Universidad Europea

GRADUATION PROJECT

Degree in Dentistry

TREATMENT OF OPEN BITE IN A GROWING PATIENT.

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ABSTRACT AND KEYWORD

Introduction: Open bite is one of the predominant malocclusions among growing patients, resulting in an imbalance of the stomatognathic system, soft tissue, and skeletal systems. It affects the function of the teeth leading to complications of chewing and breathing functions, aesthetics, and speech. First identified by Caravelli in 1842, this vertical malocclusion is characterized by a lack of occlusion between upper and lower teeth. Open bite can manifest in two forms, dento-alveolar and skeletal, that can affect the anterior or posterior regions. The etiology can vary, including genetic and environmental deleterious factors. Timely intervention and treatment during growing spurts phases of patients is imperative for successful outcomes and minimize the need of more invasive and less conservative treatment. **Objectives**: The main objective of this review is to identify the most effective dento-alveolar and/or skeletal open bite treatment protocol in a growing patient, taking into consideration treatment duration and patient compliance. The secondary objectives were to compare and describe the different appliances, evaluate the long term stability of the different treatments, finally find the limits of the different review and research, and suggest direction for next study. **Methodology**: The search strategy was conducted from October 2022 to March 2023 on PubMed and Crai Dulce. **Results**: 31 articles from the last 10 years were analyzed according to inclusion and exclusion criteria, search strategy, and keywords. **Conclusions**: Each treatment plan has to be performed according to the patient needs and characteristics. For the treatment of dento-alveolar open bite, palatal crib associated with OMT seems to have good stability over time, while for the treatment of dento-skeletal open bite, RME-BB shows great efficacy and long-term stability over the studies. For skeletal open bite, various appliances have been describing such as open bite-Bionator and Frankel appliances.

Keywords: Dentistry, Skeletal Open Bite, Dento-Alveolar Openbite, Dento-Skeletal Open Bite, Treatment, Growing Patients.

RESUMEN Y PALABRAS CLAVE

Introducción; Identificada por primera vez por Caravelli en 1842, esta maloclusión vertical se caracteriza por la falta de oclusión entre los dientes superiores e inferiores. Se puede manifestarse en dos formas, dentoalveolar y esquelética, que pueden afectas las regiones anteriores y posteriores. La etiología puede varias, incluyendo factores genéticos y ambientales perjudiciales. La intervención durante las fases de crecimiento del paciente son imperativos para obtener resultados exitosos y minimizar la necesidad de tratamientos más invasivos. **Objetivos**; El objetivo principal de esta revisión e identificar el protocolo de tratamiento más eficaz para la mordida abierta dentoalveolar y/o esquelética en pacientes en crecimiento, teniendo en cuenta la duración del tratamiento y la adherencia del paciente. Los objetivos secundarios fueron comparar y describir los diferentes aparatos, evaluar la estabilidad a largo plazo de los diferentes tratamientos, y finalmente identificar las limitaciones de las revisión y estudios existentes y sugerir direcciones para investigaciones futuras. **Metodologías**: La estrategia de búsqueda se llevó a cabo de octubre de 2022 hasta marzo de 2023 en PubMED y Crai Dulce. **Resultados;** Se analizaron 31 artículos de los últimos 10 anos de acuerdo con la estrategia de búsqueda, los criterios de inclusión y exclusión, y palabras clave. **Conclusiones**; Cada plan de tratamiento debe llevarse a cabo teniendo en cuanta las necesidades y características individual del paciente. Para el tratamiento de la mordida abierta dentoalveolar, la cuna palatina asociade con la terapia miofunctional parce tener una buena estabilidad a lo largo del tiempo, mientras que para el tratamiento de la mordida abierta dento-esquelética, la expansión rápida del maxilar con bloque de mordida muestra una gran eficacia y estabilidad a largo plazo en los estudios. Para la mordida abierta esquelética, se han descrito varios aparatos con el Bionator de mordida abierta y de Frankel.

Palabras clave: Odontología, Mordida abierta esquelética, Mordida abierta dentoalveolar, Mordida abierta dento-esquelética, Tratamiento, Pacientes en crecimiento.

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1. INTRODUCTION

In dentistry, the current standard is that the upper teeth should be in the correct relationship with the lower teeth. The concept of ideal occlusion has been discussed and refined by many experts over the years. One of the most influential figures, Edward H. Angle explained in 1899 molars and canines relationship and stated that the ideal measurement for the horizontal distance (overjet), between the upper and lower incisors is 2mm, and the vertical distance (overbite) of the upper incisors over the lower incisors should ideally be 1/3. Malocclusion is defined as any deviation from ideal occlusion.

An open bite, according to the occlusal definition, is a vertical malocclusion in which a section of the dental arch, whether anterior or posterior, does not achieve the occlusal plane and does not contact with the antagonist. (1)

1.1 Odontogenesis

The first teeth that begin to break into the gum, usually around 6 months of age, are the lower central incisors. By the age of 4, the primary dentition is complete, and occlusion is established. At around 6 years of age, the eruption of the first permanent molars and incisors marks the first transitional period, or the initial mixed dentition. Around 9-10 years old, the inter-transitional period begins, when nothing really changes; there are approximately 12 temporary teeth and 12 permanent teeth. Then the 2nd transitional period, or the final mixed dentition, begins when the temporary canines and molars are replaced by the permanent canines and premolars, and the eruption of the 2nd molar occurs. By the age of 12, all the permanent teeth have replaced the primary ones and are occluding. (2)

1.2 Definition of open bite

Open bite was distinguished from other anomalies in 1842 by Caravelli.

According to its origin, as stated by Sassouni, there are two types of open bite :

-Skeletal open bite

-Dental or dento-alveolar open bite (3)

1.2.1 Skeletal open bite

It is considered as the true open bite due to an abnormal skeletal growth pattern.

Bjork's and Skellier develop an "implant method" to study jaw growth and development. By placing a marked implant in the jawbone and by taking radiographic images over time, they found out that:

The maxilla is a complex bone that grows due to selective bone remodeling (apposition or deposition and resorption), displacement, and suture growth in order to attain its specific shape and function. (4)

The maxilla increases in height, length, and width. During the first decade of life, maxilla will grow in a horizontal way to accommodate the developing dentition. During the second decade of life, it tends to grow in a more vertical direction (with maximum vertical growth occurring at the age of 5-15 years).

Thus, the sum of all the forces will result in a forward, backward, and downward growth of the maxilla. (5)

The mandible is the only mobile bone of the face and, as such, experiences more growth than the maxilla. It should not be viewed as a single unit of growth but rather as smaller subunits. Although all the subunits participate in growth, growth is most significant on the posterior borders of the ramus and at the condylar process. Bone remodeling at the level of the ramus and the body of the mandible will move the mandible in a posterior direction, making the body longer, and appearing as a verticalization of the ramus. Remodeling at the coronoid process will increase the mandibular height superiorly, widen medially, and grow the mandible posteriorly. Bjork noted that along with the displacement of the mandible in a downward and forward direction, there is also a rotation of the core of the mandible in a counterclockwise direction (internal rotation). This rotation will be compensated by a rotation of the mandibular plane (external rotation). (5,6)

Skeletal open bite can be divided into three categories.

- When the maxillary growth is affected but the mandible growth is normal

- When the mandible growth is affected but the maxilla growth is normal
- When both maxillary and mandibular growth are affected. (4)

In the first category, according to Sassouni in 1969, most patients present:

-Tipped downward palate (large palate-mandibular plane angle) that pushes the molar down, resulting in an open-bite.

-A decrease in the anterior height of the maxilla, resulting in anterior rotation of the maxillae: The maxilla's front part is shorter than usual, causing an open bite.

-Excessive development of the upper mid-face height (cranial base to molar), pushing the upper teeth further away from the lower teeth. (7)

In the second category, clinically, patients present:

-Clockwise rotation of the mandible due to the predominance of distal condylar growth.

-Short ramus and increased gonial angle.

-Increased lower anterior facial height.

-Excessive external rotation resulting in a clockwise direction of the mandible. (7)

The third category results from a lack of coordination between maxillary and mandibular growth. In this type of patient, we will find both an anterior rotation of the maxilla and a clockwise rotation of the mandible.(8)

1.2.2 Dental or dento-alveolar open bite

Also known as pseudo-open-bite, the problem is entirely dento-alveolar, while skeletal bases are within the normal range.

Dento-alveolar open bite can be caused by maxillary infra-occlusion, mandibular infra-occlusion, or a combination of both.

The etiology of dento-alveolar open bite is complex and multifactorial. It remains uncertain, with many theories proposed. (9)

The alveolar bone is a component of both the maxilla and the mandible, and its primary function is to support and protect the teeth. The development of the alveolar bone is reliant upon the movement and development of the teeth. Alveolar bone maturation may be affected, leading to hypoplasia (underdevelopment) or hyperplasia (excess development).

In cases of generalized hypoplasia, the dental arch is too small for the teeth, resulting in teeth that are too large to fit properly. This misalignment of the tooth roots beneath the alveolar bone and the disproportionately large crowns of the teeth results in tooth proclination and can create a dento-alveolar open bite.

Hyperplasia refers to excessive growth of the alveolar bone, leading to proclination of the teeth forward. The severity of the open bite can be classified according to the degree of hyperplasia. (10)

Dental open bite can also be due to a failure of tooth development due to an excessively slow eruption of the permanent dentition that can produce a temporary lack of occlusion. We call it transitional open bite. It can be produced by the premature loss of deciduous teeth. (11)

Dental open bite can also be caused by dental pathology, such as a failure of tooth eruption due to a disturbance in the eruption mechanism. Various stages of the eruption process have been described, including intraosseous eruption, gingival penetration, and eruption up to the plane of occlusion. The eruption may cease at any of these stages. Delay or non-eruption can be partial or generalized. Some local factors currently reported in the literature are summarized in **table 1.**

TABLE 1: Resume of local factors creating dento-alveolar open bite (12–14)

LOCAL FACTOR	EXPLANATION
Mucosal barrier	When the follicle sac fails to unite the mucosa.
Gingival fibromatosis	Due to a condition where the hard connective tissue of the gum prevent the eruption of the teeth; can be hereditary or secondary due to scar formation after surgical act.
Hypodontia, oligodontia	Absence of few or complete teeth.
Microdontia	Teeth are smaller in size causing open bite.
Impacted teeth.	Meaning a tooth that fails to erupt into the dental arch, the mainly affected are the third molars, maxillary canines, mandibular premolars, and maxillary central incisor.
Embedded teeth	These are teeth that lacks eruption forces.
Supernumerary teeth	The most frequent supernumerary teeth are mesiodens that mostly cause the impaction of maxillary central incisor.
Physical obstruction	Tumors, odontomas, cyst like, infection in the dental eruption site that causes the late or non-eruption of the teeth.
Ectopic Eruption	When the eruption path varies from the normal pathway.
Ankylosis	It can happen in all stage during the eruption. It can be unique or generalized.
Gingival hyperplasia	It can be due to hormonal cause, lack of vitamin C or intake of drug like phenytoin that result in a dense connective tissue.
Injury in deciduous teeth	Premature loss, dilaceration, physical displacement of the bud.
Injury or trauma	In the place of the eruption
Iatrogenic cause	

Some systemic conditions also can affect the eruption of teeth, like endocrine deficiency, nutritional deficiency... Genetic factors and environmental factors also influence the timing of tooth eruption. (13)

According to the location, when the open bite occurs in the anterior region, meaning that the maxillary and mandibular anterior teeth don't have vertical contact when the posterior occludes, it's called anterior open bite (AOB)

When the patient occludes and only the anterior teeth come into contact, we named it posterior or lateral open bite (POB). (1)

1.2.3 Anterior open bite

1.2.3.1 Prevalence

There is a general disparity of the AOB among the world's population. It can vary from 1.5% to 11%. According to studies, AOB occurs more in the African and Afro-Caribbean populations. (15).

The prevalence is proportionally higher in females and in children in the primary dentition phase (18,5%). (16)

1.2.3.2 Classification.

In June 1971, Worms, Meskin, and Isaacson classified open bite according to the severity:

-Simple open-bite: from canines to canines.

-Compound open-bite: from premolars to premolars.

-Infantile open bite: that includes molars. (17)

AOB can be associated with all types of malocclusion: class I, class II, and class III (Except class II, division 2). It can also be associated with uni or bilateral crossbite. (18)

1.2.4 Posterior or lateral open bite

1.2.4.1 Prevalence

Most studies don't focus on the incidence of POB; therefore, insufficient data permit us to correctly evaluate it prevalence.

However, it has been shown that POB is equivalent among females and males, with a frequency of about 1%. (19)

1.2.4.2 Classification

POB can be described in two ways. The first one is when only the anterior teeth contact without any contact in the posterior region. The second possibility is when there is contact in the anterior area and some of the posterior teeth are occluding. They mostly are related to dento-alveolar open bite.

Among studies, it has been shown that POB is mostly associated with class III malocclusion (20)

1.3 Etiology of open bite.

Understanding the etiology of open bite is of paramount importance, as correcting the underlying etiological factors has a direct impact on the stability and efficacy of the treatment. This malocclusion is multifactorial in nature, encompassing both genetic and environmental factors.

1.3.1 Environmental factors.

Growing patients undergo various phases of growth and development of their jawbone structure. This growth is malleable and influenced by physiological habits.

The most important environmental factor that causes open bite is patient's injurious habits, which can alter the normal balance of the stomatognathic system.

1.3.1.1 Sucking habits.

Sucking fingers, lips, or tongue is a physiological habit that starts during fetal life. After birth, thumbs or pacifiers are used as a substitute for natural sucking habits. We call it non-nutritive sucking habits (NNSH). If the child uses it during the deciduous

phase, it is considered harmless since its interruption will auto correct the transitional open bite. This habit normally ceases around the age of 2-4 years old.

However, when the use of pacifiers or tongue sucking habit persists during the mixed dentition phase, the patient will face a future permanent open bite which will require further treatment.

The appearance of the open bite will depend on the duration, frequency, intensity, and type of the NNSH. It will also depend on the type of growth pattern of the patient.

It has been studied that the prolonged use of NNSH provokes a disturbance of the dentofacial development in the antero-posterior, sagittal, and vertical directions. (21)

According to Johnson and Larson's study:

-It will cause lip incompetence, forming a convex profile.

-At the level of the maxilla, there will be an anterior rotation of the maxilla and anterior placement of the apical base of the maxilla, as the object is placed against the palate, pushing it in a vertical direction (increasing the arch depth) and also placed against the surface of the upper incisor, producing a force that follows the level principle, provoking a labial inclination and spacing of the maxillary incisor.

-We can also see high palatal vaults, narrowing the inter-canine and inter-molar arch widths, an increase in the maxillary arch length, and a counterclockwise rotation of the occlusal place.

-The alveolar growth is reduced vertically at the frontal part

-In the mandible, the lingual inclination of the mandibular incisor is due to the strength of the tightness of the lower lip and tongue activity during sucking. (22)

1.3.1.2 Atypical tongue position.

An ideal resting position of the tongue should be behind the front teeth, touching the hard palate without any pressure. An abnormal position of the tongue is a myofunctional problem that can occur at rest, during swallowing, or during speech. It is believed to have a secondary role in the development of open bite.

Around the age of 3, there are transition from the infantile swallowing pattern to a mature one, coinciding with the maturation of the orofacial muscles. The tongue should

move toward the palate, expanding and producing an anterior seal between the exterior and the mouth. The teeth are together, and the mandible is stabilized by the mandible elevator. There is a minimal contraction of the labial muscle. (23)

During an atypical swallow, the tongue makes a forward movement toward the lower lip to establish the anterior lip seal (tongue thrust). It's a compensatory mechanism for a pre-existing open-bite, exacerbating the malocclusion. It has been seen that patients with tongue thrust during deglutition presented greater force values than those with normal tongue positions. Therefore, they accentuate the open bite further. As it happens during the maturation of the muscular system, it changes the normal pattern to an atypical swallow. We can see in this type of patient, no contraction of the masseter and the peri-oral muscle. Tongue trust can be anterior or posterior (lateral) and can be single or complex. (24)

At rest, even if the force is low, a constant pressure of the tongue over the already created space of the open bite during a long period, favoring enlargement and movement of the teeth. (25)

1.3.1.3 Mouth breathing.

The nasal cavity plays an important role in the respiratory system as it allows the air to pass while also providing cleaning, filtration, and humidification. When the obstructions occur in the nasal system, it can lead to mouth breathing as an alternative. The etiologies of nasal obstruction can be categorized into upper respiratory obstruction and lower respiratory obstruction.

1.3.1.3.1 *Upper respiratory obstacle (URO)* (26,27)

Hypertrophied adenoid	It's the most common pathologies among the URO. It's due to an enlargement of the adenoid, because of viral or bacterial infections.
Allergic rhinitis	It's defined as an inflammation of the nasopharynx mucosa with associated symptoms like nasal congestion, rhinorrhea. It can be seen between 10%-30% among the children/adolescent population.
Nasal septum deviation (NSD)	The most frequent anatomical cause. Nasal septum play an important role in the nasal structure, is centrally positioned to divide equally the passage of the air between the two nostrils. Being deviated, it causes a nasal obstruction. Children developing the NDS present an increase of the upper anterior facial height, higher horizontal plane, gonial angle, palatal height. They present retrognathic upper and lower jaw.

1.3.1.3.2 Lower respiratory obstacle (28)

Hypertrophied palatine tonsils	They are tonsil located in the oropharynx. The enlargement happens even if there is no infection provoking sleep disturbance, irregular breathing.

Mouth breathing can lead to an imbalance in the lingual, labial, and facial muscles leading to unfavorable bone structure growth, disturbances in occlusion development, as well as changes in tooth position. Indeed, to breathe through the mouth, it's necessary to lower the mandible and the tongue. If it happens during growth, it increases the facial height (long face), uncommon vertical growth of the ramus, provoking a downward rotation of the mandible and backward due to the backward pressure of the mandible muscle.

Mouth breathing leads to a sensibility of the incisor, leading to a protrusive movement and lower position of the tongue.

Studies agree that mouth breathing is related to anterior or posterior open bite. (21)

Mouth breathing can also cause sleep breathing disorder and obstructive sleep apnea, which share similar characteristics. This condition is characterized by abnormal breathing during sleep, which can cause repetitive pauses. The most frequent cranio-facial malformations include retrognathia of maxilla and mandible, macroglossia, anterior open-bite, and a typical dolichocephalic pattern. (29)

1.3.1.4 Head Posture

It has been seen that head posture also influences the appearance of bite opening. Indeed, a more backward head position will lead to maxillary elevation, rotating counterclockwise, and depression of the mandible. (30)

1.3.2 Genetic factor

The influence of hereditary factors will lead to changes in the volume, position, tone, contractility, and neuromuscular coordination of the muscles of the face, mouth, and tongue. It will also have an impact on the jawbone's development.

1.3.2.1 Associated syndrome and pathology (31,32)

There are few syndromes associated with open bite such as: Crouzon, Autosomal Pfeiffer, Pierre Robin syndrome, Down Syndrome, Wiliams Beuren syndrome, Treacher-Collins, and Beckwith Wiedemann syndrome. Typically, these patients according to the specify of their syndrome present, maxillary hypoplasia, constricted maxillary arch, anterior openbite and breathing difficulties.

-Amelogenesis imperfecta is not a common hereditary condition but causes hypomineralization of the enamel. It can be isolated or associated other with syndromes. Clinically, it has short clinical crowns, spacing in the anterior region, and increased vertical dimension.

-Primary failure of eruption (PFE) described by William Proffit in 1981. The etiology is not known but can be due to genetic disturbances affecting the dental follicle. It occurs when the teeth fail to erupt without connection with ankylosis. Many studies link posterior open bite as a consequence of the PFE because it affects more the posterior region.

1.3.2.2 Muscular deficiency

Moyers (1988) cited that the proper function of the stomatognathic system is maintaining by a harmonious relationship between the oral structures, such as the teeth and basal bone, and intra and extra-oral musculature. The teeth are enclosed by forces that arrive internally by the tongue and exteriorly by the lip and cheek muscles. The muscular system follows a fixed genetic plan.

The facial muscle influences bone development, rotation, and tooth position. Literature points out that when there is low muscular activity, the plane diverges, creating open bite.

It has been shown that the masseter and temporalis muscle deficiencies result in a low position of the mandible. It also causes wide mandibular dental arch (30)

1.3.2.3 Tongue

Macroglossia is a disorder in which, at rest, the tongue protrudes beyond the alveolar ridge or teeth. Authors presume that macroglossia is a direct cause of open bite. Enlarged tongue provoke an obstruction of the airways, affecting the swallowing. It leads to a dentoalveolar protrusion of both jaws. It can also impact the growth and development of the mandible by moving it downward and backward, provoking a retruded mandible and leading to skeletal open bite. (33)

A short lingual frenulum restricts the tongue's movement, forcing it to be placed in a lower and forward position, linked to tongue trust, disturbance in sleep breathing, therefore creating anterior open bite. (34)

1.3.2.4 Condylar resorption

Temporomandibular joint (TMJ) arthritis is common disease in juvenile idiopathic arthritis (JIA) patient. JIA is an autoimmune disease that causes joint pain and inflammation.

TMJ is a synovial joint composed of superior and inferior structures like the mandibular condyle. Any degradations in this area induce changes in shape and function. As we see, the mandibular condyle plays an important role in the mandibular growth. Any damage or direct compression causes mandibular growth disturbances, ranging from small cortical bone erosion to total destruction of the condyle head. The most common consequences are reduced vertical growth and posterior rotation of the mandible. As growth is reduced, the muscle of mastication forces the jaw into a backward rotation. We also see a shorter posterior facial height and a steeper mandibular plane. All these features will lead the patient to present open bite. (35,36)

1.3.2.5 Anterior open bite related to MMP family gene.

MMP and TIMPs gene families are involved in tissue modeling and growth. Indeed, MMPs regulate the degradation of the extracellular matrix protein, while TIMP act as inhibitors of MMPs. MMPs play an important role in bone cells (osteoblast/osteoclast, Chondroblast/chondroblast), thus playing a crucial role in bone development.

Studies demonstrate that the polymorphism Rs17576 in the MMP9 gene has an active role in the establishment of AOB by functional alterations of the gene.
Further studies need to be conducted to understand how MMPs play a role in AOB. (37)

1.4 Diagnosis of open bite.

The diagnosis is one of the essential elements of medical decision-making because appropriate identification of open bite is often the prerequisite for appropriate management of the patient and thus a suitable treatment.
A good diagnosis begins with anamnesis:

-First asking the parent if the child presents any genetical/hereditary pathologies.

-Ask about the family history of diseases.

-As we see, open bite is related to deleterious habits, so knowing if the child has some is important, like thumb sucking habit, use of pacifier…

-Asking about the sleeping quality and if parents notice any NNSH or mouth-breathing.

1.4.1 Diagnosis of skeletal open bite.

1.4.1.1 Extra-oral feature

1.4.1.1.1 Face view

Human populations are divided into three categories: mesocephalic, brachycephalic, and dolichocephalic. Skeletal open bite is more often related to dolichocephalic individuals.

1) Facial proportions

The face is divided into three parts: Trichion-Glabella; glabela-subnasale, subnasal-fost menton. They should be equally balanced.
Skeletal open bite tends to have their lower third proportion increased. (38)

2) Head and facial type.

Dolichocephalic patients tend to have more long and narrow head. They are categorized as leptoprosopic, meaning long and narrow facial form.

They appear to have a narrow nose, lack of lip sealing, and hypotonic masticatory muscles as discussed earlier.

If the patient reports mouth breathing habit, they tend to have typical facial patterns such as poor definition of the cheekbones, crooked teeth and nose, narrow face, tired eyes, set-back jaw, receding chin, and a forward head posture. (21,38)

1.4.1.1.2 Profile view

They tend to have more convex profile. The nasolabial angle seems increased as well as the neck-menton line. They have generally poor chin development. (38)

1.4.1.2 Intra-oral feature

They tend to have long and narrow dental arches form in order to get along with the long and narrow face. As a result, the upper arch appears to be triangular-shaped. The superior occlusal plane appears flat. In the lower arch, an inverted curve of spee is often observed.

If the patient exhibits a tendency for mouth breathing, it increases the risk of periodontal disease due to sensibility at the level of the incisor, dryness of the mouth, and abnormal chewing. (38)

1.4.1.3 Cephalometric analysis

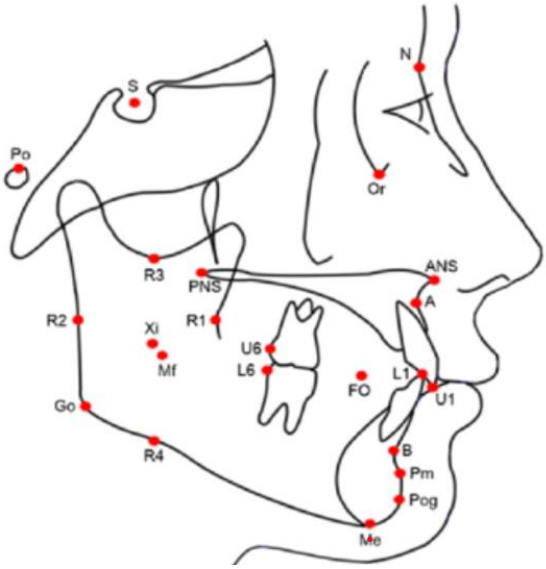


Figure 1. Cephalometric landmarks.

	Skeletal open bite value
SN.GoGN	Increased
SN.PSN-ANP	Decrease
FMA	Increased
ANS.Me	Increased
Co.Gn	Increased
Sn-Gn	Increased
OCC.SN	Increased
Ba-N-PT-Gn	Increased
FH-Mandibular plane	Increased
XI-PM.XI-ANS	Increased
ANS-PNS.GE-ME	Decreased
DC-Xi	Degree of open bite
1.NA	Inclination of the upper incisor
1.NB	Inclination of the lower incisor

The SN.GoGN angle evaluates the vertical growth pattern of the mandible. In cases of open bite, a larger angle may be observed, indicating a more vertical growth pattern, which means a downward and backward rotation of the mandible.

The SN-PNS-ANS evaluates the inclination of the maxilla relative to the cranial base. If it has lesser value; it could mean that the palatal plane is anticline.

The angle FMA or Frankfort mandibular incisor angle, is used to assess the relationship between the maxilla and mandible. A larger FMA angle indicates a more vertical growth pattern of the mandible, meaning the mandible will have clockwise growth.

The ANS-ME angle assesses the anterior-posterior position of the maxilla. A larger angle indicates a more anterior position of the maxilla, which can contribute to open bite. A decrease of ANS-PNS.GE-ME measurement indicates a vertically short mandible related to the maxilla.

The facial angle and facial axis angle may be increased when there is excessive vertical growth of the mandible.

A high value of the OCC.SN mean steeper occlusal plane.

The Ba-N-PT-Gn posterior angle defines the growth pattern of the mandible and the direction of the chin. If it's smaller, the patient presents a vertical growth of the mandible.

The FH-mandibular plane angle assesses the vertical relationship between the cranial base and the mandible. It's an angle formed by the mandibular plane and the Frankfurt plane. If it increases, it will lead to dolichocephalic pattern.

The Xi-PM.Xi-ANS angle assesses the vertical position of the maxilla in relation to the cranial base, if it increases, it means that the maxilla has a downward and/or posterior displacement.

DC-Xi angle is the degree of open bite malocclusion: it reflects the vertical position of the lower incisor in relation to the mandibular plane. If the degree is higher, it indicates a more severe open bite.

1.NA angle evaluates the inclination of the upper incisor, while 1.NB evaluates the inclination of the lower incisor: a larger angle indicates greater proclination of the

incisor, developing anterior open bite while a smaller angle contributes to the development of posterior open bite.

The normal value of SNA is 82+/-, out of this range, it represents an abnormal position of the maxilla. SNB angle gives the relation of the mandible to the cranial base; lower value means mandibular retrognathism and more vertical growth pattern of the mandible. SND should be decreased.

ANB accesses the overall position of both jaws to each other and to the rest of the facial structure. An increased of ANB indicates a more forward growth pattern of the maxilla, increasing the risk for open bite. Conversely, a decreased ANB may indicate a more retrusive and underdeveloped maxilla that may also contribute to the development of open bite.

A decrease of the interincisal angle value indicates a bimaxillary dento-alveolar proclination and procline incisors. (7,38–41)

1.4.1.4 Complementary test

Complementary tests can be needed to assess the adenoid size, presence of any nasal septum deviation, enlargement of tonsil and turbinate. To determine if there is any nasal obstruction, condylar anomaly.

Test as deglutition, mastication, ventilation, and muscular exam can also be performed. (21)

1.4.2 Diagnosis of dental open bite.

1.4.2.1 Extra-oral feature

As we mentioned, dental-open bite patients don't present any skeletal pattern disturbances, therefore, they present normal lower face third and no tension in the lip. They present a flat smile, meaning no exposure of the upper arch. (42)

1.4.2.2 Intra-oral feature

We may observe an under-eruption of the upper and lower incisors, an over eruption of the upper and lower posterior segments.

Over-erupted tooth might lead to an increased risk of periodontal disease as it can result in reduced bone support.
Additionally, more protruded teeth lead to bone loss and thickening of the soft tissue with less attached gingiva, thus leading to bacterial plaque accumulation.
We may find, as we saw previously, crowding, chewing, and speech difficulties. (43)

1.5 A growing patient

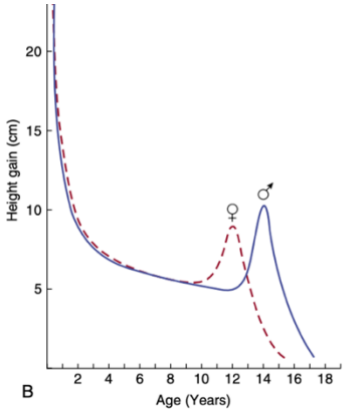
If we analyze the postnatal growth and development, we can see that the different stages of life are highly influenced by the development of the teeth. Indeed, the constant pressure exerted by erupting teeth stimulates bone growth.

During the early infancy period (0-2 years), there is rapid growth in terms of height, weight, fat... The first eruption of teeth establishes the dental arches.
The maxilla begins to grow and expand around 3-6 months of age. The mandible experiences the greatest growth in the first six months.
The later infancy period occurs between 2-5years. The maxillae continue to grow and develop but In a slower pace and more passive. The mandible continues to grow and reaches 75%-85% of its adult size.
It is important to notice that during these periods of time, the growth and development of the maxilla and mandible could affect the necessity of further orthodontic treatment. Therefore, it's important to monitor and promote healthy growth during this period.
The middle childhood lasts from 6-10 years of age, marked by the appearance of the permanent dentition during this period. Growth continues, but at an even slower rate. The mandible experiences deceleration until puberty. (44)

The proper puberty appears at 9-14yo in male while begin at 8-13 years old in female.

Adolescence is the following period, occurring in boys at 15-20 years old in boys while 14-18yo in girls. For males, the maturation of the maxilla occurs at 15 years, and the mandible maturation occurs at 16 years old. For females, maxillary maturity is around 16 years old and mandibular maturity is at 14 years old.

Figure 2. Curve of growth spurt



The growth does not take place at all times, there is period with sudden increase in growth named “growth spurts”. Two episodes of growth spurt have been described, the first one, the lesser one, occurs between 6,5 and 8,5 years of age. The more prominent growth spurt starts with the onset of puberty at 11-12 years in female and 13-14 years for males (**Figure 2**) (45)

This grow spurts are important for the treatment of open bite. During these periods of time, the bone and teeth are more malleable and can be more easily corrected with orthodontic treatment. Indeed, we can perform potential growth modifications. This means that the period just before and during puberty present the greatest opportunity to perform interceptive orthodontic plan treatment. (38)

The Baccetti classification, also denoted as the cervical vertebral maturation (CVM) methods, is a system, widely used in orthodontics to predict growth patterns in order to guide treatment decision-making. It’s a valuable diagnostic modality that helps with the determination of skeletal maturity in growing individuals predicated upon the assessment of cervical vertebral development. The vertebral age also correlates with the mandibular growth. According to the classification, the cervical vertebrae can be divided into 6 stages that correspond to the degree of skeletal maturity (**figure 3**):

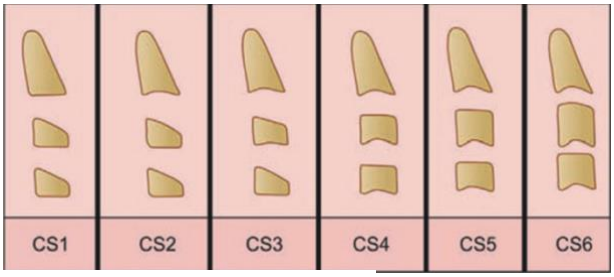


Figure 3. Baccetti classification

Stage 1: The lower borders of all three vertebrae are flat (C2-C4), this stage coincides with a patient of 6-8year old with 100% of pubertal growth remains.

Stage 2: While the C2 becomes more concave, the C3 and C4 have a trapezoidal shape, meaning that the child is between 8-10years old with 65%-85% of the growth remains. After stage 2, the mandibular peak growth occurs 1 years.

Stage 3: The lower border of C3 becomes more concave, and C4 is more rectangular. That is typical for children between 10-12years old where about 25-65% of the pubertal growth remains. The peak of mandibular growth will occur during the years of this stage.

Stage 4: corresponds to children of 12-14years old with 10-25% pubertal growth remains. because the lower border of C4 becomes straight and the C5 is more triangular in shape.

Stage 5: can be found in children between the age 14-16 while stage 6 for individuals over the age of 16, meaning that in this stage, the growth and development ends. (picture 3) (38,46)

1.6 Treatment plan

The treatment approach is different according to the development stage of the patient's dentition. Indeed, treatment in deciduous or mixed dentition will not have the same treatment as permanent dentition in terms of material, time, methods, and stability.

The planning of orthodontic treatments should be defined according to two criteria, effectiveness, and efficiency. The concept of early treatment is to stop or, at least, to minimize the alveolo-dental and skeletal disorders that would disturb the growth, function, aesthetics, and the psyche of the children. As mentioned earlier, if no interceptive treatment is done in dento-alveolar open bite, the consequences are non-modifiable sagittal open bite.

As we see, open bite could lead to periodontal disease, tooth decay, and disturbance in the beathing, that is why intercepting it and treating it early will give better hope for the permanent adult dentition.

No early treatment will lead to less conservative treatment such as surgery.

Therefore, open-bite treatment is a multifactorial task, from the prevention to more aggressive treatment.

Justification: the aim of this review is to analyze, compare, and explain the different treatments options for a growing patient.

Are the treatment options for open bite in a growing patient offers the same outcomes?

2 OBJECTIVES

In this thesis, the following objectives will be:

2.1 First objective

1. Identify the most effective dento-alveolar and/or skeletal open bite treatment protocol in a growing patient, taking into consideration treatment duration and patient compliance.

2.2 Secondary objective

1. Compare and describe the different appliances.
2. Evaluate the long term stability of the different treatments.
3. Find the limits of the different reviews and research and suggest directions for next studies.

2.3 Hypothesis

The hypothesis is that every treatment should achieve the same similar dento-skeletal effect for treating open bite.

3 MATERIALS AND METHODS

This review was conducted from October 2022 to April 2023.

3.1 Information sources:

The introduction was conducted with articles, books, and journal via online resources like PubMED, Crai dulce Chacon, sci-hub, PDF drive, and springer-link.

The data base use for the result part was effectuated through online catalogue like PubMed, google scholar and Crai Dulce Chacon. We only use article from the last 10 years.

3.2 Keywords

The keywords used to perform this review was: dentistry, open bite, dolichocephalic, high angle model, growing patient, adolescent, anterior open bite, lateral or posterior open bite, cephalometric, Etiology based treatment.

3.3 Search Strategy:

The search strategy was effectuated as below:

((("therapeutics"[MeSH Terms] OR "therapeutics"[All Fields] OR "treatments"[All Fields] OR "therapy"[MeSH Subheading] OR "therapy"[All Fields] OR "treatment"[All Fields] OR "treatment s"[All Fields]) AND (("open bite"[MeSH Terms] OR ("open"[All Fields] AND "bite"[All Fields]) OR "open bite"[All Fields]) AND (("patient s"[All Fields] OR "patients"[MeSH Terms] OR "patients"[All Fields] OR "patient"[All Fields] OR "patients s"[All Fields]) AND (("growing"[All Fields] OR "grows"[All Fields]) OR (("young"[All Fields] OR "youngs"[All Fields]) OR (("child"[MeSH Terms] OR "child"[All Fields] OR "children"[All Fields] OR "child s"[All Fields] OR "children s"[All Fields] OR "childrens"[All Fields] OR "childs"[All Fields]) OR (("adolescences"[All Fields] OR "adolescency"[All Fields] OR "adolescent"[MeSH Terms] OR "adolescent"[All Fields] OR "adolescence"[All Fields] OR "adolescents"[All Fields] OR "adolescent s"[All Fields]) OR ("Dolicocephalic"[All Fields] OR ("high"[All Fields] AND ("angle"[All Fields] OR "angled"[All Fields] OR "angles"[All Fields]) AND ("model"[All Fields] OR "models"[All Fields] OR "modeled"[All Fields] OR "modeler"[All Fields] OR "modeler s"[All Fields] OR "modelers"[All Fields] OR "modeling"[All Fields] OR "modelings"[All Fields] OR "modelization"[All Fields] OR "modelizations"[All Fields] OR "modelize"[All Fields] OR "modelized"[All Fields] OR "modelled"[All Fields] OR "modeller"[All Fields] OR "modellers"[All Fields] OR "modelling"[All Fields] OR "modellings"[All Fields] OR "models"[All Fields]) OR (("anterior"[All Fields] OR "anteriores"[All Fields] OR

"anteriorization"[All Fields] OR "anteriorized"[All Fields] OR "anteriors"[All Fields]) AND ("open bite"[MeSH Terms] OR ("open"[All Fields] AND "bite"[All Fields]) OR "open bite"[All Fields]) OR (("orthopaedic"[All Fields] OR "orthopedics"[MeSH Terms] OR "orthopedics"[All Fields] OR "orthopedic"[All Fields] OR "orthopaedical"[All Fields] OR "orthopedical"[All Fields] OR "orthopaedics"[All Fields]) OR (("orthopaedic"[All Fields] OR "orthopedics"[MeSH Terms] OR "orthopedics"[All Fields] OR "orthopedic"[All Fields] OR "orthopaedical"[All Fields] OR "orthopedical"[All Fields] OR "orthopaedics"[All Fields]) AND ("therapeutics"[MeSH Terms] OR "therapeutics"[All Fields] OR "treatments"[All Fields] OR "therapy"[MeSH Subheading] OR "therapy"[All Fields] OR "treatment"[All Fields] OR "treatment s"[All Fields]) AND (2012:2023[pdat])

3.4 Egilibity criteria

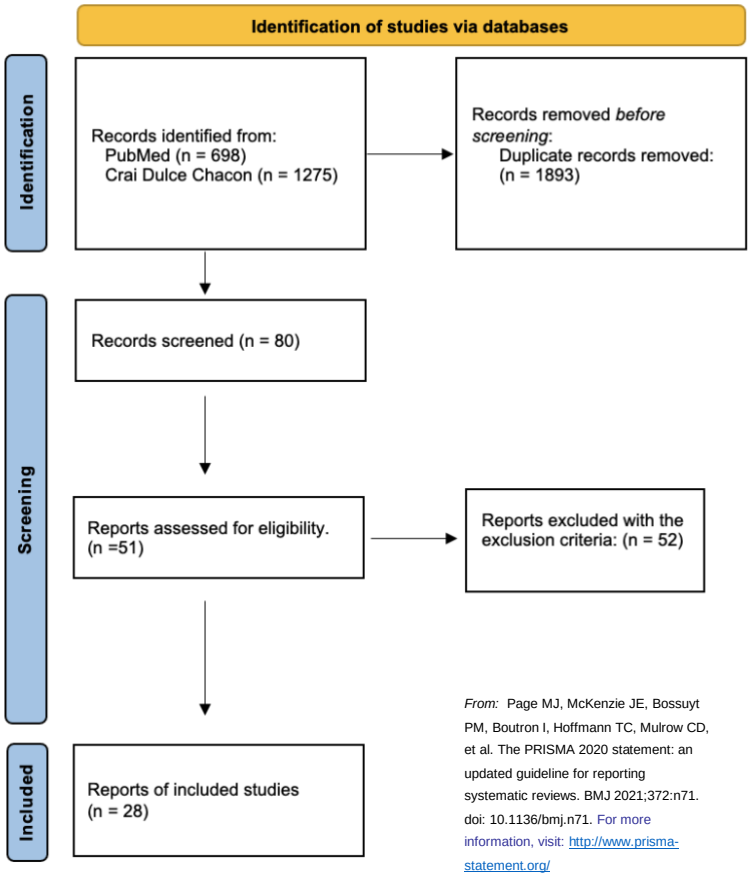
Inclusion criteria	**Exclusion criteria**
Growing patient-adolescent-children	Adult patient
Clinical trial, randomized controlled trial, clinical case	Article published less than 2012
Dolichocephalic management/treatment	Prescence of other transverse or sagittal problems associated with open bite.
Article from 2012-2023	Surgery treatment
Treatment of deleterious habits (NNSH)	Aggressive treatment
First maxillary and mandibular molars and first maxillary and mandibular incisive fully erupted	Pseudo-open bite
Patient in stage 1, 2, 3 of Bacetti classification.	Patients in stage 4-5-6 of Baccetti classification
Article in French- Spanish- English	Previously treated
	AOB associated with syndromic disease

4 RESULTS

4.1 Flow chart

The Preferred Reporting Item for Systematic Review and Meta-Analysis guideline (PRISMA) checklist was used a guideline for conducting and reporting this systematic review (Figure 4).

Figure 4. PRISMA Flow-chart



In PubMED, after introducing the keyword “Open bite treatment” in the research bar, we have a total of 2633 articles. After introducing the inclusion criteria word:

-1138 (articles from 2012-2023)

-698 with the word growing patient (including adolescent (42) and children (358)). Finally, only the articles of interest to deal with the subject were chosen, eliminating those with insufficient contributions or bases according to the exclusion criteria. Finally, a total of 21 articles were obtained that adequately responded to the theme and the objectives of the work were selected.

In Crai Dulce Chacron, after introducing the keyword “Open bite treatment” in the research bar, we have a total of 7903 articles. After introducing the inclusion criteria word:

-2470 (articles from 2012-2023)

-798 with the word adolescent, 80 with the word growing patient, 397 with the word children. Finally, only the articles of interest to deal with the subject were chosen, eliminating those with insufficient contributions or bases according to the exclusion criteria. Finally, a total of 7 articles were obtained that adequately responded to the theme and the objectives of the work were selected after the removal of duplicate.

At the end, a total of 28 articles has been selected and analyzed.

4.2 RESULTS TABLES:

References	Sample size, age, and sex	Type OB	Type of treatment	Follow-up time	Type of measurement	Outcome/Success	Stability	Side effect
Ahmed S Fouda et al 2022 Randomized clinical trial (47)	24 patients 19 females 5 males 8-11 yo	AOB	MPSC[1] and CFPC[2]	Sep 2018-june 2021	Cephalometry + impression	-Both correct -83.3% MSPC -75% CFPC -Both prevent tongue trusting	Some mini screws were loose. -Some solder joints were breaking	Both group face difficulty to adapt to the new swallowing pattern -> Slight increase of the Little's Irregularity Index overjet and crowding (due to lip trap) -More mesial movement of the upper 6 in CFPC
Michelle Alonso Cassis et al **2012** Clinical study (48)	30 patients 21 females 9 males 6-10 yo	Dental and skeletal	Bonded spurs with high pull chincup	12 month	Cephalometry	- 86.7% -↓ of the gonial angle -↑ of overbite - palatal tipping of maxillary incisors - vertical dentoalveolar dev of the maxillary and mandibular incisors	-Wearing spurs during orthodontic treatment of anterior open bite improves the posttreatment stability	- Chincup was not effective for vertical control of molar - Overbite correction was achieved primarily by dental, rather than skeletal effects
Hassan Albogha et al 2015 Clinical study (49)	30 patients 8-14 yo	Skeletal open bite	MMBs[3] and RMIs[4] with posterior bite blocks	4 months, check every 3 weeks	Cephalometry	-MBBs has greater ↓ of SNA + ANB, ↓ maxillary incisor angle and ↓ overjet and intermaxillary relationship -RMI ↓ occlusal plane (greater upward o -MBBS has more effect on maxillary bone -More retraction of the maxillary incisors in the MBBS grp	-Adjustment of the lingual arch -RMI elastics modules deforms	-Both hindered oral hygiene -> special care needed

References	Sample size, age, and sex	Type OB	Type of treatment	Follow-up time	Type of measurement	Outcome/Success	Stability	Side effect
Manuela Mucedero et al 2013 Clinical study (50)	28 subjects 17 females 11 males Mean age: 9,7+/- 1,6 years)	Skeletal and dento-alveolar open bite	Q-H/C[5]	Observation of 5 years Time of treatment: 12 months using Q-H/C	3 digital Cephalometry	With Q-H/C: -93% success -Longer ramus length -Greater downward rotation of the palatal plane -Greater dento-alveolar change -Greater increase in overbite -Lingual tipping of the mandibular incisors -Reduction in ANB -Difference in skeletal relationship in short and long term -Improvement in maxillo-mandibular divergence -All subjects ceased thumb-sucking habits -Control grp: 10 subject spontaneous correction	-After 5 years: good stability -No relapse after 5 years	-Not treat 4 subject because of their higher value at T1
Manuela Mucederoa et al 2018 Clinical study (51)	16 subjects 14 female 2 males Mean age: 8,1+/- 1,1 years	Dentos keletal open bite	RME and BB[6]	Observation for 4 years Time of treatment of RME: 8month and 12 month with BB	3 digital cephalometry	-62,5% of good patient cooperation -T1-> No significant cephalometric change -100% corrected overbite (↑ overbite) and 63% positive overbite -T3->↓ vertical skeletal relationship and facial divergence (↓ FMA) -Reduce extrusion of both maxillary and mandibular 6s. -Control grp: no spontaneous correction -Anterior rotation of the mandible -Control of the excessive vertical growth	-No post-treatment changes -> Stable at long-term follow-up	-Poor compliance for the patient to wear BB at night only
Fernando César Torres et al 2012 Clinical Study (52)	60 children 41 females 19 males 7-10years	Dentoal veolar AOB	RPC+C [7]and FPC+C[8]	Use the chincup: 14-16h/day. 1 year of follow-up	Cephalogram	At T2: -Greater correction of negative overbite in FPC+C (1,6mm)) -> 50% more effective. -U1-PP: Greater amount of U1 extrusion in FPC+C (1,3mm) -> 50% more effective. -↓overjet RPC+C, ↑overjet FPC+C -Both correct the buccally tipped incisor but U1-NA: greater improvement of the U1 inclination in the RPC+C -> 2x greater -FPC+C greater lingual tipping L1 + greater retrusion L1 -Both increase the maxillary and mandible posterior height -U1.L1 angle (interincisal) increase in both grp -**AOB correction higher in FPC+C**: 21 FPC+C: + vertical overlap 15 RPC+C: + vertical overlap -RPC: better correction of position of incisor + overjet	-Less patient cooperation -> Greater effectiveness of the treatment (FPC remove patient cooperation) -RPC+C -> greater comfort, better oral hygiene, removed for meals, might be favorable from psychological point of view	-FPC did not provide greater anterior displacement of the U6 as expected.
Valeria Paoloni et al 2022 retrospective study (53)	23 patients -16 female -7 males 9,3years +/- 1,5 years.	AOB	-Skeletal OB-> RME/BB (12 subjects) -Sucking habits (QH/C) -> 11 subject	RME: 8 months and BB: 20h/days for 12 months T1: 15 months +/-3 months T2: 4,2 years+/- 6 months	Cephalometric + panoramic + geometric morphometric analysis	-T1: All the patients have OB correction. -Remove of the oral habits -T2: RG: 7 RME/BB patients + 4 QH/C -> New AOB SG: 5 RME/BB + 7 QH/C -> No new AOB In RG: ↑ Co-Gn, NGo^GoMe and intergonial notch depth and mandibular length	-Poor compliance when BB has to be wore all night only.	At T2: Deep antegonial notching lead to a backward rotation and vertical direction of mandibular growth.

References	Sample size, age, and sex	Type OB	Type of treatment	Follow-up time	Type of measurement	Outcome/Success	Stability	Side effect
Domenico ciaVarella et al 2017 Clinical trial (54)	26 patients 9,46+/- yo	Skeletal OB with class 2	SOCIA[9]	Wear SOCIA 16h/day Follow up 24 months	Photograph Cephalometry, panoramic, lateral head film	T2: -↓ of mandibular divergence -Vertical transformation -↓ posterior rotation of jaw -↓ intermaxillary divergence -Limitation of molar extrusion -↑ posterior face height -↓ occlusal plane inclination (↓ OP/ML) -Modification of condylar axis (changeset of condyle growth and position) -Modification of downward posterior cranial base -Modification of hyoid position to the 3rd cervical vertebrae(more forward position) -Modification on tongue position -↓ U1 inclination -↓ maxillary-mandibular divergence -More downward movement of the molar -Improvement on overjet/overbite Act in vertical growth, maxillary expansion, and tongue position	-SOCIA induce: -Constant stimulation of masticatory muscles and TMJ -No tendency to procline incisors	-No great modification over the ANB
Manuela Mucedero et al 2017 Clinical study (55)	50 patients: - 33 females -17 males 7,5+/-1,4yo	Dento-skeletal AOB	Q-H/C between TPA[10], HG[11], LB[12]	HG-> 16h/ day LB-> 18h/ days Checking every 4-5 weeks	2 cephalograms	T2 (short term): -Both grp: ↓ palatal plane -↑ In overbite -↓OVJC -↓intermaxillary divergence -Greater ↓ inclination of the U1 in TPA/HG/LB + ↓ mandibular plane (L1 stay the same). LB did not influence over the L1 inclination. -Greater ↑ lingual inclination the L1 + downward rotation of the palatal plane for Q-H/C -82,2% of success for Q-H/C -50% of success for TPA/HG/LB -50% of spontaneous correction for the control grps - Q-H/C -> + physiologic closure.	-Q-HC=fixed -TPA is associated with removable HG and lower LB - Q-H/C show more stability for both dentoalveolar and skeletal change in the long term.	Poor compliance to wear the HG <12h/ days and for LB<16h/ days. -Need compliance of the patient for TPA (associated with removable HG and lower LB)
Natalia Martins Insabralde Et al 2016 Retrospective study (56)	107 patients Grp1: 30 Grp 2: 30 Grp 3: 17 Grp 4: control 23 males 44 females 7-10years	Dento-skeletal AOB	Grp 1: palatal crib + chincup Grp2: bonded spurs +chin cup Grp 3: high pull chincup	Grp 1: 14-16h/ day for 12 month Grp2: 12 months	Cephalometric	T2/ -G1: significant ↑lower facial height, U1 greater palatal tipping, more retrusion of U1 than G4 -G1+G2: greater ↑ overbite, + U1 + L1 -> + vertical development than G3/G4 -G3: less vertical development of U6/L6 -97,5% success in G1 -80% success in G2 G3:48,8% success G4: 53% spontaneous correction	Chincup may be effective at controlling molar vertical development	-No significant difference in the mandibular plane angle -Palatal crib + chincup -> not produce favorable skeletal effect of mandibular plane angle

References	Sample size, age, and sex	Type OB	Type of treatment	Follow-up time	Type of measurement	Outcome/Success	Stability	Side effect
Valeria Paolon et al 2021 Retrospective study (57)	30 subjects 20 females 10 males 8,1+/-0,8 yo	Dento-skeletal OB	G1 (15 subject): Skeletal subject -> RME/ BB G2 (15 subject): Dento-alveolar OB-> QH/C	1,5 +/- 0,6 y for G1 RME was hold for 8 months and BB for 12 months. 1,7 +/- 0,6y for G2	Dental cast and geometric morphometric analysis (GMM)	T2: -No statistically change of the palatal vault morphology between G1 and G2 -Slight greater transversal expansion and less deep in G1 -G2 no significant variation in maxillary depth -**Demonstrate the importance of manage maxillary constriction in order to correct OB**	Long term follow-up -> no information about the relapse	-BB was wear 24h/day -> Need compliance of the patient -Poor compliance when BB wear only at night -Cooperation was 86,7% for G1
Roberta Lione et al 2020 Retrospective study (58)	34 patients 26 girls 8 boys 8+/- 1,0 years	Dento-skeletal OB	G1 (17 subject): Skeletal subject -> RME/ BB G2 (17 subject): Dento-alveolar OB-> QH/C	G1: RME was hold for 8 months and BB for 12 months. G2: 6h/ day Follow up 4 years after treatment	Cephalometry + GMM	T2: -G1 : greater ↓ CoCC.MP angle + ↑ CoCC.SBL angle. Greater change in mandibular shape -> ↑ mandibular height + counterclockwise rotation of the mandible. ↓ steepness of the mandibular + occlusal plane. - No significant morphologic mandibular changes between G2 and CG groups -No difference between Condax^PF and Condax^SN measurements between G1-G2. G2: slight change in the mandibular ramus position	Long term follow-up -> no information about the relapse	Poor compliance when BB wear only at night G1: 70,6% good cooperation G1; 12 patient and G2: 11 patients need fixed conventional appliance to finish the occlusion. QH/C protocol did not affect the mandibular morphology.
Flaviana Alves Dias et al 2021 Randomized study (59)	84 patients G1: BS[12]:25 G2: CC[13]:25 G3: RPC[14]: 24 G4: PFC[14] 7-10years old	Dento-skeletal OB	G1: BS:25 G2: CC:25 G3: RPC: 24 G4: PFC	T1-T2: 1y + 2y of follow-up	Digital cephalometric	T3: -No significant difference for SNA/SNB/ANB, for extraction of incisors, soft tissue component -Improvement of vertical relationship -> more dento-alveolar no significant skeletal changes -CC present smaller mandibular change at the follow up -For all grp: Co-A and Co-Gn ↑ -G4: higher U1 extrusion + higher AOB correction -Overbite stability but for 2 patient from G4 and 1 from G3 -> negative overbite -70,97% abandon of deleterious habits (better for G3/G4 and least G2) -Higher relapse in U1/L1 inclination in G3/G4 -G1/G2 growth changes -> muscular balance	Long term analysis 2y G4 shows more stability at T3 + more clinical advantage (lower patient withdrawal) G1/G2/G3/G4 -> stable result	G2/G3 patient compliance

References	Sample size, age, and sex	Type OB	Type of treatment	Follow-up time	Type of measurement	Outcome/Success	Stability	Side effect
Aron Aliaga-Del Castillo et al 2020 Randomized controlled trial (60)	49 patients G1: BS/ PBU[15]: 24 G2: BS[16]:25 7-11y ears old	Dento-skeletal OB	BS/PBU Vs BS	12 months	Digital cephalogram	-Both grp ↓ AOB, ↓ gonial + mandibular plane angles, U1 labial and L1 labial inclination and protrusion + ↑ overbite + U1 extrusion + L1 protrusion and extrusion + L6 extrusion + ↑ lower anterior facial height, -G1: 66,7% success -G2: 72% success -G1: significant less U6 extrusion	Bonded spurs and builds-ups were debonded accidentally -> break down rate of 2,5% and 5,3% respectively	Plaque accumulation around spurs
M. A. Cassis et al 2018 Clinical trial (61)	G1: EG: 25 patients 15 females + 10 males G2: CG: 23 patients 13 female 10 males 8,10years +/- 0,66	Dento-skeletal OB	BS/HPC C	12 months for the study + follow up of 3 years post-ttx. Chin cup: 14-16h/day for 12 months	Cephalogram	During treatment: -↑ anterior + posterior face heights, overbite, and dento-alveolar height. -↓ gonial and SN.GoGn angles -> effect on the skeletal component + labial inclination of U1 and L1 After 3 years: -G2: greater ↓ gonial angle -G1: greater mandibular-incisor dentoalveolar development	No relapse of open bite (only in 1 patient) -> clinical stability 96%	No side effect reported in this article
Luiz Filiphe Goncalves Canuto 2016 Comparative study (62)	41 patients G1: 20 patients 10 girls 10 boys G2:21 patients 12 female 9 boys G3: control grp 6-11 yo	Dento-skeletal open bite	G1: BLS[18] G2: CLS[19]	G1+G2: study of 12months	Radiograph + cephalometry	T2: Both grp: ↑ openbite, U1-> greater palatal tipping + vertical development U1 -> Greater lingual tipping + vertical development G1: greater ↓ in overjet + retrusion of L1. G2: U6 -> greater vertical development. -Positive overbite: G1: 16/20 G2:16/21	Early treatment with this treatment was primarily dento-alveolar. Bonded spurs tend to be more convenient in the clinic -> Eliminate banding procedure + laboratory phases	CLS was less accepted for the patient than BLS during chewing and eating. Both grp: discomfort time was at 7 days (temporary)
Flaviana Alves Dias 2019 Case report (63)	Male patient 8 yo	Dento-alveolar OB	BLS	5 months then 2,15years	Radiograph, cephalometry, extra-oral and intra-oral assessment. Panoramic radiograph	Positive overbite after 5months and after 2,15years -> Aligned dental arch, normal overbite, and stable cephalometric measurement	Good stability after 2,15years	Spurs has to be replaced twice because of displacement

References	Sample size, age, and sex	Type OB	Type of treatment	Follow-up time	Type of measurement	Outcome/Success	Stability	Side effect
Amjad Ali Hasan et al. 2022 Randomized controlled trial (64)	42 patients 16 males 26 females 8-10years old	Skeletal open bite	G1:FPBB +LLLT[20] G2:LLLT[21]	LTT dose was applied 3,7 and 14 in the first month and then 15days until the end of the treatment	Cephalometric	At T2: -G1: requires less time for the correction of AOB, U6 intrusion was greater -> effective in accelerating the tooth movement. -Both grp: similar dentoalveolar and skeletal changes.	No stability was reported in the treatment	No adverse effect was reported in the treatment
Hakan Turkkahraman et al. 2017 Clinical study (65)	28 patients 23 female 5 male 6-11years	Dento-skeletal OB	G1: PBB-VPC[22] G2: PBB-HPH[23]	Wear the appliance for 12-14h/day.	Cephalometry	At T2: -G1: Greater ↑ in SNB angle due to ↓ SN/mandP, retraction of the L1, + lower posterior height, greater ↑ upper anterior dento-alveolar height. -G2: Greater ↓ in SNA + ANB, occlusal plane rotates anteriorly. Retraction of U1+L1, ↓ overjet, both upper and lower lips moved backward. Greater ↑ lower posterior face height Both grp: ↑ upper and lower dento-alveolar height, ↑ overbite, ↑ post/ant face height, ↑ mandibular length, ↑ posterior, anterior, and lower facial height.	The rotational change did not play a major role in the early treatment of AOB	No adverse effect reported in this literature.
Aron Aliaga-Del Castillo et al 2021 Randomized controlled trial (66)	49 patients G1: 24 S; 25 7-11 yo	Dento-skeletal OB	G1: SBU[24] G2: BS	June 2017-April 2018 Follow up-12months	Intra-oral scanning, digital dental model, cephalometry	T2: -Both grp: improvement of the AOB, ↑ overbite, similar maxillary, and mandibular anterior dento-alveolar vertical development (greater in the maxilla) and similar ↑ clinical crown heights of both central incisor (extrusion) and 1st molar. ↓ in the maxillary and mandibular arch perimeter and length. no intrusion of maxillary molar and **no vertical control of mandibular molar were re- ported.** -Success rate of 66,7% in G1 and 72% in G2 G1: ↓ maxillary intermolar and ↑ mandibular intermolar G2: ↑ maxillary intermolar and ↓mandibular intermolar	G1: 8/24 -> still have AOB. G2: 7/25 still have AOB (depend on the severity of OB in patient) Good stability after 12 months	2,5% of the spurs and 5,3% of the build-ups were debonded. Spurs -> cause speech problem.
Juliana de Brito Vasconcelos 2020 Prospective study (67)	14 patients 9,17+/- 1,03 years	Only dental open-bite	Conventional brackets on U1 and U6 + transpalatal bar	Treatment time: 7,79+/- 2,58 months.	Digital model + cephalometric	↓ overjet, ↑ overbite. No significant change in maxillary intermolar changes, ↑ clinical crown of the incisors, ↑ interincisal angle and retroclination of the U1. Palatal tipping of U1 + extrusions and ↓in the distance between the incisal edge of the U1 and U6. Correction of AOB-> 5/8months	G1: 8/24 -> still have AOB. G2: 7/25 still have AOB (depend on the severity of OB in patient) Good stability after 12 months	2,5% of the spurs and 5,3% of the build-ups were debonded. Spurs -> cause speech problem.

References	Sample size, age, and sex	Type OB	Type of treatment	Follow-up time	Type of measurement	Outcome/Success	Stability	Side effect
Juliana S. Leitea et al 2016 Prospective randomized clinical study (68)	39 patients 34 females 5 boys Mean age: 8,2 yo	Dento-skeletal OB	G1: PC G2: BLS	1 year	Cephalometry	G1: Better ↑ overbite + positive overlap in all patients (100% success) G2: 53,8 positive trespass after 12 months No statically changes between grp for cephalometric value.	No information about the stability was presented in this study	Lower performance of the spurs comparing to the crib and need laboratory time + lower initial patient acceptance because of the alteration of the speech
Rodrigo Almeida Nunes Teixeira et al 2022 Retrospective study (69)	50 patients G1/G2 : 25 patient, 15 females and 10 males 8-10yo	Dento-skeletal OB	G1: EPC[25] G2: PC	3 years after therapy	Cephalometry	G2: more U1 tipping palatally, less treatment time, greater ↓ overjet. For both grp: similar changeset, cephalometric measurements. Frequency of relapse: G1-> 8% and G2: 4%	Post treatment good stability for both grps	Normally RME reduce the overbite, but it has been demonstrated that the vertical effect + temporary
Philipp Meyer-Marcotty 2013 Controlled study (70)	15 patients Mean age: 13yo +/- 10months	Dento-alveolar open bite	Spurs appliance	9 months	Cephalometry	T2: -↓ in the anterinclination of maxilla -↓ of the divergent jaw rotation -Elongation in maxillary and mandibular alveolar process -Uprighting of L1 regarding sagittal analysis -↑ interincisal angle -↑ of the L1 lingual inclination -↑ overbite -Deepening of the bite -↑ overjet -↑ anterior tooth region.	No information about the stability was presented in this study	Spurs therapy did not act upon the sagittal position of U1. -2 patient didn't showed improvement
Claire Van Dyck et al. 2016 Pilot study (71)	22 patient 11 boys 11 girls 7,1-10,6yo	AOB	OMT	10 months of OMT Follow-up for 6 months	IOPI system to measure the tongue elevation pressure	T2: -Higher improvement of tongue pressure. -OMT grp-> Contact between the L1 and U1	Good stability after 6 months of follow-up	Some children might need more training to improve a correct swallow. Depend on the children and parent
Huang et al. 2015 (72)	91 patients G1 (OMT): 77 G2: 14 4-12old	AOB	OMT – Stomhaesive wafer spots.	4 months with a recall of 4 months	Standard clinical examination (Examination and calls ->)	G1: 89,6% ceased digit sucking habits, 16,7% still has AOB. ↓ overjet, rotation of U1. **Good efficacy of correcting AOB.**	Good stability after 4months.	Spots may be melted and took off.

References	Sample size, age, and sex	Type OB	Type of treatment	Follow-up time	Type of measurement	Outcome/Success	Stability	Side effect
Paulo Henrique Rossato et al 2021 Randomized clinical study. (73)	99 patients 8,4+/-0,8yo BS: 25 CC: 25 FPC: 25 RPC: 24	AOB	BS CC FPC RPC	12 months	Kruskal-Wallis test + Dunn's post-hoc test	T2: No significant intergrp difference in overbite correction. Success of all grp: 97,5% Main complication: Bond failure of the spur, soft tissue lesions, loss of removable appliance and abandonment (more with CC). There were also case of skin allergy due to chin-cup.	No stability information provided by this study	33,3% -> no complication. 109 complications in 66 patients. BS -> More complication (26 patients) FPC: show less complication.
Thiago Slaviero et al 2017 Prospective randomized controlled study (74)	41 patients G1: FPC: 23 8,4+/- 0,8 G2: RPC: 18 8,4+/- 0,7	AOB	FPC RPC	12 months	Dental cast Cephalometry	G1: ↓ lower arch perimeter, changes in lower vertical development, ↑ overjet G2: ↓lower + upper arch perimeter, extrusion with upper vertical development. Greater ↓overbite; ↓ overjet Both: ↑ transverse distance with U6, ↓ AOB↑ U1 height RPC: 78% success FPC: 74% success	Good stability over 12 months	No side effect reported in this literature.

U1: upper incisors
U6:upper first molar

L1: lower incisors
L6: lower first molar

1-Miniscrew-Supported Palatal Crib
2- Conventional Fixed Palatal Crib
3- Magnetic Bite-Blocks
4- Rapid Molar Intruders
5- Quad-Helix/Crib
6-Rapid Maxillary Expansion+ Bite Block
7-Removable Palatal Crib + Chincup
8-Fixed Palatal Crib + Chincup
9- Swallowing Occlusal Contact Intercept Appliance
10-Transpalatal Arch
11-High-Pull Headgear
12-Lip Bumper
13- Chincup
14-Removable Palatal Crib
15- Bonded Spurs + Posterior Build-Ups
16-Conventional Bonded Spurs
17- Bonded Spurs + High-Pull Chincup
18-Bonded Lingual Spurs
19- Conventional Lingual Spurs
20-Fixed Posterior Bite Block + Low-Level Laser Therapy
21-Low-Level Laser Therapy
22- Posterior Bite Block +Vertical Pull Chincup
23-Posterior Bite Block-High Pull Headgear
24- Bonded Spurs Associated With Posterior Build-Ups,
25-Expansion/Palatal Crib

5 DISCUSSION

The treatment of open bite will depend on the dentition phase. As reported in the literature, in normal condition, orthodontic treatment should begin after five years old.

5.1 TREATEMENTS OPTION IN DECIDIOUS PHASE

During the deciduous phase, dento-alveolar open bite represents about 95% of the cases with little to non-skeletal involvement. This stage is characterized by a relatively easier treatment option compared to the permanent dentition. As we see, the non-treatment in this phase may lead to the development of skeletal openbite.

The treatment options available during the deciduous phase are primarily focused on controlling the etiological factor responsible for dento-alveolar openbite. As explained before, the main causes are deleterious habits and abnormal tongue posture. A study conducted by **C. Laudadio et al. 2021.** (75) emphasized the crucial role of parents in encouraging their child to abandon pacifier/tongue habits by implementing positive motivation and reward strategies. If the child's habits persist after five years and the open-bite condition is persistent, orthodontic treatment should be considered.

5.2 TREATMENTS OPTION IN MIXED DENTITION:

During this stage, skeletal open bite is more common. Spontaneous correction can occur, that is why around 6 months of mandatory observation are required.

5.2.1 Orofacial Myofunctional Therapy

Orofacial myofunctional therapy (OMT) is a therapeutic approach focusing on the improvement of the function and coordination of the muscles of the orofacial region, including mouth, face, and throat. It's a non-invasive, exercise based therapy that aims to correct abnormal patterns. As we see, again in this stage, the main cause of open bite is deleterious habit, thus, practicing orofacial myofunctional exercise can correct tongue thrusting; improve swallowing and lip mobility. It can help strengthen the muscles and improve airway during sleep. A study from **Sejal S Shah et al.** (76) proposes variant exercises, including:

1. Tongue interposition exercises.

-By placing a spot behind the upper incisor, engaging the tongue to hold the spot for a specific duration and time.

-4s exercises: a four-step exercise involving spot placement, salivation, squeezing and swallowing.

-Pronunciation exercises

-Orthodontic elastic and swallow exercises by placing an elastic on the tip of the tongue and raising it.

- Lingual frenum exercise to stretch it and improve tongue mobility.

2. Oral breathing and lip exercises.

-Labial shield is an acrylic material placed in between the labial muscle, that helps to achieve a proper lip seal and create a somatic swallow pattern. It also helps the breathing through the nose at night.

-Lip puffing and stretching exercise

-Ballooning exercise to engage the nose breathing

-Respiratory exercise by adding weight during breathing.

3. Masticatory and cheek exercises.

-Puffing the cheeks with air

-Rolling the tongue from one cheek to another.

-Vibration machine

OMT should include a minimum of 20 sessions of at least 30 minutes every 15 days, and later, every 30 months.

OMT was performed as described, in a study **by Van Dyck et al.** (71), with a customized protocol for each patient. Results indicated that while OMT does not replace traditional orthodontic treatment, it serves as a valuable adjunct for patients exhibiting abnormal tongue behaviors. OMT was found to enhance the contact between the upper and lower incisors, ultimately correcting AOB with stability over a six-month period.

These findings suggest that OMT may be a beneficial addition to orthodontic treatment plans.

Study from **Harun Achmad et al.** (77) demonstrates that OMT can effectively address AOB and associated habits. The therapy was found to stimulate activity in the masseter and buccinator muscles while reducing activity in the lip muscles. This resulted in improved lip closures and AOB by the elimination of negative oral habits.

The study conducted by **Huang et al.** (72) found a positive correlation between OMT and the closure of AOB in a patients from 4-12years of age. This was achieved through the use of stomahesive wafer spots, which effectively reduced torque on the upper front teeth, and by shortening the lever arm. A significant closure of AOB was observed in 90% of patients after a 4-month of period. Additionally, OMT was shown to reduce overjet. The incorporation of behaviors shaped with positive reinforcement was also found to contribute to the high efficacy of cessation.

OMT may have potential disadvantage or limitation. OMT is a specialized therapy that may not be widely available that can be difficult for patients to access and receive consistent treatment. It also requires a significant time and full compliance from patient and parents.

5.2.2 Functional Therapy

5.2.2.1 Tongue/palatal crib.

A palatal crib is an orthodontic device designated to intercept certain oral habits. It can be removable or fixed and used for the upper or lower jaw.

As described in various studies, fixed palatal crib (FPC) is presented with two bands that are fixed into the permanent first molars with a lingual arch (0,40 wire), soldered to the molar bands, and bent to 45° to fit passively in the palatal vault. Additional wires are soldered to form a crib to create a mechanical obstruction for the digit and create an aversive sensation, reducing the comfort associate with the bad oral habits. The normal duration reported in literature is six months. It should be used in patients with no posterior crossbite.

The removable (RPC) one is made most of the time with acrylic that covers the palatal region, in contact with the lingual aspect of all teeth. It is held in place in the mouth by adam clasp placed on the first upper molar and is also composed of a palatal crib and labial arch wire. Patients are instructed to wear the appliance full time except during meals and oral hygiene.

The treatment time of palatal crib among studies is around 12 months with monthly monitoring.

Palatal crib can be used alone or combined with other functional appliances. It can also be used along with myofunctional therapy, as show a case report by **Moshabab A Asiry et al.** (78) which shows that this combination was effective in treating AOB with long-term stability due to myofunctional therapy.

A study carried out by **Thiago Slaviero et al.** (74) compared the use of FPC and RPC. No significant changes in the correction of AOB were found between both groups although RPC has slightly better result. It appears from this study that FPC appliance was more effective in promoting the counterclockwise development of the lower dento-alveolar process while RPC produced a clockwise development of the upper dento-alveolar process. Both appliances act on the reduction of both arch perimeter and length and on the increase of transverse distances. This coincides with the result of a study realized by **Flaviana Alves Dias et al** (59)**.** that explained that RPC was prone to change maxillary incisors inclination while FPC was more indicated for mandibular incisor inclination and position change.

While comparing conventional fixed palatal crib (CFPC) with mini screw supported palatal crib (MSPC) like in a study performed by **Ahmed S.Fouda et al.** (47) it appears that mini screw was more effective in increasing the overbite than the CFPC but both group produce similar correction of AOB.

According to the stability post-treatment, study agrees that in the long term stability, FPC shows higher post-treatment stable result. A study realized by **Flaviana Alves Dias et al.** (59) compared treatment option in a 2 years follow up research and compared with other appliances such as bonded spurs or chin cup, FPC and RPC show more relapses in incisor tipping because of the mechanism of action of the crib that only retrains and not retain patient tongue.

Despite its benefits, there are some potential disadvantages associated with this appliance. The palatal crib can cause mesial movement of maxillary first molar, leading to a class II worsening the malocclusion. Palatal crib seems to only act on the dento-alveolar process and lack skeletal changes. Patient may also take longer time to adapt to the new swallow pattern. Also, FPC can make oral hygiene difficult. According to a study performed by **Paulo Henrique Rossato et al.** (79) patients who wear RPC are less likely to experience soft-tissue complications than those wearing FPC. This research also supports previous finding that patients wearing removable appliance tend to abandon their treatment more frequently than those wearing fixed appliances, which may be due to the discomfort or unesthetic of the appliance. This highlights the importance of considering patients conformity and aesthetics when choosing treatment.

5.2.2.2 Tongue spurs

Spurs can be proposed as a treatment option in the correction of open bite with the correction of deleterious habit by directing the tongue pressure away from the incisors. Founded by Roger in 1927, they can be presented in various forms; the conventional lingual spurs (CLS) structure is composed of stainless steel wire with anteriorly attached spurs placed in the cingulum of the maxillary incisor at a downward and backward 45° angle to promote proper tongue posture. Additionally, the appliance includes bands placed into the maxillary first molar to provide anchorage.

Bonded spurs (BLS) appliances are small metals spurs placed and bonded in the palatal/lingual surface at the level of the cervical and incisal parts of the maxillary and mandibular incisors.

A study from **Luiz Filiphe Goncalves Canuto et al.** (62) compared the two appliances in terms of their success, stability, and side effects. They found that, compared to the conventional one, the bonded was found more effective but non-significantly, in decreasing the overjet. Both appliances provoke a palatal tipping of the maxillary incisor and corrected the overbite in a similar manner. Patients tended to prefer the BLS appliance over the conventional one.

In general, bonded spurs are a preferred option compared to conventional ones due to their smaller size, lower cost, improved aesthetic, and ease of installation.

Additionally, they are more accepted by patients. The smaller size reduces the risk of irritation or discomfort in the oral cavity.

A study presented by **Meyer-Marcotty P et al.** (70), shows that spurs therapy has effect on the elongation of the alveolar processes of both jaws and correcting the overbite. A tendency to tip the mandibular incisor lingually. Spurs only present changes at the dento-alveolar level, with no improvement at the skeletal base. These results agree with other studies like the one by **Paulo Henrique Rossato et al.** (73) exhibit that BS provokes the extrusion of the maxillary incisor better than the mandible with no skeletal changes. When comparing to palatal crib like the study of **Juliana S.leite et al.** (68)both appliances successfully treat open bite, but the advantage is given to palatal crib. These results are agreeing with further study, we will see through this discussion.

Regarding post-treatment stability, studies agree with the long term stability of BLS. A study realized by **Flaviana Alves Dias et al.** (59), demonstrated that no relapse was found in the study after 2 years of follow-up. In comparison to the crib appliance, BLS was found to be associated with less breakage of deleterious habits. This results coincide with a case report authored by **Flaviana Alves Dias et al.** (63), that also shows great stability over 2,15 years with BLS appliance.

Spurs can also be associated with posterior build-up, a resin block bonded in the maxillary posterior teeth. **Aron Aliaga del Castillo et al** (60) conducted two studies, analyzing dental arch changes using this combination compared to the use of spurs alone. In the study of 2018, 66,7% of success was observed after 12 months, with better improvement at the dental level but no effect on the vertical control. 72% of success was observed for the use of spurs alone. In 2022, similar result was found, both treatments were useful in the correction of open bite.

The disadvantages of this appliance are controversial among the different studies but important to consider. One of the main disadvantages reported, is speech impairment. This is due to the position of the spurs on the inside of the teeth. In addition, it can cause difficulty with eating and oral hygiene. Spurs can provoke discomfort and irritation and may not be well tolerated by the patient. As mentioned earlier, spurs only act on the dento-alveolar component.

In terms of complications during the treatment, the study of **Paulo Henrique Rossato et al.** (79), demonstrates that BS appliance shows the highest record of complications compared to other appliances, such as bond failure of the spurs and maladjustment of the appliance.

5.2.2.3 The open-bite Bionator (OBB) appliance

It's a proposed appliance by Wilhem Balter in 1960 and consists of posterior acrylic plate on the posterior teeth to prevent further eruption of them and a labial bow that run between upper and lower incisors at the height of lip closure. To prevent tongue trusting, the lingual acrylic extends into the upper incisor area, and the labial bow goes across the interincisal area. It has to be worn day and night, except during meals for at least 12 months with monthly monitoring. The duration of wear has a direct impact on the effect of the appliance; full-time wear will stimulate skeletal change, whereas part time wear will stimulate only dental change. A study from **Murilo Fernando Neuppmann Feres et al.**(80), demonstrates that OBB was effective in the AOB correction and also decreased the palatal and mandibular plane divergence and prove the long-term stability of the appliance. When comparing to removable posterior bite plane with palatal crib, like in a study of **Mahran Mousa et al.** (81), both appliances were effective in correcting skeletal open bite with no significant skeletal changes between the two groups.

5.2.2.4 Bimler type A appliance

This removable appliance was originally developed by Hans Peter Bimler in 1949. It involves a buccal bow joined together by two small acrylic plates located on the upper posterior buccal segment. The lower part is made of two lingual wires called dorsal arches attached to a lower shield. Patients are instructed to wear the appliance 24 hours a day except during mealtime and oral hygiene routines.

Only one study **Ramirez-Yañez GO et al.** (82) explored the effect and stability of this appliance in three cases reports. They found out that this appliance has both dento-alveolar and skeletal effects, meaning it plays an important role in the counterclockwise rotation of the mandible and in the clockwise rotation of the maxilla. The duration of

treatment was around two years for each cases and successfully corrected the overbite and overjet in all three patients and shows no relapse during a follow-up of 14 years or more. Although these findings are promising, more studies are needed to evaluate the reliability and effectiveness of the Bimler appliance for treating open bite.

5.2.2.5 Frankel type 4 appliance (FR-4)

It's an appliance developed by Fränkel and Fränkel to address the correction of skeletal open bite and the activity of orofacial musculature. Previous studies claimed that this appliance helps to reverse the backward rotational growth of the mandible. It includes a palatal bow, an upper labial wire, two buccal shields, two lower lip pads, and four occlusal rests placed on the upper first permanent molars. Patients are advised to wear the appliance for at least 20 hours per day, except during mealtime and oral hygiene routines. A literature review made by **Murilo Fernando Neuppmann Feres et al.** (80), evaluated several previous studies and concluded that Frankel appliance was effective in correcting skeletal open bite as it corrected the steep mandibular plane. It also emphasized the long-term post-treatment stability. Another study conducted by **Elaine Marcílio Santos et al.** (83), shows great stability of the appliance after 24 months of treatment and present that FR-4 was effective in correcting overbite and the angulation of the upper incisor related to the palatal plane (1-ANS-PNS) but no correction in SNA, SNB, ANB angle. However, further research needs to be conducted in order to confirm the effectiveness of this appliance in clinical practice.

5.2.2.6 Vertical pull chin cup

The vertical pull chin cup (CC) is an extraoral appliance created in 19th century that applies an upward and backward pressure on the mandible by applying force on the mandibular condyle, which prevents a forward growth. The recommended orthopedic force among the study is 300-500g per side. The suggested time to wear the appliance is 14 hours per day.

The study carried out by **Paulo Henrique Rossato et al.** (73), analyzed the dento-alveolar effect produced by the CC. It appears that the CC was effective in treating open bite and presenting greater extrusion of the mandibular incisor compared to the

maxillary one but was not effective for vertical control of the maxillary molar. That is why, according to the authors, it should be use combined with other devices. This corresponds to the result of the research performed by **Flaviana Alves Dias et al.** (59), that CC alone presented smaller mandibular changes and should be combined.

The chin cup can be associated with other appliances, like bounded spurs: the study of **Cassis. M et al.** (61) analyze the effect and stability of this combined appliance. In fact, BS therapy will act upon dento-alveolar base while CC will act at skeletal level. This combination should be suitable for the correction of a dento-skeletal open bite. The research found that after 12 months of treatment, there were significant increases in the anterior and posterior face heights, correction of open bite and change in the dento-alveolar height but no effectiveness in the maxillary vertical control (coinciding with the previous studies). After 3 years of follow-up, only one relapse was found due to the persistent of deleterious habit. In the study of **M.Cassis et al.** (48)**,** this combination was effective in correcting open bite in 86,7% of the cases achieved by a decrease of the gonial angle with a palatal tipping of the maxillary incisor and a vertical development of the dento-alveolar but not effective in the vertical control in the sample of patients (coinciding with the previous studies).

When comparing the association of chin cup with bounded spurs with the association of chin cup with removable palatal crib and with chin cup alone like in the study of **Natalia Martins Insabralde et al.** (56), it appears that the combination of CC+RPC shows a greater increase of the anterior facial height, retrusion, and palatal tipping of the maxillary incisor. Both combinations show greater increase of the overbite, greater vertical development than the CC alone. This comfort, along with previously mentioned studies that the use of chin-cup alone is not well appreciated. The combination of CC with RPC tends to be more effective. This study also agrees on the non-favorable vertical control of the CC.

The study of **Fernando C. Torres et al.** (52), compares the combination of the chincup whether with fixed crib or the removable crib. After 1 year of treatment, RPC + CC has greater improvement in overjet due to better upper and lower incisor inclination, but FPC+CC has greater amount of maxillary incisor extrusion resulting in a greater correction of the open bite. The research of **Fernando Ferreira et al.** (84) **,** evaluates

that this combination was stable in 95% of the cases after a follow-up of 15 months. The failure was due to the proclination of the lower incisor after the removal of the crib due to tongue pressure.

Stability of the CC is exclusively discussed in a study of **Flaviana Alves Dias et al.** (59), After 2 years of follow-up, CC shows great stability but records less breakage of deleterious habits compared to BS, RPC, FPC.

The disadvantage of this appliance is that the chin cup has negative impact on facial aesthetics. It requires full compliance of the patient and parent. In terms of complication during the treatment, the study of **Paulo Henrique Rossato et al.** (79), demonstrates that CC was the second appliance that caused the most complication, preceded by the bounded spurs therapy, mainly due to skin allergy and abandon of the treatment (CC group presented the highest prevalence of abandon)

By comparing to other treatments, **Paulo Henrique Rossato et al.** (73) research demonstrates that FPC and RPC shows better results than BS or CC in term of dental changes.

5.2.2.7 Quad-Helix appliance.

The quad helix fixed appliance, as introduced by Rickett, is composed of four helices, a palatal bridge, an anterior helix, an anterior bridge located in the canine region, and an outer arm. These helices are strategically designed to enhance flexibility and adjustability. The posterior helix should not extend beyond 2mm distal to the permanent first molar, and the buccal arm is soldered into a molar band. The primary purpose of this appliance is to address maxillary transverse deficiency by applying a force of 200-400g. The treatment should last at least 12 months based on articles.

This appliance is more often used in conjunction with tongue crib in order to correct both dental and skeletal open bite. The study of **Mucedero et al.** (50), analyzed the stability and effect of this combined appliance approach. They conclude that this combination results in a downward rotation of the palatal plane, correcting overbite in 93% of the cases. Dento-alveolar change was observed by a lingual tipping of the mandibular incisor. A reduction of ANB means change in maxilla-mandibular relationship. It means that this combination produces both dento and skeletal effects.

After 5 years of follow-up, this combination shows no relapse, and all the patients have ceased the tongue-sucking habits. The failure of this treatment in some patients was due to a more severe form of open bite.

5.2.2.8 Rapid maxillary expansion (RME)

RME is an appliance is used by placing bands on the molars and joining them both labially and palatally with an expansion screw usually positioned in the midline of the palate. RME produces split opening of the maxillary suture, causing the palatal shelves to move away from each other. It can also increase nasal air passage and decrease nasal airway resistance. It is particularly effective when used during the pre-pubertal stage, as it can produce more skeletal change.

For the treatment of open bite, RME are more often associated with posterior bite block.

5.2.2.9 Posterior bite-block (PBB).

This appliance consists of an acrylic platform that is positioned parallel to the occlusal plane. This appliance is designed to induce a forward and upward rotation of the mandible. It also provides intrusion of the molars or limits their extrusion, which helps correct the open bite condition.

When the PBB is used in combination with the RME for the treatment of dentoskeletal open bite, it avoids the extrusion of the molar and controls the vertical dimension, as we see in the study of **Manuel Mucedeo et al** (51). This study demonstrates that this conjunction of appliances produces a decrease of the vertical skeletal dimension and increase of overbite (100%) with no relapse observed after 5 years of follow-up.

The aim of the **Hakan Turkkahraman et al.** (65) research was to compare the association of PBB with either vertical pull chin cup (VPC) or high pull headgear (HPH). PBB-HPH presented greater decrease of SNA and ANB, more upper incisor retraction, and greater reduction in the overjet. Overall, it produces more changes in the maxilla than in the mandible. On the other hand, PBB-VPC presented more increases of the

upper anterior dento-alveolar height and of the lower posterior face height, with lesser effects on the maxilla but more pronounced changes in the mandible.

PBB can also be used along with low-laser therapy (LLLT) as shown in a study by **Amjad ali Hasan et al.** (64) to accelerate the early treatment of the skeletal AOB. The combination with laser produces similar dento-alveolar and skeletal changes. Further studies are needed to analyze the effect of the laser therapy.

Another approach for correcting open bite involves the use of magnetic bite blocks by rotating the mandible supero-anteriorly and making changes in the gonial angle. It consists of magnets embedded in posterior bite blocks and works as the same manner as conventional bite block but with a force on it. The force is from 350 to 450g. Correct placement of the magnet is therefore crucial for this technique. The study of **Hassan Albogha et al.**(49) **,** compared the growth changes when using magnetic bite blocks and rapid molar intruded. We can observe that MBB group showed greater decrease in SNA, ANB, overjet meaning greater effect on the maxilla and at the dentition level. This is in accordance with the review of **Elaine Marcilio Santos et al.**(83)

When comparing QH/C with RME/BB appliance, like the study of **Valeria Paoloni et al**. (57) it appears that both appliances were effective in correcting the dento-skeletal open bite with no statistical difference. But it appears that RME/BB group presented a more expanded palatal vault and less deep. When comparing their results with other studies, they found that that RME/BB has greater impact on the counterclockwise rotation of the mandible and more maxillary expansion while Q-H/C has no impact on the mandible but produce a more downward rotation of the maxilla. This is in accordance with previous study mentioned earlier (study of **Mucedero et al.** (50)**.** This result concords with the research of **Roberta Lione et al** (58)**.** showing that RME/BB group has more impact on the change in the mandibular morphology producing elongation and change in the orientation with a counterclockwise tendency.

5.2.2.10 *<u>High pull headgear appliance .</u>*

In 1822, Gunnel was reported to be the first to use a headgear. The basic component of the headgear is a stainless steel facebow wire; this provides force to the jaw. This facebow is made of two parts: the outerbow is made of heavy stainless steel

wire (0,059-1,5mm) that fits the cheek area into a “u” form. The innerbow is a stainless steel wire of 0,045-0,050mm that fit the dental arch of the patient. It’s in contact with the maxillary first molar. In this type of headgear, the pull will produce distal and intrusive forces on the maxilla and the upper molars that will cause, molar intrusion, maxillary growth modification, counterclockwise rotation of the mandible. It is associated with functional appliance to maintain the vertical position of the maxilla and inhibit extrusion of the maxillary posterior teeth.

A study by **Mucedero et al.** (55), compares the outcome of fixed Q-H/C with sample of patients using removable TPA/HG/LB (Transpalatal arch/headgear/lip bumber). At the end of 12 months of treatment, both groups presented a reduction of the palatal plane angle, increase in overbite. TPA/HG/LB presented effects on the inclination of the maxillary incisors while Q-H/C presented more effects on the mandibular incisor inclination. Overall, both appliances presented more effect at the dentoalveolar effect. Even if both appliance demonstrate a closure of open bite, Q-H/C was more physiological and stable in the long term because of the cessation of the habits, while TPA/HG/LB closure was due mainly to intrusion of the molar.

5.2.2.11 *Others approaches.*

1) A study of **Juliana. Vasconcelos et al.** (67)**,** evaluated the maxillary dentition effect with the use of maxillary incisor extrusion arch for the correction of anterior open bite. It’s a fixed appliance that exacerbates 40-60g of force in the anterior teeth to extrude them. The arch is fused with brackets placed on the maxillary first molar and on the distal part of the maxillary lateral incisor. The mean treatment time was 7,79 months. This appliance produces an extrusion of the maxillary incisors, producing similar results in the correction of the open bite as the other appliances seen earlier. We see a reduction of the overjet, arch perimeter, and length. But one of the disadvantages seen is an unfavorable anterior tipping of the maxillary molar. Further study needs to be conducted to analyze the dental effects of this concept.

2) The SOCIA (Swallowing Occlusal Contact Intercept Appliance) appliance was analyzed in the study of **Domenico Ciarella et al**.(54) It’s a functional appliance that doesn’t have intra-oral anchorage but gives continuous stimulation at the level of the

periodontium, muscles, and articulation in order to reduce the unfavorable skeletal growth. It consists of palatal acrylic appliance with vestibular pad with metallic posterior bite blocks embedded in them. A labial wire in running to the vestibular side of the anterior dentition. No dental retention is appreciated with this appliance, it is held in place by the masticatory system. The active treatment lasts 24 months. It has been seen that SOCIA produces both changes in the skeletal and dental components; it reduces skeletal divergence and increases posterior face height trough a distraction at the level of the condyle but has little effect on the ANB angle. It also has an impact on the incisor and molar positions without producing unfavorable proclination. Further study needs to be conducted to analyze the dental effects of this concept.

6 CONCLUSIONS

After conducting a thorough review of relevant articles to responds to the objectives we have reached the following conclusions:

1) In the deciduous phase, the most effective treatment plan focuses on controlling the etiological factors responsible for dento-alveolar open bite as it is the most prevalent cases. The importance of parents is crucial for encouraging abandon of deleterious habits.

In the mixed dentition phase, the treatment protocol varies upon whereas the patient presents dento-alveolar open bite, skeletal open bite, or combination of both.

If the patient presents dento-alveolar open bite with clear deleterious habits, the most efficient treatment plan, considering patient compliance, treatment time, efficacy and complications involves the use of fixed palatal crib combined with orofacial myofunctional therapy (OMT). FPC+OMT is preferred when a counterclockwise development of the lower dento-alveolar process is needed while RPC+OMT is more effective for patients where a clockwise development of the upper dento-alveolar process is researched. The choice between fixed and removable appliance depends on patient compliance and oral hygiene as FPC can make cleaning challenging. The treatment time among studies is generally around 12 months with monthly monitoring.

If the patient presents both skeletal and dento-alveolar open bite, the use of Rapid Maxillary Expansion in combination with posterior bite blocks seems to have both effect in skeletal and dento-alveolar bases by expanding upper palatal vault and producing counterclockwise rotation of the mandible with good control over the vertical dimension. RME-BB has a treatment time of around 4-8 months and can be used with low laser therapy in order to have a faster treatment. Magnets can be added to the bite block to add more pressure on the teeth. The use of Quad-Helix appliance in combination with palatal crib or palatal crib in association with PBB is well appreciated for the treatment of dentoskeletal open bite. It doesn't require patient compliance and is proposed treatment for patient that present deleterious habits and maxillary transverse deficiency.

In cases where the patient presents skeletal open bite, functional appliance such as open-bite bionator or Frankel type 4 are used. Both appliances need full patient compliance for successful treatment. Further study needs to be conducted in order to compare both appliances to each other and with other in order to select which one seems to be the more effective.

2) In mixed dentition phase, various appliances have been proposed:

-Tongue/palatal spurs are great appliances for correcting anterior open bite in terms of cost, size, and patient comfort, but it shows the most record of complication like bond failure.

-Combination of palatal spurs or palatal crib with chincup appliance seems effective in the correction of anterior open bite, but one disadvantage is that chincup does not appear to have a vertical control. Additionally, it's unesthetic and needs full patient compliance.

-High pull headgear, this device produces distal and intrusive force over the maxillary molar for correcting open bite. In studies, it is associated with trans palatal arch.

-Other approaches like, maxillary incisor extrusion associated with bracket and the use of SOCIA for the correction of open bite has been proposed, but further study need to be achieved in order to understand and compare these appliances.

3) Overall, the stability and long-term results are close to 100% for all the treatments proposed. For the management of strictly dento-alveolar open bite, fixed palatal crib and tongue spurs, studies agree on the long term stability (mean follow-up time after treatment of 2,5years) of both appliances. Relapse can occur in patient that does not abandon their habits or because the crib focuses on retraining rather than retaining the tongue.

Functional appliance OBB and Frankel shows greater stability after 24months, Bimler type A shows no relapse after more than 15years. Vertical chin-cup shows good stability after 3 years of follow-up after treatment. No relapse was found after 5 years of follow-up for quad helix appliance because of the physiological closure of open bite. Same result was found for RME associated with PBB. If relapse were found in studies,

it's because of the persistence of oral deleterious habits, respiratory problem, severe T1 skeletal open bite, non-compliance of the patient/parent.

4) Articles of this review may have limitations in terms of the sample size of patients that affect the generalizability of the finding to a broader population and may not accurately represent the overall effectiveness of a treatment approach. Another limitation is the heterogeneity in the patient population, with more females than males. The duration of follow-up may not capture the long-term stability outcome or potential relapse after treatment completion. Additionally, there may be lack of study comparisons of efficacy and effect for certain appliances. Throughout this study, no article was found to correct posterior open bite.

For further studies, monitoring patient compliance with the prescribed treatment can help to accesses the impact of the treatment outcome, to include more males in the study and with longer follow-up study. It should also assess cost and side effects of different treatment options, as well as patient satisfaction. New studies to compare the OBB, bimler and frankel appliances.

The hypothesis of this review is rejected.

The treatment plan of open bite in a growing patient remains complex and requires careful consideration of various factors such as severity, timing, skeletal maturity, etiology, and patient compliance.

7 ANNEX

7.1 ABREVIATIONS:

AOB – Anterior Open Bite
POB – Posterior Open Bite
NNSH – Non-Nutritif Sucking Habits
URO – Upper Respiratory Obstacle
NSD – Nasal Septum Deviation
PFE – Primary Failure of Eruption
TMJ – Temporo-Mandibular Joint
JIA – Juvenil Idiopathic Arthritis
CVM – Cervical Vertical Maturation
MPSC – Miniscrew-Supported Palatal Crib
CFPC – Conventional Fixed Palatal Crib
MMBS – Magnetic Bite-Blocks
RMI – Rapid Molar Intruders
Q-H/C – Quad-Helix/Crib
RME – Rapid Maxillary Expansion
BB – Bite Block
RPC + C – Removable Palatal Crib With Chincup
FPC + C – Fixed Palatal Crib With Chincup
SOCIA – Swallowing Occlusal Contact Intercept Appliance
TPA – Transpalatal Arch
HG – High-Pull Headgear
LB – Lip Bumper
BS – Bonded Spurs
CC – Chin-Cup
RPC – Removable Palatal Crib
FPC – Fixed Palatal Crib
BLS – Bonded Spurs With Posterior Build-Ups
CLS – Conventional Bonded Spurs
FPBB + LLLT – Fixed Posterior Bite Block + Low-Level Laser Therapy
LLLT – Low Level Laser Therapy
PBB + VCC – Posterior Bite Block-Vertical Pull Chin Cup
PBB + HPH – Posterior Bite Block-High Pull Headgear
SBU – Bonded Spurs Associated With Posterior Build-Ups
EPC – Expansion/Palatal Crib
OMT – Oral Myofunctional Therapy
FR4 – Frankel type 4

7.2 TABLES:

7.3 FIGURES:

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FIGURES :

Figure 1: https://www.researchgate.net/figure/Landmarks-and-reference-lines-used-for-the-cephalometric-analysis_fig1_346720729

Figure 2 : https://eu-ireland-custom-media-prod.s3-eu-west-1.amazonaws.com/UKMEAEU/eSample/extraits/9780323378321-.pdf

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