.

Results: 642 articles were identified from the initial search, of which 11 met the inclusion criteria. Only two articles found a significant correlation between mouth breathing and the ANB angle, indicating skeletal class II malocclusion. Three articles reported different maxillary and mandibular positions relative to the cranial base in mouth breathers. While no clear correlation was found between mouth breathing and sagittal skeletal malocclusion in most articles, the meta-analysis showed a tendency towards bimaxillary retrusion and similar skeletal patterns. Increased facial height, mandibular backward and downward rotation, narrower dental arches, and open bite were more significant findings in mouth breathers regarding craniofacial morphology alterations.

Conclusion: The review did not show a clear correlation between mouth breathing and sagittal skeletal malocclusion (ANB $p=0.704$). However, the meta-analysis indicated bimaxillary retrusion in mouth breathers, shown by significantly lower SNA and SNB angles ($p=0.022$ and $p<0.001$, respectively). Mouth breathing significantly impacts other anatomic landmarks of the craniofacial structures.

Keywords: mouth breathing, oral habits, skeletal sagittal malocclusions, craniofacial deformities

Resumen

Introducción: Las maloclusiones esqueléticas sagitales y las deformidades craneofaciales reciben creciente atención debido a una mayor concienciación y los medios de comunicación social. El impacto en la calidad de vida del individuo puede variar de leve a sustancial según la gravedad de los trastornos. Un comportamiento que se cree afecta la morfología craneofacial son los hábitos orales, como la respiración bucal.

Objetivos: Investigar los efectos de la respiración bucal en la maloclusión esquelética sagital y en la morfología craneofacial en pacientes en crecimiento.

Materiales y Métodos: Se realizó una búsqueda bibliográfica sistemática en PubMed, Cochrane Library y SCOPUS. La pregunta PICO fue "¿La respiración bucal causa deformidades craneofaciales y maloclusiones esqueléticas sagitales en pacientes en crecimiento?". El metaanálisis se realizó utilizando el software R 4.3.1 (R Core Team, 2018) y los estudios elegidos para combinar los datos.

Resultados: De 642 artículos encontrados, 11 cumplieron los criterios de inclusión. Solo en dos artículos se encontró una correlación significativa entre la respiración bucal y el ángulo ANB, indicando maloclusión de clase II esquelética. Tres artículos señalaron una posición maxilar y mandibular diferente en relación con la base craneal en respiradores bucales. Aunque no se pudo determinar una correlación clara entre la respiración bucal y la maloclusión esquelética sagital en la mayoría de los artículos, el metaanálisis mostró una tendencia hacia la birretrusión de los maxilares y un patrón esquelético similar. Los hallazgos más significativos en respiradores bucales fueron el aumento de la altura facial, la rotación mandibular hacia atrás y abajo, el estrechamiento de las arcadas dentales y la mordida abierta.

Conclusiones: La revisión no señaló una clara correlación entre la respiración bucal y la maloclusión esquelética sagital (ANB $p=0{,}704$). Sin embargo, el metaanálisis indicó retrusión bimaxilar en los respiradores bucales, evidenciada por ángulos SNA y SNB significativamente más bajos ($p=0{,}022$ y $p<0{,}001$, respectivamente). La respiración bucal tiene un impacto significativo en otros puntos de referencia anatómicos de las estructuras craneofaciales.

Palabras clave: respiración bucal, hábitos orales, maloclusiones esqueléticas sagitales, deformidades craneofaciales

List of Abbreviations

Term	Meaning
Occlusion (normoclusion)	Ideal alignment of teeth and jaws resulting in normal occlusion and function **Static**: shape and alignment of teeth between arches and supporting structures **Dynamic**: holistic function of stomatognathic apparatus
Malocclusion	Any anomaly from normoclusion beyond accepted normal deviations Skeletal: anomalies origins in basal bone Dental: anomalies origins in the alignment of teeth
Stomatognathic apparatus	Collective term for the structures involved in chewing, swallowing, and speech, including the jaws, teeth, and associated muscles and ligaments
Crossbite	Upper teeth occlude inside lower teeth
Scissorbite	Upper teeth occlude buccally of lower, and they do not touch
Openbite	Lack of vertical overlap between upper and lower teeth
Deepbite	Excessive vertical overlap of upper teeth over lower teeth.
Crowding	Insufficient space for teeth resulting in overlapping or misalignment
Diasthema/Spacing	Gaps or spaces between teeth, often due to size discrepancies or missing teeth
Preventive	Before condition emerges
Interceptive	While the condition is emerging
Corrective	After the condition has been established
Growth modification	Orthodontic treatment aimed at altering the growth patterns of the jaws to achieve improved facial harmony and dental alignment

Cephalometry	Craniometry + Anthropometry
Transversal	Oriented across the width of the body or a body part
Sagittal	Oriented from front to back, dividing the body into left and right sides
Vertical	Oriented up and down, perpendicular to the ground or horizon
Frankfurt plane	Imaginary horizontal plane passing through the superior margin of the external auditory meatus and the lower margin of the left orbit. Commonly used as a reference plane
Centre of ossification	Point within a bone where the formation of bone tissue, begins during skeletal development
Endochondral ossification	Within cartilage (length, genetic)
Intramembranous ossification	With a membrane (diameter, environmental)
WHO	World Health Organization
Recessive	Genetic trait or disorder that is expressed only when two copies of the recessive allele are present
Dominant	Genetic trait or disorder that is expressed when one copy of the dominant gene is present, often overshadowing recessive traits.
AAPD	American Association of Paediatric Dentistry

I. INTRODUCTION

1. Concepts of Malocclusion

According to the World Health Organization malocclusion represents the third most common oral health problem after dental caries and periodontal diseases. (1) The classification of the understanding of malocclusion was established by Edward Angle who is considered the father of modern orthodontics. He described a normal and healthy occlusion as follows: ''*The upper first molars are the key to occlusion and the upper and lower molars should be related so that the mesiobuccal cusp of the upper molar occludes in the buccal grove of the lower molar" (E. Angle,1900)*. He published his classification in Roman numerals consisting of malocclusions class I, II, and III, where class II is divided into subdivisions 1 and 2 with Arabic numbers (2), This system constitutes a universal way of communication and categorization for a proper diagnosis and treatment planning among orthodontic practitioners. It should not be unmentioned that this classification is primarily based on the relationship between mandibular and maxillary first molars and does not include other existing terms and conditions of malocclusions. The orthodontic field of study encompasses various other characteristic parameters of malocclusion which can affect an individual and cause the fall below or exceed the cephalometric harmony at the dental and skeletal level within its average norm as defined by Cecil Steiner and Robert Rickets. Moving out of the balanced norm can have mild to severe consequences for an affected person regarding the functionality of the stomatognathic apparatus, structural balance and integrity of muscles, bones, and aesthetic appearance of the face. The latter is currently experiencing high and gradually increasing attention, which is being driven by greater awareness within the population and, among other things, through the importance of social media. Even if beauty is the responsibility of the eye of the beholder, society or culture sets a certain corridor of the ideal which forces to clearly illustrate the perception of an agreeable normal, and attractive physical appearance. Conditions of malocclusion do not constitute a disease in the classical sense but rather an anatomical variation that may or may not create a morbid condition. Our current understanding of malocclusion characterizes malocclusion as ''*Malrelationship between the arches in any of the planes or in which there are* *anomalies in tooth position, number, form, and developmental position of teeth beyond normal limits"* (3)'. Adding on to that, a uniform recording of the malocclusions given is a subdivision and classification into the anatomical reference planes of malocclusions transversal, sagittal and vertical to enable orientation and location of characteristic parameters which in turn ultimately bear the professional terms of the individual or multiple malocclusions that can be diagnosed and which are as follows according to E.Angle (1900): the sagittal plane to evaluate the molar relationship to determine a healthy or deviating pre- or post-normal occlusion, the vertical plane that focuses on overbite such as deep bite, open bite at the anterior as well as on the posterior level whereas the latter one can appear uni- or bilateral, and finally, the transverse plane that encompasses crossbite and scissor bite, respectively.

2. Cephalometric Analysis

An extended diagnostic assessment of great importance to highlight anatomical landmarks on the skeletal structures. It involves the previously mentioned cephalometric analysis such as Rickets analysis which utilizes the Frankfurt plane as a fundamental reference to systematically evaluate angular correlation between other defined planes originating from standardized landmarks of the skull and jaws. Steiner's methodological analysis represents another way of cephalometric measurement but is distinguished by its reliance on the Sella-Nasion reference plane. Both systems serve as a key to a better understanding and interpretation of craniofacial structures. It is important to keep in mind that Angel's classification system has been doubted for its lack of providing information on whether the aetiology for the malocclusion lies either solely in the position of the basal bone of the mandible and maxilla, the tooth and tooth-supporting structures like alveolar bone or in a combination of both clinical entities by extension of the circumstances.

Among the most important cephalometric parameters regarding the classification of sagittal skeletal malocclusions lie the ANB, SNA and SNB angles. Cephalometric parameters usually have mean values that describe a standardized healthy physiological average angle from which a relatively harmonious occlusion should result. These measurements play a crucial role and should be considered because they facilitate precise diagnosis and tailored treatment protocols to correct the underlying causes. An overview of the interpretation of these angles and their description can be seen in *Table 1* below.

Table 1. Characteristics of SNA, SNB and ANB angle

Steiner Cephalometry	Mean Value	Interpretation	Description
SNA	82º (±2º)	84º: maxillary protrusion. < 80º: maxillary retrusion.	• Formed by the lines S-Na and Na-A. • Determines the anteroposterior position of the maxilla in relation to the cranial base
SNB	80º (±2º)	> 82º: mandibular protrusion <78º: mandibular retrusion	• Formed by the lines S-Na and Na-B • Determines the anteroposterior position of the mandible in relation to the cranial base
ANB	2º (±2º)	0º≤ skeletal class I ≤4º > 4º: skeletal class II. <0º: skeletal class III.	• Formed by the lines Na-A and Na-B. • Determines the anteroposterior relationship of the maxilla and the mandible. • Skeletal class

In order to be able to orient oneself in the stomatognathic apparatus, it is also necessary to have knowledge of other anatomical landmarks that serve as a reference point for measurements during a cephalometric examination and a subsequent comparison with a control group. These are systematically shown in the following *Table 2.*

Table 2. Characterizing cephalometric parameters

Point	Description
Nasion (N)	Most anterior point on fronto-nasal suture.
Point (A)	Position of deepest concavity on anterior profile of maxilla (subspinal).
Point (B)	Position of deepest concavity on anterior profile of mandible (supramental).
Gonion (Go)	Most posterior inferior point on angle of mandible.
Pogonion (Pg)	Anterior most point in the mandibular symphysis.
Menton (Me)	Point located in the intersection between cortical external mental portion and cortical inferior mandible portion. Lowest point on the mandibular symphysis.
Posterior Nasal Spine (PNS)	Median point formed by the union of the posterior borders of both palatine bones.
Anterior Nasal Spine (ANS)	Point located at the end of the anterior nasal spine.
Porion (Po)	Upper most point on bony external auditory meatus.
Gnathion (Gn)	Most anterior and lowest point on the mandibular symphysis determined by bisecting of the angle formed between the mandibular plane and a perpendicular line of it tangentially to the most anterior region of the symphysis.
Basion (Ba)	The point at the front border of the foramen magnum in the median plane.
Orbitale (Or)	Most inferior anterior point on margin of orbit.
E line (Aesthetic line)	Line connecting the nasal tip and the most prominent anterior point of the soft tissue chin (Pogonion).

ANS-Me	Linear measurement determined by the union of the anterior nasal spine and mental points corresponding to the lower anterior facial height.
Go-Gn	Linear measurement determined by the union of the gonial and gnathion points corresponding to the mandibular plane (Steiner).
Y axis angle	Formed by the Y axis, from point (S) to point (Gn), with the Frankfurt horizontal plane.
S-Go	Linear measurement determined by the union of the sella and gonial points corresponding to the total posterior facial height.
N-Me	Linear measurement determined by the union of the nasion and mental points corresponding to the total anterior facial height.
Go-Gn to SN Angle	Determined by the intersection of mandibular plane (Go-Gn) with the S-N line. Gives the inclination of the mandibular plane relative to the anterior base of the skull.

3. Growth and Development

In the profession of orthodontics, it is crucial to determine the growth stage, and, in this case, it is even more important because this thesis aims to evaluate individuals of growing age pointing out the physiological ramifications of mouth breathing. There are some age-related factors impacting the craniofacial development in growing patients. Consequently, it is essential to elucidate the concepts of growth and development by focusing on the innate physiological and biochemical processes underlying. From the biological perspective, the terms growth and development describe two distinct processes of a human undergoing the ageing process. Growth is described as an increase in size or number of body parts and is an anatomic quantitative entity (body height/weight). On the other hand, development refers to an increase in complexity and specialization materializing a qualitative physiologic or behavioural phenomenon(cognitive/motoric). This transformation usually comes with of loss of growth potential. (4) In the human body the dynamic proportions that can be observed during various growth phases are a sequel of physiological growth spurts that are confined to anatomic regions of growth. These shifts indicate an accurate reflection of the developmental condition and provide information about the transition of the body's framework within a period. The cephalocaudal gradient of growth describes the skull growth which is subject to proportionality and in children represents a relatively large skull compared to the rest of the body. Those parts of the body that are further away from the cranium undergo a later growth spurt, which also applies to the maxillary bone, which begins to grow earlier than the mandibular bone. (4) Empirical observations in everyday life suggest gender-specific differences in growth, a phenomenon proved by multiple studies. The underlying reason for this disparity can be found at the hormonal level, which is orchestrated, among other things, by the hormones oestrogen and testosterone as well as the human growth hormone (5). The peak growth spurts of boys and girls going through puberty occur on average at 12 (girls) and 14 years (boys) of age respectively. (4) However, individuals differ in the manner they grow, and it must be distinguished between extreme variations of the normal and entities outside the frame considered normal. In the common use of language, we often refer to age when talking about the lifespan or chronological age since the moment of birth which is a very general and superficial way to characterize a person's condition from an anatomic point of view. The scientific connotations that are important in the realm of orthodontics extend beyond the pure lifespan including skeletal age which encompasses the state of skeletal maturation and is commonly assessed through a radiograph of the hand/wrist or the cervical vertebra. (4) Dental age which includes the maturity and eruption pattern of the teeth can be seen on an Orthopantomography. Skeletal growth can occur naturally through pathways. Through hyperplasia, an increase in the cells which can be found in numerous processes, hypertrophy, which is characterized by an enlargement of the cell and is not quite as important as the previous process, or through the secretion of the extracellular material (ECM). In addition, in skeletal growth, we differentiate between soft tissue/uncalcified cartilage growth and hard mineralized tissue (teeth, bones, and some cartilage). Bone growth is governed by two fundamental processes. Firstly, endochondral ossification, managing bone growth directly over genetic control from within a cartilage precursor template inside the bone that is successively replaced by mineralized mature bone at the centre of ossification and adds up to the bone length. Secondly, Intramembranous Ossification is the process characterized by external apposition and augmentation of the bone diameter and orchestrated and influenced by environmental factors. It unfolds at the periosteum and plays an essential role in the reshaping of bone. In contrast, it is the prevailing process with a pivotal role in the cranial vault and both jaws. Some bones are formed by directed mineralization of connective tissue without the intermediate step of cartilage formation involving the Cranial vault, Naso-Maxilla Bone and Mandible-bone excluding the Condyle area. With the mineralization of tissues, a point of no return is reached because interstitial growth is no longer possible and growth processes can only manifest on the bone surface by direct apposition by the cells of the periosteum. (4)

4. Mouth Breathing Habit

When we talk about the oral cavity, respiration should not go unmentioned as an integral reflexive part of the supply of oxygen besides the other functions including articulation, chewing, and swallowing. Our respiratory needs are one of the primary determinants that affect the posture of the jaws, lips, and tongue. The correct way individuals are supposed to breathe in air is to inhale and exhale over the nasal cavity with diaphragmic support (Nasal breathing). It not only helps to filter allergens and lowers the exposure to foreign substances furthermore, it humidifies and warms the inhaled air, regulating airflow for more efficient oxygen uptake and playing a role in promoting normal craniofacial development. (6). The habit of Mouth Breathing synonymously called oral breathing is defined as a repetitive inhalation and exhalation through the oral cavity instead of the nose. Mouth breathing is currently in focus, especially in younger individuals, i.e. those who are still growing and whose bone structure is not yet mature and therefore lacks complete ossification. The scientific literature examines and reports numerous cases of mouth breathing in connection with other structures of the stomatognathic apparatus and craniofacial integrity. If the breathing process does not take place through the nose but rather through the mouth, the cold, dry and dirty air can damage the tissues lining the respiratory tract and oral cavity. It has been found that oral breathers suffer from more infections of the respiratory tract and tonsils. (7,8) Oral breathers are also more likely to suffer from periodontal disease due to dry mouth where the saliva cannot fully achieve its beneficial functions. (9) The impact on gingival inflammation is well studied but the effect of mouth breathing on malocclusion is very complex. Oral breathing indicates that the mouth is constantly or at least opened for a long period of time which sequels in a constant disocclusion followed by the supraeruption of posterior teeth and an increase in facial height. The increased stretching muscle force of the cheek and facial muscles is not balanced by the tongue and the palatal vault narrows by constriction of the maxillary bone (V-shaped arch). A common clinical picture that can be observed externally is the so-called ‘’adenoid facies’’ patients, which is often directly or indirectly related to this habit represented by narrow facial width dimensions, lip insufficiency at rest, hypodevelopment of the maxilla and protruding teeth. (10,11) This condition is often accompanied by a tendency to class II malocclusion. While children with nasal obstruction have a higher frequency of these occlusal findings, most children with airway problems do not match the stereotype, indicating that mouth breathing may have an environmental impact on children who are genetically predisposed to a constricted, retrognathic growth pattern that is hyperdivergent/dolichofacial. (12) A very fundamental aspect of Mouth Breathing is the interdisciplinary approach from various scientific areas. The rhinologist examines the effects of mouth breathing on the nose and paranasal sinuses while the periodontist focuses on the soft tissues in the oral cavity. Furthermore, the expertise of an otorhinolaryngologist (ENT) is also required in this habit since mouth breathing often comes with conditions like allergic rhinitis and obstructive sleep apnoea. The most important thing for this elaboration, however, is the orthodontic and paediatric perspective to do justice to the numerous factors that children are exposed to as they grow. (7,8)

5. Aetiology

To comprehend the correlation between oral habits and malocclusion, it is important to delve into the pathophysiological features inherent in malocclusion. The causative factors of malocclusion are based on a correlation that is genetic, environmental, or combined synergistic in nature. (13) In the subsequent paragraphs we will have a closer exploration of the etiological factors underpinning malocclusion, their origins, and frequent oral habits found in patients. This paragraph is based on illustrative examples and scientific discourses to enhance clarity in delineating the key determinants contributing to the understanding of the processes resulting in malocclusion.

The inaugural part of this section relies on the genetic determination of a disorder. This biological dimension involves the hereditary transmission of genetic material. The pioneer research work of Johann Gregor Mendel dating back to the 19th century laid the foundation stone of the interest in the realm of genetics introducing a scientific field that has become an integral part of investigation across biology and medicine. Genetic tracing is directly connected to the diagnosis of the familiar inheritance pattern thus it is imperative for the modern orthodontist to be aware of the teachings of genetic sciences, recent publications of advancements and their applications. In the literature, the suspected underlying cause of a genetic malocclusion is expressed frequently but the provided evidence is very sparse.(14) For the majority of malocclusions, the aetiology could not be easily categorized and precisely assigned to one or another origin which can be explained by the previously mentioned synergistic nature. Newer molecular genetic testing methods can provide relief but only to a certain point. Evidence gathered from public studies with a focus on familial and twin heritage cases proved the genetic factor for malocclusion. Research on siblings and even identical twins unveils a significant role of environmental factors. Twin studies are unique cases with the standalone feature of a commonly shared identical genome. This aspect aids in the investigative process by facilitating the isolation of environmental factors from genetic ones. Genetic influence on dental arch form and size seems to be affected by environmental factors rather than genetics. (15) (16)The mentioned inheritance pattern also involves a phenomenon that is called, ''Habsburg Jaw'' (*Figure 1*), a colloquial description of evident mandibular prognathism constituting a class III malocclusion that was notably apparent among the members of the European noble Habsburg dynasty and notoriously prominent on the Spanish and Austrian branches of the family.

Figure 1. Habsburg Jaw

This observation has led to speculation about the effect of inbreed mating between close relatives which was often practiced in noble families at many moments throughout history. Inbreeding increases the likelihood of inheriting genetic traits. Historical records show a significant degree of intermarriage among close relatives within the family resulting in a restricted gene pool. (17)

Apart from the genetic determinants directly exerting influence on craniofacial morphogenesis and skeletal growth, malocclusions can also be a symptom of an accompanying genetic disorder as some of them have been identified to exert discernible anomalies on the development of the craniofacial complex. Examples of mandible-related syndromes are the Pierre-Robin, Treacher Collins and Marfan syndrome. (14) Another aspect that can lead to malocclusions is that in the course of evolution, our jaw size has become smaller and less prominent due to our eating habits and behaviour, which is why anatomical misalignments also occur due to space problems. (18) In the next paragraph we focus on oral habits that constitute a part of the environmental factors of aetiology.

Oral habits are learned or acquired patterns of behaviour that appear as repetitive muscular activities or inactivities without a functional benefit. They are linked to mundane things and are often based on emotion, feelings, or situations like anger, hunger, sleep, tooth eruption and fear. The way habits are performed can be consciously or unconsciously (19). Multiple studies proved the effect of environmental factors as a cause but to what extent oral habits contribute to the development of malocclusions is still the subject of scientific discussion and therefore remains not fully investigated. In any case, if these habits are identified it is decisive that they are discontinued as soon as possible with therapeutic interventions to ensure future functionality and healthy physiological growth within the orthopaedic norm (20,21). A well-known and common cause of habits is coping with stress, affecting behaviour positively or negatively. The oral cavity, being a major and congenital site for expressing emotion, serves as a catalyst for relieving passion and anxiety in both children and adults. The repetitive stimulation of this area with the tongue, finger, nails, or a cigarette can provide relief.

A well-known example of this is thumb-sucking. It is a behaviour that primarily occurs in childhood and is classified in a list of habits known as non–nutritive sucking habits. The activity of thumb sucking is believed to be a primitive reflex to serve as stimulation or self-soothing since a finger or thumb could also imitate the nipples of the mother's breast and they might therefore express a feeling of hunger if they are too young to speak. A study from Italy points out that the stimulation of nasopalatal receptors proved an effect releasing psychological and physical tension.(20) These non-nutritive sucking habits are very common behaviours in young children which in most cases cease as the individual ages and matures. They tend to stop the habit spontaneously before 5 years of age as their psycho-emotional maturity improves.(20) Persistent habits during permanent teeth eruption can lead to malocclusions, such as anterior open bite with proclined maxillary incisors and retroclined mandibular incisors. Clinical features may include increased overjet, posterior crossbite due to finger placement disrupting occlusion, leading to supraeruption of posteriors, and subsequent facial height increase with mandibular rotation (22).

A phenomenon like thumb and finger sucking is lip sucking. It may be a result of a skeletal maxillary protrusion, an inherited interference, or the agenesis of anterior teeth and mouth breathing. It is also suspected to be a substitute for thumb-sucking from a psychological point of view. The protrusion of the upper anteriors and retrusion of the lower anteriors are commonly observed. The lower lip which is mostly sucked can appear reddish glossy and can suffer scaring and pigmentation. This is very important considering the interface of the lower incisor with the lip creating a trauma on the lip and skin around it. (23)

Another habit important to mention is tongue thrusting referring to a myofunctional pattern that describes the forceful push of the tongue against or in between the dental arches during swallowing, deglutition, and speech also known as abnormal or infantile swallow. This is because Tongue thrusting is considered normal in neonates where the tongue moves in between the gum pads and thus stabilizes the mandible by the facial muscles during the swallowing process. That habit is supposed to discontinue as soon as the primary teeth start erupting. Normal physiologic swallowing refers to the positioning of the tongue in an elevated position on the palate behind the maxillary incisors without any lip and cheek activity. Some kind of transitional swallowing pattern can be observed in the mixed dentition and the permanent successors are yet to erupt or erupting. Transitional swallowing is self-correcting as well but in cases of anterior open bite where this habit goes along with thumb sucking the tongue is thrusted to achieve lip seal. (24,25)

The final habit we will address is bruxism, a parafunctional habit characterized by the repetitive and excessive activities of teeth grinding and jaw clenching. The origin of this habit is neurophysiological and can induce spontaneous involuntary rhythmic or spasmodic muscle contractions and TMJ disorders. Bruxism is multifactorial in origin, but many cases are suspected to be of genetic cause because the individual is susceptible to other factors like stress, anxiety, tension, or aggressiveness which is diagnosed with increasing tendency nowadays. (26)

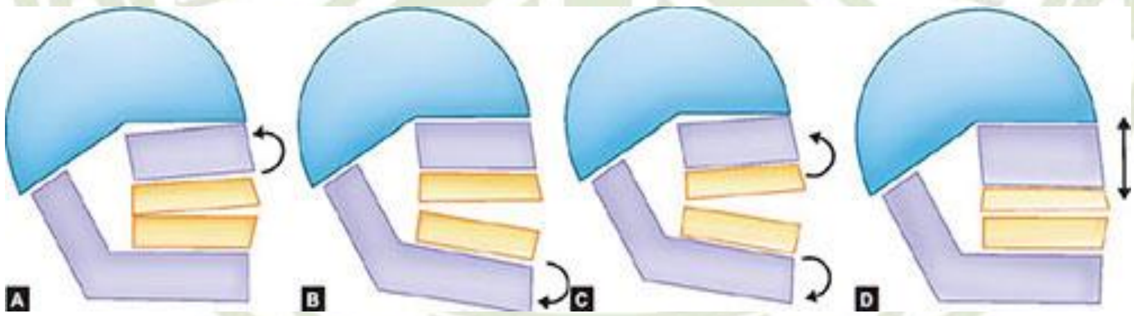
6. Diagnosis

In orthodontic understanding we primarily refer to the position of the teeth and their underlying alveolar and basal bone, therefore we diagnose malocclusions based on our classifications classified in all 3 spatial dimensions.

Transverse malocclusions are examined in front when they are seated so that we can compare the patient's midline with other facial reference structures or asymmetric anomalies. Using the Schwartz method, crossbites of skeletal and dentoalveolar origin can be differentiated using a cast. Statements can also be made via a radiographic analysis if you use a frontal radiograph to determine the parameters: maxillary width, occlusal plane, facial midline-upper dental to facial, Dental midlines-upper to lower, and Chin location. (4)

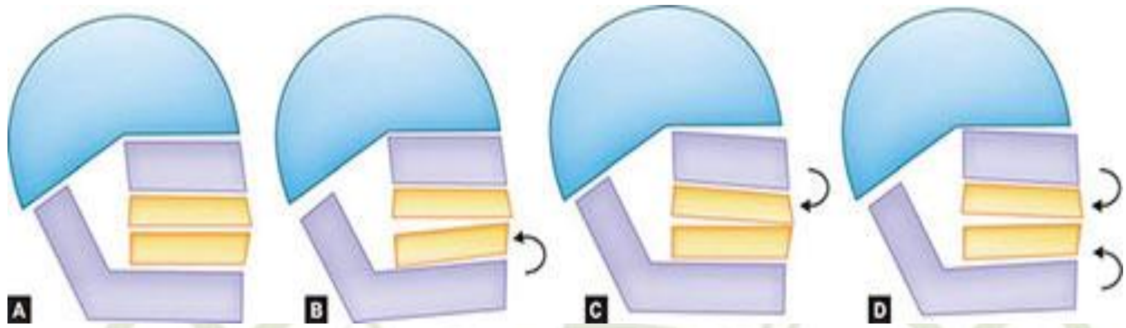
Vertical malocclusions are diagnosed as follows: dental anterior open bite presents the condition in the upper and lower anterior segment with proclination and potential spacing in between while biting. Often the maxillary arch is narrowed giving the patient a fishmouth appearance. Skeletal open bite shares aspects of incompetent lips in cases with hypertonicity, increased anterior facial height, decreased posterior facial height, steep mandibular angle, and a shallow mentolabial sulcus. At the intraoral level skeletal open bite represents a narrow maxilliary arch, excessive gingival display, and decreased freeway space. A cephalometric measurement may reveal an anticlockwise rotation of the maxilla (A), a clockwise rotation of the mandible (B), both (C), or vertical maxillary excess (D) as seen in *Figure 2*. (4)

Figure 2. Variations of bimaxillary rotation I



Accounting for deep bite, the dentoalveolar deep bite is known for decreased lower facial height, increased overbite, decreased overjet, extruded anteriors, and intruded posteriors whereas skeletal deep bite shares similar properties. The skeletal deep bite is characterized by a counterclockwise rotation of the mandible (B), a clockwise rotation of the maxilla (C) or lastly, a combination of both (D) as seen in *Figure 3.* An increased ramus height and hypodivergent mandibular plane can therefore also be determined during a radiographic analysis This condition can be observed in Angles class II division 2. (4)

Figure 3. Variations in bimaxillary rotation II



Sagittal malocclusions like Class II and III are as known to be defined by molar relationships. For class II/1 we can find intraorally increased overjet, elongated narrow upper arch and normal lower arch with extruded incisors. Radiographically we use cephalometric reference angles to distinguish between skeletal and dental patterns like ANB (norm: 2° +-2°) where an angle bigger than 4 points out the skeletal class. We can also work with the angles SNA and SNB and compare them in relation to the cranial base.

Furthermore, the stage of dentition, eruption status, caries, restorations, developmental anomalies, and interrelationships should be carefully considered to incorporate these into the diagnosis. Malocclusion commonly manifests in the transitional phase of mixed dentition in which children are at a critical stage where erupting permanent teeth coexist with the deciduous teeth in the oral cavity. (4)

The importance of the tooth-eruption process as a diagnostic criterion represents an easily observable phenomenon among the spectrum of dynamic dental transformations. Evidently, the chronological sequence carries a degree of constancy, and thus it constitutes a reliable and commonly accepted method for age determination through examination in individuals (27). The possibility of treatments often depends on the developmental age of the patient, as these options can have an effect mainly or only during this period of growth. With increasing age, ossification progresses, and as described above it reduces the treatment options of mechanical therapies targeted at tooth and facial bones if we face more severe dental problems and deformations. After taking the patient's dental and medical history, the orthodontist can use a variety of tools to complement diagnosis. In the general clinical examination, we look at height and weight to assess physical growth and maturation in combination with posture and gait as these parameters can accentuate the developing or already existing malocclusions or indicate an underlying neuromuscular disorder. (4) To determine the maxillomandibular relationship a sagittal analysis of the facial profile by two reference lines connecting anatomic points (Forehead – Point A, Point A – Pogonion 1) is performed. Two lines forming an almost straight one is considered normal as seen below in *Figure 4*. (4)

Convex profile	Point A well ahead Pogonion	→ Class II/1 malocclusion
Concave profile	Point A well behind Pogonion	→ Class III malocclusion

Table 3. Facial profile assessment interpretation

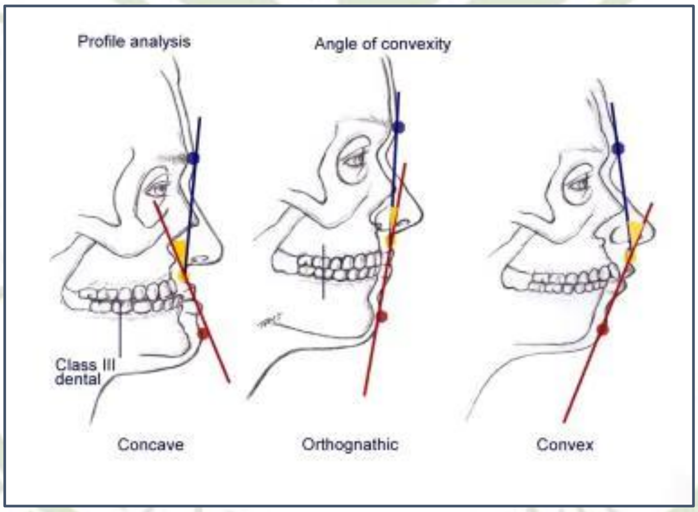


Figure 4. Facial profile assessment

An analysis of the functional status of the craniomandibular apparatus to check its integrity can be ensured by auscultation and palpation of the TMJ and the masticatory muscles, which, in the case of dysfunction, results in clicking, crepitus or pain in combination with hyper or hypomobility, deviation of the mandible or morphological changes. The diagnosis is complemented by the assessment of the interocclusal space, path of closure, respiration, swallowing pattern, phonation, and oral photographs for documentary purposes. (28)

Now that we have covered clinical examination, we now turn to diagnostic methods that require a more complex armamentarium. To conduct a thorough radiographic analysis, it is essential to possess an understanding of the anatomical reference points of cephalometric studies. These pivotal landmarks obtained through lateral cephalic radiographs or a CBCT allow the establishment of vectors connecting them by delineation thus creating angles where measurements can be derived that constitute a comparable parameter with standardized values.

7. Treatment

A basic requirement for successful orthodontic treatment is thorough oral hygiene and the patient's willingness to cooperate with the associated measures. Certain considerations are essential to the treatment planning process, as they significantly influence the substantial success and duration of the intervention. These encompass the patient's age, potential systemic complications, the consequences of untreated conditions, as well as the economic aspects, and the exploration of viable alternative treatment modalities. (29)

II. JUSTIFICATION, HYPOTHESIS & OBJECTIVES

Justification

As previously outlined in the introduction, dental malocclusion stands out as a prevalent issue within dental pathology. The increase in the incidence of orthodontic problems can be attributed to the multifactorial nature of this condition and, significantly, the evolutionarily induced reduction in the spectrum of the jaw which has led to a discernible disproportionality between tooth and jaw dimensions. Consequently, there is a growing interest in comprehending the intricate interplay of individual genetic factors and environmental influences to elucidate the aetiology of craniofacial morphologies and skeletal sagittal malocclusions.

Malocclusions can manifest through several modalities, exhibiting an impact on individuals, ranging from mild to substantial. The increasing focus on the aesthetic part of the structural equilibrium and functional integrity of the stomatognathic apparatus is evident. This heightened attention is influenced by societal factors such as the internet, social media, and advertising, which propagate explicit beauty ideals. The expanding frontier of scientific knowledge and the evolving possibilities of treatment modalities collectively form the framework for a more precise approach towards the condition of craniofacial deformities.

In the ensuing scientific exposition, we shall delve into the field of craniofacial morphologies often manifesting through sagittal skeletal malocclusions due to the position of the maxillary and mandibular bone and concurrently elucidating its interrelationship with mouth breathing. The growth phase is assumed to play a pivotal role in both the origin of the condition and the available corrective or preventive modalities. This study aims primarily to establish the correlation between the mouth breathing oral habit and craniofacial morphology focusing on Maxillary sagittal position and its manifestation of skeletal malocclusion based on the SNA, SNB and ANB angle, intending to incorporate these variables into a meta-analysis. In the Meta-Analysis all the articles are based on observations of mouth breathing habits and their consequences. We made the decision to concretize the results. Ultimately, this work serves for a better comprehension of the societal implications, delineating issues such as prolonged adoption of oral habits often performed in a daily sequence while monotonous time is spent using electronic media frequently observed in growing individuals. (30) Furthermore, it is intended to establish recommendations aimed at mitigating these issues to improve an individual's life quality.

Hypothesis

$H0_1$: Mouth breathing has little to no impact on sagittal skeletal occlusion in growing patients.

Ha_1: Mouth breathing has a significant impact on sagittal skeletal occlusion in growing patients.

$H0_2$: Mouth breathing has little to no impact on craniofacial morphology.

Ha_2: Mouth breathing has a significant impact on craniofacial morphology.

Objectives

General:

The fundamental objective of the study is the review and combination of the results derived from a series of articles that analyse the effects of mouth breathing, on sagittal skeletal malocclusion & craniofacial morphology in growing patients.

Specific:

1) Investigate the potential relationship between, mouth breathing, and the occurrence of sagittal skeletal malocclusion by monitoring ANB, SNA, and SNB angles to scrutinize the causality in a Meta-Analysis further
2) Analyse potential consequences of Mouth breathing and on the craniofacial morphology.
3) Provide protocol recommendations for preventing sagittal skeletal malocclusion and craniofacial deformities resulting from mouth breathing or other unfavourable oral habits.

III. MATERIALS AND METHODOLOGY

3.1 Pico Question

This systematic review rigorously followed the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines. Before the Systematic Review is performed a PICO-Question is worked out containing four main components: Population, Intervention, Comparison, and Outcome. Using this method, we want to get to the bottom of the key question: ‘’Does mouth breathing cause sagittal skeletal malocclusions and craniofacial deformities in growing patients?’’ as it is visually portrayed in *Table 4* below.

Population	Intervention	Comparison	Outcome
Growing age patients	Mouth breathing	Cephalometric & Clinical anatomic landmarks with nasal breathers	Consequences of mouth breathing on sagittal skeletal malocclusion & craniofacial morphology

Table 4. PICO Question Overview

3.2 Study Design

The design of this systematic review was based on the Reporting Items for Systematic Reviews and Meta-analysis (PRISMA) statement guidelines.

3.3 Eligibility Criteria

The studies included had to adhere to the following criteria:

• **Type of study**: Randomised controlled clinical studies, systematic reviews and meta-analysis; studies retrospective cohorts and non-randomised controlled clinical studies; observational studies; Publications in English; Articles published between 2000 and 2024

• **Types of patients**: Patients with sagittal skeletal malocclusions & craniofacial deformities that are currently suffering or have suffered in the past from mouth breathing

• **Type of Intervention**: Radiographic, photographic, interrogative, or clinical assessment of oral habits

• **Type of Outcome variables**: Studies reporting data on the effects of mouth breathing causing sagittal skeletal malocclusions and craniofacial deformities

3.4 Search Strategy and Study Selection

Comprehensive research was performed utilizing the following databases: PubMed, SCOPUS, and Cochrane Library. Initial keywords used listed are: ''Mouth breathing'', ''Malocclusion'', ''Orthodontic Growth and Development'', ''Craniofacial morphology'' ''Skeletal Sagittal Malocclusions''. The more complex synthesis of keywords was conducted via Boolean operators like "AND" or "OF" or ''IN'' as part of an advanced search to adequately address the intricate interdependencies inherent in this subject matter. This resulted in search queries like: 'Mouth breathing AND Malocclusion IN Childhood'', ''Mouth breathing AND Craniofacial Morphology IN Childhood'', Malocclusion IN Childhood'', ''Craniofacial Morphology IN Childhood''.

Supplementary to the MeSH terms derived for PubMed, a search strategy was devised to optimize the relevance and spectrum of results. Database searches were further refined through the implementation of filters, specifically targeting full-text articles, and restricting the publication timeline (from 2000 to 2024). The article research was initiated in late November and throughout December of the year 2023 and finished after a break in April 2024. A sequential collection of the final study and reference articles gathered are credited in the bibliography section according to Vancouver rules.

Database	Objective	MeSH-Terms	Number of Articles
PubMed	Oral Habits causing Malocclusions	''Mouth breathing AND'', ''Mouth Breathing AND Malocclusion' 'Effects of Mouth Breathing and Craniofacial Morphology''	365

Cochrane	Oral Habits causing Malocclusions	''Mouth Breathing AND Malocclusions'', ''Mouth breathing AND craniofacial morphology''	23
SCOPUS	Oral Habits causing Malocclusions	''Mouth breathing AND'', ''Mouth breathing AND Malocclusion'' ''Mouth breathing and Craniofacial Morphology''	254
TOTAL			**642**

Table 5. Database research overview

3.4.1 Selection Process of Studies

The studies in the articles were collected and organized according to title, abstract and full text and listed in a ZOTERO software folder. At first, duplicates that were found within the content across multiple databases were excluded. Adding on to that the titles were analysed and the ones not meeting the requirements and the ones of little relevance based on the objectives were removed from the research pool. Subsequently, during the screening phase, the abstracts underwent scrutiny. This involved reviewing the synopsis of objectives, methodology, conclusions, and discussions. The selection criteria were applied, leading to the elimination of articles that did not align with the specific objectives. Ultimately, a comprehensive screening was executed, entailing an examination of full-text studies filtered by the inclusion and exclusion criteria where essential data was extracted for further analysis. A collection of all the study articles will be handed out to the supervising tutor to verify the validity and applicability of the studies.

3.4.2 Data Extraction

Based on the statistical data and the extracted parameters from the studies, a comprehensive summary table was formulated where the relevant information is highlighted. This table is attached in the annexes. The results addressing specifically sagittal skeletal malocclusions (SNA, SNB and ANB) are given in italics and the observations made at the more general craniofacial level are given in normal font.

This encompasses various categories, incorporating the article's title, type of study, authors, publication year, documented sample size, and conclusion derived from the results of the respective articles.

3.5. Inclusion and Exclusion Criteria

	Inclusion Criteria	Exclusion Criteria
Population	-Individuals of all genders and all ethnic backgrounds -Paediatric (growing age) patients -Studies with participants exhibiting mouth breathing habits -Individuals diagnosed with skeletal malocclusions -Studies with populations at different stages of growth	-Individuals under 4 years of age as in younger years some habits are still considered ''normal''. -Studies focused exclusively on specific subgroups (e.g., certain medical conditions, deformities, diseases) that may not be representative of the general population -Studies with inadequate information on mouth breathing and sagittal skeletal malocclusions -Studies that include too many other variables that could influence and alter the parameters of the outcome
Time frame	-Articles published from 2000 to present time -Studies with long-term follow-ups that track the progression of skeletal malocclusions	-Articles published before 2000 -Studies with limited follow-up duration
Language	-Study published in English/Spanish	-Study only published in another language than English/Spanish
Study design	-Prospective and retrospective cohort studies, case-control studies, reviews, Systematic Reviews, Meta-Analyses, and cross-sectional studies.	-Case reports, opinion articles, letters, and reviews without original data - Studies with inadequate methodologies or insufficient statistical analyses -Studies that are behind a paywall

	-Longitudinal studies tracking the development of malocclusions	-Studies without clear mention of Mean values and Standard deviation of respective Study and Control groups
Study outcome	-Studies that investigate the relationship between mouth breathing and the development of sagittal skeletal malocclusions -Studies with clinically relevant outcome measures related to oral habits and craniofacial deformities	-Studies lacking relevant outcome measures related to mouth breathing and sagittal skeletal malocclusions -Studies focusing on unrelated outcomes not pertinent to the research question - Studies without concrete results and conclusions useful for scientific evaluation

Table 6. Inclusion and Exclusion criteria

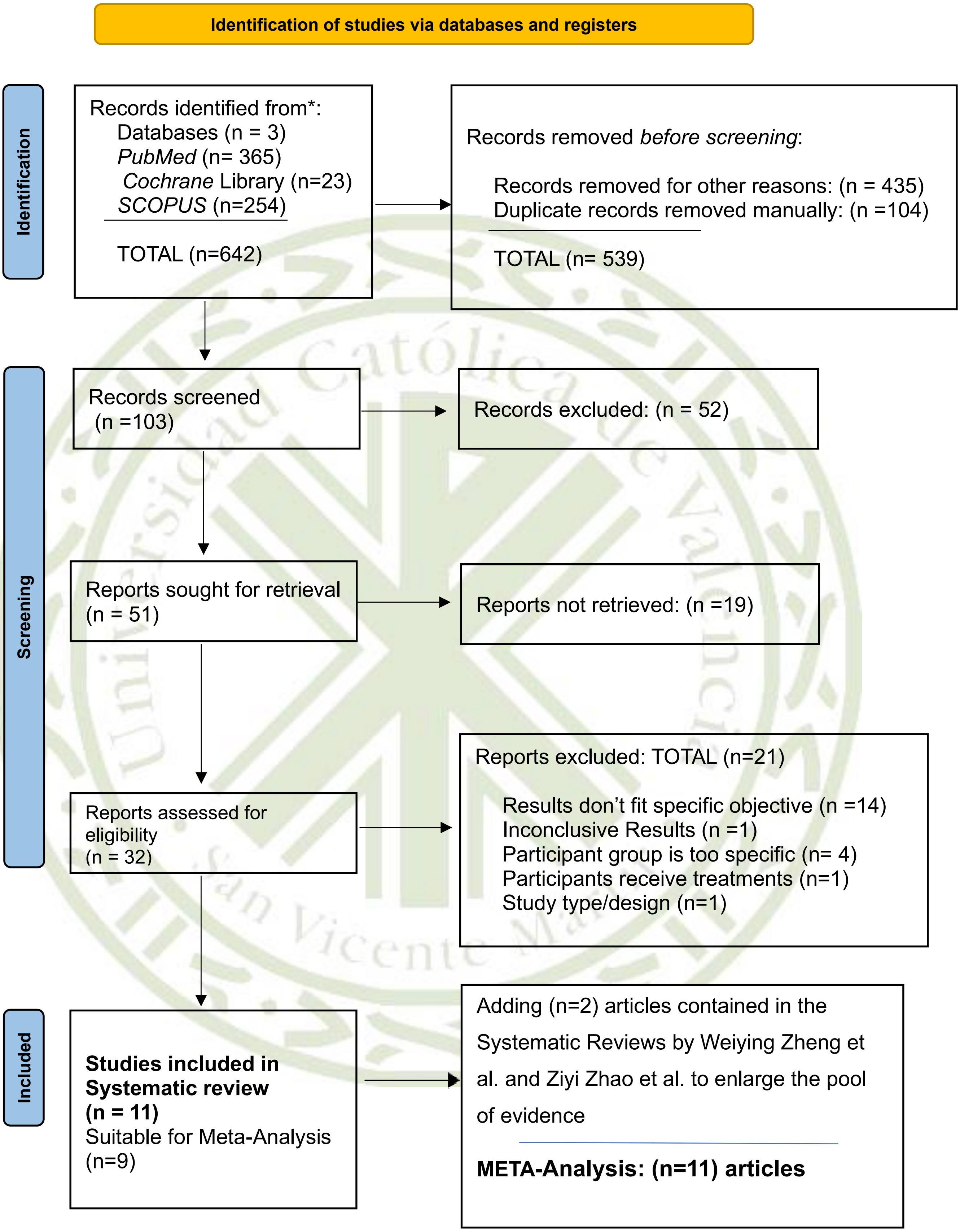


Figure 5. PRISMA Flowchart

3.6: Risk of Bias Assessment & Quality Evaluation of Studies

In order to check the scientific validity of the articles, they were subjected to a thorough risk of bias assessment, which examined various parameters of evidence based on a standardized guideline and ultimately created an overall rating. This procedure is performed to analyse the methodological quality of the research article in a standardized evaluation. In the final pool of articles, the study design varies across the papers so different scientific assessment scales were applied depending on the type of study.

3.6.1 STROBE Statement Scale

The STROBE (Strengthening the Reporting of Observational Studies in Epidemiology) statement offers guidelines for improving the reporting quality of observational studies in epidemiology. It contains a checklist covering various parameters in the sections study design, methods, results, and discussion. Research papers checked by STROBE enhance the reliability and usefulness of article findings. The checklist scale evaluates researchers' adherence to these guidelines, ensuring thorough reporting in study reports.

3.6.2 PRISMA Statement Scale

The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement (revised 2020 version), serves as an essential tool for systematic reviewers in providing comprehensive documentation of their review process. Comprising a checklist of 27 item parameters with subsections, PRISMA facilitates authors in furnishing a transparent and precise portrayal of the review methodology. Its structured approach does not only check reporting quality but also enables evaluators to discern the methodological robustness of systematic reviews.

IV. RESULTS

A total of 642 articles were acquired from the initial search: PubMed (n=365), Cochrane Library (n=23) and SCOPUS (n=254). Before screening (n =104) duplicate records were removed via the ZOTERO software. Of the remaining collection (n = 435) records were removed manually due to a lack of alignment between their titles and the specified study objectives. Following that (n=103) articles are retrieved and thus enter the screening and filtering process. The first step involves reading titles and abstracts in which (n = 52) records were filtered out and providing (n = 51) records to be analysed in-depth reading the full text. In this step (n = 19) records were not retrieved making up (n = 32) reports assessed for eligibility. In this last step, the predefined Inclusion and Exclusion criteria were applied and a total of (n= 21) articles were deemed unsuitable for inclusion with the exact reason for exclusion enlisted in the respective flowchart box. Ultimately, (n=11) articles were found adequate and were then included in the final systematic review. The 2 systematic reviews are not entering the Meta-Analysis process since most of the articles included in them were already gathered by the research making up (n=9) articles suitable for the Meta-Analysis. A decision was taken to enlarge the pool of evidence with (n=2) articles that are included in the selected Systematic reviews by Weiying Zheng et al. and Ziyi Zhao et al. So, a total (n=11) articles were found adequate for a META-Analysis.

4.1 STROBE Statement Scale

For the 11 observational studies (both cross-sectional and case-control) included in the Meta-Analysis, a Risk and Bias assessment was conducted. A guideline parameter that was fully met was marked with "Yes" (1 point), while a parameter that was not completely fulfilled or had missing information was marked with "Partially" (0.5 points). Parameters that were not met at all were marked with "No" (0 points), contributing to the final score. The scientific evidence across nearly all the observational studies is generally low, with the exceptions of Cuccia et al. and Harari et al., which stand out as medium-quality studies.

Score	Quality
x<10	**Very Low**
10<x<16	**Low**
16≤x<25	**Medium**
x≥25	**High**

Table 7. STROBE Scale evaluation ratings

Articles	Faria et al.	Frasson et al.	Cuccia et al.	Harari et al	Ucar et al.	Malhotra et al	El Aouame et al.	Chambi-Rocha et al.	Augostinho et al.	Juliano et al	Mattar et al.
Title and abstract											
a)	No	Yes	No	No	No	Yes	No	No	No	No	Yes
b)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Introduction											
Background/Rationale	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Objectives	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Methods											
Study design	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Partially	Yes	Yes
Setting	Yes	No	Yes	No	Yes	Partially	Partially	Partially	Yes	Yes	Partially
Participants	Yes	No	Yes	Yes	Yes	Partially	Yes	Yes	Yes	Yes	Partially
Variables	Yes	Partially	Yes	Yes	Partially	Yes	No	Yes	Partially	Partially	No
Data sources/measurement	Partially	No	Yes	Partially	Yes	Partially	Partially	Yes	Partially	Partially	Partially
Bias	Yes	No	Yes	Partially	No	No	No	Partially	No	Partially	No
Study size	Partially	No	Partially	Partially	Yes	No	No	No	No	Partially	No
Quantitative variables	No	No	Yes	Yes	No	No	No	Partially	No	Partially	Partially
Statistical methods											
a)	Partially	No	Yes	Yes	Partially	No	No	No	Partially	Partially	Partially
b)	No	No	Yes	No	No	No	No	No	Partially	No	No
c)	No	No	Partially	No	No	No	No	No	Partially	No	No
d)	No	No	Yes	Partially	No	No	No	No	No	No	No
e)	Partially	No	Yes	No	No	No	No	No	No	No	No

Results											
Participants											
a)	No	No	No	Partially	Yes	No	No	Yes	No	Partially	Yes
b)	No	No	Partially	No	No	No	No	Partially	No	No	Yes
c)	No	No	No	No	No	No	No	No	No	No	No
Discriptive Data											
a)	No	Yes	Partially	Yes	Yes	Partially	No	Partially	Partially	Partially	Partially
b)	No	No	No	Partially	No	No	No	Partially	No	No	No
Outcome Data	No	No	No	Partially	Yes	Partially	No	No	No	No	No
Main results											
a)	No	No	Partially	Yes	Partially	No	No	No	No	No	No
b)	No	No	Partially	No	No	Partially	No	Partial	No	No	No
c)	No	No	No	No	No	No	No	No	No	No	No
Other Analyses	No	No	No	Yes	No	Yes	No	No	No	No	No
Discussion											
Key results	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Limitations	Partially	Yes	No	Yes	Yes	Yes	No	Yes	Yes	Yes	Partially
Interpretations	No	Yes	Yes	Yes	No	Partially	Yes	Yes	Yes	Yes	Yes
Generalisability	No	Yes	No	Yes	Partially	Partially	No	Yes	Yes	Yes	Yes
Other Information											
Funding	No	No	No	No	Yes	No	Yes	No	Yes	No	No
TOTAL SCORE	***11,5 / 32***	***10,5 / 32***	***19 / 32***	***18,5 / 32***	***13 / 32***	***13 / 32***	***9 / 32***	***15,5 / 32***	***13,5 / 32***	***14 / 32***	***13, 5 / 32***
	Low	***Low***	***Medium***	***Medium***	***Low***	***Low***	***Very Low***	***Low***	***Low***	***Low***	***Low***

Table 8. STROBE evaluation overview

4.2 PRISMA Statement Scale

The PRISMA checklist results for the two systematic reviews included in this study indicated that they were of medium to high scientific evidence, as they incorporated the key elements required for a systematic review, as detailed in the evaluation table. The same evaluation procedure was performed here so if a guideline parameter was fully met it was marked with "Yes" (1 point), while a parameter that was not completely fulfilled or had missing information was marked with "Partially" (0.5 points). Parameters that were not met at all were marked with "No" (0 points), contributing to the final score. In the PRISMA statement scale, more parameters are contained so the interpretation of the evaluation scores can be seen in the table below. Both reviews included a Meta-Analysis. Additionally, while the reviews provided information on the methods used for assessing the risk of bias, they did not address the risk of bias for individual studies, presenting a limitation for both reviews. Furthermore, the review by Weiying Zheng et al. did not discuss any limitations of the review process nor the implications of the results for practice, policy, and future research.

Score	Quality
$x<15$	**Very Low**
$13 \leq x < 21$	**Low**
$21 \leq x < 32$	**Medium**
$x \geq 32$	**High**

Table 9. PRISMA Scale evaluation ratings

ARTICLE			Ziyi Zhao et al.	Weiying Zheng et al.
Section and Topic	Item #	Checklist item		
TITLE				
Title	1	Identify the report as a systematic review.	Yes	Yes
ABSTRACT				
Abstract	2	See the PRISMA 2020 for Abstracts checklist.		
INTRODUCTION				
Rationale	3	Describe the rationale for the review in the context of existing	Yes	Yes

ARTICLE			Ziyi Zhao et al.	Weiying Zheng et al.
Section and Topic	Item #	Checklist item		
		knowledge.		
Objectives	4	Provide an explicit statement of the objective(s) or question(s) the review addresses.	Yes	Yes
METHODS				
Eligibility criteria	5	Specify the inclusion and exclusion criteria for the review and how studies were grouped for the syntheses.	Yes	Yes
Information sources	6	Specify all databases, registers, websites, organisations, reference lists and other sources searched or consulted to identify studies. Specify the date when each source was last searched or consulted.	Yes	Yes
Search strategy	7	Present the full search strategies for all databases, registers and websites, including any filters and limits used.	Partially	No
Selection process	8	Specify the methods used to decide whether a study met the inclusion criteria of the review, including how many reviewers screened each record and each report retrieved, whether they worked independently, and if applicable, details of automation tools used in the process.	Yes	No
Data collection process	9	Specify the methods used to collect data from reports, including how many reviewers collected data from each report, whether they worked independently, any processes for obtaining or confirming data from study investigators, and if applicable, details of automation tools used in the process.	Yes	Partially
Data items	10a	List and define all outcomes for which data were sought. Specify whether all results that were compatible with each outcome domain in each study were sought (e.g. for all measures, time points, analyses), and if not, the methods used to decide which results to collect.	Partially	Yes
	10b	List and define all other variables for which data were sought (e.g. participant and intervention characteristics, funding sources). Describe any assumptions made about any missing or unclear information.	Partially	Partially
Study risk of bias assessment	11	Specify the methods used to assess risk of bias in the included studies, including details of the tool(s) used, how many reviewers assessed each study and whether they worked independently, and if applicable, details of automation tools used in the process.	Yes	Partially
Effect measures	12	Specify for each outcome the effect measure(s) (e.g. risk ratio, mean difference) used in the synthesis or presentation of results.	Yes	Yes
Synthesis methods	13a	Describe the processes used to decide which studies were eligible for each synthesis (e.g. tabulating the study intervention characteristics and comparing against the planned groups for each synthesis (item #5)).	Yes	Yes
	13b	Describe any methods required to prepare the data for presentation or synthesis, such as handling of missing summary statistics, or data conversions.	No	No
	13c	Describe any methods used to tabulate or visually display results of individual studies and syntheses.	Yes	Yes
	13d	Describe any methods used to synthesize results and provide a rationale for the choice(s). If meta-analysis was performed, describe the model(s), method(s) to identify the presence and extent of statistical heterogeneity, and software package(s) used.	Yes	Yes
	13e	Describe any methods used to explore possible causes of heterogeneity among study results (e.g. subgroup analysis, meta-	Yes	No

ARTICLE			Ziyi Zhao et al.	Weiying Zheng et al.
Section and Topic	**Item #**	**Checklist item**		
		regression).		
	13f	Describe any sensitivity analyses conducted to assess robustness of the synthesized results.	Yes	Yes
Reporting bias assessment	14	Describe any methods used to assess risk of bias due to missing results in a synthesis (arising from reporting biases).	No	No
Certainty assessment	15	Describe any methods used to assess certainty (or confidence) in the body of evidence for an outcome.	Yes	No
RESULTS				
Study selection	16a	Describe the results of the search and selection process, from the number of records identified in the search to the number of studies included in the review, ideally using a flow diagram.	Yes	Yes
	16b	Cite studies that might appear to meet the inclusion criteria, but which were excluded, and explain why they were excluded.	Yes	No
Study characteristics	17	Cite each included study and present its characteristics.	Yes	Yes
Risk of bias in studies	18	Present assessments of risk of bias for each included study.	No	No
Results of individual studies	19	For all outcomes, present, for each study: (a) summary statistics for each group (where appropriate) and (b) an effect estimates and its precision (e.g. confidence/credible interval), ideally using structured tables or plots.	Yes	No
Results of syntheses	20a	For each synthesis, briefly summarise the characteristics and risk of bias among contributing studies.	Yes	No
	20b	Present results of all statistical syntheses conducted. If meta-analysis was done, present for each the summary estimate and its precision (e.g. confidence/credible interval) and measures of statistical heterogeneity. If comparing groups, describe the direction of the effect.	Yes	Yes
	20c	Present results of all investigations of possible causes of heterogeneity among study results.	Yes	No
	20d	Present results of all sensitivity analyses conducted to assess the robustness of the synthesized results.	No	No
Reporting biases	21	Present assessments of risk of bias due to missing results (arising from reporting biases) for each synthesis assessed.	No	No
Certainty of evidence	22	Present assessments of certainty (or confidence) in the body of evidence for each outcome assessed.	No	No
DISCUSSION				
Discussion	23a	Provide a general interpretation of the results in the context of other evidence.	Yes	Yes
	23b	Discuss any limitations of the evidence included in the review.	Yes	Yes
	23c	Discuss any limitations of the review processes used.	Yes	No
	23d	Discuss implications of the results for practice, policy, and future research.	Yes	No
OTHER INFORMATION				
Registration and protocol	24a	Provide registration information for the review, including register name and registration number, or state that the review was not registered.	Yes	Yes
	24b	Indicate where the review protocol can be accessed, or state that a protocol was not prepared.	Yes	Yes

ARTICLE			Ziyi Zhao et al.	Weiying Zheng et al.
Section and Topic	Item #	Checklist item		
	24c	Describe and explain any amendments to information provided at registration or in the protocol.	Yes	Yes
Support	25	Describe sources of financial or non-financial support for the review, and the role of the funders or sponsors in the review.	Yes	Yes
Competing interests	26	Declare any competing interests of review authors.	No	Yes
Availability of data, code and other materials	27	Report which of the following are publicly available and where they can be found: template data collection forms; data extracted from included studies; data used for all analyses; analytic code; any other materials used in the review.	Yes	Yes
TOTAL SCORE			**33,5 / 42**	**23,5 / 42**
			High	**Medium**

Table 10. PRISMA evaluation overview

META- Analysis

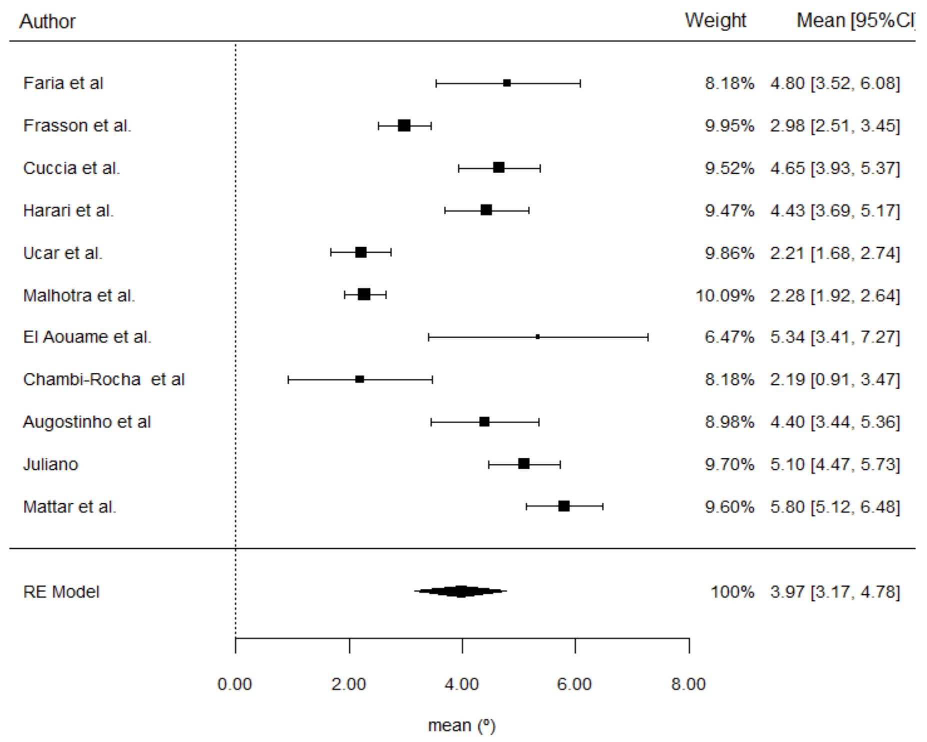
To shed more light on the correlation between mouth breathing and sagittal skeletal malocclusions, we will subject the values for ANB, SNA and SNB to a statistical check in the following META analysis.

4.3. ANB

Test (oral) group

The following table shows articles which will be included in meta-analysis:

ID	AUTHOR	n	GROUP	mean	SD
1	**Faria et al**	20	Test	4.8	2.91
3	**Frasson et al.**	25	Test	2.98	1.21
5	**Cuccia et al.**	35	Test	4.65	2.17
7	**Harari et al.**	55	Test	4.43	2.81
9	**Ucar et al.**	34	Test	2.21	1.57
11	**Malhotra et al.**	20	Test	2.28	0.83
13	**El Aouame et al.**	23	Test	5.34	4.72
15	**Chambi-Rocha et al**	23	Test	2.19	3.12
15	**Augostinho et al**	35	Test	4.4	2.9
15	**Juliano**	52	Test	5.1	2.3
15	**Mattar et al.**	44	Test	5.8	2.3



Mean ANB was estimated at 3.97 ± 0.41º. This is a magnitude significantly non-zero (p<0.001).

Table 4.3.1.- Results of meta-analysis of **ANB**: weighted mean (WM), standard error (SE), 95% confidence interval, z test (p-value), I^2 index, Cochran´s Q statistic (p-value) for heterogeneity; Egger´s test (p-value) for publication bias

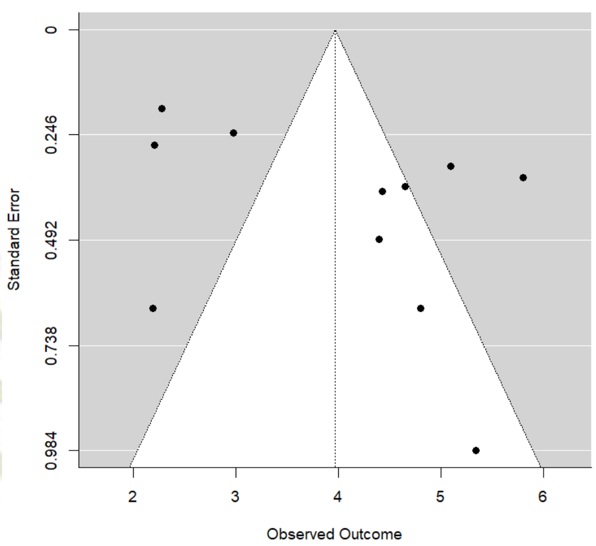
WM	SE	95% CI	z (p-value)	I^2	Q_H (p-value)	Egger (p-value)
3.97	0.41	3.17 4.78	<0.001***	93.4%	<0.001***	0.286

*p<0.05; **p<0.01; ***p<0.001

Observe that 95% confidence interval (3.17-4.78) suggested that this group shows a tendency to be class II.

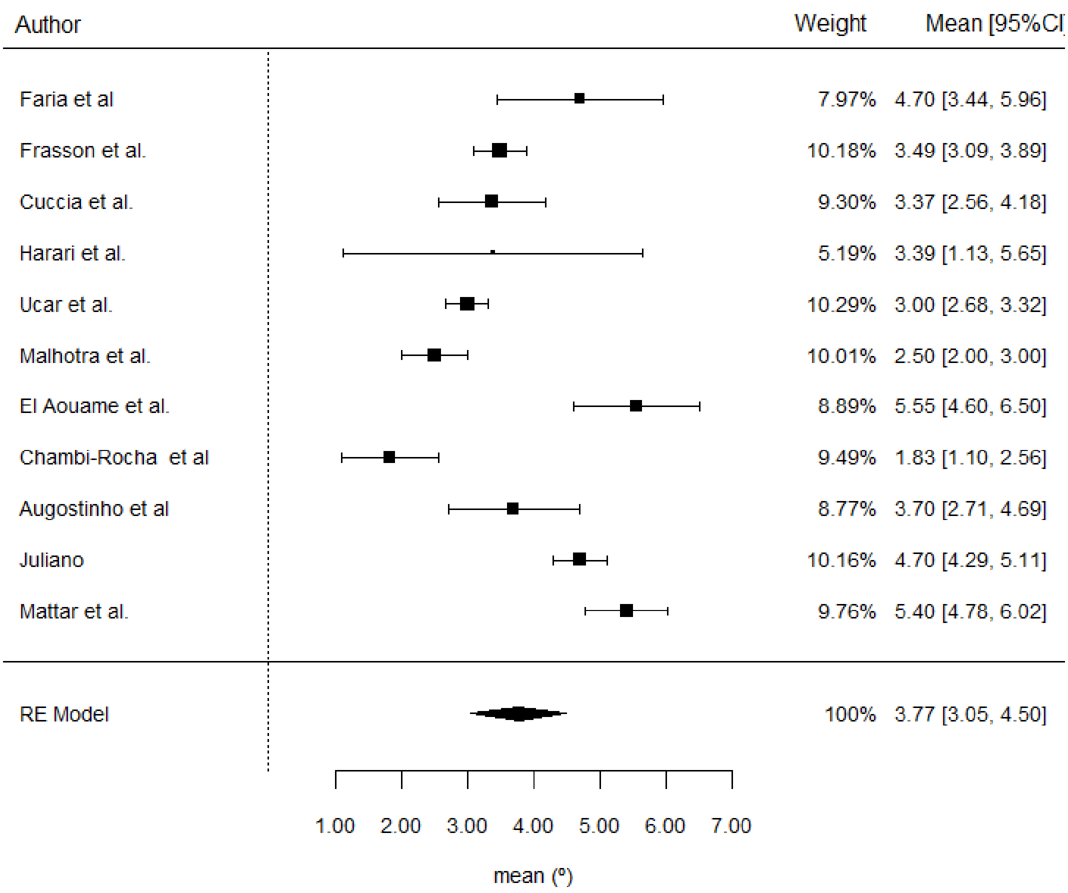
The model was estimated under high level of heterogeneity (I^2=93.4%).

Funnel´s plot shows absence of publication bias (p=0.286), but a high heterogeneity.



Control (nasal) group

ID	AUTHOR	n	GROUP	mean	SD
2	**Faria et al**	15	Control	4.7	2.49
4	**Frasson et al.**	25	Control	3.49	1.02
6	**Cuccia et al.**	35	Control	3.37	2.43
8	**Harari et al.**	61	Control	3.39	9
10	**Ucar et al.**	32	Control	3	0.93
12	**Malhotra et al.**	18	Control	2.5	1.08
14	**El Aouame et al.**	30	Control	5.55	2.66
16	**Chambi-Rocha et al**	20	Control	1.83	1.67
16	**Augostinho et al**	35	Control	3.7	3
16	**Juliano**	90	Control	4.7	2
16	**Mattar et al.**	29	Control	5.4	1.7



Mean ANB was estimated at 3.77 ± 0.37º. This is a magnitude significantly non-zero (p<0.001).

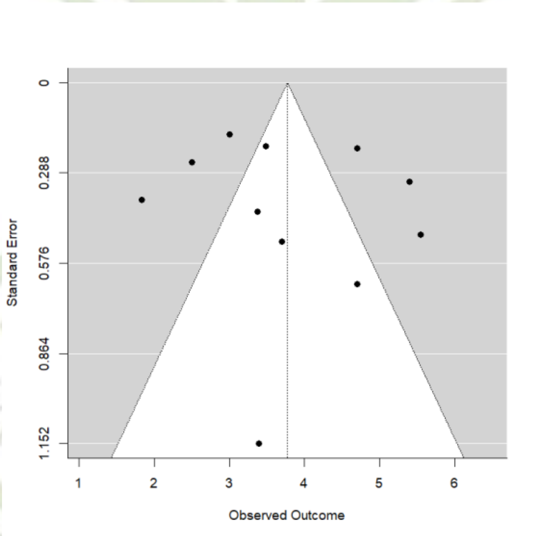
Table 4.3.2.- Results of meta-analysis of **ANB**: weighted mean (WM), standard error (SE), 95% confidence interval, z test (p-value), I^2 index, Cochran´s Q statistic (p-value) for heterogeneity; Egger´s test (p-value) for publication bias

WM	SE	95% CI		z (p-value)	I^2	Q_H (p-value)	Egger (p-value)
3.77	0.37	3.05	4.50	<0.001***	93.5%	<0.001***	0.715

*p<0.05; **p<0.01; ***p<0.001

The model was estimated under high level of heterogeneity (I^2=93.5%).

Funnel´s plot shows absence of publication bias (p=0.715), but a high heterogeneity.



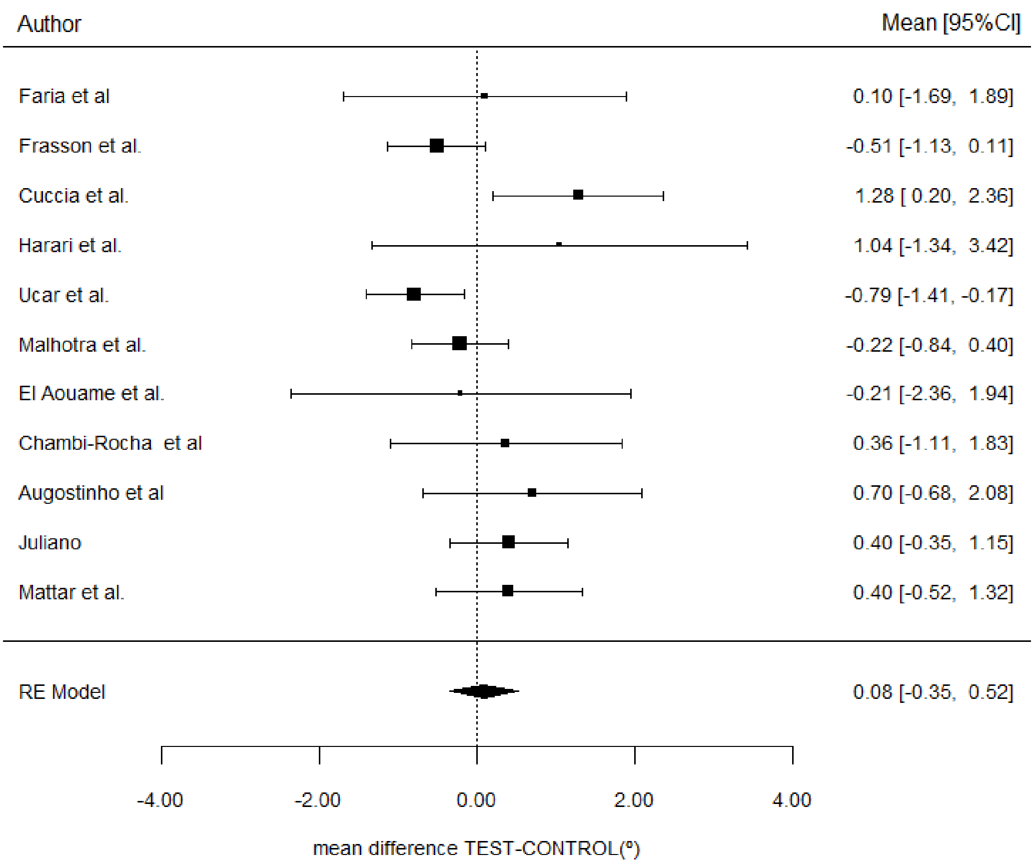
Comparison Test (oral) vs. Control (nasal)

The following table shows articles which will be included in meta-analysis:

		TX			Control		
ID	AUTHOR	nTX	mTX	sTX	nCT	mCT	sCT
1	Faria et al	20	4.80	2.91	15	4.70	2.49
2	Frasson et al.	25	2.98	1.21	25	3.49	1.02
3	Cuccia et al.	35	4.65	2.17	35	3.37	2.43
4	Harari et al.	55	4.43	2.81	61	3.39	9.00
5	Ucar et al.	34	2.21	1.57	32	3.00	0.93
6	Malhotra et al.	20	2.28	0.83	18	2.50	1.08
7	El Aouame et al.	23	5.34	4.72	30	5.55	2.66
8	Chambi-Rocha et al	23	2.19	3.12	20	1.83	1.67
9	Augostinho et al	35	4.40	2.90	35	3.70	3.00
10	Juliano	52	5.10	2.30	90	4.70	2.00
11	Mattar et al.	44	5.80	2.30	29	5.40	1.70

n=number of patients; m=mean; s=SD; TX=ORAL Test group; CT=NASAL control group

The Forest graph summarizes results of meta-analysis for the outcome ANB difference:



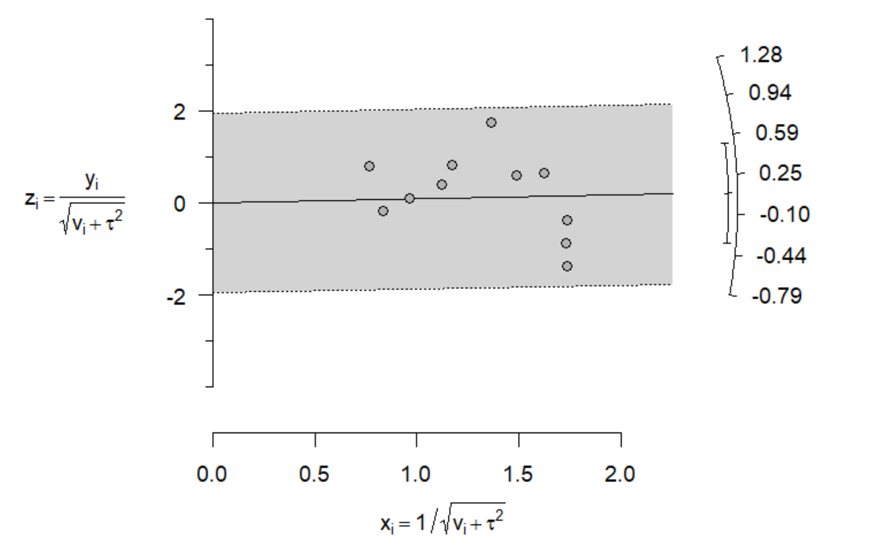
Meta-analysis concluded a WMD=0.08º (this is the difference between test oral minus control nasal group). This result is not statistically significant (p=0.704), that is to say, there is no enough statistical evidence of a different effect of the type of breathing.

Table 4.3.3.- Results of meta-analysis of mean differences of **ANB by Group**: weighted mean difference (WMD), standard error (SE), 95% confidence interval, z test (p-value), I^2 index, Cochran´s Q statistic (p-value) for heterogeneity; Egger´s test (p-value) for publication bias

WMD	SE	95% CI	z (p-value)	I^2	Q_H (p-value)	Egger (p-value)
0.08	0.22	-0.35 0.52	0.704	50.5%	0.050	0.089

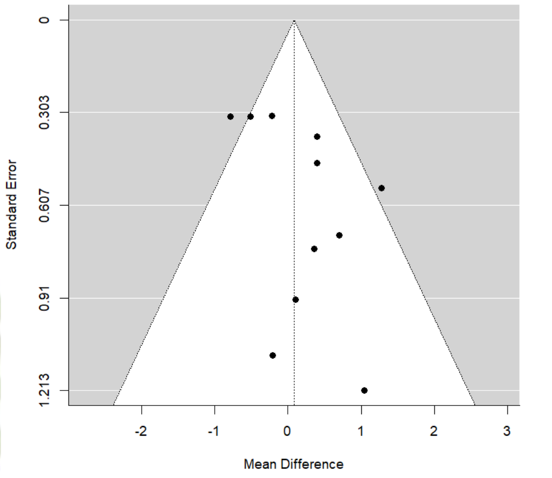
*p<0.05; **p<0.01; ***p<0.001

Observe that the heterogeneity associated to the model is moderate (I^2=50.5%). The following Galbraith graph shows that all papers contributed with a similar weight to between-subjects variability:



P-value for Cochran´s homogeneity test was estimated at 0.05, in the border of statistical significance, as expected from the moderate level of heterogeneity.

Observe the following Funnel plot showing a moderate level of asymmetry (p=0.089, Egger´s test):



Pay attention to the mid-lower part of the graph. There are articles in the right side, those which reported higher differences of ANB favoring test group but there is a lack of studies with similar accuracy in the left side.

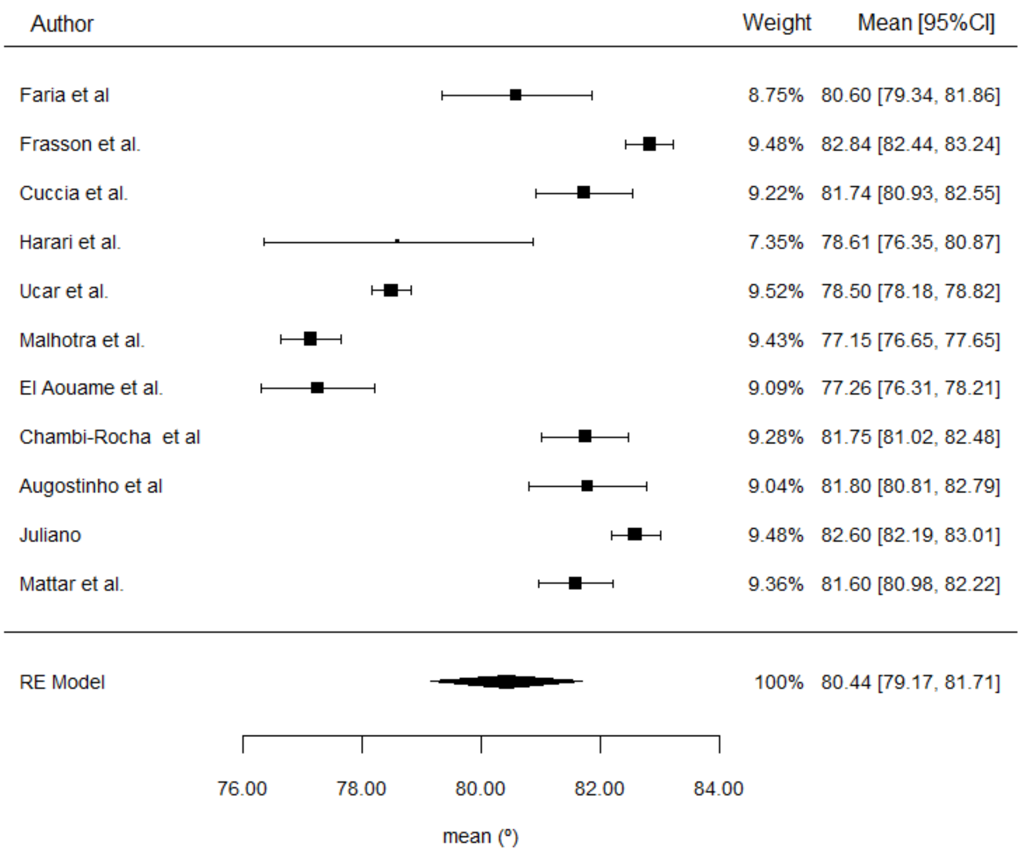
Anyway, most of papers were inside the funnel, avoiding the significance.

4.4. SNA

Test (oral) group

The following table shows articles which will be included in meta-analysis:

ID	AUTHOR	n	GROUP	mean	SD
1	**Faria et al**	20	Test	80.6	3.53
3	**Frasson et al.**	25	Test	82.84	3.46
5	**Cuccia et al.**	35	Test	81.74	4.45
7	**Harari et al.**	55	Test	78.61	6.61
9	**Ucar et al.**	34	Test	78.5	3.29
11	**Malhotra et al.**	20	Test	77.15	1.68
13	**El Aouame et al.**	23	Test	77.26	5.05
15	**Chambi-Rocha et al**	23	Test	81.75	4.57
15	**Augostinho et al**	35	Test	81.8	4.2
15	**Juliano**	52	Test	82.6	3.8
15	**Mattar et al.**	44	Test	81.6	3.9



<u>Mean SNA was estimated at 80.4 ± 0.65º.</u>

Table 4.4.1.- Results of meta-analysis of **SNA**: weighted mean (WM), standard error (SE), 95% confidence interval, z test (p-value), I^2 index, Cochran´s Q statistic (p-value) for heterogeneity; Egger´s test (p-value) for publication bias

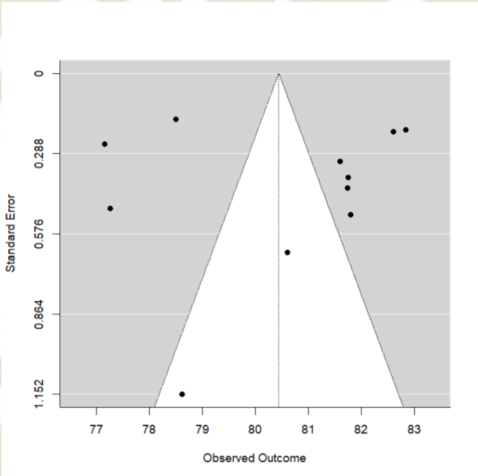
WM	SE	95% CI		z (p-value)	I^2	Q_H (p-value)	Egger (p-value)
80.4	0.65	79.2	81.7	<0.001***	98.0%	<0.001***	0.489

*p<0.05; **p<0.01; ***p<0.001

Observe that confidence interval excluded 82º, suggesting that this group tends to be maxillary retrusion.

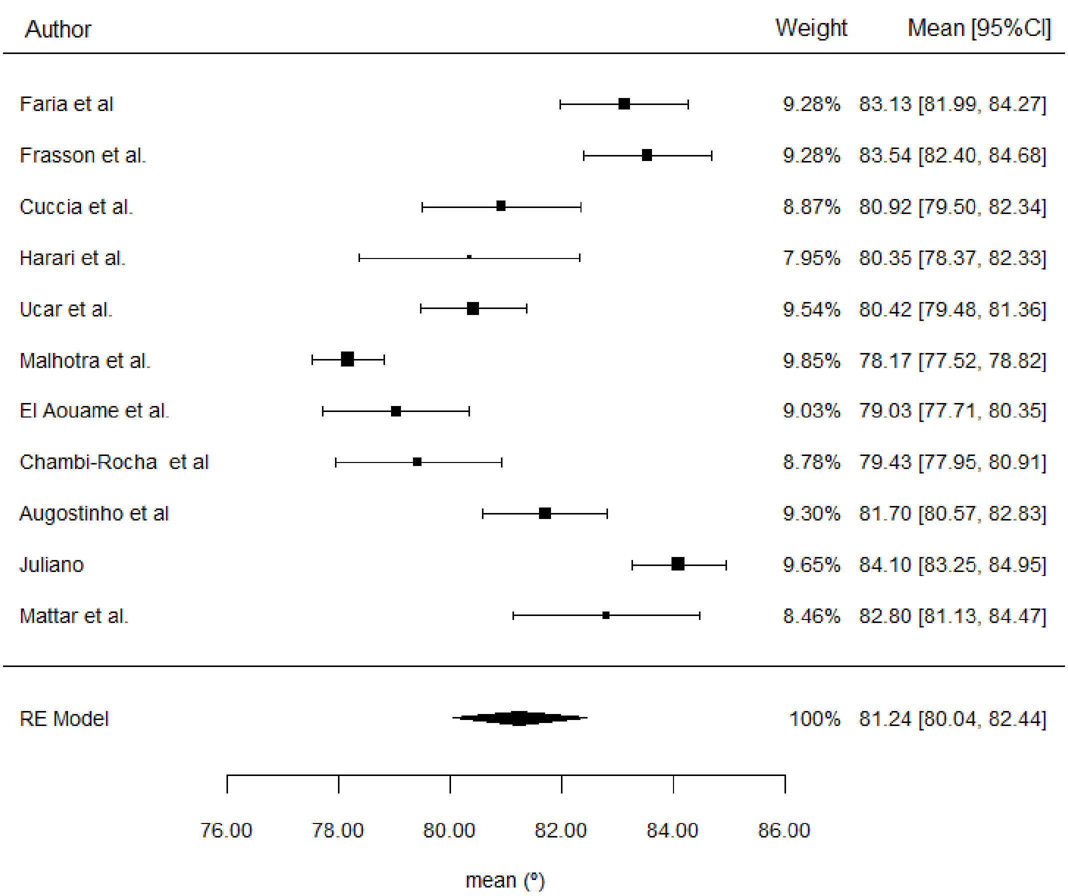
The model was estimated under high level of heterogeneity (I^2=98%).

Funnel´s plot shows absence of publication bias (p=0.489), but a high heterogeneity.



Control (nasal) group

ID	AUTHOR	n	GROUP	mean	SD
2	**Faria et al**	15	Control	83.13	2.26
4	**Frasson et al.**	25	Control	83.54	2.91
6	**Cuccia et al.**	35	Control	80.92	4.29
8	**Harari et al.**	61	Control	80.35	7.88
10	**Ucar et al.**	32	Control	80.42	2.71
12	**Malhotra et al.**	18	Control	78.17	1.4
14	**El Aouame et al.**	30	Control	79.03	3.68
16	**Chambi-Rocha et al**	20	Control	79.43	3.38
16	**Augostinho et al**	35	Control	81.7	3.4
16	**Juliano**	90	Control	84.1	4.1
16	**Mattar et al.**	29	Control	82.8	4.6



<u>Mean SNA was estimated at 81.2 ± 0.61º.</u>

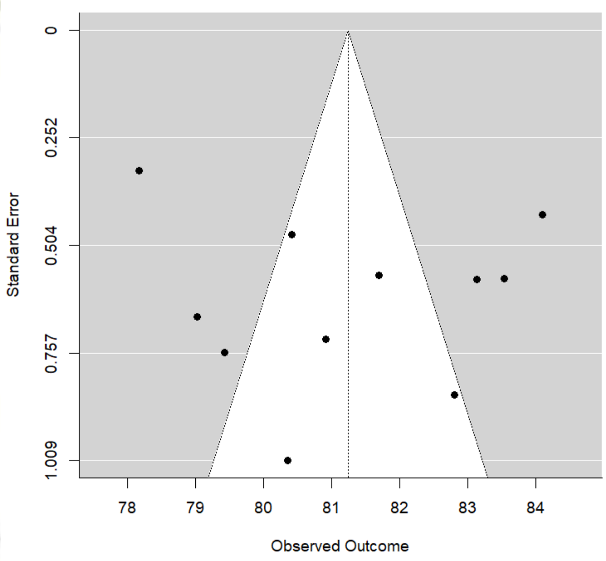
Table 4.4.2.- Results of meta-analysis of **SNA**: weighted mean (WM), standard error (SE), 95% confidence interval, z test (p-value), I^2 index, Cochran´s Q statistic (p-value) for heterogeneity; Egger´s test (p-value) for publication bias

WM	SE	95% CI		z (p-value)	I^2	Q_H (p-value)	Egger (p-value)
81.2	0.62	80.0	82.4	<0.001***	92.0%	<0.001***	0.988

*p<0.05; **p<0.01; ***p<0.001

The model was estimated under high level of heterogeneity (I^2=92%).

Funnel´s plot shows absence of publication bias (p=0.988), but a high heterogeneity.

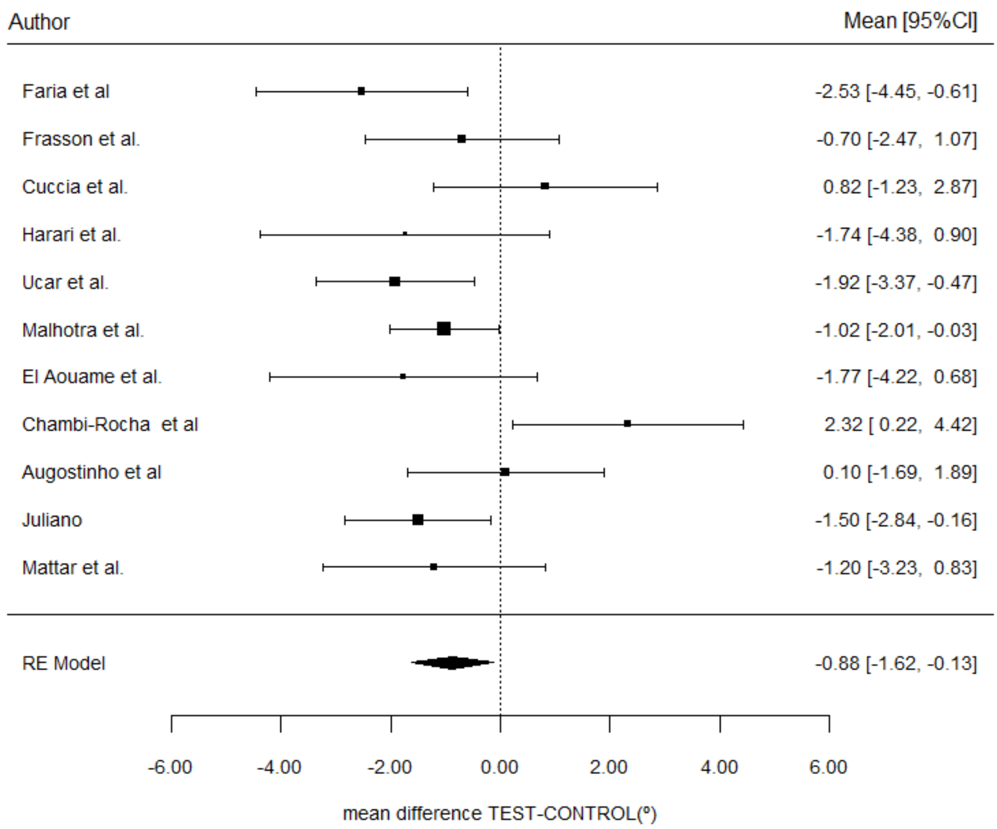


Comparison Test (oral) vs. Control (nasal)

		TX			Control		
ID	AUTHOR	nTX	mTX	sTX	nCT	mCT	sCT
1	Faria et al	20	80.60	3.53	15	83.13	2.26
2	Frasson et al.	25	82.84	3.46	25	83.54	2.91
3	Cuccia et al.	35	81.74	4.45	35	80.92	4.29
4	Harari et al.	55	78.61	6.61	61	80.35	7.88
5	Ucar et al.	34	78.50	3.29	32	80.42	2.71
6	Malhotra et al.	18	77.15	1.68	20	78.17	1.40
7	El Aouame et al.	23	77.26	5.05	30	79.03	3.68
8	Chambi-Rocha et al	33	81.75	4.57	22	79.43	3.38
9	Augostinho et al	35	81.80	4.20	35	81.70	3.40
10	Juliano	52	82.60	3.80	90	84.10	4.10
11	Mattar et al.	44	81.60	3.90	29	82.80	4.60

n=number of patients; m=mean; s=SD; TX=ORAL Test group; CT=NASAL control group

The Forest graph summarizes results of meta-analysis for the outcome SNA difference:



Meta-analysis concluded a WMD=-0.88º (this is the difference between test oral minus control nasal group). This result reached statistical significance (p=0.022). Oral patients showed lower SNA than nasal patients. Oral patients showed a stronger propension to maxillary retrusion.

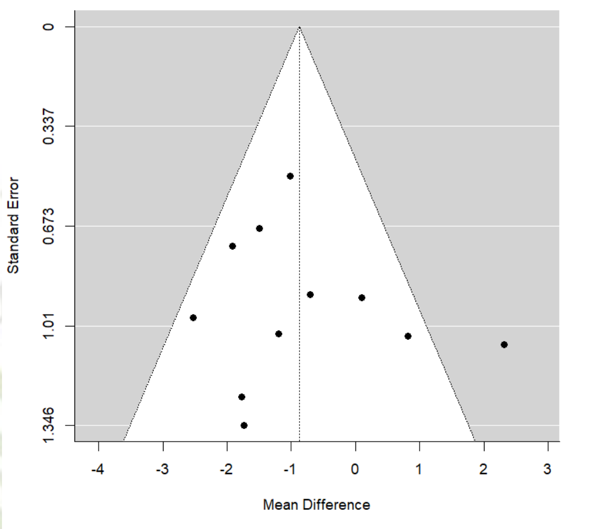
Table 4.4.3.- Results of meta-analysis of mean differences of **SNA by Group**: weighted mean difference (WMD), standard error (SE), 95% confidence interval, z test (p-value), I^2 index, Cochran´s Q statistic (p-value) for heterogeneity; Egger´s test (p-value) for publication bias

WMD	SE	95% CI	z (p-value)	I^2	Q_H (p-value)	Egger (p-value)
-0.88	0.38	-1.62 -0.13	**0.022***	50.0%	0.036*	0.609

*p<0.05; **p<0.01; ***p<0.001

Heterogeneity was estimated as moderate (I^2=50%).

No signs of publication bias (p=0.609).

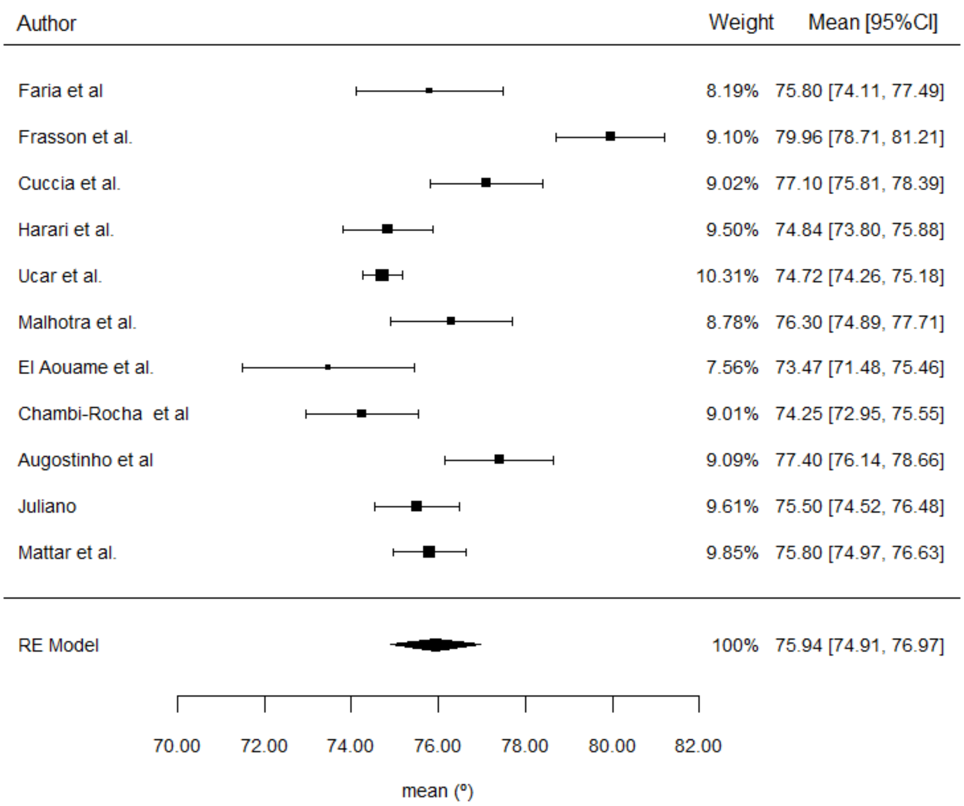


4.5. SNB

Test (oral) group

The following table shows articles which will be included in meta-analysis:

ID	AUTHOR	n	GROUP	mean	SD
1	**Faria et al**	20	Test	75.8	3.86
3	**Frasson et al.**	25	Test	79.96	3.2
5	**Cuccia et al.**	35	Test	77.1	3.9
7	**Harari et al.**	55	Test	74.84	3.94
9	**Ucar et al.**	34	Test	74.72	1.36
11	**Malhotra et al.**	20	Test	76.3	3.22
13	**El Aouame et al.**	23	Test	73.47	4.86
15	**Chambi-Rocha et al**	23	Test	74.25	3.18
15	**Augostinho et al**	35	Test	77.4	3.8
15	**Juliano**	52	Test	75.5	3.6
15	**Mattar et al.**	44	Test	75.8	2.8



<u>Mean SNB was estimated at 75.9 ± 0.53º.</u>

Table 4.5.1.- Results of meta-analysis of **SNB**: weighted mean (WM), standard error (SE), 95% confidence interval, z test (p-value), I^2 index, Cochran´s Q statistic (p-value) for heterogeneity; Egger´s test (p-value) for publication bias

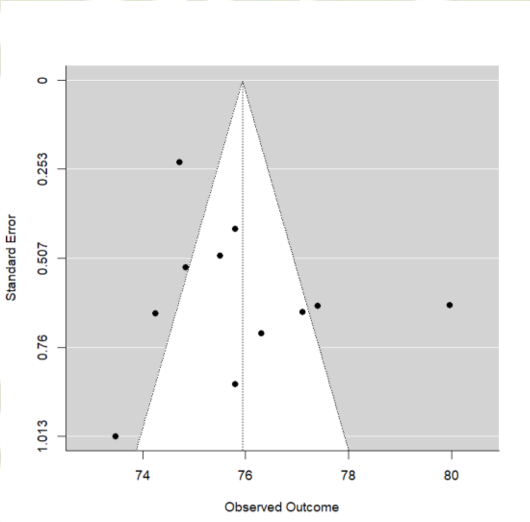
WM	SE	95% CI		z (p-value)	I^2	Q_H (p-value)	Egger (p-value)
75.9	0.52	74.9	77.0	<0.001***	90.4%	<0.001***	0.988

*p<0.05; **p<0.01; ***p<0.001

Observe that confidence interval excluded 78º, suggesting that this group tends to have mandibular retrusion.

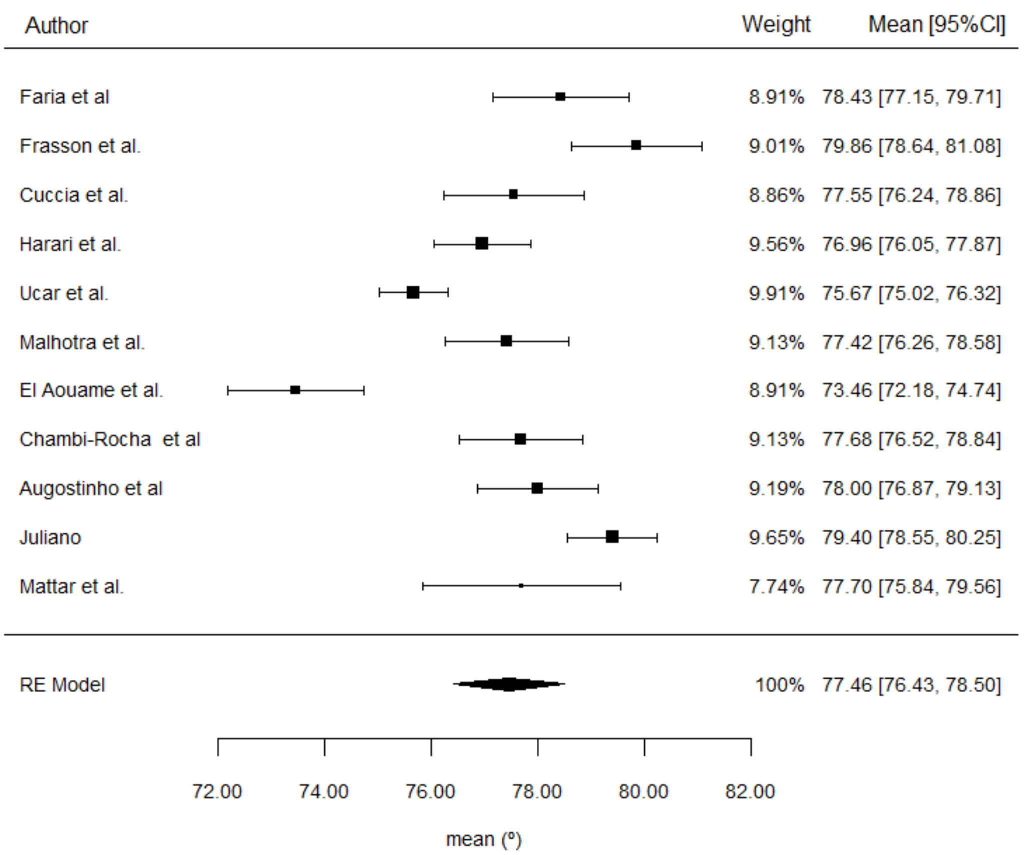
The model was estimated under high level of heterogeneity (I^2=90%).

As usual, Funnel´s plot shows absence of publication bias (p=0.998), but a high heterogeneity.



Control (nasal) group

ID	AUTHOR	n	GROUP	mean	SD
2	**Faria et al**	15	Control	78.43	2.53
4	**Frasson et al.**	25	Control	79.86	3.12
6	**Cuccia et al.**	35	Control	77.55	3.94
8	**Harari et al.**	61	Control	76.96	3.61
10	**Ucar et al.**	32	Control	75.67	1.87
12	**Malhotra et al.**	18	Control	77.42	2.51
14	**El Aouame et al.**	30	Control	73.46	3.57
16	**Chambi-Rocha et al**	20	Control	77.68	2.65
16	**Augostinho et al**	35	Control	78	3.4
16	**Juliano**	90	Control	79.4	4.1
16	**Mattar et al.**	29	Control	77.7	5.1



Mean SNB was estimated at 77.5 ± 0.53°.

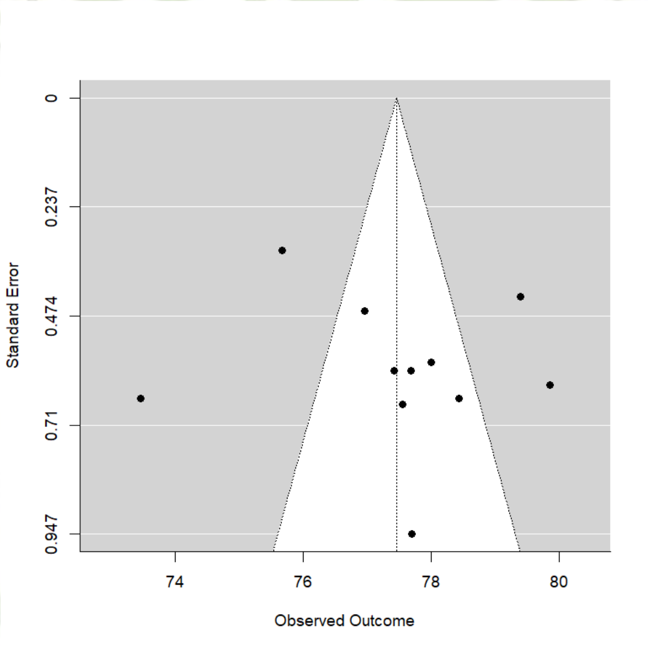
Table 4.5.2.- Results of meta-analysis of **SNB**: weighted mean (WM), standard error (SE), 95% confidence interval, z test (p-value), I^2 index, Cochran´s Q statistic (p-value) for heterogeneity; Egger´s test (p-value) for publication bias

WM	SE	95% CI		z (p-value)	I^2	Q_H (p-value)	Egger (p-value)
77.5	0.53	76.4	78.5	<0.001***	90.1%	<0.001***	0.809

*p<0.05; **p<0.01; ***p<0.001

The model was estimated under high level of heterogeneity (I^2=90%).

As usual, Funnel´s plot shows absence of publication bias (p=0.809), but a high heterogeneity.

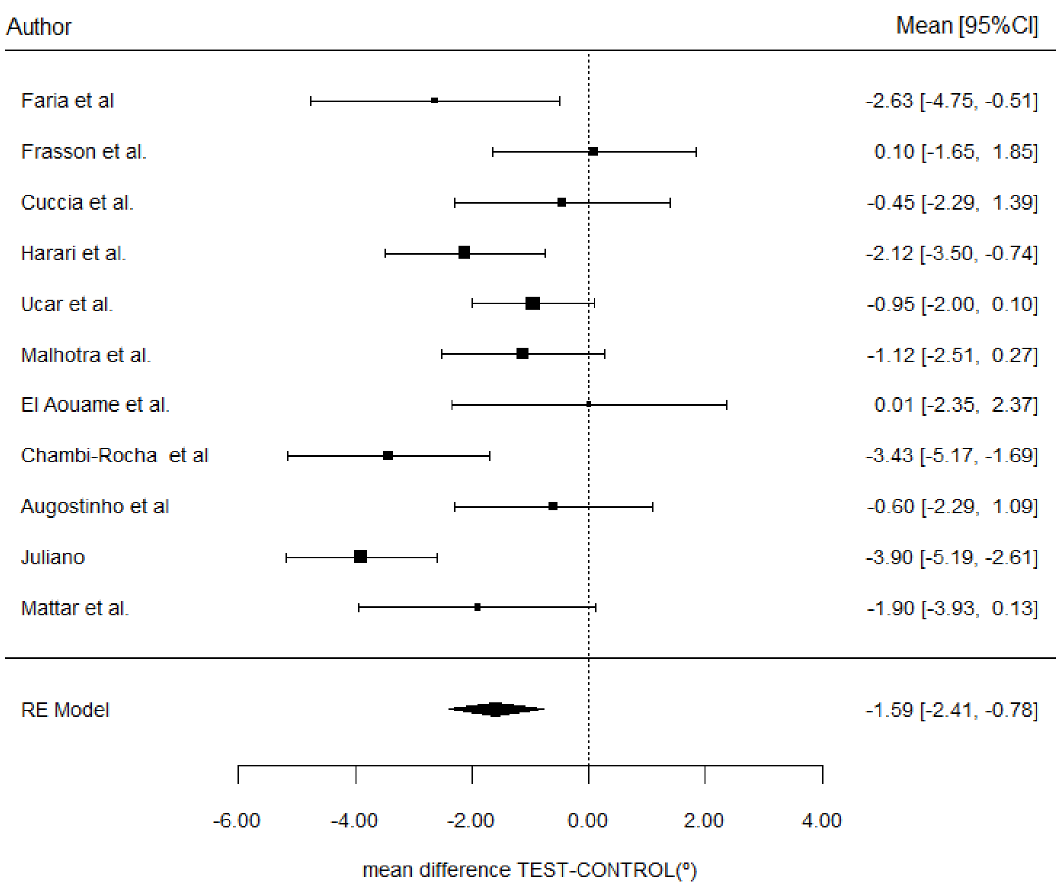


Comparison Test (oral) vs. Control (nasal)

		TX			Control		
ID	AUTHOR	nTX	mTX	sTX	nCT	mCT	sCT
1	Faria et al	20	75.80	3.86	15	78.43	2.53
2	Frasson et al.	25	79.96	3.20	25	79.86	3.12
3	Cuccia et al.	35	77.10	3.90	35	77.55	3.94
4	Harari et al.	55	74.84	3.94	61	76.96	3.61
5	Ucar et al.	20	74.72	1.36	18	75.67	1.87
6	Malhotra et al.	34	76.30	3.22	32	77.42	2.51
7	El Aouame et al.	23	73.47	4.86	30	73.46	3.57
8	Chambi-Rocha et al	23	74.25	3.18	20	77.68	2.65
9	Augostinho et al	35	77.40	3.80	35	78.00	3.40
10	Juliano	52	75.50	3.60	90	79.40	4.10
11	Mattar et al.	44	75.80	2.80	29	77.70	5.10

n=number of patients; m=mean; s=SD; TX=ORAL Test group; CT=NASAL control group

The Forest graph summarizes results of meta-analysis for the outcome SNB difference:



Meta-analysis concluded a WMD=-1.59º (this is the difference between test oral minus control nasal group). This result reached statistical significance ($p<0.001$). Oral patients showed lower SNB than nasal patients. Oral patients showed a stronger propension to mandibular retrusion.

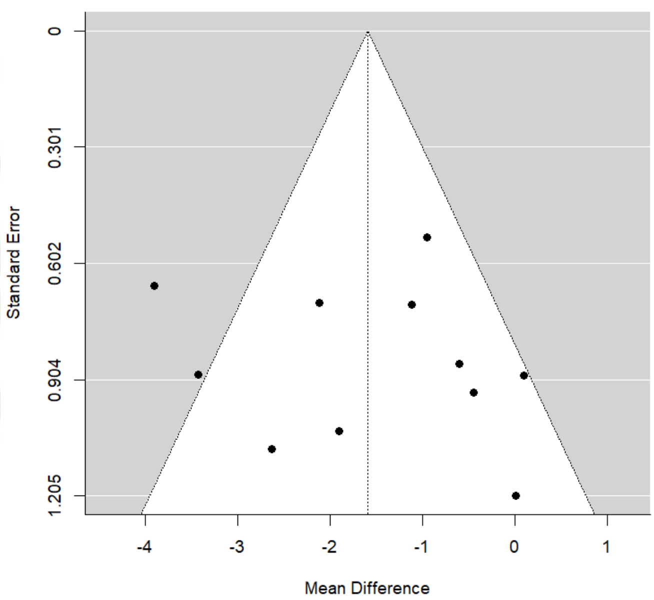
Table 4.5.3.- Results of meta-analysis of mean differences of **SNB by Group**: weighted mean difference (WMD), standard error (SE), 95% confidence interval, z test (p-value), I^2 index, Cochran´s Q statistic (p-value) for heterogeneity; Egger´s test (p-value) for publication bias

WMD	SE	95% CI	z (p-value)	I^2	Q_H (p-value)	Egger (p-value)
-1.59	0.41	-2.41 -0.78	**<0.001*** **	64.0%	0.002**	0.541

*p<0.05; **p<0.01; ***p<0.001

Heterogeneity was estimated as moderate-high (I^2=64%).

No signs of publication bias (p=0.541).



4.6 CONCLUSIONS OF THE META-ANALYSIS

1. There were found significant differences in SNA between groups (p=0.022). Oral patients showed lower SNA than nasal patients. Oral patients showed a stronger propension to maxillary retrusion.

2. There were found significant differences in SNB between groups (p<0.001). Oral patients showed lower SNB than nasal patients. Oral patients showed a stronger propension to mandibular retrusion.

3. There were no found differences in ANB between groups (p=0.704). Both patients showed a similar skeletal pattern

V. DISCUSSION

This systematic review was conducted to investigate the consequences of mouth breathing on sagittal skeletal occlusion and craniofacial morphology. The subsequent meta-analysis examined the correlation between mouth breathing and sagittal skeletal malocclusions more in detail to appraise their numerical significance through statistical scrutiny. As previously outlined, craniofacial deformities stand for an escalating concern in the field of orthodontic dentistry and is a variable that needs to be considered if we are talking about treatment strategies aimed at optimizing patient outcomes and promoting overall oral health and well-being in a community or the general population.

5.1 Specific Objective

In total 11 articles examining the connection between mouth breathing and skeletal sagittal malocclusions were compiled. The findings revealed predictable and sometimes unexpected information about the different anatomical landmarks and features of the cranium and stomatognathic system

Mouth breathers have significantly larger retrognathic maxillae and mandibles, as seen by lower SNA and SNB angles, according to research by Faria et al. Because of changed tongue posture and nasopharyngeal blockages, allergic mouth breathers had a significantly smaller SNB angle, which suggests that the mandible is positioned lower and more backwards. Despite these findings, the ANB angle did not show a statistically significant difference between the participant groups, indicating no deviations in the sagittal relationship between the upper and lower jaw. Regarding other anatomical structures, significant differences were explored.

Mouth breathers displayed mandibular angles that were larger and longer faces with higher vertical growth. Surprisingly, Frasson et al. did not find any significant variations in cephalometric values between nasal and oral breathers, nor in face height or bone base correlations (ANB, SNA, and SNB). Normal fluctuation in these angles was observed among both groups, indicating similar craniofacial anatomy. This implies, that oral breathing may not have a significant effect on changes in face patterning or sagittal skeletal malocclusion. Cuccia et al. reported variations in the

SNA and SNB angles between children who breathed orally (OB) and those who breathed nasally (NB), but these differences were not determined as statistically significant, suggesting that among the two groups upper and lower jaw positions were alike. OB infants did, however, have a noticeably raised ANB angle, indicating a Class II skeletal pattern and an upper jaw protrusion relative to the lower jaw. Moreover, children with OB exhibited a raised maxillomandibular plane angle, signifying a more open angle between the lower jaw and the base of the skull. This greater angle implies a propensity for a vertical growth pattern, which may have an impact on occlusal features and face elongation. It's interesting to note that Harari et al. did not find any relevant variations in ANB, SNA, or SNB angles among the two groups, indicating that the maxillomandibular relationships were similar. On the other hand, notable variations were detected in other dimensions. Mouth breathers exhibited a higher mandible plane angle, narrower dental arches, increased overjet, and mandibular backward and downward rotation.

Furthermore, they displayed a higher prevalence of specific malocclusions, such as class II malocclusion and posterior crossbites. Ucar et al. found out that mouth breathers exhibited diminished SNA and ANB angles, pointing to potential maxillary deficiency or retrusion. On the other hand, SNB angle variations were not statistically significant. Additionally, measurements like anterior facial height were elevated in mouth breathers, implying increased mandibular inclination and a tendency toward a dolichocephalic skeletal pattern. While there wasn't a statistically significant difference, mouth breathers showed a trend towards a higher rate of Class II malocclusion compared to nose breathers. Malhotra et al. found no statistically significant differences between oral breathers and mouth breathers in the SNA, SNB and ANB angles. According to El Aouame et al., the SNA, SNB, and ANB angles of mouth- and nose-breathers did not differ, indicating comparable skeletal relationships. Notably, both groups exhibited an average ANB angle suggestive of skeletal Class II malocclusion. The mandibular retrognathism and posterior tilting of the mandibular plane among mouth-breathers pointed out potential distinctions in their growth patterns compared to nose-breathers. According to Chambi-Rocha et al., there were virtually no variations in SNA, SNB, and ANB angles between oral breathers (OB) and nasal breathers (NB) amongst children and teens having a normal growth pattern. In contrast to their NB counterparts, OB teenagers showed increased lower anterior face height and palate length. The findings demonstrate that breathing habits, particularly during adolescence, may have an impact on variations in craniofacial development. For clarification on the effect of breathing patterns on craniofacial growth and development, additional scientific investigation was advised. Agostinho et al. found no statistically significant distinctions emerged in the skeletal sagittal relationships denoted by the SNA, SNB, and ANB angles among children with varying breathing patterns. While not statistically significant, a propensity towards a skeletal Class II relationship was noted in children with mouth breathing, as evidenced by a slightly higher ANB angle in this group. Juliano et al. highlighted, that children who breathed through their mouths had lower SNA and SNB angles and a more retruded maxilla and mandible than children who breathed through their noses. Furthermore, a slightly higher ANB angle indicated that mouth breathing children exhibited a propensity towards a skeletal Class II relationship, but the association was not statistically significant. Mattar et al. found that SNA and SNB angles had no statistical difference between the mouth and nasal breathing groups. Also, the ANB angle was insignificant but was slightly elevated indicating a skeletal class II tendency. Making a definitive judgment regarding the impact of mouth breathing on sagittal skeletal malocclusions is challenging when examining the evaluations of the study records again. The evidence is to be considered inconclusive; however, the outcome of the META analysis offers a little more clarity. Significant variations in SNA were seen across the groups ($p=0.022$), with lower SNA values in oral patients indicating a higher propensity for maxillary retrusion than in nasal individuals. Significant variations were also noted in SNB ($p<0.001$), with lower SNB values in oral patients, suggesting a higher propensity for mandibular retrusion. All patient groups, however, appeared to have a similar overall skeletal pattern with regard to the mutual position of the mandible and maxilla, as no significant changes in ANB were observed across groups ($p = 0.704$). The results provide significant insight into the different craniofacial characteristics linked to nasal and oral breathing patterns. The retrusive tendency observed in mouth breathing patients could have significant implications for respiratory function. In addition to altering the facial profile, a retruded maxilla and mandible may decrease the amount of space available for the airway.

This narrowed airspace puts you at higher risk for respiratory issues like sleep apnoea and breathing difficulty. Even if the correlation between mouth breathing and sagittal skeletal malocclusion was found to be low and insignificant across most of the studies various other anatomic landmarks showed a clear connection that could be proven empirically. In mouth-breathing patients, Faria et al. found greater retrognathism of the maxilla and posterior rotation of the palatal plane. Frasson et al. surprisingly found no significant differences in facial patterns or profiles between nose and mouth breathers, suggesting that mouth breathing may not be the only factor in facial pattern changes, and recommended further longitudinal studies since they were aware of the limitations of the study design. These findings have a certain unique selling point since most other studies have been able to demonstrate a significant correlation between mouth breathing and craniofacial deformities. Cuccia et al. reported that mouth breathing influences head posture and craniofacial morphology and that an early transition from mouth to nose breathing could normalize craniofacial dimensions. Harari et al. observed significant backward and downward rotation of the mandible, increased overjet, increased mandibular plane angle, increased palatal plane, narrower dental arches, and higher prevalence of posterior crossbite in mouth breathers. Malhotra et al. associated mouth breathing with increased facial height increased mandibular plane angle and more pronounced gonial angle. El Aouame found that mouth breathers had posterior mandibular rotation, increased anterior facial height, decreased posterior facial height, retrognathia, and open bite, highlighting the need for early diagnosis and multidisciplinary intervention. Teenagers who breathe orally showed decreased anteroposterior airway dimension, longer palates, greater incidence of lower hyoid position, and greater lower frontal face height, as described by Chambi-Rocha et al. According to Agostinho et al., mouth breathers especially those suffering from allergic rhinitis frequently feature smaller upper and lower jaws, a more vertical skeletal structure, an open bite tendency, and a decreased airway space. In accordance with Juliano et al., mouth-breathing kids have cephalometric characteristics that are comparable to those of obstructive sleep apnoea syndrome (OSAS) patients, indicating an early onset of apnea pattern development. Finally, Mattar et al. stated that mouth breathers showed higher mandibular plane inclination, blunter gonial angle, dolichofacial morphology, and reduced lower posterior facial height. The findings collectively indicate a strong correlation between mouth breathing and craniofacial deformities. In contrast to the findings relating to skeletal sagittal malocclusion, these findings showed a more concrete burden of evidence. It should not be overlooked that the stomatognathic apparatus requires a fine balance of the musculoskeletal framework to maintain physiological integrity. It can therefore be assumed that an interaction of several factors such as mouth breathing or other damaging oral habits can disrupt this balance and therefore have a negative effect on the individual and his or her quality of life.

Shifting from the interpretation of findings, it is imperative to comprehend the critical role of preventive measures and interventions aimed at oral habits. These essentially focus on the use of habit-breaking appliances as reported by Awuapara et al.(31) Starting with the first habit treatment for non-nutritive sucking habits usually starts around age 3 with dental check-ups and early parental guidance. Between the ages of 4 and 6, using positive reinforcement can be an initial strategy to reduce digit-sucking behaviour. If these efforts do not succeed, deterrents such as bitter-tasting nail polish, gloves, or mittens may be used to discourage the habit. In persistent cases, appliances might be required. One common device is the palatal crib, a stainless-steel fixture embedded between the palate, preventing finger insertion, and facilitating the closure of an anterior open bite. Another option is the bluegrass appliance, which provides a physical barrier and in addition includes a tongue-stimulating roller. This tool, called a habit correction roller, is well-known for its efficiency and little impact on day-to-day activities, frequently resulting in successful habit eradication in a brief amount of time.

A variety of appliances, such as cemented spurs, fixed or detachable palatal grids, myofunctional treatment, and the bluegrass appliance, can be used to treat abnormal swallowing patterns such as tongue thrusting. Whether fixed or detachable, the palatal grid should be tall enough to keep the patient from sticking their tongue through it. Conventional orthodontic spurs serve as the foundation for the creation of cemented spurs, also known as tongue spurs. They have several benefits, including compact size, affordability, attractiveness, simplicity of installation, and shortened cementation therapy times. Another treatment approach for correcting atypical swallowing is myofunctional therapy, either alone or in combination with orthodontic treatment. Improvements in myofunctional capacity have been linked to adequate jaw growth and development, tongue thrust correction, and dentition adaptation to novel occlusal patterns, according to studies. Myofunctional therapy addresses changes and dysfunctions of the orofacial muscles that impede the development, growth, and functions of the stomatognathic apparatus. This includes problems with mandibular deviation, tongue thrust habits, lip incompetence, orofacial anomalies, mouth breathing patterns, and improper joint patterns during speaking, chewing, and swallowing. In addition, it promotes functional and environmental balance for the healthy development of oral and perioral structures and assists in the correction of parafunctional oral behaviours including thumb sucking, bruxism, and abnormal swallowing.

Treatment options for myofunctional disorders have ranged from simple instructions to abstain from and discourage the habits to various combinations of fixed intraoral appliances or removable devices. Several types of myofunctional treatment protocols have been applied, all focused on increasing patients' awareness of oral and perioral muscle exercises. However, the long-term effectiveness of myofunctional therapy alone or in combination with other treatments requires further evaluation. It is important to emphasize that the treatment of this condition must be accompanied by a thorough medical diagnosis of a specialist to determine the exact aetiology.

While addressing lip sucking the "lip bumper" serves as a treatment option for this habit, effectively preventing lip pressure on the teeth. Therapeutically, it promotes labial displacement of the incisors, the distal inclination of the first lower molars, and increases transverse dimensions of the arch. (31). The AAPD continues to suggest the "lip bumper" for habit treatment despite a shortage of scientific evidence supporting its effectiveness. Its beneficial advantages in clinical practice are nevertheless highlighted, despite the fact that the available research indicates a low to extremely low degree of assurance regarding its dentoalveolar effects.

A comprehensive strategy is used to treat the underlying causes of mouth breathing and encourage healthy breathing patterns as part of preventive actions against it. First and foremost, a thorough medical evaluation is necessary to determine and treat any contributing factors, including allergies, nasal obstructions, or anatomical anomalies. Treatment for these underlying issues will diminish the probability of mouth breathing. That is essential to promote correct nasal breathing. This can be accomplished by using a variety of breathing exercises and methods that increase nasal airflow and lessen the need for mouth breathing patterns Developing healthy physiological practices is essential. This includes encouraging nasal breathing when awake and asleep, maintaining lip seals, and ensuring the tongue is positioned correctly. By reinforcing these habits, individuals can gradually shift from mouth breathing tendencies to nasal breathing. Orthopaedic or orthodontic treatments may be required when skeletal or dental abnormalities are present. By addressing problems related to mouth breathing, these procedures hope to foster better facial and oral development. Especially for parents and other caregivers, education is essential. It is necessary to educate them on the significance of prompt identification and action in order to avert possible problems associated with mouth breathing. By raising awareness, families can take proactive steps to address the issue promptly. Collaboration among healthcare professionals is essential for comprehensive management. Dentists, orthodontists, otolaryngologists, and paediatricians should work together to develop personalized treatment plans tailored to everyone’s needs, ensuring holistic care and long-term success in combating mouth breathing and its associated challenges.

A recent study by S. Saccomanno et al. revealed a positive shift in parental attention towards dental health and occlusion. Differently from the past, there is now greater recognition of the consequences of an improper relationship between jaws and teeth that can have negative effects on various areas of a patient’s health. The findings reported by Saccomanno et al. showed that general dentists are the main professionals responsible for identifying dental malocclusion, with orthodontists also contributing significantly. Although paediatricians have a minor role in diagnosing malocclusion, they are essential in referring young patients for early evaluations by specialists. So, the optimal approach seems to include fostering collaboration among paediatricians, orthodontists, and the patient's family. In conclusion, Preventive Orthodontics relies on a multidisciplinary approach to effectively prevent the spread of oral habits and to limit their influence on skeletal occlusion and the craniomandibular structure. A table with therapeutic protocols can be found in the appendix. (32)

5.2 General Objective

As stated in the specific objective, the scientific evidence from the studies indicates that mouth breathing has little to no impact on the craniofacial morphology. The evidentiary value of the papers is sometimes not very meaningful and is therefore not satisfactory when viewed individually, which the authors also state is a limitation. This issue was addressed through this work based on a wide range of articles included in a systematic review to enlarge the pool of evidence of the different parameters. Our main objective was to analyse the consequences of mouth breathing on skeletal sagittal malocclusions and craniofacial morphology constituted by the ANB, SNA and SNB angle and other anatomic parameters. Nearly all the studies collected and further processed in the meta-analysis, despite their limitations, concluded that there was no significant difference in the ANB angle between the mouth and nasal breathing group. However, the SNA and SNB angles were found to be significantly lower in mouth-breathing individuals indicating a bimaxillary retrusion in mouth breathers. El Aouame et al. and Juliano et al. reported a tendency to skeletal class II malocclusion according to ANB values in the mouth breathing group, although not statistically significant. It needs to be mentioned that even if the evidence does not point out a significant difference between sagittal skeletal malocclusions based on ANB angle, there were significant other cephalometric differences between mouth breathers and nasal breathers. Mouth breathers often display a greater anterior facial height compared to nasal breathers resulting in longer faces often as part of the condition termed as ‘’Adenoid facies’’. They tend to have a higher mandibular plane angle, suggesting a more open angle between the base of the skull and the lower jaw, coupled with a tendency towards mandibular retrognathism and a dolichofacial pattern, characterized by a downward and backward positioning of the mandible (Zhao et al). Lastly Harari et al. mentioned a higher prevalence of posterior crossbites observed in mouth breathers.

To have a better overview of the various other oral habits that can exhibit negative consequences the studies by Rodríguez-Olivos et al and Laganà et al. provide insightful information. Rodríguez-Olivos et al. identified significant associations between atypical swallowing, thumb-sucking, and lip-sucking habits with various malocclusions. Specifically, they found vertical malocclusions linked to atypical swallowing and mouth breathing, transverse malocclusion associated with mixed breathing (nasal and oral), and sagittal malocclusion correlated with atypical swallowing and labial sucking. Thumb sucking was associated with anterior open bite and posterior crossbite, while bottle-feeding during weaning increased the risk of anterior open bite. Laganà et al. further emphasized the impact of oral habits on malocclusion, with continued pacifier use being the most prevalent habit, followed by oral breathing and atypical swallowing.

Now that the impact of mouth breathing on craniofacial morphology is investigated, we focus on the question if potential consequences can persist into adulthood if there is a lack of intervention to mitigate these habits. It can be assumed that with the completion of bone growth through endochondral or intramembranous ossification, a sagittal skeletal malocclusion or other types of craniofacial deformities, can persist into adulthood even though self-correcting cases are reported(4). As we saw in the paragraph on preventative measures a first approach to address these skeletal malocclusions is through education and appliances thus keeping the musculoskeletal structures in physiologic balance. This is preferably done for the most skeletal defects like in earlier years with growth modification as Karamesinis et al. comprehensively presented and explained in their work. (33) In the adult age changes are more difficult to achieve and often require more time or invasive interventions because bone completes its growth via the ossification processes. (34) The biological principles described are essential for the professional's understanding of a timely diagnosis, supplemented by a structured treatment plan. The times when which treatments are used often depend on the skeletal age and growth spurt. If an individual has reached adulthood, an interdisciplinary intervention by performing camouflage or orthognathic surgery is usually the only option left to cure severe cases of malocclusion as reported since growth modification is no longer possible (35). malocclusion usually manifests earlier in life so monitoring in time is key with a helpful protocol presented by L Paglia represented in the annexes. (36) It is therefore of interest to carry out further studies with a longer follow-up period to explore the nature of mouth breathing and sagittal skeletal malocclusions more in detail. A sagittal skeletal malocclusion alone or accompanied by more severe craniofacial deformities can limit an individual's quality of life and thus remain an important issue in orthodontics due to their frequency within the general population. It also be noted that the investigation of the effects of mouth breathing in relation to the ANB, SNA and SNB angle may oversimplify more complex correlations altering the depth of insights obtained from the findings. For that reason, it is imperative to view the impact concerning other anatomic landmarks combined with the understanding of the biochemical processes and musculoskeletal factors. With an outlook to the future, it remains to be said that these conditions will continue to represent a fundamental area of orthodontics and a scientific field of study to ultimately benefit the physiological and aesthetic well-being of the individual.

5.3 Quality and Limitations of the Studies

The assessment of the quality of the individual study articles of the Meta-Analysis revealed certain difficulties in terms of scientific evidence. While the background of the studies and their objectives are well reported in the introduction across all the studies, in the Materials and Methods section the first lack of information appears speaking particularly of the studies by Frasson et al., Malhotra et al, El Aouame et al. and Chambi-Rocha et al. The statistical methods are almost not mentioned at all and if so, only barely described. The same accounts also for the description of the results part since the evaluation parameters are very specific in nature and the study design is more focused on an observational point of view. Only Harari et al. showed relatively meticulous compliance with STROBE guidelines in that aspect. Regarding the parameters in the discussion, almost all studies demonstrated exemplary scientific elaboration, especially Chambi-Rocha et al. and Augostinho et al. with impeccable care. The overall quality score of the study is judged as ‘’Low’’ for most of the studies with the exception like El Aouame et al. found to be ‘’Very Low’’ and Cuccia et al. Harari et al. stand out as positive examples with ‘’Medium’’ quality. The two systematic reviews by Weiying Zheng et al. and Ziyi Zhao et al. are to be considered separately here because they clearly stand out from the observational studies due to the nature of their study design and their elaboration thus outweighing the rest of the studies in the evidentiary value of their results, judged for “Medium” and “High” respectively.

While our study provides valuable insights into oral habits together with their associated consequences, it is important to acknowledge several limitations that may alter the interpretation of our findings. The first limitation that needs to be addressed is the fact that most of the final study articles are observational studies with mostly low and only one with medium evidence quality as outlined in the risk and bias assessment. So, the homogeneity of study designs and the nature of cross-sectional studies which, according to the scientific evidence pyramid, only carries a medium evidential value, constitute a not insignificant disadvantage in answering the objectives of this paper. This concern, mentioned by some authors, underscores the challenge of discerning temporal patterns and inferring causality from static observations. The constantly evolving interplay between mouth breathing and craniofacial morphology remains unclear since changes over time have not been tracked. Furthermore, there is a considerable risk of bias when subjective evaluations are used, as mentioned by Frasson et al., Cuccia et al., Harari et al., Ucar et al., Chambi-Rocha et al., and Juliano et al. Studies that used clinical history and parental accounts as the basis for diagnostic criteria may be more prone to subjectivity and recall bias, which could compromise the validity and reliability of the results. The strongest source of evidence is the systematic review. Two systematic reviews were included in our pool of research articles to guarantee the sophisticated validity and transparency of our findings (Weiying Zheng et al., Ziyi Zhao et al.). This approach enhances the robustness of our conclusions by synthesizing broad data from high-quality studies and minimizing the risk of bias or inconsistency in the results.

As highlighted above, characteristics like age, race and gender of the participants are decisive factors that is barely included as part of a subgroup analysis. From a demographic standpoint, the number of participants and their geographical distribution are important variables, especially in studies with epidemiological and educative objectives. A recurrent limitation across several studies is the relatively small sample sizes, as evidenced by Frasson et al., Cuccia et al., Ucar et al., El Aouame et al., Chambi-Rocha et al., Augostinho et al., and Mattar et al. The restricted sample sizes not only raise concerns regarding the generalizability of findings but also alter the statistical power to detect meaningful effects. Often participants were picked from a school, orthodontic clinic or a medical facility which resulted in a homogenic study and control group. In the analysed papers, geographical distribution and ethnicity were not given further consideration. Additionally, individual properties such as allergies and obstructive sleep apnoea were not regarded in the majority of the studies except for Faria et al and Agostinho et al. The comprehension of the correlations under study is severely limited by the exclusion of plausible confounding variables, as mentioned by Harari et al. and Malhotra et al. The true nature of relationships seen in the data may be obscured if confounders like genetic influences, environmental factors, or concurrent therapies are not taken into account. The largest limitation pertains to the measurement methodology employed. Almost universally, studies acknowledge susceptibility to errors in measurement due to inconsistent diagnostic criteria particularly in relation to intra-examiner variability, as highlighted by Frasson et al. The risk of measurement bias due to inconsistencies in measurement techniques or interpretation underlines the importance of accepted methodological standards and examiner training. When it comes to assessing the mouth breathing habit, the reported absence of a standardized diagnostic device specifically designed to measure the extent of air intake through the mouth versus the nose states a limitation. Nasopharyngoscopy and/or rhinomanometry present potential solutions in this regard as seen in the study of Habumugisha et al (37). Those methods make it possible to assess nasal airflow and blockage objectively, which can provide necessary details on the prevalence and seriousness of mouth breathing. The measurement's limitation to a two-dimensional viewpoint is another notable drawback. Numerous writers have suggested that research be done from a three-dimensional perspective as well. By extending the study to include three-dimensional views, scientists can obtain a more thorough representation of anatomical components and their relationships. As indicated by the study findings a certain causality between mouth breathing and the development of sagittal skeletal malocclusions could not be established. The burden of proof is relatively clear and yet, from a scientific perspective, the need for further studies with more sophisticated diagnostic criteria as well as larger study groups with accompanying subgroup analysis and a longer observation period is a dampener in the search for a definitive answer.

VII. CONCLUSION

6.1 General Objective

Analysis and Interpretation of data suggests that:

- There is no evidence to reject the null hypothesis H01 stating that mouth breathing has little to no impact on the sagittal skeletal malocclusion.
- There is sufficient evidence to reject the null hypothesis H02 stating that mouth breathing has a significant impact on other anatomic structures of the craniofacial complex.

6.2 Specific Objective

- The Systematic review was unsuccessful in pointing out a certain correlation between mouth breathing and sagittal skeletal malocclusion (ANB), while the meta-analysis indicated bimaxillary retrusion in mouth breathers (SNA, SNB)
- Mouth breathing has a significant impact on other anatomic landmarks of the craniofacial structures especially lower anterior facial height, mandibular inclination and dental arch shape.
- As a protocol we can consider early intervention through prevention, using education and oral appliances, to avoid future impact of mouth breathing.

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IX. FIGURE AND TABLE BIBLIOGRAPHY

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- **Table 5.** Database research overview
- **Table 6.** Inclusion and Exclusion criteria
- **Table 7.** STROBE evaluation ratings
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- **Annexes Table 1.** Search Query
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- **Annexes Table 4.** SNA Angle Results
- **Annexes Table 5.** SNB Angle Results
- **Annexes Table 6.** Appliance Protocol Saccomanno S, De Luca M, Gallusi G, Saran S, Fioretti P. Prevention of malocclusion and the importance of early diagnosis in the Italian young population. Eur J Paediatr Dent. 2022;23(3):178–82.
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X. ANNEXES

Annexes Table 1. Search Query

Database	Parameter	Search Query
PubMed	Mouth breathing and Craniofacial Morphology	(("mouth breathing"[MeSH Terms] OR ("mouth"[All Fields] AND "breathing"[All Fields]) OR "mouth breathing"[All Fields]) AND (("face"[MeSH Terms] OR "face"[All Fields] OR "facial"[All Fields] OR "facials"[All Fields]) AND ("anatomy and histology"[MeSH Subheading] OR ("anatomy"[All Fields] AND "histology"[All Fields]) OR "anatomy and histology"[All Fields] OR "morphology"[All Fields] OR "morphologies"[All Fields])) AND ("hasabstract"[All Fields] AND 2000/01/01:2024/12/31[Date - Publication])) AND ((fha[Filter]) AND (fft[Filter]) AND (humans[Filter]) AND (english[Filter]))
	Mouth Breathing and Malocclusions	(("mouth breathing"[MeSH Terms] OR ("mouth"[All Fields] AND "breathing"[All Fields]) OR "mouth breathing"[All Fields]) AND ("malocclusal"[All Fields] OR "malocclusion"[MeSH Terms] OR "malocclusion"[All Fields] OR "malocclusions"[All Fields] OR "malocclusive"[All Fields])) AND ((fha[Filter]) AND (fft[Filter]) AND (english[Filter]) AND (2000:2024[pdat]))
SCOPUS	Mouth breathing and Craniofacial Morphology	mouth AND breathing AND craniofacial AND pattern AND PUBYEAR > 1999

		AND PUBYEAR < 2025 AND (LIMIT-TO (EXACTKEYWORD , "Child") OR LIMIT-TO (EXACTKEYWORD , "Mouth Breathing") OR LIMIT-TO (EXACTKEYWORD , "Adolescent")) AND (LIMIT-TO (SUBJAREA , "DENT")) AND (LIMIT-TO (DOCTYPE , "ar")) AND (LIMIT-TO (LANGUAGE , "English")) AND (LIMIT-TO (OA , "all"))
	Mouth Breathing and Malocclusions	mouth AND breathing AND malocclusion AND PUBYEAR > 1999 AND PUBYEAR < 2025 AND (LIMIT-TO (OA , "all")) AND (LIMIT-TO (SUBJAREA , "DENT")) AND (LIMIT-TO (DOCTYPE , "ar")) AND (LIMIT-TO (LANGUAGE , "English")) AND (LIMIT-TO (EXACTKEYWORD , "Child") OR LIMIT-TO (EXACTKEYWORD , "Adolescent") OR LIMIT-TO (EXACTKEYWORD , "Orthodontics") OR LIMIT-TO (EXACTKEYWORD , "Malocclusion"))

Annexes Table 2. Results

Article	Type of Study	Author	Year	Sample size	Conclusion
Meta-Analysis Articles					
Dentofacial Morphology of Mouth Breathing Children	Observational study	Patrícia Toledo Monteiro Faria, Antonio Carlos de Oliveira Ruellas, Mírian Aiko Nakane Matsumoto, Wilma T. Anselmo-Lima, Fabiana C. Pereira	2002	N= 35 children,	*The study found that the SNA and SNB angles showed statistically significant differences between mouth-breathing and nasal-breathing children. Specifically, the SNB angle was smaller in the mouth-breathing group, indicating a more retrognathic (posteriorly positioned) mandible. The SNA angle also differed, suggesting the maxilla was more retrognathic in mouth breathers due to reduced nasal airflow. However, the ANB angle, which measures the relative positions of the maxilla and mandible, showed no significant difference between the groups. This indicates that while both the maxilla and mandible were more retruded in mouth breathers, their relative positions to each other remained comparable to those in nasal breathers.*

					In mouth-breathing patients, the maxilla exhibited greater retrognathism, accompanied by a posterior rotation of the palatal plane.
Comparative Cephalometric Study Between Nasal and Predominantly Mouth Breathers	Observational study	Jussara Marinho Dias Frasson, Maria Beatriz Borges de Araújo Magnani, Darcy Flávio Nouer, Vânia Célia Vieira de Siqueira, Nádia Lunardi	2006	N= 50 Children	*The study found no statistically significant differences in the SNA, SNB, and ANB angles.* No statistically significant differences in facial patterns (FMA, SN-GoGn, Y-axis angle) or facial profiles (Z angle) between nasal and oral breathers were found. Similarly, there were no significant differences in anterior and posterior facial heights. Therefore, oral breathing may not always be the sole etiological factor for facial pattern changes. Given the cross-sectional nature of the study, the authors recommend conducting new longitudinal studies.
Oral Breathing and Head Posture	Observational Study	Antonino Marco Cuccia; Maurizio Lotti Domenico Caradonna	2008	N= 70 Children	*The ANB angle, was found to be increased in children with oral breathing (OB) compared to predominantly nasal breathing (PB) children in the study. This suggests a*

					tendency towards a Class II skeletal pattern in OB individuals. The study found no statistically significant differences in the SNA and SNB angles between oral breathers and nasal breathers. Oral breathing (OB) causes increased head elevation, greater head extension relative to the cervical spine, and influences the position of the hyoid bone and intermaxillary divergence. OB during growth can alter natural head posture (NHP) and craniofacial morphology. Changing from oral to nasal breathing early in adolescence may help normalize craniofacial dimensions as growth progresses.
The Effect of Mouth Breathing Versus Nasal Breathing on Dentofacial and Craniofacial	Observational Study	Doron Harari; Meir Redlich; Shalish Miri; Tachsin Hamud. Menachem Gross,	2010	N= 116 Children	*No significant differences were found in SNA, SNB, and ANB angles between mouth breathers and nose breathers*. Mouth breathers demonstrated considerable backward and downward

Development in Orthodontic Patients					rotation of the mandible, increased overjet, higher mandibular plane angle, elevated palatal plane, and narrower upper and lower arches at the canines and first molars compared to nasal breathers. Posterior crossbite was more prevalent in mouth breathers than nasal breathers. Additionally, abnormal lip-to-tongue anterior oral seal was more common in mouth breathers than in nasal breathers.
Comparison of craniofacial morphology, head posture and hyoid bone position with different breathing patterns	Cross-sectional study	Faruk Izzet Ucar, Abdullah Ekizer Tancan Uysal	2012	N= 66 Children	*MB patients showed reduced SNA and ANB angles, indicative potential malocclusion tendencies. While the SNB angle did not show significant differences. The decreased SNA angle suggests a retruded maxilla, while the unaffected SNB angle indicates relative mandibular position stability. The reduced ANB angle implies a Class II malocclusion tendency among MB patients*

The effect of mouth breathing on dentofacial morphology of growing child	Observational study	Malhotra S, Pandey, Nagar, Agarwal, Gupta	2012	N= 100 Children	*In comparing mouth breathers (MB) and nasal breathers (NB) groups, the differences in ANB, SNA and SNB angles were not statistically significant*. Mouth breathing was correlated with increased facial height, enlarged mandibular plane angle, and a more pronounced gonial angle.
Nasal breathing and the vertical dimension: A cephalometric study	Observational study	Amal El Aouame, Asmaa Daoui, Farid El Quars	2016	N= 53 Children	*Study revealed ANB, SNA and SNB angles, did not reach statistical significance*. Cephalometric differences between nose-breathers and mouth-breathers, with the latter showing abnormal parameters. Mouth-breathers tend to have posterior mandibular rotation, increased anterior facial height, reduced posterior facial height (hyperdivergence), retrognathism, and open bite, affecting the vertical dimension. It underlines that Pediatric dentists and orthodontists should diagnose mouth-breathing

					early, identify its causes, and collaborate with a multidisciplinary team to address this dysfunction and its future consequences
Breathing mode influence on craniofacial development and head posture	Observational study	Annel Chambi-Rocha, Ma Eugenia Cabrera-Domínguez, Antonia Domínguez-Reyes	2017	N=98 Children	*No statistical differences were found in SNA, SNB, and ANB angles, in oral breathers (OB) and nasal breathers (NB) groups.* In comparison to nasal breathers, children who breathe orally exhibit a reduced anteroposterior dimension of the airway. Additionally, teenage oral breathers tend to have increased lower anterior facial height, a longer palate, and a lower position of the hyoid bone relative to the mandibular plane.
Cephalometric Evaluation of Children with Allergic Rhinitis and Mouth Breathing	Observational study	Helena Afonso Agostinho, Ivo Álvares Furtado, Francisco Salvado e Silva, Josep Ustrell Torrent	2015	N= 70 Children	*In this study, SNA, SNB, and ANB angles showed no statistical significance between the two groups.* Children suffering from allergic rhinitis and mouth breathing tend to exhibit a more vertical skeletal structure with an open bite tendency. They also have

					smaller maxilla and mandible compared to nasal breathing children. Although there are no significant sagittal base alterations, there is an increased tendency for skeletal Class II. Lastly it was found that there is a reduced airway space in all of its extension, except between the posterior wall of the tongue and the posterior pharyngeal wall, probably due to an anterior position of the tongue in children that may present obstruction.
Mouth breathing children have cephalometric patterns similar to those of adult patients with obstructive sleep apnea syndrome	Observational study	Maria Ligia Juliano, Marco Antonio Cardoso Machado, Luciane Bizari Coin de Carvalho, Lucila Bizari Fernandes do Prado, Gilmar Fernandes do Prado	2009	N=142 Children	*Study found that mouth-breathing children exhibited a retruded maxilla and mandible compared to nose breathers (lower SNA and SNB angles but no information on the statistical significance), alongside a higher ANB angle, indicating a potential difference in skeletal relationships.* Mouth-breathing children exhibit abnormal cephalometric parameters resembling those of patients with obstructive sleep apnoea

					syndrome (OSAS), indicating an early development of the apnoeic pattern in their clinical history. This underscores the importance of vigilance among clinicians, especially neurologists attending to children referred for behavioural or learning issues.
Changes in facial morphology after adenotonsillectomy in mouth-breathing children	Observational study	Sara E. M. Mattar, Fabiana C. P. Valera, Gisele Faria, Miriam A. N. Matsumoto, & Wilma T. Anselmo-Lima	2011	N=55 Children	*SNA, SNB, and ANB did not show statistically significant differences between the mouth breathing MB and nasal breather (NB) groups*. Mouth breathers showed higher inclination of the mandibular plane; more obtuse gonial angle; dolichofacial morphology and a decrease in the inferior posterior facial height
Systematic Reviews from the Research Articles					
Effects of mouth breathing on facial skeletal development in children: a systematic review and meta-analysis	Systematic-Review and Meta-Analysis	Ziyi Zhao, Leilei Zheng, Xiaoya Huang, Caiyu Li, Jing Liu and Yun Hu	2021	N= 10 Studies	*SNA/SNB showed lower values in MB.* *ANB showed higher values in MB*

Facial morphological characteristics of mouth breathers vs. nasal breathers: A systematic review and meta-analysis of lateral cephalometric data	Systematic Review and Meta-Analysis	Weiying Zheng, Xi Zhang, Jiazeng Dong, and Jianming He	2020	N= 19 Studies	*The study found that mouth-breathing individuals, compared to nasal breathers, exhibit a statistically significant decrease in the SNA angle, indicating a retrognathic maxilla, and a reduced SNB angle, indicating a retrognathic mandible. However, there was no significant difference in the ANB angle, suggesting normal association between the maxilla and mandible.*

nSP= Number of Study Group Participants
mSO= Mean Study Group Outcome Value
sdS= Standard Deviation Study Group
nCP= Number of Control Group Participants
mCO= Mean Control Group Outcome Value
sdC= Standard Deviation Control Group

Annexes Table 3. ANB Angle results for Meta-Analysis

ANB Angle						
Study Authors	**nSP**	**mSO**	**sdS**	**nCP**	**mCO**	**sdC**
Faria et al	20	4,8	2,91	15	4,7	2,49
Frasson et al.	25	2,98	1,21	25	3,49	1,02
Cuccia et al.	35	4,65	2,17	35	3,37	2,43

Harari et al.	55	4,43	2,81	61	3,39	9
Ucar et al.	34	2,21	1,57	32	3	0,93
Malhotra et al.	20	2,28	0,83	18	2,5	1,08
El Aouame et al.	23	5,34	4,72	30	5,55	2,66
Chambi-Rocha et al	23	2,19	3,12	20	1,83	1,67
Augostinho et al	35	4,4	2,9	35	3,7	3
Juliano et al.	52	5,1	2,3	90	4,7	2
Mattar et al.	44	5,8	2,3	29	5,4	1,7
TOTAL NUMBER	**366**			**390**		

Annexes Table 4. SNA Angle results for Meta-Analysis

SNA Angle						
Study Authors	**nSP**	**mSO**	**sdS**	**nCP**	**mCO**	**sdC**
Faria et al.	20	80,6	3,53	15	83,13	2,26
Frasson et al.	25	82,84	3,46	25	83,54	2,91
Cuccia et al.	35	81,74	4,45	35	80,92	4,29
Harari et al.	55	78,61	6,61	61	80,35	7,88
Ucar et al.	34	78,5	3,29	32	80,42	2,71
Malhotra et al.	18	77,15	1,68	20	78,17	1,4
El Aouame et al.	23	77,26	5,05	30	79,03	3,68

Chambi-Rocha et al	33	81,75	4,57	22	79,43	3,38
Agostinho et al.	35	81,8	4,2	35	81,7	3,4
Juliano et al.	52	82,6	3,8	90	84,1	4,1
Mattar et al.	44	81,6	3,9	29	82,8	4,6
TOTAL NUMBER	**374**			**394**		

Annexes Table 5. SNB Angle results for Meta-Analysis

SNB Angle						
Study Authors	**nSP**	**mSO**	**sdS**	**nCP**	**mCO**	**sdC**
Faria et al.	20	75,8	3,86	15	78,43	2,53
Frasson et al.	25	79,96	3,2	25	79,86	3,12
Cuccia et al.	35	77,1	3,9	35	77,55	3,94
Harari et al.	55	74,84	3,94	61	76,96	3,61
Ucar et al.	20	74,72	1,36	18	75,67	1,87
Malhotra et al.	34	76,3	3,22	32	77,42	2,51
El Aouame et al.	23	73,47	4,86	30	73,46	3,57
Chambi-Rocha et al	23	74,25	3,18	20	77,68	2,65
Agostinho et al.	35	77,4	3,8	35	78	3,4
Juliano et al.	52	75,5	3,6	90	79,4	4,1
Mattar et al.	44	75,8	2,8	29	77,7	5,1
TOTAL NUMBER	**366**			**390**		

Annexes Table 6. Appliance protocols

Habit	Measure
Non-nutritive sucking	Dental check-ups and parental guidance
	Positive reinforcement (ages 4-6)
	Foul-tasting nail polish, gloves, or mittens
	Palatal crib
	Bluegrass appliance with habit correction roller
Atypical swallowing	Fixed or removable palatal grids
	Cemented spurs
	Myofunctional therapy
Lip sucking	Lip bumper
Mouth breathing	Behavioral instructions
	Intraoral appliances
	Myofunctional therapy

Annexes Table 7. Time of treatment protocol

Age range	Implication
0–3 years	Jaw growth is positively impacted by breastfeeding during infancy. The transition from liquid to solid foods promotes jaw growth at the same time as the eruption of the deciduous teeth. During this time, it is advised to monitor and intervene when low tongue postures and muscle hypotonia occur.

	It is imperative that parents receive instruction on appropriate dietary and lifestyle practices to support their child's healthy growth of the oral cavity and general wellbeing.
4–6 years	Ensure diligent observation of the deciduous dentition and the development of upper and lower maxillary bones. Proactively intercept and eliminate harmful behaviors such as extended usage of pacifiers, finger sucking, mouth breathing, and irregular swallowing patterns.
>6 years	Vigilant monitoring of arch space, deciduous tooth exfoliation, permanent tooth eruption, and occlusal relationships is crucial. Examine the maxillomandibular connections thoroughly at this stage. Based on occlusal and skeletal examinations, take into consideration the use of fixed or removable orthodontic appliances. It is critical to identify malocclusions early on. Effective treatment planning and therapy execution for children require collaboration and information exchange amongst physicians, parents, and caregivers.

The Role of Mouth Breathing in Growing Patients on the Sagittal Skeletal Malocclusion & Craniofacial Morphology

SYSTEMATIC REVIEW AND META-ANALYSIS

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Tutor: Prof. Dr. Tawfiq Hijazi Alsadi

Catholic University of Valencia San Vicente Mártir

INTRODUCTION

Skeletal Sagittal Malocclusion stands out as an increasing concern of craniofacial deformities in the general population. Deformative anomalies can have a mild to substantial impact on the functional and aesthetic integrity of an individual. A decisive factor in the early development of the craniofacial structures is the neuromuscular balance which guarantees sane physiologic growth and development. Common behaviour traits, that can disrupt this equilibrium are oral habits like mouth breathing.

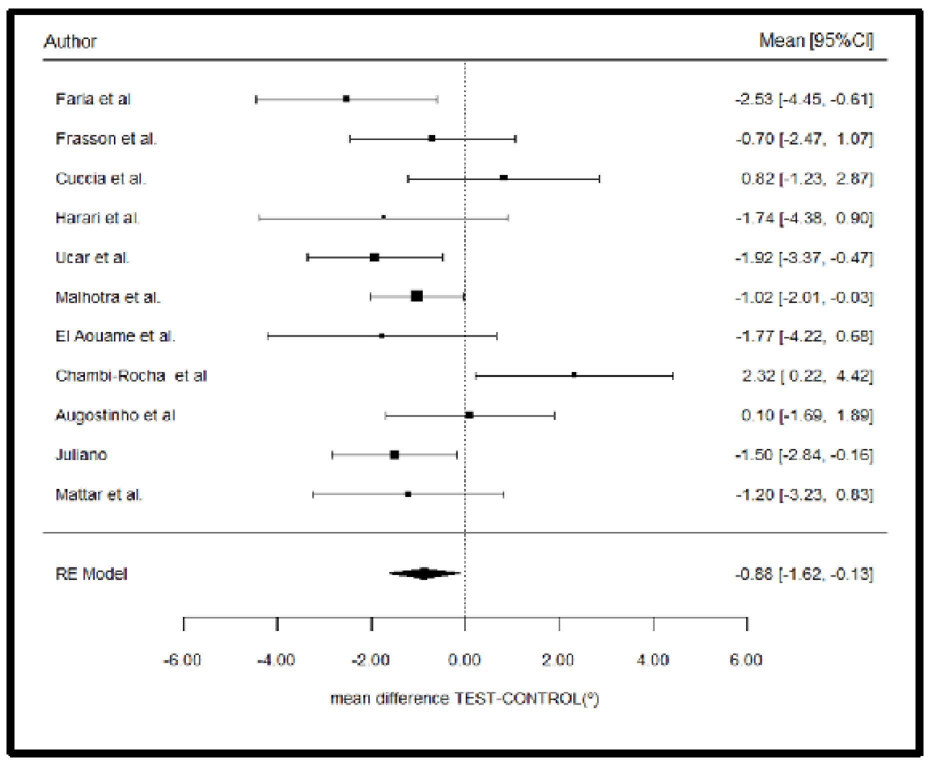

Figure 1. Forest graph SNA comparison oral vs. nasal

WMD	SE	95% CI	z (p-value)	I^2	Q_H (p-value)	Egger (p-value)
-0.88	0.38	-1.62 -0.13	**0.022***	50.0%	0.036*	0.609

*p<0.05; **p<0.01; ***p<0.001

Table 1. META-Analysis Results SNA comparison oral vs. nasal

RESULTS:

The database research initially gathered 642 articles and after the application inclusion and exclusion criteria, a total of 11 articles were finally included in this systematic review.

META-ANALYSIS:

Across the 11 studies included in the Meta-Analysis following findings were stated:

Significant differences in SNA (p=0.022): Oral patients had lower SNA, indicating a stronger propensity for maxillary retrusion. (Diagrams left)

Significant differences in SNB (p<0.001): Oral patients had lower SNB, indicating a stronger propensity for mandibular retrusion. (Diagrams right)

No significant differences in ANB (p=0.704): Both groups showed a similar skeletal pattern.

BIBLIOGRAPHY

MATERIALS AND METHODS

A comprehensive electronic literature search was performed based on the PRISMA Guide across several databases, including PubMed, Cochrane Library, and SCOPUS. The PICO question was developed, and the relevant MeSH terms were determined gathering articles published between 2000 and 2024 thoroughly selected by the inclusion and exclusion criteria.

Risk and Bias Quality Assessment**:** STROBE, PRISMA Scale guidelines.

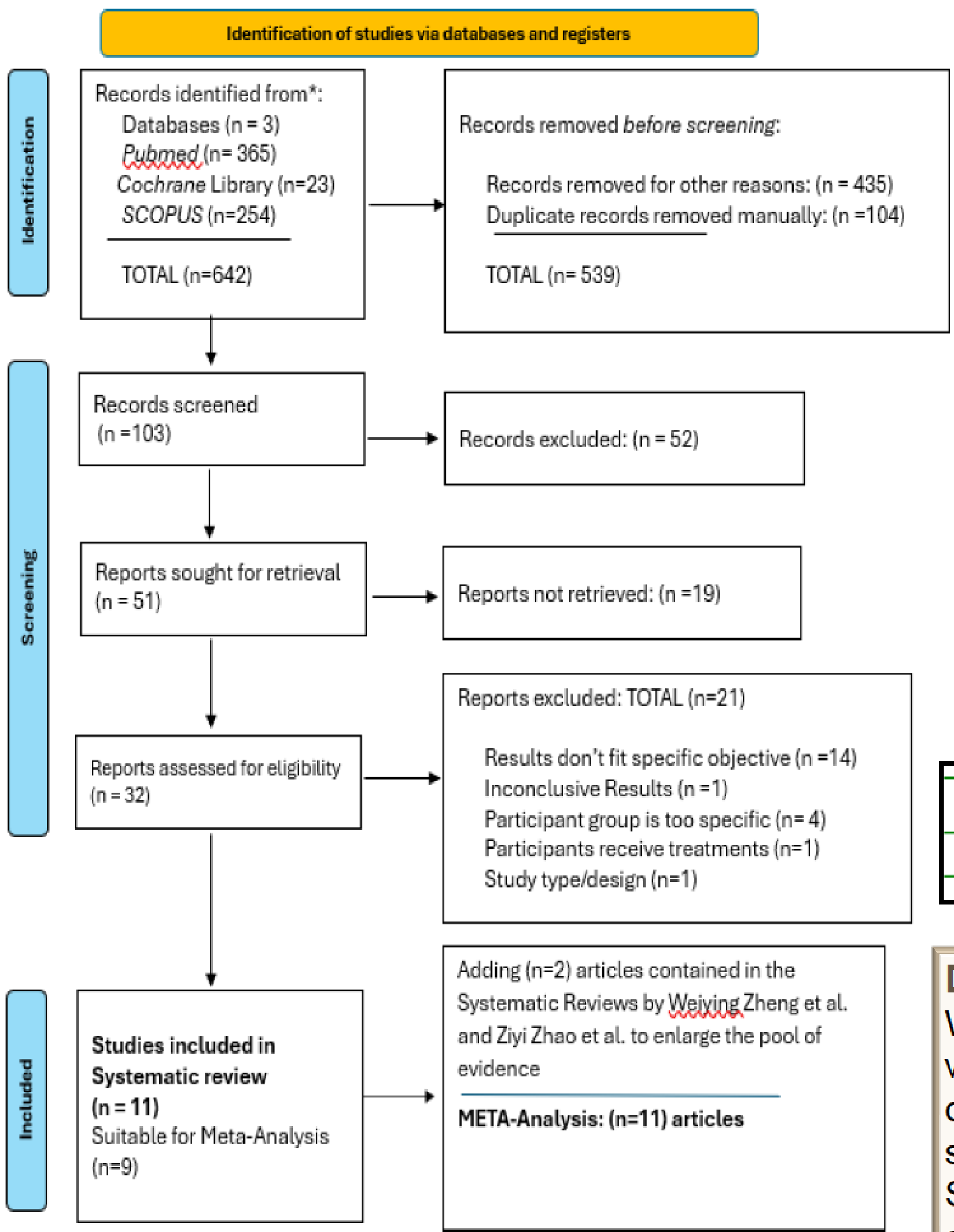

Figure 3. PRISMA Flowchart

Figure 4. Clinical Biretrusion of Jaws

CONCLUSION:

The review was unsuccessful in pointing out a clear correlation between mouth breathing and sagittal skeletal malocclusion, while **the meta-analysis indicated bimaxillary retrusion in mouth breathers**

Mouth breathing has a significant impact on other anatomic landmarks of the craniofacial structure

OBJECTIVES

GENERAL:

Investigate the effects of mouth breathing on sagittal skeletal malocclusions and craniofacial morphology in growing patients.

SPECIFIC:

- Investigate the relationship between mouth breathing and sagittal skeletal malocclusions
- Investigate the impact of mouth breathing on other craniofacial structures
- Create a prevention protocoll

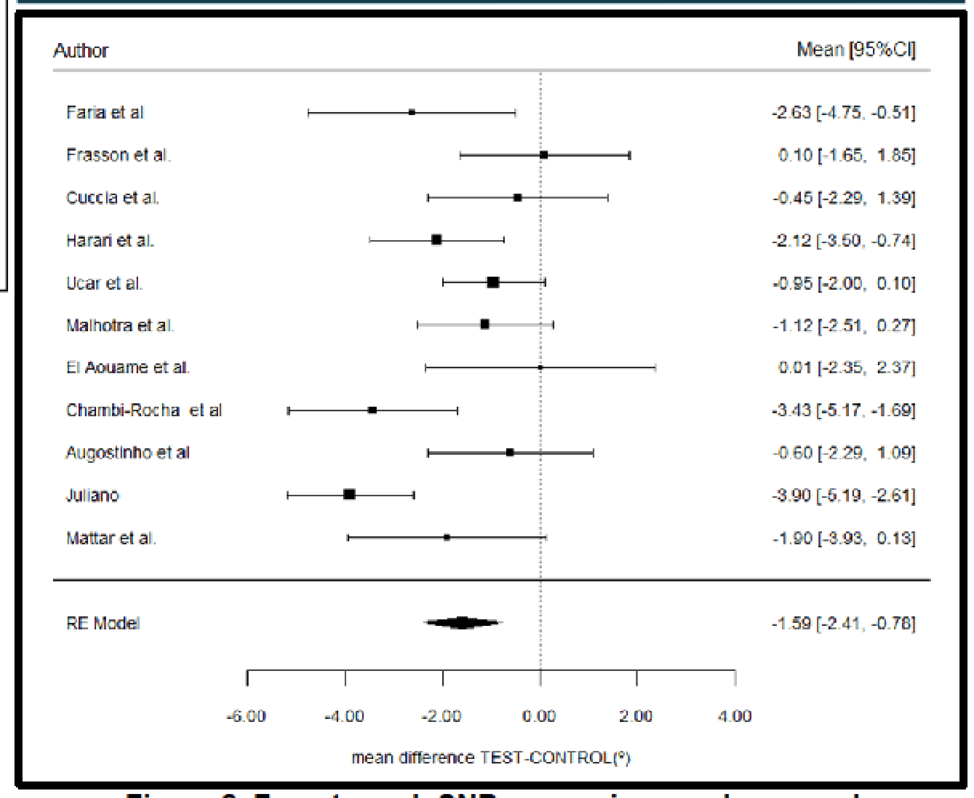

Figure 2. Forest graph SNB comparison oral vs. nasal

WMD	SE	95% CI	z (p-value)	I^2	Q_H (p-value)	Egger (p-value)
-1.59	0.41	-2.41 -0.78	**<0.001*** **	64.0%	0.002**	0.541

*p<0.05; **p<0.01; ***p<0.001

Table 2. META-Analysis Results SNB Comparison oral vs. nasal

DISCUSSION:

When the results of the 11 individual studies were compiled, no clear correlation could be determined between mouth breathing and sagittal skeletal malocclusion regarding SNA, SNB, and ANB values across most of the articles, but the meta-analysis was able to determine a clear tendency towards biretrusion of the jaws (lower SNA/SNB angles) and similar skeletal pattern in relation to each other (similar ANB angles). Increased facial height, mandibular backward and downward rotation, narrower dental arches, and open bite were more significant findings in mouth breathers regarding craniofacial morphology alterations.

Limitations: Consisted of the homogenous study design of the observational studies, the lack of long follow-up periods, the absence of standardized diagnostic criteria, and two- instead of three-dimensional measurements.

PREVENTION PROTOCOLL:

0-3 years: Transition to solid food promotes jaw growth. Parents should be guided for introducing proper diet and lifestyle habits

4-6 years: Monitor teeth and jaw growth proactively. Adress oral habits like mouth breathing or finger sucking

>6 years: Monitor arch space, tooth eruption, occlusal relations. Consider removed or fixed appliances. Early intervention is crucial for treatment success