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Efficacy and stability of orofacial myofunctional therapy on restoring mature pattern of swallowing and nasal breathing in children before orthodontic treatment

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Ce mémoire intitulé:

Efficacy and stability of orofacial myofunctional therapy on restoring mature pattern of swallowing and nasal breathing in children before orthodontic treatment

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Abstract

Introduction:

Mouth breathing is often associated with a weak orofacial musculature and a low resting tongue position, leading to malocclusion and potentially sleep-disordered breathing in children.

Objective:

To evaluate the effect of orofacial myofunctional therapy on the reestablishment of a mature pattern of swallowing and nasal breathing by stabilizing a proper position of the tongue and lips at rest.

Methods:

This prospective randomized single-blind controlled study evaluated 37 patients (age six to fourteen years) divided into two groups who received either a complete orofacial myofunctional therapy (7 sessions) including swallowing pattern and tongue posture, or a simplified therapy modifying their tongue posture (3 sessions). Both groups were seen at three months and one year following treatment completion.

Results:

Results suggested that treatment outcomes were similar when treating tongue-lip posture at rest along with tongue thrust, and treating without addressing tongue thrust ($p = 0.59$). Both treatments were efficacious as there was a significant difference between the pre- and post-evaluations for both groups ($p < 0.001$), and these differences remained stable at the one year follow-up.

Conclusion:

Treating a tongue thrust habit with specific related exercises, may not be a necessary component of an orofacial myofunctional therapy to reestablish tongue posture at rest and nasal breathing in children with no other functional problems.

Keywords :

Orofacial myofunctional therapy, atypical swallowing, tongue thrust, nasal breathing, orthodontics, malocclusion, incorrect tongue position at rest, open-mouth posture

Résumé

Introduction:

Une respiration buccale est souvent associée à une faible musculature oro-faciale et à une position basse de la langue, pouvant mener aux malocclusions et au potentiel de développer des problèmes de respiration pendant le sommeil chez les enfants.

Objectifs:

Évaluer l'efficacité de la thérapie oro-faciale myofonctionnelle sur le rétablissement d'une déglutition physiologique et d'une respiration nasale en développant une posture linguale et labiale normale au repos.

Méthodes:

Cette étude contrôlée randomisée prospective à simple aveugle a évalué 37 patients (six à quatorze ans) divisés en deux groupes où un groupe a reçu une thérapie complète (7 séances), comprenant des exercices pour la correction du patron de déglutition et de la posture linguale, et l'autre groupe a reçu une thérapie sommaire, corrigeant seulement la posture linguale (3 séances). Des suivis à trois mois et à un an post-traitement ont été effectués pour les deux groupes.

Résultats:

Les résultats des deux traitements, soient la thérapie complète et la thérapie sommaire, sont similaires ($p = 0.59$) et également efficaces pour la correction de la déglutition atypique et le rétablissement d'une respiration nasale, avec une différence significative entre les évaluations avant et après traitement ($p = 0.001$), qui demeure stable après un an post-traitement.

Conclusion:

Le traitement avec des exercices spécifiques pour une correction d'une propulsion linguale ne serait pas une composante absolue d'une thérapie oro-faciale myofonctionnelle afin de rétablir une posture linguale adéquate au repos et un patron de respiration nasale chez les enfants n'ayant pas d'autre problème fonctionnel connu.

Mots-clés:

Thérapie oro-faciale myofonctionnelle, déglutition atypique, propulsion linguale, respiration nasale, orthodontie, malocclusion, position linguale incorrecte au repos, ouverture buccale au repos

Table of Contents

List of Tables

Article

List of Figures

<u>Article</u>

List of Abreviations

OMT	Orofacial myofunctional therapy
OMD	Orofacial myofunctional disorder
SD	Standard deviation

For my parents, who were always there to offer their support and encouragement. For Michel, who will always be a pillar in my life with his daily moral support and unconditional love. For my brother, who will always be a role model.

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1. Introduction

Mouth breathing and low anterior position of the tongue at rest can potentially affect long term stability of orthodontic treatment, as well as worsen the risks of sleep apnea. Mouth breathing is associated with lack of muscular tension in the lips, leading to an open mouth at rest position, and a low anterior position of the tongue which can result in dental and skeletal malocclusions.[1, 2] In recent studies, tongue thrusting has been shown to be the most common of oral habits and tongue thrusting during swallowing is considered to be an abnormal pattern of deglutition which can lead to orofacial muscle imbalance and malocclusion.[3] The fact that the tongue pushes against the incisor teeth during deglutition has increased the intervention of speech language pathologists and orofacial myologists to correct atypical swallowing, as part of a complete pre-orthodontic orofacial myofunctional therapy (OMT). Proffit[4] suggested that one of the factors responsible for causing a malocclusion is the continuous force applied by the tongue at rest against the teeth, contrary to the intermittent and heavier force applied by the tongue while swallowing.[2] While this theory has not been proven, speech language pathologists continue to apply long term treatment in order to reprogram tongue position during deglutition to help maintain an alveolar position of the tongue at rest. According to Proffit[4], the OMT should focus on establishing nasal breathing and normal tongue and labial position at rest and not during deglutition as this represents only a fraction of the force applied by the tongue on the teeth throughout the day.[4]

Normal breathing is considered to be primarily nasal breathing. Mouth breathing tends to occur in cases where there is nasal obstruction associated with choanae hypertrophy, deviated septum, seasonal allergies, chronic rhinitis or tonsils and/or adenoids hypertrophy. Nasal breathing versus mouth breathing requires different muscle functions in both the nasal and oral cavities. In humans, mouth breathing is associated with modifications in both craniofacial growth and posture.[5-7] In children, mouth breathing is associated with a hyperextension of the head, a retrognathic mandible, an increased lower facial height, a lower position of the hyoid bone, and an anterior-inferior position of the tongue.[8] The lower position of the mandible causes an anterior and inferior position of the tongue at rest, which creates a decrease in orofacial muscle tone and function.[9, 10] This directly affects skeletal craniofacial growth, and can create a narrow maxillary process, an elevated palatal arch, a long and narrow face, and an increased overbite and overjet.

It is critically important to establish nasal breathing, a normal swallowing pattern, and an adequate tongue position on the alveolar process at rest in growing children, in order to develop adequate oral habits and craniofacial development.[4] The aim of OMT is to normalize muscle patterns that participate in buccal movements during normal swallowing and nasal breathing. This therapy will optimize lingual and labial muscle tone and mobility in order to maintain the lingual apex on the alveolar palatal process and to maintain lip closure at rest. Once the lingual position at rest is corrected, the therapy focuses on correcting the atypical swallowing pattern with specific exercises and demonstrations. Posture is also addressed in order to avoid head hyperextension, thereby helping develop strong upper body strength.

2. Literature Review

2.1 The Prevalence of Orofacial Myofunctional Disorders in Children

The prevalence of orofacial myofunctional disorders (OMD) in various North American populations has been the subject of numerous studies.[11] The targeted populations to determine the prevalence of OMD have been mostly school children and orthodontic patients. According to a retrospective study examining 229 orthodontic patients, 73.3% had tongue thrust swallow, 71.6% had an abnormal resting posture of the tongue, 68.6% had an open mouth posture, 63.3% reported a history of mouth breathing, and 48% had abnormal tongue placement for lingual-alveolar phonemes. They concluded that the incidence of oral muscle factors, negative oral habits, and articulation and voice disorders is fairly high in orthodontic patients.[11]

The high percentage of tongue thrust swallow from infancy through elementary school has been the subject of multiple studies in the past years. A study produced by Fletcher et al.[12] found the following percentages of tongue thrust swallowers: 52.3% in 216 six year olds, 52.8% in 301 seven year olds, 38.5% in 322 eight year olds, 41.9% in 274 nine year olds, and 34.0% in 141 ten year olds. On the contrary, Ward et al.[13] found higher percentages comparing 120 first-graders (65.8%), 122 second-graders (78.7%) and 116 third-graders (78.6%).[13] These comparative differences may be due to the fact that Fletcher et al. used a more rigid protocol and a stricter set of criteria for classification. In order to be considered as having atypical deglutition, subjects had to meet the following criteria: in addition to tongue thrust beyond the edges of the incisor teeth, two other features needed to be observed, namely, no palpable contraction of the masseter muscles during swallowing and extreme difficulty in swallowing when the lips were kept apart.[12] On the other hand, Ward et al.[13] had a much simpler classification scheme which based the tongue thrust diagnosis on the sole principle of whether or not the tongue separated the incisor teeth during deglutition. Ward's analysis may better reflect the actual number of children with classic tongue thrust during the swallowing process.

Jann et al.[14] evaluated 92 children longitudinally in grades three, four, and five using the same classification as Ward et al.[13] They found that the prevalence of atypical deglutition was 75.0% in third, 73.9% in fourth, and 70.7% in fifth grade.

Rogers[15] studied 290 five to twelve year olds and observed that 52.9% had atypical deglutition. Bell and Hale[16] assessed a group of 353 five to six year olds and concluded that 82% demonstrated a low, forward tongue position, and a slightly depressed mandible during swallowing. Hanson et al.[17] found that in 214 preschool children, 39% had a tongue thrust swallowing pattern for saliva swallowing, 55% for liquid swallowing, and 68% for solid swallowing.

During adolescence, tongue thrust becomes less frequent, as demonstrated by Fletcher et al.,[12] where they observed that less than 30% of a group of students aged sixteen to eighteen years old had atypical deglutition.[18] The development of an adult swallowing pattern naturally occurs between the ages of eight and twelve without treatment, and the adult mastication pattern usually develops when the permanent canines erupt, around the ages of ten or eleven.[4, 19]

A thirteen year longitudinal study produced data contradicting the popularly held belief that tongue thrust, while normal in infancy and the early elementary years, decreased with maturity.[20] Among their subjects, the incidence of tongue thrust did not decline through adolescence, but slightly increased. Although the percentages varied in these studies, most researchers agree that tongue thrust is normal in infancy, decreases in prevalence to about 50% at age five, and to 33% at age eight.[20] The generally accepted prevalence of OMD in the general population is 38%. However, there are few studies done in the general population regarding OMD and the interaction of myofunctional variables.[21] In a study conducted by Wadsworth, Maul and Stevens,[22] which analyzed the prevalence of OMD among public school children receiving speech and language therapy, it was found that speech-language therapists working in the public school setting might expect to find some type of OMD in approximately 50% of the children comprising their caseload.[22] Although this study established a significant statistical relationship between the presence of abnormal resting posture of the tongue and various dental abnormalities, no direct causal relationship between those variables was demonstrated. Therefore, the question remains unresolved as to whether the forces involved in tongue thrust swallow and abnormal resting posture cause dental abnormalities or whether the abnormal tongue function is caused by the presence of dental abnormalities.

2.2 Tongue Tip Position, Tongue Thrust and Atypical Swallowing

The assumed interrelationship between the movements of the tongue, lips, and mandible during swallowing and the form of the surrounding skeletal structures has generated the concepts of normal and abnormal swallowing. The latter is also known as atypical, visceral or infantile swallowing. Normal or somatic swallowing occurs when the facial muscles of expression are at rest, the muscles of mastication bring the teeth and jaws together during the entire act of deglutition, the tongue remains within the confines of the oral cavity and the lingual tip is ideally touching the alveolar process of the anterior palate. Abnormal swallowing would then be associated with lip, jaw and tongue activity. Thus there would be lip contraction, no contact between the posterior teeth and tongue protrusion against or between anterior teeth (Fig. 1).[3]

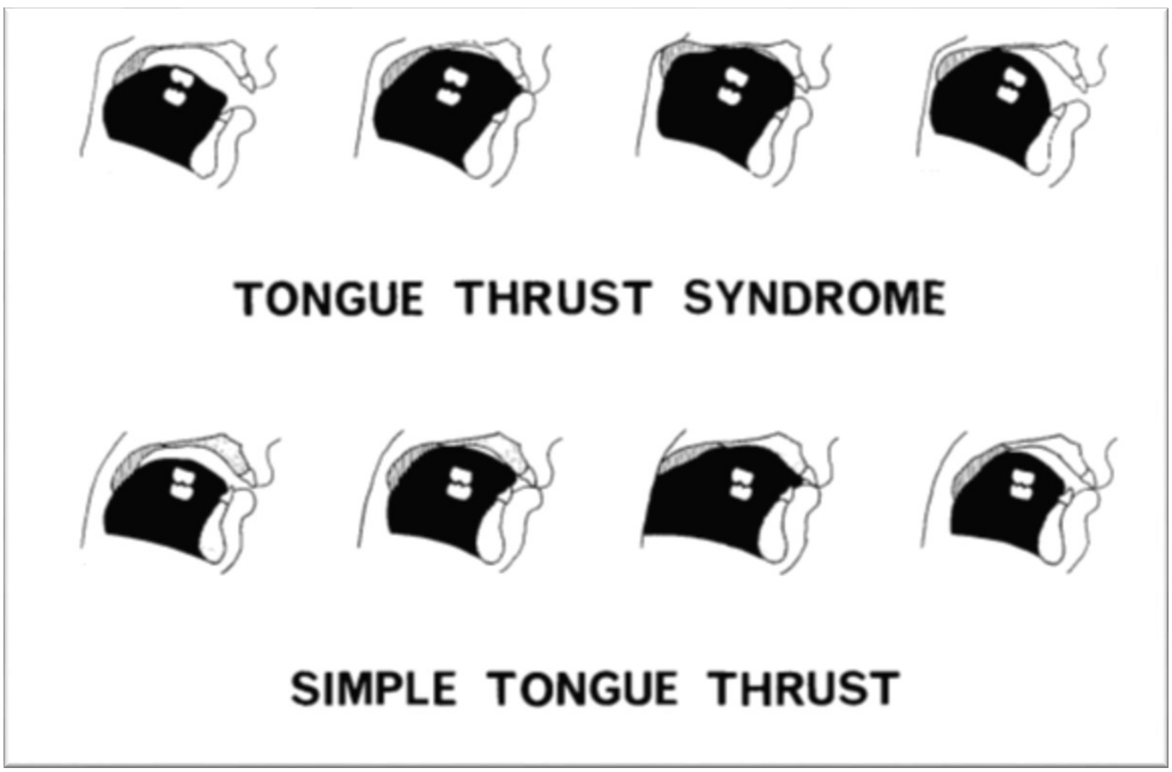

Figure 1: Tracings of cineradiographs of two individuals depicting features of prevailing concepts of abnormal patterns of swallowing. Tongue thrust syndrome: Tongue-tip protrusion, circumoral contraction, no molar contact. Simple tongue thrust: Tongue-tip protrusion. (Figure adapted from Subtelny, JD, 1973)[3]

These definitions presuppose a direct cause-and-effect relationship between the pattern of swallowing and the form of the surrounding hard structures. This view was accepted by Rix[23] when he described atypical swallowing behavior as being directly related to malocclusion. His use of the “teeth-open” and “teeth-shut” behavioral patterns as diagnostic criteria for assessing normality and abnormality, and Straub’s[24] emphasis on the detrimental effects of abnormal swallowing are examples of work inferring the dominant role that abnormal soft-tissue patterns of movement have in the production of malocclusion. In contrast, Scott[25] believes that the form of the dental arches is based on the growth of the alveolar processes and that the pressure of adjacent muscles is probably of minor importance in archform determination. Moyers,[26] as a result of his electromyographic studies, proposes what is probably a more intermediate position by suggesting that tooth position and function of the surrounding muscles are associated, but not in a complete, cause-and-effect relationship. Furthermore, Graber[27] has suggested that one of the important active agents in the etiology of malocclusion is the resting postural pressure of the muscles, especially the tongue, rather than the forces generated during function.

2.2.1 Tongue Position at Rest

According to Nijdam and Teunissen,[28] the maintenance of tongue thrust swallowing during childhood depends on the tongue’s rest position in the mouth. The deglutition is considered to be somatic if the tongue apex or tip lies against the lingual aspect of the upper incisors or against the upper alveolar ridge, and is considered to be visceral, if the tongue lies behind or between the upper and lower anterior teeth. However, this perspective is not universally shared. Many other studies advocate that a low tongue rest position with the tip slightly below the edges of the lower incisors is more frequent than a high tongue position on the maxillary alveolar ridge.[18] According to the literature, no strong correlation could be found between the tongue position at rest and the swallowing pattern.[18]

2.2.2 Tongue Thrust and Atypical Swallowing

There is much debate in the recent and past literature on whether tongue thrust should be considered a habit. The question is relevant and important, because the therapeutic approach can vary if we are dealing with a habit or instead with an innate behavior pattern. Straub[29] evaluated bottle feeding as an etiological factor in tongue thrust, which he described as an abnormal swallowing habit. He assumed cause and effect relationships based upon correlation statistics, an approach which is highly controversial and considered unreliable.[29] Furthermore, a study conducted by Hanson and Cohen,[30] did not support Straub's conclusion on bottle feeding. The swallowing pattern of an infant differs greatly from that of an adult. In the beginning, lip activity is more prominent than tongue movement because of the early maturation of the lips. The tongue movements increase later in infancy but the fronting of the tongue on the lower lip remains.

A tongue thrust swallow can be observed in normally developing children and is not generally considered as problematic. However, if the transition from an infant-like swallow toward a mature adult swallow is delayed by a thumb-sucking habit, this situation will need to be addressed quickly to avoid creating dental and skeletal problems. Normally, the tongue thrust swallow remains as long as the thumb sucking habit persists. In young children, it would be considered a normal transition stage but if the thumb-sucking habit continues into puberty and creates an open bite, the anterior tongue positioning may be considered as a classic habit.[31]

2.2.3 Anatomical and Developmental Causal Factors

Certain anatomical and developmental factors can predispose to tongue thrusting but there is a lack of evidence as to which specific aspects of growth and development of the head and neck relate to tongue thrust.[19]

Firstly, there is a growth differential between the tongue and the jaws. The tongue grows steadily and follows the growth curve established for the neural tissues of the body, to achieve its maximum size near the age of eight years. However, the mandible grows slowly and reaches a plateau between age eight and twelve years, and continues its growth mainly during the pubertal and post-pubertal spurt, and can even continue into the early twenties. Clinically, there is a natural tendency for the tongue to be positioned relatively high and forward in the oral cavity in the early years of growth.[3]

Secondly, the adequacy of the airways influences respiratory demands which strongly affect tongue and jaw position. As a result, airway problems or deficiencies in the nose and pharynx can produce anterior tongue position at rest. Accordingly, prominent tonsils in children can force the tongue forward and the mandible downward to an open mouth position in order to provide clearance for breathing and swallowing. There is often a direct clinical association between enlarged tonsils and mouth breathing.[19] Thus, if the throat is chronically inflamed and sore, it reinforces the tendency to carry the tongue low and forward, in order to reduce contact with the sore area.[19] Excessive adenoid tissue can also cause malposition of the tongue and the mandible. Chronic allergies, nasal infections, and mechanical blockage due to turbinates or a deviated nasal septum can also lead to chronic mouth breathing. In order to open the oral airway, it is necessary to carry the tongue low and forward and maintain the mandible in a lower rest position. In order to resolve the tongue thrust and other associated factors, the respiratory problems need to be corrected.[19]

Thirdly, there is a need to evaluate the adaptation of function as it relates to craniofacial form. In patients who have undergone surgical jaw repositioning, we see the adaptation of the tongue to changed respiratory demands. For example, if the lower jaw is positioned posteriorly, the tongue is also carried posteriorly but does not block the airway as it is repositioned downward and forward as necessary to maintain the airway. Pressures on hard tissues during swallowing are often increased postoperatively but usually stabilize to normal levels during the year following surgery. Relapse of tooth position related to failure of physiologic adaptation occurs in only a small percentage of patients after surgery. Although the changes in oral morphology with conventional orthodontic treatment are slower, similar adaptations of tongue position usually occur.[31]

Fourthly, we know that the developmental sequence of swallowing patterns is related to growth. Normally, between eight and twelve years of age, tongue thrusters develop a normal adult swallowing pattern without therapy. During puberty, there is growth of the mandibular ramus and the oropharyngeal air space increases. The tongue then shifts downward in the oral cavity. The space in the oropharynx is increased due to vertical growth of the cervical vertebrae and the decreased amount of lymphoid tissue in the pharynx, in conjunction with the normal reduction in size of the tonsils and adenoids. In response to these physiological and morphological adaptations, there is closer approximation of the dental arches because the tongue is able to adopt a more posterior rest position.[19]

Finally, one must consider the innervation patterns of the tongue and the oral cavity. In younger children, there is an increased sensory innervation in the front of the mouth and this encourages protrusion of the tongue in order to generate a tactile response. As Mason and Proffit have stated "the primitive neuromotor pattern of the tongue is an anteriorly directed gesture and even a child with a neuromotor deficit can usually protrude his tongue to some degree, whereas he may not be able to elevate the tongue tip with any control or effectiveness".[19] Lingual protrusion is also rudimentary in infants who adopt this lingual position as a means for breast feeding or to adapt for a smaller airway space.

2.3 Atypical Swallowing and Dental Malocclusion

Clinically, atypical deglutition is classified as simple or complex.[32] The simple form is characterized by contraction of the lips, the chin muscle and elevator jaw muscles, due to the presence of an open bite that forces interposition of the tongue between the dental arches, in order to ensure an anterior seal.[33] An increase in overjet is typical in these cases, due to the vestibular inclination of the upper incisors and the lingual inclination of the lower incisors.[34] The complex form is characterized by contraction of the labial, facial, and chin muscles, but not of the elevator muscles.[35] In this case, stabilization of the lower jaw is produced by the mimic muscles, and deglutition takes place with the teeth apart, since the tongue falls completely between the arches and not in a well-defined area on the anterior palate, as occurs in the simple form.[36, 37]

2.3.1 Open Bite

The existing relationship between atypical swallowing and malocclusion, particularly open bite, is currently one of the most debated subjects.[19] The opinions and findings on this topic are fairly conflicting, because some authors state that atypical deglutition causes the open bite, while others believe that atypical swallowing is a consequence of it. In this regard, Proffit[4, 31] has underscored that patients presenting with anterior open bites, as is often the case in children using pacifiers, have great difficulty obtaining mouth closure to prevent spilling of fluids during swallowing. In addition, the position of the tongue between the arches and the contraction of the mimic muscles, represent a physiological adaptation whose purpose is to restore the anterior seal. Almost every patient with an anterior open bite is affected by this type of deglutition, but the contrary is not necessarily true.[4] Indeed, the tongue is often in an anterior position during deglutition, even in children with good occlusion.[4] Therefore, according to Proffit, the anterior position of the tongue can be considered the result of an open bite and not its cause.[4] Indeed, the pressure exerted by the tongue during swallowing, which takes about a second to complete does not last long enough to modify the position of the teeth:.[38] An average individual swallows about 1000 times a day, for a total of about 1000 seconds of pressure, which is certainly not enough to modify the muscular balance.[38] The tongue, in addition to assuming an anterior position during swallowing, also maintains the same posture at rest, causing facial and dentomaxillary changes.[4]

2.3.2 Malocclusion and Abnormal Oral and Body Postures

Abnormal oral function can be an important causal factor of malocclusion and includes articulation, swallowing, and chewing.[39] Therefore, tongue thrust, tongue biting, mouth breathing, low tongue posture, and unilateral chewing may play a potential role.. According to Angle, mouth breathing is associated with Class II division 1 malocclusion with maxillary incisor protrusion.[39] Conversely, Class II division 2 malocclusion with deep bite is related with normal nasal breathing. Therefore, oral function and occlusion are closely interrelated.[39]

Oral function also plays an important role in maintaining an adequate body posture. It is generally accepted that forces from unintentional and habitual behaviors acting constantly on the maxillofacial and alveolar regions can affect the bony structures, leading to jaw deformity and malocclusion. These habitual forces are generally called abnormal posture.[39] Thumb or finger sucking and lip sucking are relatively common, and if these habits persist, severe malocclusions may result (Fig. 2-3). Maxillary protrusion is seen with digit sucking habits, and anterior crossbite is seen with lip sucking. Mouth breathing, protrusion of upper incisors and tongue thrusting may occur as a consequence of these habits.[39]

Figure 2: Malocclusion due to thumb and finger sucking. (Figure adapted from Google images)

Figure 3: Two finger sucking and thumb sucking. (Figure adapted from Yamaguchi et al., 2003) [39]

The skeletal shape of the mandible changes in response to external forces. The effects of lateral force on the dentition and occlusion depend upon the mode, frequency, duration, and degree of force application, as well as upon environmental factors, which can differ from one individual to another. Natural muscle and body postures are important in order to allow normal growth and development in children. Poor postural habits, such as a slouched back with poor shoulder muscle tone, resting the chin on the palm of the hand or sleeping on the stomach with increased lateral force on the tilted mandible, may negatively affect or decrease the growth processes of the upper body and maxillofacial structures, causing possible asymmetry.[39] Forces that maintain a well-balanced occlusion are generated through normal morphology, normal function, and natural posture.[39]

A study by Hale et al.[11] suggested that oral muscle factors, negative oral habits, and articulation and voice disorders are found with a high incidence in orthodontic patients, and mentioned the importance of incorporating an assessment of those factors and behaviors prior to starting orthodontic treatment. Therefore, this type of interdisciplinary approach should increase the chances of providing a successful orthodontic result.[11] The occurrence of muscle risk factors found in Hale's study is summarized in Table 1.

Table 1: Muscle risk factors occurrence in 229 orthodontic patients (6- to 19-year-olds). (Table adapted from Hale et al., 1988)[11]

Risk Factors	% of Occurrence
Tongue-thrust on swallow	73.3
Low, forward tongue rest posture	71.6
Open-mouth posture	68.6
Reported history of mouthbreathing	63.3
Upper lip restriction	54.5
Lip movement during swallow	50.2
Lingua-dental/lingua-alveolar articulation without accoustic difference from normal production	48.0
Frenum restriction	26.2
Mentalis wrinkle	24.8

2.4 Breathing Routes and Dentofacial Abnormalities

2.4.1 Evaluation of Upper Airway Obstruction

Genetics and environment play an important role in growth and development. While one may have favorable genetics, environment may negatively alter growth. Prolonged use of pacifiers, thumb and lip sucking, nibbling on foreign objects such as pencils and pens, lack of mastication due to our modern softer diet, or other negative interferences like allergies, rhinitis, and hypertrophy of tonsils or adenoids can induce abnormal myofunctional habits and may lead to chronic mouth breathing. The nasal airway is excellent for cleaning, heating, and humidifying the air thus protecting the oral cavity and inferior airways. If mouth breathing is used as the general mode of breathing, negative consequences are more likely to occur, such as irritation of the buccal mucosa, dryness, and growth alterations.[40, 41]

The tongue may adopt a different position in an attempt to protect the oropharynx and the tonsils, as well as to facilitate air passage, although other diverse, harmful tongue positions are possible. The tongue with an elevated dorsum and a low tip may inhibit mandibular growth and stimulate anterior maxillary growth, creating a possible Class II malocclusion. It may also result in a high and narrow palatal vault.[40] A tongue lowered to the floor of the mouth may direct the mandible forward, thus stimulating prognathism and a Class III malocclusion. Finally, an open bite can be induced by a tongue positioned between the upper and lower teeth.[41]

Other common characteristics of chronic mouth breathing are gingival hypertrophy, hypotonic lips, atypical swallowing, anterior tongue position, dark circles below the eyes, deep labiomental fold, hyperactive mentalis, facial asymmetries, postural problems (hyperextension of the head and slouched back), noisy breathing, and chewing with an open mouth.[40, 41] Furthermore, mouth breathers can experience chronic earaches, tinnitus, chronic recurrent throat infections, obstructive sleep apnea, fatigue, and an inability to concentrate in school.[40]

2.4.2 Nasal Obstruction and Facial Growth

The relationship between nasal airway obstruction and aberrant facial growth is controversial, although a significant number of scientific studies, each with different emphases, point to a likely association between the two.[42] Linder-Aronson and Backstrom[43] evaluated 115 children with a mean age of ten years and compared the dental occlusion in mouth and nose breathers and investigated the influence of adenoid size and nasal resistance on facial growth.[42, 43] They concluded that nasal resistance was greater in children who had long and narrow jaws, and that the height of the palate was greater in mouth breathers.[43] In a later study, Linder-Aronson[44] observed patients who had undergone adenoidectomy to discern whether removing the interference to the nasal airway resulted in a return to relatively normal facial growth.[44] One year after adenoidectomy, significant changes had occurred in dental arch width, sagittal depth of the nasopharynx, and the angle between the mandibular and nasal planes indicating a reduction in facial height. Assuming that the correction in growth was related to a corrected balance between pressure exerted by the lips and tongue, Linder-Aronson[44] suggested the schema shown below (Fig 4.).

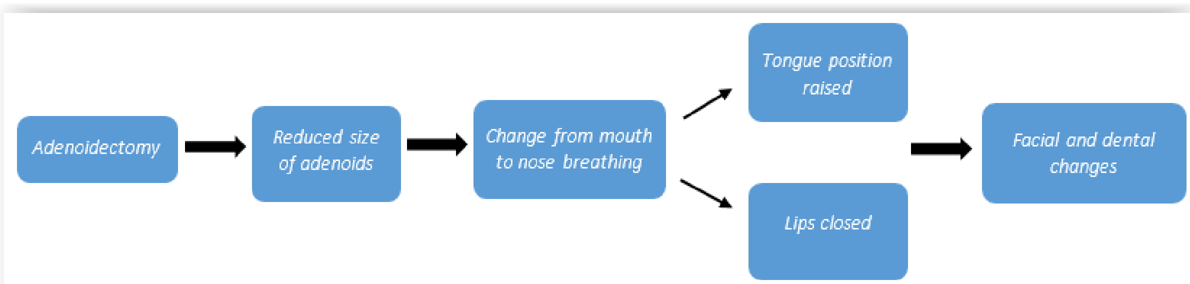

Figure 4 : Schema explaining the correction of facial growth. (Figure adapted from Linder-Aronson et al., 1974)[44]

A number of authors during the 1960's and 1970's, including Ricketts,[45] Subtelny,[46] Marks,[47] and Quinn,[48] concluded that nasal obstruction plays a significant role in creating an altered pattern of facial growth.[49] Experimental nasal obstruction studies on rhesus monkeys, performed by Harvold and coworkers[50], indicated an alteration in facial growth patterns as well as changes in the dentoalveolar morphology. Mawson and al.[51] had previously reported improvement in nasal respiration with a reduction in mouth breathing following surgical excision of tonsillar and adenoidal hyperplasia. Later studies, which evaluated a number of different etiologies leading to mouth breathing, have reported similar results in that allergic rhinitis and asthma have specifically been shown to be associated with divergent facial pattern and posterior crossbites. [52-54] It must be noted, however, that the development of malocclusion is multifactorial, having both genetic and epigenetic influences.[49]

In his article, Jefferson[40] states that upper airway obstruction should be corrected prior to orthodontic treatment, and that the presence of any abnormal myofunctional habits should be treated by a qualified myofunctional therapist after orthodontic treatment. If these problems remain untreated, there is a greater chance of relapse after orthodontic treatment.[40]

2.4.3 Allergies and Rhinitis

Allergies remain a common medical condition experienced by a great number of children and adults. The allergic conditions that have the greatest impact on the development of malocclusion include rhinitis, both allergic and vasomotor, and to a lesser extent asthma of atopic origin.[49] Rhinitis is an inflammatory process that develops in the nasal mucosal membrane, and allergic rhinitis is described as an immunoglobulin E (IgE) mediated response to a specific allergen. Allergic rhinitis is most frequently associated with pollens and is a year-round phenomenon. Vasomotor rhinitis produces the inflammatory response without any specific allergen and is usually associated with changes in humidity and temperature, as well as with other nonspecific airborne pollutants, and can also be seen year-round.[49] Allergic rhinitis is also closely related to asthma which is considered a chronic inflammatory disorder of the airway, and is associated with decreased nasal airflow.[49]

The most important mediator associated with the development of rhinitis is histamine, which induces vasodilatation of the blood vessels within the nasal mucosa. This results in the release of plasma proteins, which creates rhinitis mucosal congestion. The resulting air flow obstruction produces mouth breathing which can potentially initiate the development of malocclusion depending on the age of onset.[49]

Throughout growth, respiratory needs can alter the progression of developmental oral activities. Changes in the normal pattern of oral development can lead to alterations in the mandible and tongue.[49] Hence, in the presence of chronic mouth breathing, the mandible is lowered and the lips are parted. This results in an alteration on the forces affecting the facial skeleton. The tongue assumes a lower position in the oral cavity reducing the support of the palate and maxillary arch; the lower lip moves away from the labial surface of the maxillary incisors; the mandibular teeth may not contact the maxillary teeth during swallowing, permitting unrestrained vertical alveolar development and posterior tooth eruption.[49] These changes can impact the facial development in the following ways (Fig. 5-6):

1. An elongated vertical development of the face (adenoid facies)
2. An increased anterior open bite
3. Hyperplastic and inflamed gingival tissues
4. A high palatal vault
5. Narrow maxilla leading to posterior crossbite
6. A steep mandibular plane angle
7. Class II malocclusion

Figure 5 : Patient displaying a long face with hyperactivity of the mentalis and an intraoral photo of a high and narrow palatal vault associated with nasal airway obstruction. (Figure adapted from Lampasso et al., 2004) [49]

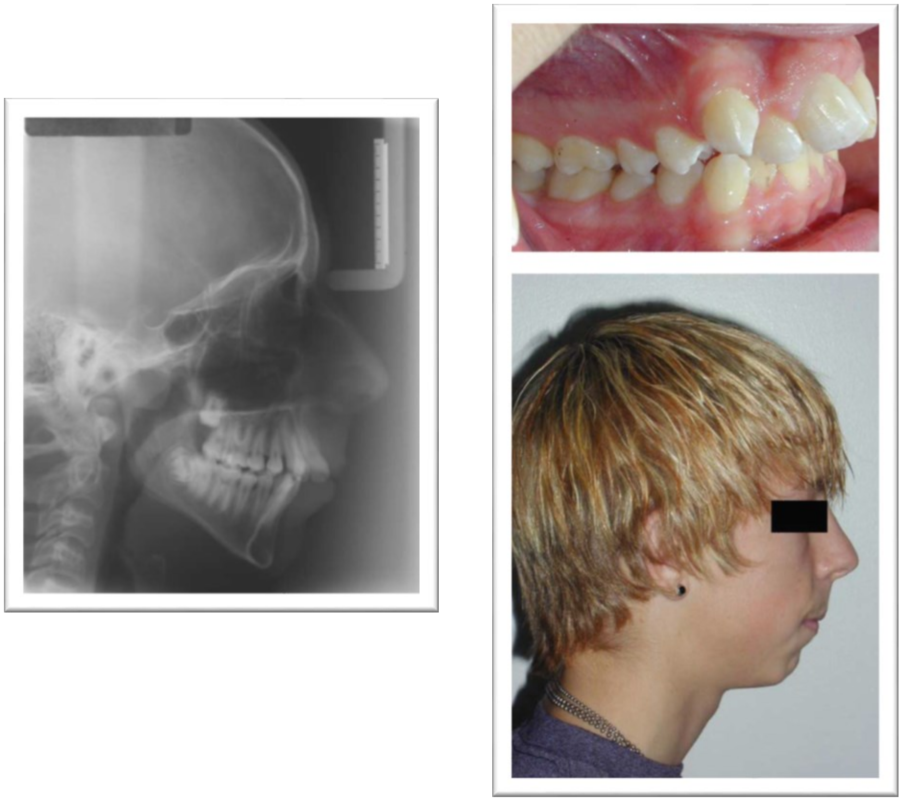

Figure 6 : Lateral cephalogram displaying an increased mandibular plane angle, a right lateral intraoral photograph displaying a class II division 1 malocclusion, and a lateral extraoral photograph of a patient with a retrusive mandible, convex profile, and a hyperactivity of the mentalis. (Figure adapted from Lampasso et al., 2004)[49]

2.4.4 Treatment Modalities

The importance of treating mouth breathing cannot be overemphasized and studies have shown that if corrected early, some facial and dental problems can be reversed.[8, 40, 55]

For allergic patients and mouth breathers, the objective of OMT is to reestablish breathing through the nose and the respiratory function of the diaphragm, while at the same time, raising patient awareness of their orofacial muscle implication. The treatment provides the patient with the necessary conditions to maintain nasal breathing, which is unquestionably one of the basics for controlling respiratory diseases.[56]

The treatment options for a patient presenting with a malocclusion associated with nasal obstruction, enlarged adenoids, and allergies will require an interdisciplinary approach for appropriate care. Ideally, the mode of breathing should be assessed as early as two years of age, so that if any problems are detected, proper medical management can be instituted, or preventive management can be rendered. Referral to an otolaryngologist for surgical intervention may not be sufficient, and so referral to an allergist should be considered.[49] Orthodontists are trained to monitor facial growth and should routinely assess the breathing patterns of patients in order to detect any potential problem that may alter facial growth, which can possibly lead to malocclusion. Even though orthodontic treatment is required to correct any presenting malocclusions, early treatment of allergic disorders may result in fewer orthodontic complications. Treatment of allergies involves focusing on avoidance of the offending agent and on patient education. Pharmacological treatment is also an option in order to diminish the inflammatory reaction.[49]

2.5 Orofacial Myofunctional Therapy

While the orthodontic literature is in agreement that treatment of tongue thrust is not always indicated, it often fails to specify limiting conditions or neglects to discuss possible interventions.[57] Although swallowing correction appears to be a recommended procedure by some investigators, there has been little evidence presented to indicate that an abnormal pattern of swallow can be changed to a more favorable involuntary swallowing pattern.[57] There have been multiple discussions on the necessity to change the pattern of swallowing and even more on how the training should be accomplished. What is lacking, is evidence that the training procedures are effective. Hanson[58] has reported four categories of therapeutic intervention for pathological tongue thrust, namely, surgery, orthodontic appliances with spurs that restrict tongue movement, speech therapy and OMT which consists of a series of tongue and functional oral muscle exercises. With the exception of surgery, all these approaches have, as their treatment goal, a change in behavior.[58]

2.5.1 Patient Evaluation

According to Weiss et al.,[59] it is important to determine if the patient's tongue thrust is benign or detrimental, and if there is an associated malocclusion. In order to properly evaluate the severity of the tongue thrust, the patient should be observed while swallowing different textures and types of food, namely, saliva, water, dry and hard food. These observations are made while depressing the patient's lower lip with thumbs, and palpating masseter activity with the index fingers (Fig. 7). The criteria needed to diagnose a detrimental tongue thrust are: tongue protrusion against the upper incisors or between upper and lower incisors during swallowing; an open-bite directly related to tongue thrust; a severe overjet requiring orthodontic correction; teeth separated while swallowing; and excessive lower lip activity during chewing and swallowing. Not only should the patient's pattern of swallowing be analyzed, but his speech and tongue position at rest should be observed. It is also important to evaluate the patient's parents and siblings as heredity can play a role in the etiology of tongue thrust. The distinction between benign and detrimental tongue thrust is made on the basis of malocclusion. If no malocclusion is present but there are signs of tongue thrust, then it is considered benign. Prior to commencing treatment, information regarding airway infections, sucking habits and neuromuscular problems should be obtained. Furthermore, analyses of past and present orofacial myofunctional abilities as well as patient motivation should be undertaken.[59]

Figure 7 : Position of index fingers and thumbs during assessment of tongue thrust. (Figure adapted from Weiss et al, 1972)[59]

Prior to starting the OMT, Weiss et al.[59] suggest establishing the goals and purposes of the therapy with the patient and the parents in order to obtain maximum cooperation. The patient should be aware that the success of the treatment relies on them and their responsibility to practice the exercises correctly and assiduously. The goal is to establish patient awareness regarding the current swallowing habit as well as the new pattern of swallowing, and to ultimately make the new pattern habitual.[59]

2.5.2 Treatment Phases

The therapy that Weiss et al.[59] propose is divided into four main treatment phases. Phase I incorporates the most important aspect of treatment, which is to assure that the tongue position during swallowing is located on or slightly above the alveolar ridge. Once this position is acquired and compatible with normal orofacial muscle physiology, exercises are given for tongue posture and placement during deglutition and at rest. An individualized approach is given depending on other associated problems such as mouth breathing, articulatory abnormality and tongue fronting anterolaterally, in function or at rest. Firstly, the patient is supervised by the clinician while swallowing liquids. Secondly, exercises to maintain tongue in bilateral contact with the maxillary teeth while swallowing are practiced by suctioning the tongue to the roof of the mouth and sealing either saliva, water, or eventually solids. The patient can also practice this exercise without swallowing by trapping a small quantity of water between the tongue and the palate while parting the lips and approximating upper and lower teeth. These tongue positions can be practiced at rest while the patient is reading, watching television, or listening to music, and the patient is encouraged to practice all the exercises in front of a mirror in order to better visualize and avoid errors in exercise execution.[60] Weiss et al.[59] also suggest other activities to develop a more supero-posterior tongue posture, such as clicking the tongue on the palate, producing back of the mouth sounds, and sucking and holding the tongue to the roof of the mouth.

During phase II, in addition to the tongue exercises, attempts are made to approximate upper and lower posterior teeth while swallowing. This is also known as the bite and swallow procedure and is done in conjunction with facial muscle strengthening exercises, such as biting on a small pliable rubber or soft plastic tubing. Masseter and temporalis activity can be monitored by the clinician or parent by palpation. If the muscles contract, then swallowing is done correctly.[59]

Phase III consists of chewing and swallowing with the lips apart and lower lip immobile. This allows the clinician to properly assess the pattern of deglutition and appears to encourage facial muscle symmetry. This third phase also puts emphasis on the mobility and development of the upper labial muscles. Weiss et al.[59] state that "a more active involvement of the upper lip, both at rest and during function, may expedite orthodontic treatment by providing a counter force for the forward-thrusting tongue".

The final phase of treatment, phase IV, is for the patient to maintain his new pattern of swallowing. For one month, the patient is seen once a week and practices his exercises daily. In order to maintain progress, a "reminder appliance" is worn intra-orally. A groove is carved in the acrylic as a reference for correct tongue-tip placement. The groove is widened and deepened progressively until the tongue-tip contacts the alveolar ridge. The appliance is used until complete correction of tongue thrust is obtained, which takes up to three months. Regular follow-ups are scheduled to determine if relapse has occurred.

One conclusion brought up by Weiss et al.[59] regarding the four-phase program is that it may be used totally or in part, depending on the specific habit of the patient. An individualized approach should be used and "treatment should be consistent, systematic, meaningful, quantifiable, and based on a carefully made differential diagnosis." [59, 60] Pretreatment and posttreatment casts assist in objectifying the results of tongue-thrust and orthodontic treatment (Fig. 8).

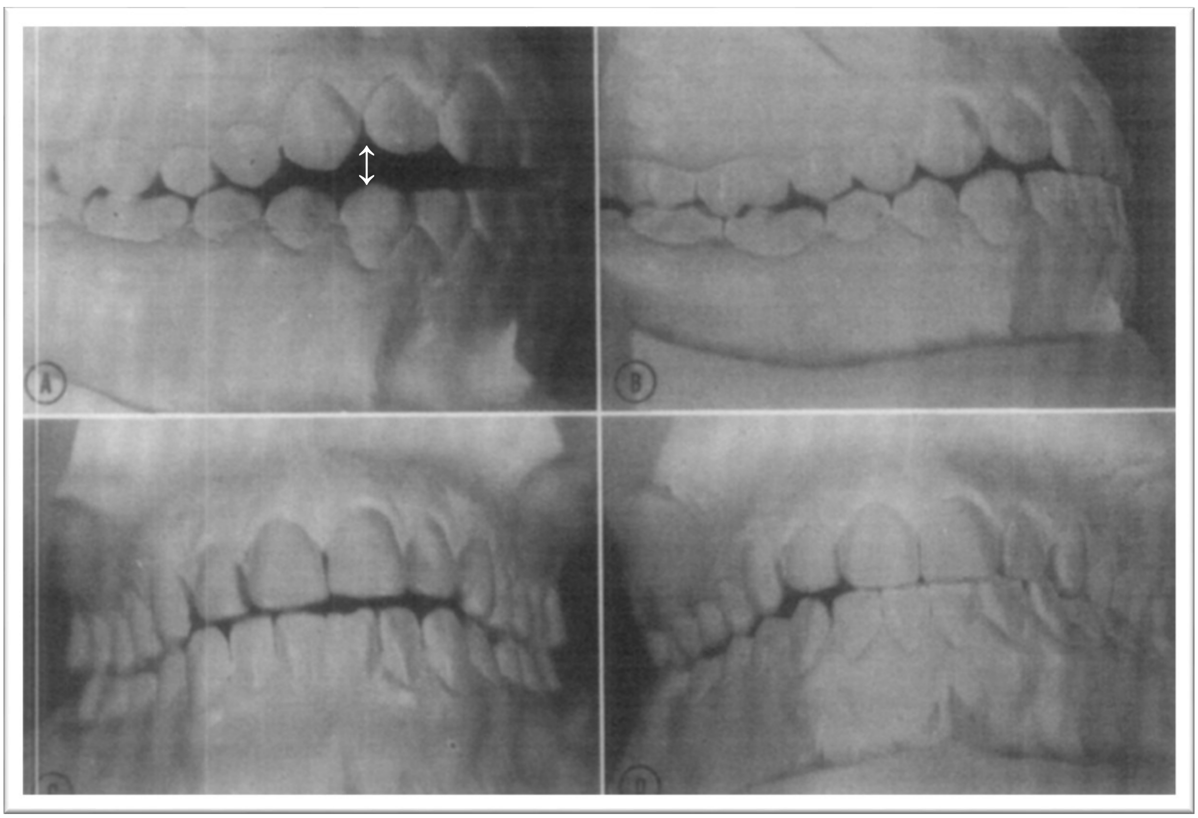

Figure 8 : Anterior tongue-thrust treated by procedures described in text. Posttreatment casts are on the right. (Figure adapted from Weiss et al, 1972)[59]

2.5.3 To Treat or Not to Treat

Young and Vogel[57] studied the use of cueing and positive practice in the treatment of tongue thrust swallowing. They concluded that this technique can increase the frequency of an appropriate tongue position. The positive effects occur rapidly and are maintained long term. However, this technique requires patient motivation and full cooperation.[57]

Subtelny et al.[3] tried to answer a controversial question in their article – whether to treat or not to treat abnormal deglutition. If the surrounding dental and skeletal environment changes, can a better tongue and perioral soft tissue function be achieved (Fig. 9).[3] Subtelny et al.[61] studied five subjects with tongue thrust swallowing after OMT, comprising various exercises, and again after complete orthodontic treatment. The OMT did not appreciably modify the swallowing pattern or the malocclusion, but the correction of the malocclusion was associated with a positive change in the pattern of deglutition. This showed that muscular patterns during swallow changed as the occlusion was changed.[61] Similar findings were found in surgically corrected malocclusions, whether these cases were dental open bites, or cases with severe maxillary or mandibular retrusion or protrusion.[3] Adaptation of the tongue activity was observed on cineradiographs taken before and after orthodontic correction, whether they were surgical or not. Hence, if the environment has been judiciously altered, muscular patterns of function will also be modified accordingly.[3]

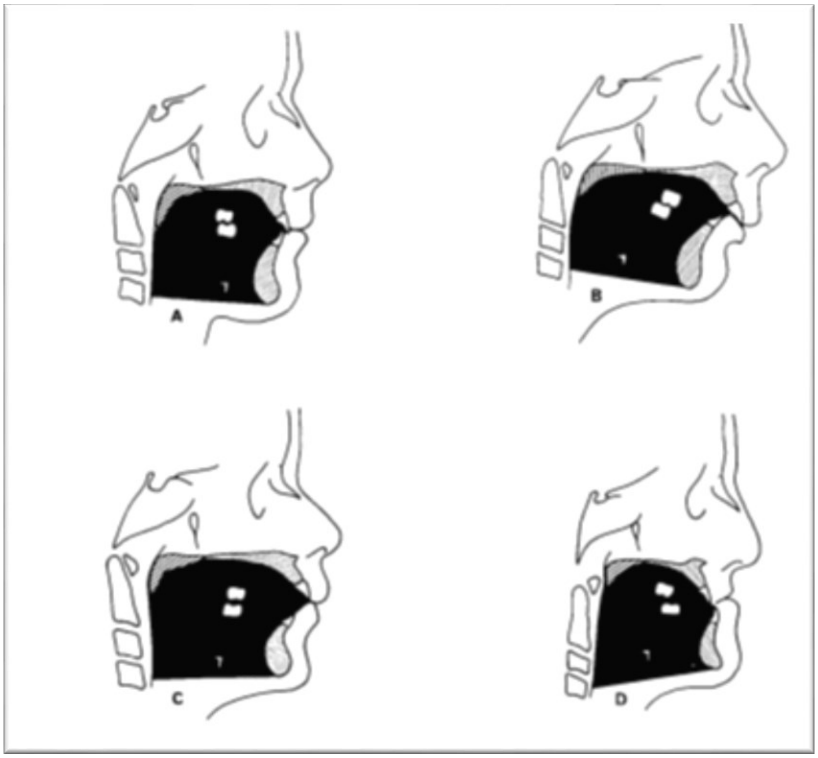

Figure 9: Tracings of cineradiographic frames of four different individuals taken during the act of swallowing. Adaptation of tongue-tip activity to the anterior dental environment is noted: A-normal occlusion, B-maxillary protrusion, C-open bite, and D-maxillary deficiency or retrusion. (Figure adapted from Subtelny JD, 1973)[3]

However, some patients are considered unfavorable candidates for orthodontic treatment because of their abnormal skeletal relationships, neurologic impairment in the control of orofacial muscle function, and/or increased abnormal tongue size.[3] If the tongue is too large to be confined within the oral cavity, the undesirable lingual posture and movement may result in an open bite deformity and abnormal speech. In these circumstances, OMT and orthodontic treatment are unlikely to resolve the lingual posture. A surgical partial resection of the tongue to decrease its size may be a possible option. If the problem is due to a severe skeletal malrelationship, then it cannot be anticipated that OMT will permit spontaneous correction of the open bite. Functional adaptation during swallowing after surgical correction of abnormal skeletal relationship may be anticipated if the surrounding environment has not become too confining for the existing tongue dimensions.[3]

Subtelny's article[3] firmly concludes that although objective data is still needed in some areas, especially concerning the effect of OMT upon occlusion, the majority of the evidence shows that the specific pattern of muscular activity associated with deglutition is dictated principally by form. When form is modified by orthodontic treatment and/or surgical procedures within the anatomical and physiological limitations of the patient and with reference to the anticipated changes incident to growth and development, stable adjustments in occlusion and favorable adaptations in orofacial muscle activity may be anticipated.[3]

2.5.4 Orofacial Myofunctional Treatment for Open Bites

There is general agreement in the orthodontic community that anterior open bites are challenging to treat, and relapse is common after orthodontic treatment.[62] Tongue position or activity has been cited as reasons for difficulty in achieving long-term closure of open bites. Many authors have stated that OMT or other muscle training and habituation exercises may be useful. However, the benefits of OMT remain questionable to many.[62, 63] Multiple reasons have been cited for the lack of enthusiasm for OMT among orthodontic practitioners and they include.[63, 64]

- Limited office space for therapy
- Absence of OMT providers
- Difficulty and amount of time required
- Inadequate training
- Hope that function will follow form
- Belief that there is insufficient scientific evidence to support OMT
- Observations that not all OMT providers have the same expertise

Because of these variables, successful results are unpredictable and there is a need for further research to evaluate OMT's effectiveness in the treatment of open bites. A study conducted by Smithpeter et al.,[63] found that OMT in conjunction with orthodontic treatment was successful in closing and maintaining closure of dental open bites in Angle Class I and Class II malocclusions, and it significantly reduced open bite relapse in patients who had forward tongue posture at rest and a tongue thrust. Therefore, correcting low forward tongue posture and tongue thrust swallowing minimized the risk of orthodontic relapse. It was also demonstrated that the only common denominators in patients who received OMT were palatal tongue rest posture and a correct swallowing pattern.[63]

3. Problematic and Hypothesis

3.1 Problematic

As stated in the literature review, mouth breathing, low and forward tongue posture and atypical swallowing may lead to malocclusion and can be detrimental for the stability of orthodontic corrections. Evaluating if a shorter and less complex at home OMT is as beneficial as a complete and more strenuous therapy consisting of multiple clinical appointments will allow us to demonstrate whether clinical results can be achieved more quickly and with better patient motivation and compliance. With a basic and less time consuming therapy, patients could practice their exercises more efficiently and provide more rapid results. Furthermore, a better understanding of the effects of both types of therapy on the correction of atypical swallowing, tongue posture and lip closure at rest, will permit clinicians to better manage myofunctional corrections on a short and long term basis. Globally, this study will contribute to the general knowledge development on the effects of the diverse orofacial myofunctional therapies.

The primary objective of this study is to compare and evaluate the efficiency of both basic and complete orofacial myofunctional therapies on the correction of atypical swallowing, orofacial muscle tone, and mode of breathing.

The secondary objective of this study is to evaluate the effect of OMT on the short and long term stability of orthodontic corrections.

3.2 Hypothesis

The experimental hypothesis suggested for this study is that the treatment of a low and forward tongue posture and lip closure at rest, with a basic OMT, comprising of individual at home exercises, is sufficient to ensure successful short and long term orofacial myofunctional corrections, in comparison with a complete OMT, which includes exercises for the correction of atypical swallowing.

The null hypothesis is that a complete OMT with correction of an atypical swallowing pattern and multiple clinical appointments, is more efficient for the correction of normal tongue posture and lip closure at rest.

4. Article

Manuscript in preparation to be submitted for publication in the ***American Journal of Orthodontics and Dentofacial Orthopedics***

Efficacy and stability of orofacial myofunctional therapy on restoring mature pattern of swallowing and nasal breathing in children before orthodontic treatment: A randomized trial

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4.1 Abstract

Introduction:

Mouth breathing is often associated with a weak orofacial musculature and low resting tongue position leading to malocclusion and potentially sleep-disordered breathing in children.

Objective:

To evaluate orofacial myofunctional therapy on the reestablishment of a mature pattern of swallowing and nasal breathing by stabilizing a proper position of the tongue and lips at rest.

Methods:

This prospective randomized single-blind controlled study evaluated 37 patients (ages six to fourteen years) divided into two groups who received either a complete orofacial myofunctional therapy (7 sessions) including swallowing pattern and tongue posture, or a simpler regimen of modifying their tongue posture (3 sessions). Both groups were seen at three months and one year following treatment completion.

Results:

Results suggested that treatment outcomes were similar when treating tongue-lip posture at rest along with tongue thrust, and treating without addressing tongue thrust ($p = 0.59$). Both treatments were efficacious as there was a significant difference between the pre- and post-evaluations for both groups ($p < 0.001$), and these differences remained stable at the one year follow-up.

Conclusion:

Treating a tongue thrust habit with specific related exercises may not be a necessary component of an orofacial myofunctional therapy to reestablish tongue posture at rest and nasal breathing in children with no other functional problems.

Keywords:

Orofacial myofunctional therapy, tongue thrust, atypical swallowing, nasal breathing, orthodontics, malocclusion, incorrect tongue position at rest, open-mouth posture

4.2 Introduction

Mouth breathing and low anterior position of the tongue at rest can potentially affect long term stability of orthodontic treatment, as well as worsen the risks of sleep apnea. Mouth breathing is associated with a lack of muscular tension in the lips, causing an open mouth at rest position, and a low anterior position of the tongue, which can result in dental and skeletal malocclusions.[1, 2] In recent studies, tongue thrusting has been shown to be the most common of oral habits and tongue thrusting during swallow is considered an abnormal pattern of deglutition leading to orofacial muscle imbalance and malocclusion.[3] The fact that the tongue pushes against the incisor teeth during deglutition has increasingly caused speech language pathologists and orofacial myologists to intervene and correct atypical swallowing in light of a complete pre-orthodontic orofacial myofunctional therapy (OMT). However, Proffit[2] has suggested that one of the factors responsible for causing a malocclusion is the continuous force applied by the tongue at rest against the teeth, contrary to the intermittent and heavier forces applied by the tongue while swallowing. Since this theory has not been proven, speech language pathologists and orofacial myologists continue to apply long term treatment in order to reprogram tongue position during swallowing, to help maintain an alveolar position of the tongue at rest. According to Proffit[4], the OMT should focus on establishing nasal breathing and normal tongue and labial position at rest, and not during deglutition, as this represents only a fraction of the force applied by the tongue on the teeth throughout the day.

Normal breathing is said to be primarily nasal breathing. In cases where there is a nasal obstruction associated with choanae hypertrophy, deviated septum, seasonal allergies, chronic rhinitis or tonsils and/or adenoids hypertrophy, mouth breathing occurs. Nasal breathing versus mouth breathing require different muscle functions in the nasal and oral cavities. In humans, mouth breathing is associated with modified craniofacial growth and posture, leading to a hyperextension of the head, a retrognathic mandible, an increased lower facial height, a lower position of the hyoid bone, and an anterior-inferior position of the tongue.[5-8] The lower position of the mandible causes an anterior and inferior position of the tongue at rest creating a decrease in orofacial muscle tone and function.[9, 10] This directly affects the oral cavity and can create a narrow maxillary process, an elevated palatal arch, and an increased overbite and overjet.[4]

The importance of establishing nasal breathing, a normal swallowing pattern and an adequate tongue position on the alveolar process at rest in growing children is crucial in order to develop adequate oral habits. The aim of OMT is to normalize muscle patterns that participate in orofacial movements during normal swallowing and nasal breathing. This therapy will optimize lingual and labial muscle tone in order to maintain the lingual apex on the alveolar palatal process and to maintain lip closure at rest. Once the lingual position at rest is corrected, the therapy focuses on correcting the atypical swallowing with specific exercises and demonstrations. Posture is also addressed in order to avoid head hyperextension, and help develop increased upper body strength.

The main objectives of this study were to compare and to evaluate the efficiency of two types of orofacial myofunctional therapies. We hypothesized that, in an orthodontic population, the basic OMT is sufficient to establish a short and long term mature pattern of swallowing and a correct tongue position and lip closure at rest compared to a complete OMT, which includes the correction of atypical swallowing. We theorized that a less time consuming therapy, would result in better patient compliance and motivation. Short and long term stability were also evaluated by three month and one year follow-ups after completion of OMT.

4.3 Materials and Methods

4.3.1 Study Population and Recruitment

This randomized clinical trial was carried out at the orthodontic clinic of the *Université de Montréal*. The patients were screened and recruited during the orthodontic selection clinics for patients applying for orthodontic care.

The inclusion criteria were defined as follows: 1) healthy patients, 2) aged between six and fourteen years old, 3) being followed at the orthodontic clinic at the *Université de Montréal*, 4) atypical swallowing pattern, 5) mouth breathing, 6) low tongue position at rest, 7) ability to speak and understand French. The exclusion criteria included: 1) syndromic patients or patients having a systemic illness, 2) patients with previous orthodontic treatment history, and 3) non-compliant patients (missed appointments, did not perform at-home exercises).

All participants and their parents signed the informed consent form before participating in the study. The *Université de Montréal* Research Ethics Committee approved all study procedures (protocol number: 13-104-CERES-P).

Two variables were evaluated at baseline in order to ensure comparable groups. Nasal obstruction and resistance was objectively evaluated with rhinomanometry, and the malocclusion was also evaluated by the clinician prior to commencing OMT. Orthodontic related data was collected in the patients' files from the orthodontic clinic at the *Université de Montréal*. Cephalometric angles, N-A-Pog, MP-FH, SNB, as well as the amount of crowding/spacing, the overbite/open bite, and the shape of the palatal vault were analyzed clinically in order to evaluate their relationships with the swallowing pattern, with tongue and lip posture at rest, and with labial muscle tone.

4.3.2 Orofacial Myofunctional Therapy and Evaluation Protocol

Patients were randomly assigned to two different groups. Group A patients received a complete OMT in order to correct atypical swallowing, tongue position and lip closure at rest. Group B patients were only given verbal instructions and at-home exercises in order to correct tongue position and lip closure at rest, without addressing the atypical swallowing pattern.

Patients in group A were seen for a total of 7 visits and patients in group B were seen for a total of 3 visits during a three month period, and each visit was individually held with each patient. Group A patients were seen once a week for the first month, once every two weeks for the second month, and only once during the last month. At T0 (T = time), the pre-evaluation, rhinomanometry, and exercise overview and explanations were given to each patient in groups A and B. All patients received a log journal which they were required to complete in order to evaluate their at-home exercise compliance. Patients in group A were also given their swallowing exercises. During each visit, all exercises were practiced and reviewed with the patient. For patients in group A, the swallowing exercises were executed with different food consistencies in order to increase the exercise difficulty and to progress with the correction of the swallowing habit (Fig. 1). The patients were asked to swallow a soft food (apple sauce), a solid food (dry arrowroot cookie), and a liquid (water), three to four times during the session. All patients (groups A and B) had at-home exercises to complete on a daily basis and had to note their progress and compliance in the log journal given to them at T0. At the end of the three month period (T1), a post-evaluation of all patients was completed by means of clinical evaluation to determine if positive short-term corrections of the swallowing pattern, breathing mode, and elevated tongue position and lip closure at rest were noted. Patients were seen again at their one year follow-up (T2), to evaluate the long-term stability of the corrections.

The evaluation protocol consisted of a clinical evaluation of the swallowing pattern, the tongue position, and the lip closure at rest. The breathing mode, either nasal or mouth breathing, was evaluated by the clinician at the beginning and at the end of each visit and also reported by the patients' parents. Patients were strongly encouraged to maintain labial seal and breathe through the nose.

At T1 and T2, the nasal permeability was evaluated with a mirror as the patients breathed through their noses with their mouths closed. The swallowing pattern was evaluated clinically as the patients from both groups were asked to swallow a solid food in the form of a dry arrowroot cookie. The patients' lips were slightly separated with finger pressure to visualize tongue position. Other muscle tone exercises were done with the help of tongue depressors, straws, small oral swab sponges, and orthodontic intermaxillary rubber bands were used to evaluate tongue coordination, posture, and muscle tone. The bands were placed on the tip of the tongue (apex), and brought up to the level of the incisive papilla and down to the floor of the mouth multiple times.

Myofunctional exercises included resonance and articulation exercises, lingual and labial muscle tone and posture, swallowing, as well as body posture exercises. Tongue position during sound production was recorded as the patient spoke various tongue tied sentences. Using a similar protocol established by Stahl[65], the tongue posture at rest was clinically visualized and evaluated by asking the child where their tongue was located, and thereafter classified as being in one of the three categories. Two positions were considered as physiological, either on the anterior palate, or as inter-dental with the tip of the tongue pressing between upper and lower anterior teeth; one was considered abnormal with the tip of the tongue pressing against lower incisors. Study data were collected and managed using REDCap electronic data capture tools hosted at *Université de Montréal*. [66]

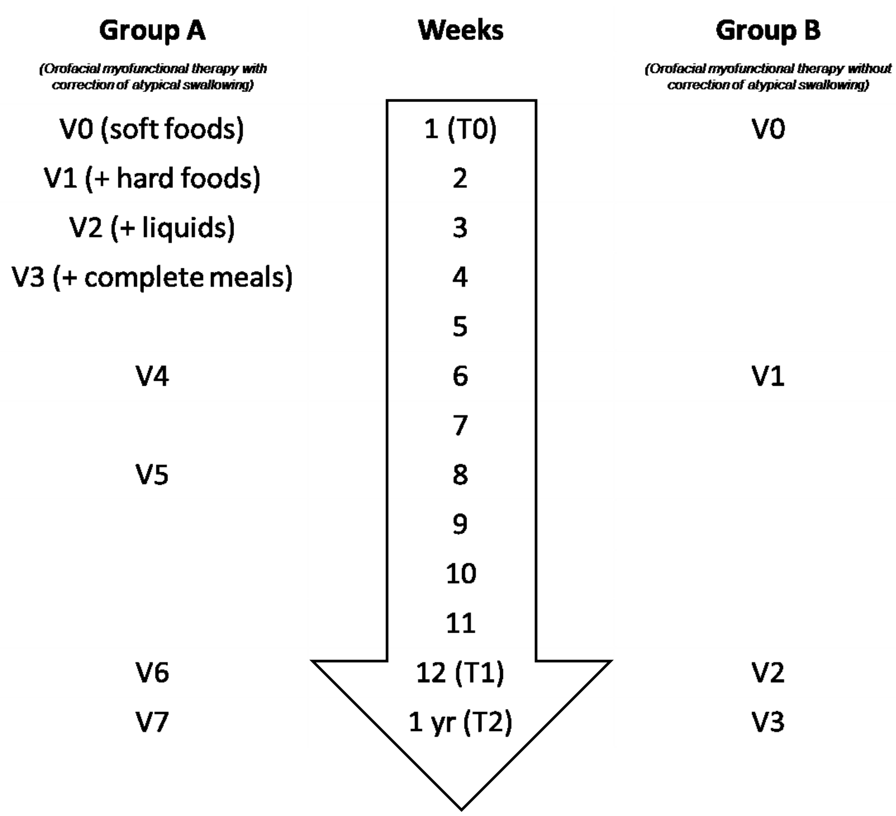

Figure 1: Description of patient visits for groups A and B and week intervals. Description of types of food used for swallowing exercises for group A patients.
T (time); V (visit) Soft food (apple sauce); Hard food (arrowroot cookie); Liquid (water)

4.3.3 Statistical Analysis

Descriptive statistics are presented for clinical characteristics and are interpreted as percentages and proportions. Cephalometric and orthodontic measurements (overbite and open bite) were used to evaluate craniofacial, skeletal, and soft tissue characteristics in order to verify if the randomization was done accurately, so that the two groups were equivalent at T0. This was done using the chi-squared and the Fisher's exact tests. Rhinomanometry was cross-evaluated with the breathing mode variable and was measured with the Mann-Whitney *U* test.

Generalized estimating equations method (GEE) was applied. Interactions between groups and visits were tested. However, when the number of patients in a cell was too low and caused estimation problems, the Cochran-Mantel-Haenszel test and the Fisher's exact test were used (apex muscle tone, tongue mobility, swallowing, tongue posture at rest and thumb sucking). The Bonferroni correction was used for pairwise comparisons (T0, T1, and T2). The Mann-Whitney *U* test was used to evaluate patient compliance and compare the two study groups. Inter-rater reliability (Natasha Cassir and Alla Sorokin) of patient evaluation variables was measured using Cohen's Kappa coefficient for the primary variables at T1 on a sub-sample of 14 patients. A mean kappa value of 0.327 was obtained (minimum: -0.256, maximum: 1.000), indicating a fair and acceptable inter-rater reliability. A poor reliability of -0.256 was obtained for the evaluation of tongue position at rest.

The frenum was evaluated in order to determine if an abnormal frenum (short and attached anteriorly), acted as a physical barrier, and had a negative effect on treatment success. It was cross-evaluated with tongue position at rest, tongue mobility, tongue muscle tone, and swallowing pattern, using the Cochran-Mantel-Haenszel test.

Data analysis was performed using SAS/STAT® software (SAS Institute, Cary, NC, USA). Statistical significance was established as $p \leq 0.05$.

4.4 Results

Of the 340 patients screened for orthodontic treatment at the *Université de Montréal*, 42 fulfilled the eligibility criteria and were randomized to group A (n = 21) or group B (n = 21). Among those patients, five were withdrawn due to non-compliance and lost to follow-up. Therefore, a total of 37 patients with a higher proportion of girls (19 girls; 18 boys) completed the study (Fig. 2), 20 in Group A and 17 in Group B. The age distribution (mean $\pm$ SD) was 12.49 $\pm$ 1.24 years with a range (minimum-maximum) of 11-14 years.

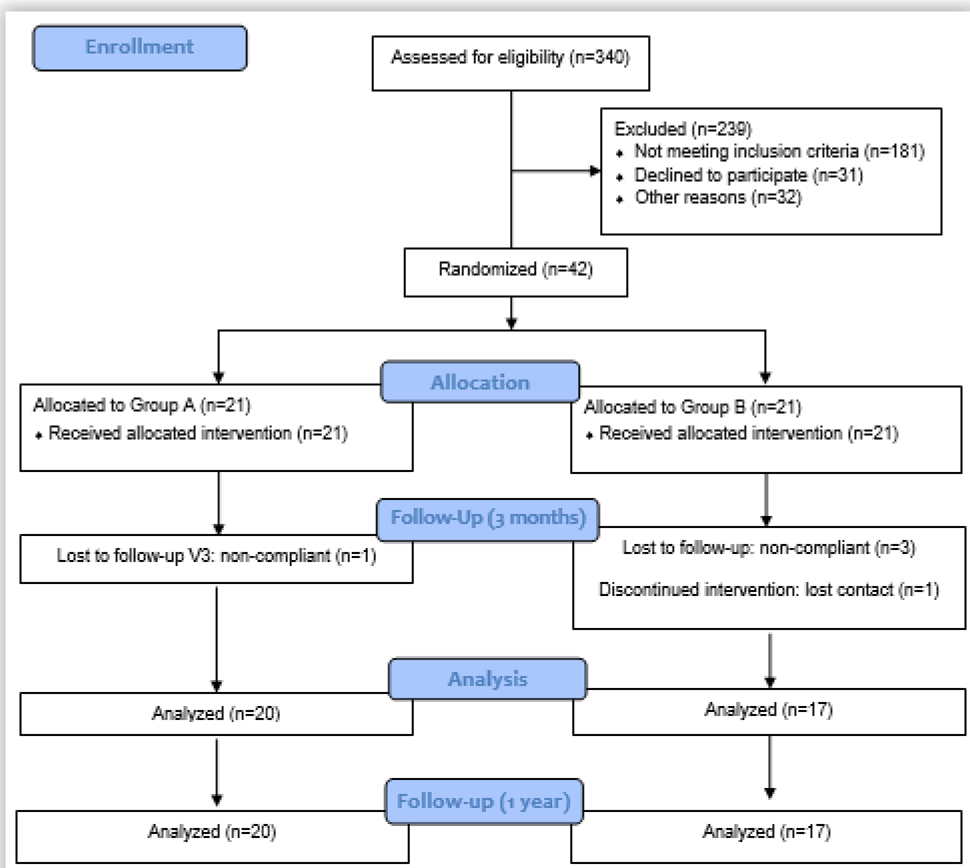

Figure 2: Flow diagram of patient selection and sample size.[67]

Table 1: Descriptive data of evaluation protocol.

	Total (n = 37)			Group A (*n* = 20)			Group B (*n* = 17)		
Age (mean, SEM)	**12.49 (0.20)**			**12.60 (0.29)**			**12.35 (0.28)**		
Gender (girls : boys)	**19 : 18**			**10 : 10**			**9 : 8**		
	T0	**T1**	**T2**	**T0**	**T1**	**T2**	**T0**	**T1**	**T2**
Feeding, *n*(%)									
Eating with *open mouth*	7(18.9)	1(2.7)	--	4(20.0)	1(5.0)	--	3(17.6)	--	--
Slurping	4(10.8)	--	--	3(15.0)	--	--	1(5.9)	--	--
No related problems	23(62.2)	32(86.5)	34(91.9)	13(65.0)	18(90.0)	19(95.0)	10(58.8)	14(82.4)	15(88.2)
Ears-Nose-Throat (ENT), *n*(%)									
Respiratory problems	2(5.4)	2(5.4)	2(5.4)	1(5.0)	1(5.0)	1(5.0)	1(5.9)	1(5.9)	1(5.9)
Allergies	3(8.1)	2(5.4)	2(5.4)	1(5.0)	1(5.0)	1(5.0)	2(11.8)	1(5.9)	1(5.9)
Adenoidectomy-tonsillectomy	3(8.1)	3(8.1)	3(8.1)	--	--	--	3(17.6)	3(17.6)	3(17.6)
Chronic congestion	1(2.7)	1(2.7)	--	--	--	--	1(5.9)	1(5.9)	--
Tonsillitis	4(10.8)	4(10.8)	4(10.8)	3(15.0)	3(15.0)	3(15.0)	1(5.9)	1(5.9)	1(5.9)
Face, *n*(%)									
Brachyfacial	14(37.8)	14(37.8)	14(37.8)	5(25.0)	5(25.0)	5(25.0)	9(52.9)	9(52.9)	9(52.9)
Dolichofacial	1(2.7)	1(2.7)	1(2.7)	1(5.0)	1(5.0)	1(5.0)	--	--	--
Hard palate, *n*(%)									
Narrow	9(24.3)	9(24.3)	9(24.3)	6(30.0)	6(30.0)	6(30.0)	3(17.6)	3(17.6)	3(17.6)
Nasal septum, *n*(%)									
Deviated	8(21.6)	8(21.6)	9(24.3)	3(15.0)	5(25.0)	6(30.0)	5(29.4)	3(17.6)	3(17.6)
Nostrils, *n*(%)									
Deviated	3(8.1)	3(8.1)	3(8.1)	2(10.0)	2(10.0)	2(10.0)	1(5.9)	1(5.9)	1(5.9)
Nasal permeability, *n*(%)									
Low	1(2.8)	--		--	--	--	1(6.2)	--	--
Asymmetry Right/Left	16(44.4)	14(38.8)		8(40.0)	9(45.0)	10(50.0)	8(47.0)	5(29.4)	8(47.0
Tongue, *n*(%)									
Fasciculation	2(5.6)	--	--	2(10.0)	--	--	--	--	--

Table 2: Orofacial myofunctional exercise results.

	Total (n = 37)			Group A (*n* = 20)			Group B (*n* = 17)			*p*-value (GEE analysis)		
	T0	T1	T2	T0	T1	T2	T0	T1	T2	Group	Visit	Group*Visit
Breathing, *n*(%)												
Mouth breathing	20(54.1)	6(16.2)	2(5.4)	13(65.0)	3(15.0)	2(10.0)	7(41.2)	3(17.6)	0	0.280	**< 0.001**	--
Nasal breathing	17(45.9)	31(83.8)	35(94.6)	7(35.0)	17(85.0)	18(90.0)	10(58.8)	14(82.4)	17(100.0)			
Lingual frenum, *n*(%)												
Normal	29(78.4)	29(78.4)	29(78.4)	16(80.0)	16(80.0)	16(80.0)	13(76.5)	13(76.5)	13(76.5)	0.796	1	1
Attached anteriorly/short	8(21.6)	8(21.6)	8(21.6)	4(20.0)	4(20.0)	4(20.0)	4(23.5)	4(23.5)	4(23.5)			
Cheeks and lips muscle tone, *n*(%)												
Normal/strong	6(16.2)	14(37.8)	12(32.4)	3(15.0)	6(30.0)	3(15.0)	3(17.6)	8(47.1)	9(52.9)	0.089	0.102	0.235
Abnormal/weak	31(83.8)	23(62.2)	25(67.6)	17(85.0)	14(70.0)	17(85.0)	14(82.4)	9(52.9)	8(47.1)			
Tongue muscle tone, *n*(%)												
Normal/strong	17(45.9)	26(70.3)	25(67.6)	6(30.0)	16(80.0)	12(60.0)	11(64.7)	10(58.8)	13(76.5)	0.495	**0.035**	**0.022**
Abnormal/weak	20(54.1)	11(29.7)	12(32.4)	14(70.0)	4(20.0)	8(40.0)	6(35.3)	7(41.2)	4(23.5)			
Apex muscle tone, *n*(%)												
Normal/strong	12(32.4)	17(45.9)	15(40.5)	4(20.0)	11(55.0)	9(45.0)	8(47.1)	6(35.3)	6(35.3)	0.971	0.311	**0.021**
Abnormal/weak	25(67.6)	20(54.1)	22(59.5)	16(80.0)	9(45.0)	11(55.0)	9(52.9)	11(64.7)	11(64.7)			
Tongue posture at rest, *n*(%)												
Normal/elevated/anterior palate	21(56.8)	30(81.1)	34(91.9)	10(50.0)	15(75.0)	18(90.0)	11(64.7)	15(88.2)	16(94.1)	0.357	**0.002**	0.909
Abnormal/floor of mouth/interdental	16(43.2)	7(18.9)	3(8.1)	10(50.0)	5(25.0)	2(10.0)	6(35.3)	2(11.8)	1(5.9)			
Tongue mobility, *n*(%) *												
Normal/full range	27(73.0)	33(89.2)	37(100.0)	14(70.0)	18(90.0)	20(100.0)	13(76.5)	15(88.2)	17(100.0)	≥0.743	0.018A 0.135B	--
Abnormal/reduced	10(27.0)	4(10.8)	0	6(30.0)	2(10.0)	0	4(23.5)	2(11.8)	0			
Swallowing, *n*(%) *												
Normal	0	22(59.5)	22(59.5)	0	12(60.0)	13(65.0)	0	10(58.8)	9(52.9)	≥0.516	**< 0.001**	--
Atypical/infantile	37(100)	15(40.5)	15(40.5)	20(100)	8(40)	7(35.0)	17(100.0	7(41.2)	8(47.1)			
Posture, *n*(%)												
Normal/straight	14(37.8)	16(43.2)	8(21.6)	6(30.0)	9(45.0)	4(20.0)	8(47.1)	7(41.2)	4(76.5)	0.576	0.102	0.591
Abnormal/slouched/hyperextension	23(62.2)	21(56.8)	29(78.4)	14(70.0)	11(55.0)	16(80.0)	9(52.9)	10(58.8)	13(76.5)			

* Cochran-Mantel-Haenszel test and the Fisher's exact test

As noted in Table 2, there was a significant increase in nasal breathing between T0 and T2 for both groups ($p < 0.001$). At T2, 94.6% of patients had a nasal breathing pattern (Fig. 3A). The tongue posture at rest improved significantly between T0 and T2 ($p < 0.001$), where 91.9% of total patients adopted a normal, elevated, and anterior tongue posture at T2 (Fig. 3B). Furthermore, there was a statistical decrease in the atypical swallowing pattern between T0 and T2 ($p < 0.001$), where 59.5% of total patients developed a physiologic swallowing pattern at T1 ($p < 0.005$), which remained stable at T2 ($p = 1.000$) (Fig. 3C). There was a significant increase in the tongue muscle tone between T0 and T2 ($p = 0.035$) but with a significant difference in the interaction between groups and visits ($p = 0.022$) (Fig. 3D). At T0, 67.6% of all patients had an abnormal apex muscle tone, which decreased to 54.1% at T1, but increased slightly at T2 with 59.5%. However, no differences were found in cheek and lip muscle tone and bodily posture either between groups or between T0 and T2.

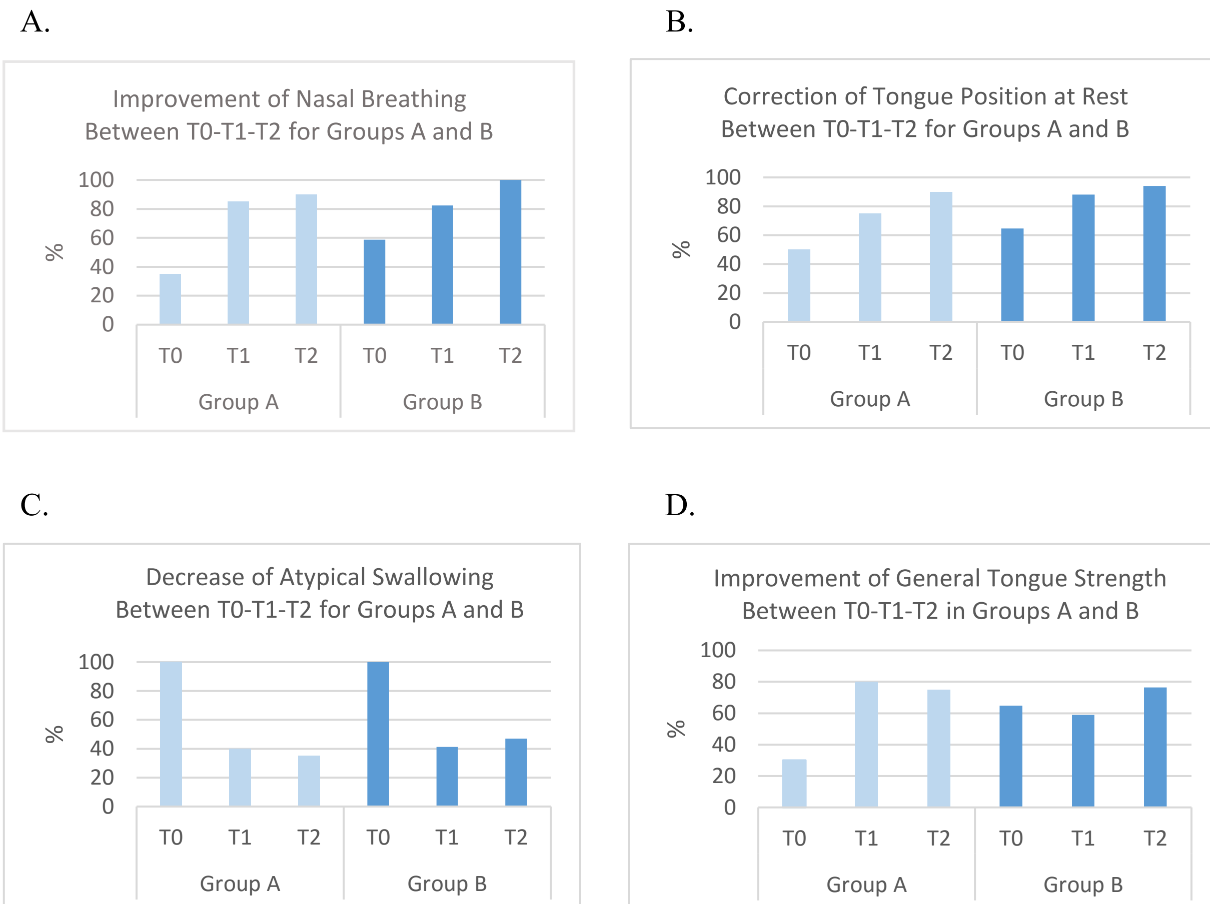

Figure 3: Comparison between groups A and B at T0, T1, and T2. A-Improvement of nasal breathing, B-Correction of tongue position at rest, C-Decrease of atypical swallowing, and D-Improvement of general tongue strength.

In order to evaluate patient compliance, patients from both groups had to complete daily at-home orofacial myofunctional exercises and keep a log journal for the duration of the treatment (three months). Average compliance was 5.2 days/week for group A and 4.3 days/week for group B. This difference, although not significant, could be explained by the reduced number of follow-ups in group B (3 follow-up visits in group B compared to 7 follow-up visits in group A). Furthermore, there was no significant difference in compliance between patients with global myofunctional improvement versus patients with no improvement.

There were no statistical differences between the orthodontic and cephalometric variables in the two groups which indicates that the initial randomization was done accurately. Similarly, rhinomanometry measurements indicated that there were no significant differences between patients with a nasal breathing pattern and patients with a mouth or mixed (mouth and nasal) breathing pattern ($p > 0.25$). This may be due to environmental and behavioral influences as opposed to physical or mechanical obstructions. Therefore, both groups were similar and well controlled at T0 in regards to their breathing patterns and nasal respiratory resistance (Table 3).

Table 3: Rhinomanometry measurements

VARIABLES	GROUP A (N = 20)	GROUP B (N = 17)	P VALUE
Effective resistance, inspiration (right)	1.18 (0.46)	1.18 (0.60)	0.49
Effective resistance, inspiration (left)	1.26 (0.36)	1.36 (0.54)	0.26
Effective resistance, expiration (right)	1.04 (0.50)	1.09 (0.62)	0.64
Effective resistance, expiration (left)	1.09 (0.41)	1.17 (0.62)	0.25
Effective resistance, total breath (right)	1.09 (-0.1 – 1.9)	1.20 (-0.1 – 2.2)	0.61
Effective resistance, total breath (left)	1.21 (0.36)	1.30 (0.55)	0.32
Vertex resistance, inspiration	1.11 (0.3 – 1.89)	1.24 (0.1 – 2.21)	0.48
Vertex resistance, expiration	1.07 (0.52)	1.09 (0.61)	0.62

Parametric variables → mean (SD)

Non-parametric variables → median (min – max)

Statistical results suggest a higher proportion of tongue elevation ($p = 0.04$) with an abnormal frenum between T0 and T2 which translates into an improvement in tongue mobility in patients with an abnormally positioned frenum. Furthermore, there was an improvement in the swallowing pattern in patients with an abnormal frenum ($p = 0.04$) but the improvement was significantly greater in patients with a normal frenum ($p < 0.0001$).

4.5 Discussion

This pilot study is unique as it is the first to compare the use of two different orofacial myofunctional therapies before commencing orthodontic treatment. It also aims to stimulate further research in the field of OMT. In this study, the orthodontic patients were randomized into two groups and underwent two different protocols of myofunctional training. In typical clinical settings, OMT exercise regimens and duration of therapy are often tailored to the needs and responses of each individual patient. More research concerning different treatment protocols would be of value because there is no consensus in the literature regarding the ideal protocol to treat orofacial dysfunction. Furthermore, whether OMT should start prior to, during, or after orthodontic treatment is controversial. Speech language pathologists, orofacial myologists, and orthodontists seem to have different opinions on this subject. There is a definite lack of evidence defining the ideal age to start OMT and more research is needed.

Orofacial myofunctional therapy, also known as neuro-muscular re-education of the oral facial muscles, is a modality that promotes the stability of the stomatognathic system. The vast majority of patients from both groups had an increase in tongue muscle tone and mobility and an improved tongue posture at rest, but there was also a significant difference between groups regarding the increase in the tongue and apex muscle tone; the group who received a complete OMT with swallowing exercises surpassed the group receiving the basic OMT without swallowing exercises. This could be explained by the increased number of tongue exercises for correction of the swallowing pattern for the complete OMT group. While a primary function of the tongue is to protect the airway, improper oral resting posture of the tongue will have a negative influence on the development of the oral cavity.[60] Furthermore, today's modern diet of processed and soft foods may lead to low muscle tone and mobility by diminishing the frequency and intensity of mastication,[4] and a smaller oral volume may not support the proper development of optimal dental arches or upper airways. A significant proportion of patients from both groups established correct and physiologic nasal breathing following OMT and maintained stable results after one year. Increased labial muscle tone, proper positioning of the tongue on the anterior palate, and labial seal at rest contributed to the development of nasal breathing. Although the OMT protocols in our study included some articulation and resonance screening, as well as strengthening of the anterior and mid part of the tongue musculature, no significant improvement in sonority was found as most patients (95%) had a normal articulation evaluation at baseline.

As part of OMT the tongue can be re-trained, meaning that optimal mobility of the tongue can be created. At T1, both OMT protocols did increase the proportion of subjects performing a correct swallowing pattern. This increase might have been caused by the fact that some of the OMT children effectively achieved the habit correction, but it might also have been biased by the fact that some of these children just performed a correct swallow during the clinical trials or by the fact that the evaluation was not performed blindly. However, the transition from conscious to unconscious habit correction cannot be assessed during a clinical examination. An intra-oral device sensitive for detecting tongue position and movements during daily activities could elucidate this problem. The proportion of patients who maintained an atypical swallowing pattern could be explained by their need for more training or more time to achieve a correct conscious swallow, or that in some children, OMT could not correct the aberrant swallowing pattern. The myofunctional protocol has to be adapted to the needs of every individual. As an active exercise protocol, the success of OMT is also crucially dependent on motivation and compliance of both child and parents. Although the compliance rate was above average in both groups, this could have been biased by a falsified log journal. Patients were strongly encouraged to fill their log journals daily, but some may have quickly and blindly filled their journals before their appointment in order to receive positive feedback from the clinician. The use of an intra-oral compliance device with a micro-recorder could be an effective solution in order to adequately and objectively evaluate patient compliance. However, further validation and research on these devices are needed in order to verify their degree of accuracy.

Many studies state that the instruction to position the tongue on the anterior palate during deglutition or to perform tongue reposition manoeuvres appears to be a valid aid in training tongue-palate contact.[68, 69] However, various types of appliance therapy for impaired tongue function and posture have been reported in the literature and include the use of tongue cribs, spurs and functional appliances.[38, 59, 70] More research is needed to explore the benefits of these kinds of treatment modalities.[71] Although these appliances are used regularly in orthodontic and pediatric settings, little is known about the adaptation of the soft tissues after the discontinuation of the treatment, which can influence the stability of the obtained result. When a habit appliance is removed and the cause of the tongue pattern is not addressed, the forward tongue posture and functions are expected to return.[19, 72, 73]

Restriction of tongue movements and posture can be seen in patients with a short lingual frenum attached anteriorly. This physical barrier of the muscle attachment can actively restrain tongue movement, hence preventing the patients from positioning their tongue in an adequate position on the anterior palate. The need for a frenectomy, before commencing OMT or orthodontic treatment in general, is highly controversial. Moeller et al.[60] suggest that lingual frenectomies are essential for a full range of mobility if the tongue is restricted, and it is ideal to release the restricted frenum as early as possible, meaning at birth, because the tongue will achieve optimal function through the activity of breastfeeding. A tight lingual frenum has a critical impact on normal function and the development of the orofacial complex. The restricted frenum may not only affect the oral resting posture of the tongue, but may also disrupt both the intrinsic and extrinsic tongue muscles of their normal functions. If the frenum is restricted, the genioglossus muscle may not function normally and may impact the airway patency.[60] Suter et al.,[74] in a systematic review on ankyloglossia, stated that no conclusive suggestions regarding the timing of frenectomy could be made because of the lack of agreement between studies. Although only a few patients included in the study had a short anteriorly attached frenum, this variable should have been analysed in association with low tongue posture at rest prior to OMT, to evaluate if the orofacial myofunctional disorder was due to a short lingual frenum and anterior attachment or simply resulted from a bad habit.

Observation of the tongue movements during swallowing with lips apart is a simple and rapid method for diagnosing the swallowing pattern, but is entirely subjective. However, since the lips are involved in the act of swallowing, some authors argue that a forced opening of the lips might disturb an individual swallowing pattern.[1, 75] Efforts have been made in the literature to evaluate the swallowing type in a more objective way, by using techniques like radiocinematography, electropalatography, and electromagnetic articulography.[58, 76 35, 77] The use of ultrasonography to assess swallowing type has also been described.[78] Yet, the reliability of this method has not been extensively verified. However, due to many reasons, especially the risk associated with irradiation, these techniques did not prove to be appropriate for observation in growing children.[33, 79] The clinical diagnosis is subjective in nature and inter- and intra-individual variability of tongue position and mobility must be taken into account since they might influence the swallowing type assessment.

In the present study, several factors could have altered the results, one of which was the restricted number of patients. The strict inclusion and exclusion criteria, the lack of time available to see patients, and the inevitable loss of patients throughout the study due to lack of interest or motivation resulted in the limited sample size of active patients. This study was fully dependent on the cooperation of each patient as most of the work was done with the at-home exercises. Although patient compliance scores were relatively high, there was no statistical difference between patient compliance and treatment success. In addition, clinical data acquisition for most values, like the evaluation of the swallowing pattern and tongue posture is subjective and could be misrepresented in our results. Furthermore, the reliability score was rated as fair and acceptable. The raters should have been retrained and recalibrated in order to obtain a higher and more acceptable score. This type of evaluation can also reflect the subjectivity and the variability of the approaches used by the different therapists in this domain, and would require the need for further standardization.

Our study confirmed that in the orthodontic setting, a much simpler OMT was as successful as a complete and more time consuming therapy in establishing a physiologic pattern of swallowing. Further research is recommended by means of larger, blindly performed and long-term follow-up studies, in order to confirm our results and to clarify the success of OMT as an adjunct both to orthodontic treatment and to long term stability of orthodontic results.

4.6 Conclusion

- There was no significant difference in the swallowing pattern and the breathing mode between the two orofacial myofunctional therapies. Both therapies improved swallowing pattern in 60% of patients and nasal breathing was achieved in 84% of patients.
- Treating a tongue thrust habit with specific related exercises may not be a necessary component of an orofacial myofunctional therapy to reestablish tongue posture at rest and nasal breathing in children with no other functional problems.
- The corrections were maintained one year after initial treatment, thus tongue-thrust re-education does not influence maintenance of the results on a long term basis.
- The second phase of this study will evaluate the efficacy of orofacial myofunctional therapy on the long term stability of orthodontic treatment.

4.7 Conflict of Interest

The authors declare that they have no conflict of interest.

4.8 Source of Funding

This study was funded by the Canadian Association of Speech Therapists and Audiologists and Dr. Nelly Huynh's start-up fund.

5. Discussion

5.1 Clinical Interest

The present wave of interest in OMT has been promoted primarily by speech language pathologists and orofacial myologists. Their vocation has been to perfect teaching methods that change the habitual pattern of tongue movements and postures, and to normalize speech articulation resulting from OMD. They have also expanded their knowledge regarding the effects of good and bad habits on the alignment of the teeth.

An attempt has been made to review and interpret how swallowing, breathing methods, and orofacial musculature relate to occlusion and to the treatment of malocclusion. The effect of growth and development, thumbsucking and other bad habits, OMT, mechanical restraints and surgical treatment have been considered as related to the correction of malocclusion and to the modification of orofacial muscle activity during swallowing. Although objective data remain sparse in some areas, especially in regard to the effect of OMT upon occlusion, the bulk of evidence indicates that the specific pattern of muscular activity associated with swallowing is dictated principally by form.[4] When form is modified by orthodontic or surgical procedures within the anatomical and physiological limitations of the patient and within the reference of anticipated changes incident to growth and development, stable adjustments in occlusion and favorable adaptations in orofacial muscle activity may be anticipated.[31]

This study helped us understand the relationships between resting tongue posture, swallowing, and occlusion. It also permitted us to establish that the primary component of this relationship is the resting tongue posture, as opposed to the swallowing pattern. It helped guide the therapy to target this essential component and thus minimize the treatment duration. This is especially applicable for most orthodontic patients who seek treatment in private offices and who usually have a relatively normal orofacial function without extensive neuromuscular disorders. In today’s busy modern lifestyle, patients can thus benefit from a less strenuous protocol of OMT, thereby increasing motivation and compliance.

5.2 Summary of Evidences

This pilot study is unique as it is the first to compare the use of two different orofacial myofunctional therapies before commencing treatment. It also aims to stimulate further research in the field of OMT. In this study, the orthodontic patients were randomized into two groups and underwent two different protocols of myofunctional training. In typical clinical settings, OMT exercise regimens and duration of therapy are often tailored to the needs and responses of each individual patient. More research concerning different treatment protocols would be of value because there is no consensus in the literature regarding the ideal protocol to treat orofacial dysfunction. Different opinions are expressed in the literature regarding the ideal age to start OMT.[4, 31] Some dentists recommend treatment for, or have successfully treated pediatric patients under the age of ten years with the aid of OMT.[80] On the other hand, other authors suggest waiting until patients are ten years of age or older, because of continued growth and the possibility of spontaneous closure of the anterior open bite.[31, 63] OMT aims to harmonize the orofacial functions and to exclude factors interfering with the normal development of the dental arches. In this study, the OMT was to be completed before the beginning of orthodontic treatment and the children were assumed to be mature enough to understand the aim and exercises of the therapy. Furthermore, whether OMT should start prior to, during, or after orthodontic treatment is controversial. Speech language pathologists and orthodontists seem to have different opinions on this subject. There is a definite lack of evidence defining the ideal age to start OMT and more research is needed.

Observation of the tongue movements during swallowing with lips apart is a simple and rapid method for diagnosing the swallowing pattern, but is entirely subjective. However, since the lips are involved in the act of swallowing, some authors argue that a forced opening of the lips might disturb an individual swallowing pattern.[1, 75] Efforts have been made in the literature to evaluate the swallowing type in a more objective way, by using techniques like radiocinematography, electropalatography, and electromagnetic articulography.[58, 76 35, 77] The use of ultrasonography to assess swallowing type has also been described.[78] Yet, the reliability of these methods has not been extensively verified, and due to many reasons, especially the risk associated with irradiation, these techniques did not prove to be appropriate for observation in growing children.[33, 79] The clinical diagnosis is subjective in nature and interand intra-individual variability of tongue position and mobility must be taken into account since they might influence the swallowing type assessment.

The tongue can be re-trained as part of OMT, meaning that optimal mobility of the tongue can be created. At T1, both OMT protocols did increase the proportion of subjects performing a correct swallowing pattern. This increase might be caused by the fact that some of the OMT children effectively achieved the habit correction, but it also might be biased by the fact that some of these children just performed a correct swallow during the clinical trials, or by the fact that the evaluation was not performed blindly. However, the transition from conscious to unconscious habit correction cannot be assessed during a clinical examination. An intra-oral device sensitive for detecting tongue position and movements during daily activities could elucidate this problem. The proportion (40.5 %) of patients in our study who maintained an atypical swallowing pattern could be explained by their need for more training or more time to achieve a correct conscious swallow, or that in some children OMT could not correct the aberrant swallowing pattern. The myofunctional protocol has to be adapted to the needs of every individual. As an active exercise protocol, the success of OMT is also crucially dependent on motivation and compliance of both child and parents. Although the compliance rate was above average in both groups, this could have been biased by a falsified log journal. Patients were strongly encouraged to fill their log journals daily, but some may have quickly and blindly filled their journals before their appointment in order to receive positive feedback from the clinician. The use of an intra-oral compliance device with a micro-recorder could be an effective solution in order to adequately and objectively evaluate patient compliance. However, further validation and research on these devices are needed in order to verify their degree of accuracy.

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Orofacial myofunctional therapy, also known as neuro-muscular re-education of the oral facial muscles, is a modality that promotes the stability of the stomatognathic system. The vast majority of patients from both groups had an increase in tongue muscle tone and mobility, and an improved tongue posture at rest between baseline and the one year follow-up. There was also a significant difference between groups regarding the increase in the tongue and apex muscle tone, where patients who received the complete OMT surpassed patients who received the basic therapy. This could be explained by the increased number of tongue exercises for the correction of the swallowing pattern in the complete OMT group. While a primary function of the tongue is to protect the airway, improper oral resting posture of the tongue will have a negative influence on the development of the oral cavity.[60] Furthermore, today's modern diet of processed and soft foods may lead to low muscle tone and mobility by diminishing the frequency and intensity of mastication,[4] and a smaller oral volume may not support the proper development of optimal dental arches or upper airways. A significant proportion of patients from both groups established correct and physiologic nasal breathing following OMT, and maintained stable results after one year. Increased labial muscle tone, proper positioning of the tongue on the anterior palate and labial seal at rest contributed to the development of nasal breathing. Although the OMT protocols in our study included some articulation and resonance screening, as well as strengthening of the anterior and mid part of the tongue musculature, no significant improvement in sonority was found as most patients (95%) had a normal articulation evaluation at baseline.

5.3 Study Limitations

In the present study, several factors could have biased the results, one of which was the restricted number of patients. The strict inclusion and exclusion criteria, the lack of time available to see patients and the inevitable loss of patients throughout the study due to lack of interest or motivation resulted in the limited sample size of active patients.

This study was fully dependent on the cooperation of each patient as most of the work was done with the at-home exercises. Furthermore, the increased amount of visits at the orthodontic clinic and the completion of the log journal by the patients, made the compliance difficult for the very busy families involved in this study. Although patient compliance scores were relatively high, there was no statistical difference between patient compliance and treatment success.

In addition, clinical data acquisition for most values, like the evaluation of the swallowing pattern and tongue posture is subjective and could be misrepresented in our results. As mentioned earlier, special techniques exist in order to objectively evaluate swallowing patterns but their effectiveness is yet to be proven clinically.

Restriction of tongue movements and posture can be seen in patients with a short lingual frenum attached anteriorly. This physical barrier of the muscle attachment can actively restrain tongue movement and prevent the patients from positioning and maintaining their tongue in an adequate position on the anterior palate. The need for a frenectomy, before commencing OMT or orthodontic treatment in general, is highly controversial. Moeller et al.[60] suggest that lingual frenectomies are essential for a full range of mobility if the tongue is restricted, and it is ideal to release the restricted frenum as early as possible, meaning at birth, because the tongue will achieve optimal function through the activity of breastfeeding.[60] A tight lingual frenum has a critical impact on normal function and the development of the orofacial complex. The restricted frenum may not only affect the oral resting posture of the tongue, but may also disrupt both the intrinsic and extrinsic tongue muscles of their normal functions. If the frenum is restricted, the genioglossus muscle may not function normally and may impact the airway patency.[60] Suter et al., in a systematic review on ankyloglossia stated that no conclusive suggestions regarding the timing of frenectomy could be made because of the lack of agreement between studies.[74] Although only a few patients included in the study had a short anteriorly attached frenum, this variable should have been analysed in association with low tongue posture at rest prior to OMT, to evaluate if the OMD is due to a short lingual frenum and anterior attachment or simply resulted from a bad habit.

In addition, upper and lower airway measurements on cephalometric radiographs should have been analysed. A direct correlation between the airway volume and the mode of breathing would have been a great adjunct to the study to evaluate if the airway constriction is associated with a mouth breathing pattern.

Inter-rater reliability was another area of shortcoming in this study. Although both raters were trained in the same manner, their educational backgrounds and professional training were different, which reflected poorly in the homogeneity score for the method of evaluation of the patients. One of the raters came from an orthodontic background while the other came from a speech language pathology background. Although the reliability score was fair and acceptable, the raters should have been retrained and recalibrated in order to obtain a higher and more acceptable score. Furthermore, because the patient compliance was already subject to high demand due to the numerous clinical visits to complete the OMT protocol, intra-rater scores were not evaluated. The increased number of visits needed to calibrate the raters would have probably resulted in a higher drop-out rate.

5.4 Future studies

Future studies are needed in order to evaluate the effect of OMT on the short and long term stability of orthodontic treatment. A second phase of the study will have to be undertaken by another clinician once all the patients have completed their orthodontic treatment. The patients will be re-evaluated for atypical swallowing, tongue posture at rest, and their breathing mode (nasal vs. buccal). Orthodontic records will have to be assessed immediately after treatment and new records will need to be taken at different time intervals post-orthodontic treatment. These intervals will have to be determined by the future clinician attributed to this study and the patients will have to be compared to a control group in order to evaluate the efficacy of the OMT. It will also be necessary and interesting to evaluate whether the correction of the tongue posture at rest and on swallow is the direct effect of the OMT administered before the beginning of the orthodontic treatment, or whether it is directly related to the change in the oral structure produced by correction of the initial malocclusion. Furthermore, cephalometric radiographs should be taken at the end of treatment in order to evaluate and establish if there is a direct correlation between upper and lower airway measurements and nasal versus buccal mode of breathing.

Another interesting avenue to explore would be to integrate a more vigorous clinical and theoretical educational program in speech language therapy into the post-graduate orthodontic program, in order to acquire a more profound understanding of this aspect of the orofacial environment. Most programs have limited training in speech therapy and it is evident that in the current scientific literature, there is a lack of knowledge and consistency in the orthodontic scientific community. According to Moeller[60], an orofacial myofunctional therapist in the USA, there has been a great increase in discussion of this subject in the last few years, especially in Brazil. Although there is a growing interest in research on OMT, more advancement is needed and this can only be achieved by promoting the subject within various professional university programs.

Although our study confirmed that a much simpler OMT was as successful as a complete and time consuming therapy in establishing a physiologic pattern of swallowing, further research is recommended by means of larger, blindly performed, long-term follow-up studies, in order to confirm our results and to clarify the success of OMT as an adjunct to orthodontic treatment and to long term stability of orthodontic results.

6. Conclusion

The swallowing reflex is fairly unpredictable with regards to maturation times. This creates many difficulties in trying to identify the line between physiological and pathological function, and therefore in planning a suitable treatment which is able to correct its causes and yet still ensure a normal growth of the maxillofacial region.

In conclusion, this study supports our hypothesis that a basic OMT, consisting of simple exercise instructions and at-home exercise compliance, is sufficient to improve the swallowing pattern and tongue position at rest. A complete OMT with correction of the tongue thrust habit is not necessary to establish tongue posture at rest and nasal breathing. Consequently, there is no significant difference between the two therapies, and treatment of the atypical swallowing pattern is not a necessary component of an OMT in children with no other functional problems. In the future, long term stability after completion of the orthodontic treatment should be evaluated in order to assess if the beneficial effect of the OMT is valid on a long term basis.

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Annex 1 – Evaluation Form

Faculté de médecine dentaire
Université de Montréal

Projet NH-13-OP-DegluLang
VISITE 1

Évaluation

Code: DEG☐☐☐ Date : 201☐-☐☐-☐☐ (YYYY-MM-DD)

Histoire de cas : ____

____

Alimentation

Bouche ouverte	☐	Étouffement	☐
Bruit en mangeant (sapement)	☐	Douleur quand avale	☐
		Repas lents	☐

Oto-rhino-laryngologie

Otites à répétition	☐	IVRS	☐
Problèmes respiratoires	☐	Congestion chronique	☐
Allergies	☐	Reflux o-n	☐
Apnée	☐	Amygdalites	☐
Adénoi-amygdalectomie	☐		

Solutions : ______________________

Visage

Brachyfacial	☐	Mésofacial	☐
		Dolichofacial	☐

Nez

Apparence :

	Normal	Anormal	
Septum nasal	☐	☐	Dévié : ☐G ☐D
Narines	☐	☐	Affaissement : ☐G ☐D

Tâches :

Perméabilité adéquate :

Bonne	☐	Faible	☐		
Moyenne	☐	D>G	☐	G>D	☐

Palais dur

Arqué ☐ Normal ☐

Grosseur des amygdales :

Normales ☐ élargies ☐ hypertrophiées ☐

Autres : ______________________

Lèvres

Apparence :

	Normal	Anormal
Symétrie au repos	☐	☐

Description : ______________________

	Normal	Anormal
Bouche au repos		
-Ouverte	☐	☐
-Fermée	☐	☐
-Desfois ouverte	☐	☐
Cicatrice	☐	☐

Encoche G☐ D☐

Frein labial G☐ D☐

Tâches :

	Normal	Anormal	
Tonus – souffler en gonflant les joues	☐	☐	☐G ☐D
Tonus – tenir abaisse langue entre les lèvres	☐	☐	

Position au repos :

Ouvertes ☐ Fermées ☐

Mixte (ouvert/fermé) ☐

Contrôle salivaire :

Normal ☐ Faible ☐ Moyen ☐

Alvéoles

Peu développées ☐ Normales ☐

1

Faculté de médecine dentaire
Université de Montréal

Projet NH-13-OP-DegluLang
VISITE 1

Évaluation

Langue

Apparence :

Position au repos :

Élevée(aux alvéoles) ☐
Basse(au plancher buccal) ☐
Interdentaire ☐

	Normal	Anormal
Surface	☐	☐
Frein	☐	☐

	Oui	Non	Dévié :
Macroglossie	☐	☐	☐ G ☐ D
Microglossie	☐	☐	
Ankyloglossie	☐	☐	
Fasciculation	☐	☐	

Tâches :

Tonus – pousser sur bâton protrusion antérieure : (apex plie sous pression/langue droite)

Normal ☐ Faible ☐ Moyen ☐

Sans protrusion :	réussit	non réussit
-élévation	☐	☐
-recul de l'apex	☐	☐
-déplacement latéral	☐	☐

Avec protrusion :		
-élévation	☐	☐
-abaissement	☐	☐
-déplacement latéral	☐	☐

- Avec imprécision de l'apex ☐
- Avec manque de séparation langue-mandibule ☐

-grimace ☐ ☐

- Avec manque de séparation langue-mandibule ☐

Résonance

Perméabilité nasale :

Normale ☐ Moyenne ☐ Faible ☐

Symétrie des narines :

Normale ☐ D>G ☐ G>D ☐

Fuites nasales sur :	Oui	Non
-m, n, gn, en, on, in	☐	☐
-mamama/nanana	☐	☐
-mabamaba/natanata	☐	☐
M ressemble à B	☐	☐
N ressemble à T	☐	☐
Hyponasalité	☐	☐
Phrases :		
1-Nina a la lune	☐	☐
2-Maman aime le miel	☐	☐
3-L'agneau aime l'oignon	☐	☐
4-Blanche Neige pique son bâton brun	☐	☐
5-Mon ami a un long nez	☐	☐
6-Tu mets du papier dans le panier	☐	☐

Déglutition

Normale ☐

Infantile ☐ Avec propulsion linguale: Oui ☐ Non ☐

	Oui	Non
Sapement	☐	☐
Mange bouche ouverte	☐	☐

Habitudes péri-orales

	Oui	Non
-sucement du pouce	☐	☐
-rongement des ongles	☐	☐
-met objets en bouche	☐	☐

Posture dorsale

	Oui	Non
-droite	☐	☐
-hyperextension de la tête	☐	☐
-affaissée	☐	☐

2

Annex 2 – Log Journal

Université de Montréal
Faculté de médecine dentaire

Projet : NH-13-OP-DegluLang – Évaluation de l'impact de la thérapie myofonctionnelle sur le rétablissement de la respiration nasale et la stabilité des corrections orthodontiques.

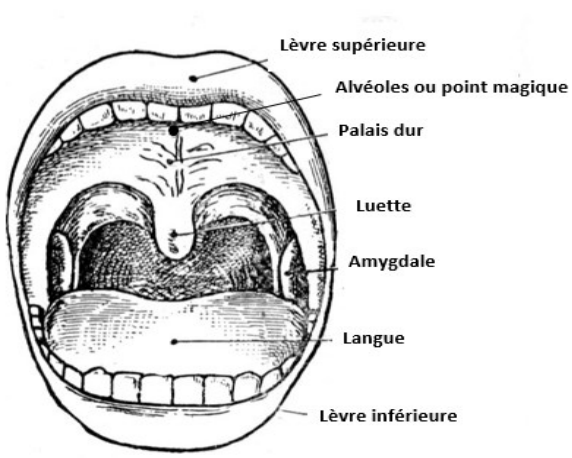
Journal de Bord – Groupe A :

Code : DEG ☐☐☐

Émis le :

201☐-☐☐-☐☐

L'intérieur de la bouche :



1

Il est important que chaque exercice soit réalisé et pratiqué correctement. Tous les exercices doivent donc être réalisés avec un miroir et préférablement en présence d'un adulte qui peut donner de la rétroaction sur la performance du jeune.

<u>Pour développer la langue et trouver l'alvéole (« le point magique »)</u> :

1- Toucher le coin des lèvres avec le bout de la langue le plus vite et rythmé possible. Faire le mouvement le plus précis possible. **Répéter 10 fois de chaque côté.**

2- Mettre le bout de la langue dans la joue comme pour faire « une saucisse » dans la joue, avec la bouche fermée. Mettre son doigt ou le doigt d'un autre adulte à l'endroit de la langue. Presser contre le doigt avec la langue. **Répéter 10 fois de chaque côté.**

3- Sortir la langue et toucher un bâton en avant de la bouche avec le bout de la langue. Pousser légèrement contre le bâton tout en maintenant une langue droite et immobile pendant **5, 10 secondes. Répéter 10 fois.**

4- «Push-ups» de la langue : toucher l'alvéole avec l'apex de la langue puis relâcher la langue. Lorsque la langue est sur le point magique, l'adulte place son doigt entre le menton et la gorge pour sentir une contraction de la base de la langue.
   a. Amener un élastique orthodontique sur l'alvéole avec la langue et pousser légèrement l'élastique contre le « point magique » (faire semblant d'écraser une mouche contre le point magique). **Répéter 10 fois.**
   b. Tenir l'élastique contre le « point magique » pendant **5 et 10 secondes. Répéter 5 fois.**

5- Placer le bout de la langue sur « le point magique ». Garder la langue à cette place en ouvrant et fermant les dents. Répéter **10 fois.**

6- Claquer la langue sur le palais comme pour faire le bruit du cheval qui galope fort mais lentement (faire semblant qu'un cheval marche dans la boue). *Le frein de langue doit être visible*. **Répéter 10 fois.**

7- Placer toute la langue au palais. *Le frein de langue doit être visible*. Garder la langue à cette place en ouvrant et fermant la bouche. **Répéter 10 fois.**

8- Retenir une petite quantité d'eau au palais avec la langue. Pendant 5, 10 secondes. Puis ramener la langue sur le point magique. **Répéter 10 fois.**

2

<u>Pour développer le tonus (force) des lèvres pour maintenir une bouche fermée</u> :

1- Tenir un bâton ou un bouton entre les lèvres. Placer la langue sur l'alvéole et la tenir là sans que le bâton ou le bouton ne tombe de la bouche pendant **5, 10 et 15 secondes**, pendant les pauses commerciales d'une émission de télévision. **Répéter 10 fois.**

2- Faire des bisous exagérés tout en étirant les lèvres vers l'avant le plus possible et ensuite faire un sourire exagéré avec des lèvres fermées. Alterner ces mouvements **10 fois.**

3- Aspirer des petits morceaux de kleenex à travers une paille tout en faisant un ``rond`` avec les lèvres. Placer ainsi **10** petits morceaux de kleenex dans un verre tout en les inspirant à travers une paille.

4- Écraser des petites éponges mouillées avec les lèvres **pendant une minute.**

5- Boire à la paille en tout temps. Boire du jello et du yogourt.

6- Manger avec la bouche fermée en tout temps.

3

Travailler l'habitude de garder la langue sur les alvéoles et la bouche fermée au repos :

1- Maintenir la bouche fermée : bout de la langue (l'apex) sur le «point magique» les dents fermées, mais non serrées, les lèvres fermées, une posture dorsale droite (cou aligné avec colonne vertébrale). Placer un bâton entre les lèvres pendant_____**minutes.** Utiliser un compteur visuel (chronomètre, sablier, time timer, etc).

2- Faire **5** rappels visuels (dessins, photos, images trouvées sur l'internet et/ou colorier les images fournies dans le journal de bord) de la position correcte au repos. Les apporter à la prochaine rencontre. Placer les visuels aux endroits visibles au quotidien. Varier les images à chaque semaine.

3- Maintenir la bouche fermée : bout de la langue (l'apex) sur le «point magique» les dents fermées, mais non serrées, les lèvres fermées, une posture dorsale droite (cou aligné avec colonne vertébrale). **Pendant des activités quotidiennes suivantes. Ajouter 30 minutes par jour à chaque semaine.**

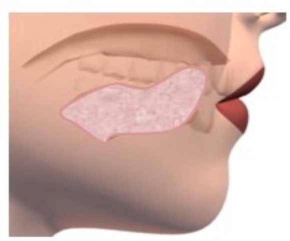
a. Télévision (pendant les pauses commerciales), une émission de ________ minutes.
b. Les écrans : ipad, ipod, jeux électroniques, ordinateurs
c. Jeux de société
d. Lecture d'un livre
e. Dessins
f. Devoirs
g. Dans l'auto, autobus, métro en s'en allant et revenant de l'école
h. En écoutant le professeur en classe : établir un rappel 'secret' avec le professeur.
i. S'endormir le soir avec la bonne position de la langue et la bouche fermée
j. Autres activités/opportunités de l'enfant:
____
____
____
____

4

ATTENTION : Il faut toujours avoir une posture droite du dos. Le cou doit être aligné avec la colonne vertébrale.

Exemples des rappels visuels :

L'apex qui touche les alvéoles.



Position repos : lèvres fermées, apex touche les alvéoles.

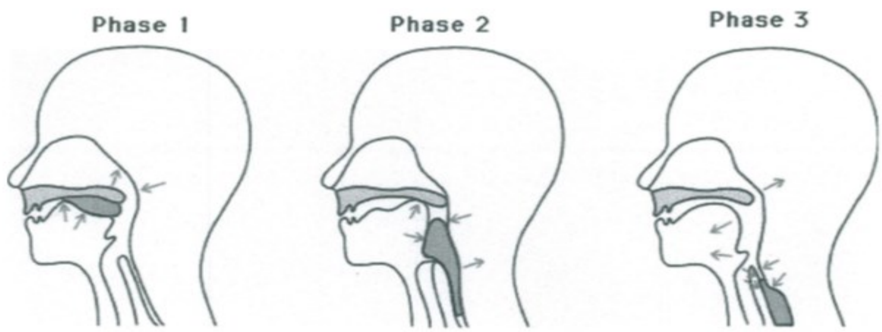
Garder les lèvres fermées

Déglutition

5

La déglutition:

Les phases de la déglutition mature:



6

NB : Les exercices de déglutition ci-dessous sont seulement à faire pour les patients du groupe A.

Apprendre à avaler avec un mouvement de langue vers l'arrière et non vers l'avant.

Les étapes d'une déglutition correcte (voir le visuel ci-haut) :

1- Ouvrir la bouche et déposer l'aliment sur la langue. Attention de ne pas sortir la langue vers la cuillère et/ou l'aliment.
2- Mâcher l'aliment. Faire une petite boule de l'aliment (bolus) sur la langue.
3- Placer le bout de la langue sur « le point magique ».
4- Fermer les dents et la bouche.
5- Serrer les dents tout en « aspirant » la nourriture vers l'arrière de la bouche comme avec un aspirateur, tout en maintenant la langue bien haute au palais et/ou en faisant un mouvement vers l'arrière.

Pratique : pratiquer avec les lèvres ouvertes

1- Pratiquer les étapes de la déglutition correcte sans la nourriture.
2- Pratiquer avec un aliment mou : une compote de fruit ou un yogourt.
3- Pratiquer avec de l'eau. Prendre une gorgée d'eau et avaler chaque gorgée d'eau individuellement.
4- Pratiquer avec un aliment plus dur : de la viande, ou un biscuit.
5- Pratiquer à avaler 2 fois de suite correctement.
6- Faire des rappels visuels (dessins, collants, etc). 5 dessins/images. Les apporter à la prochaine rencontre.
7- Pratiquer avec un repas
8- Pratiquer avec un repas et des distractions.
9- Avaler sa salive

ATTENTION :

- Maintenir une posture droite du dos et du cou
- Ne pas basculer la tête vers l'arrière et ne pas faire de bruit de claquement avec la langue.
- Ne pas aller chercher l'aliment sur la cuillère avec la langue.
- Au début, pratiquer avec des lèvres ouvertes pour s'assurer que la langue est bien placée et que les dents sont serrées.
- Avaler 2 fois de la bonne façon au besoin.

7

Calendrier – Semaine : 1 – (Visite 0)

	Exercices	Bout de Langue et point magique									Tonus des lèvres				L'habitude			Déglutition
Jour:	Heure:	1	2	3	4a	4b	5	6	7	8	1	2	3	4	1	2	3	Étapes
Lundi	Matin																	
	Midi																	
	Soir																	
Mardi	Matin																	
	Midi																	
	Soir																	
Mercredi	Matin																	
	Midi																	
	Soir																	
Jeudi	Matin																	
	Midi																	
	Soir																	
Vendredi	Matin																	
	Midi																	
	Soir																	
Samedi	Matin																	
	Midi																	
	Soir																	
Dimanche	Matin																	
	Midi																	
	Soir																	

Date prochaine visite (1 semaine) : 201☐-☐☐-☐☐@ _______________