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## Review Article

# Model of oronasal rehabilitation in children with obstructive sleep apnea syndrome undergoing rapid maxillary expansion: Research review

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## ARTICLE INFO

## Article history:

Received 6 May 2014

Accepted 3 October 2014

Available online 17 November 2014

## Keywords:

Palatal expansion technique

Mouth breathing

Myofunctional therapy

Speech therapy

Obstructive sleep apnea

## ABSTRACT

Rapid maxillary expansion (RME) is a widely used practice in orthodontics. Scientific evidence shows that RME can be helpful in modifying the breathing pattern in mouth-breathing patients. In order to promote the restoration of physiological breathing we have developed a rehabilitation program associated with RME in children. The aim of the study was a literature review and a model of orofacial rehabilitation in children with obstructive sleep apnea undergoing treatment with rapid maxillary expansion. Muscular training (local exercises and general ones) is the key factor of the program. It also includes hygienic and behavior instructions as well as other therapeutic procedures such as rhinosinusal washes, a postural re-education (Alexander technique) and, if necessary, a pharmacological treatment aimed to improve nasal obstruction. The program should be customized for each patient. If RME is supported by an adequate functional rehabilitation, the possibility to change the breathing pattern is considerably amplified. Awareness, motivation and collaboration of the child and their parents, as well as the cooperation among specialists, such as orthodontist, speech therapist, pediatrician and otolaryngologist, are necessary conditions to achieve the goal.

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## 1. Introduction

Rapid maxillary expansion (RME) is a widely used practice in orthodontics. The purpose of RME is to correct transverse maxillary deficiency, a rather common skeletal anomaly of

the maxillofacial area. It is often found in children with impaired respiratory function [1–5]. Scientific evidence shows that RME can be helpful in modifying the breathing pattern in these patients. This modification involves nasal cavities [6–11] and, indirectly, the jaw. The jaw is thus repositioned

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and this causes the root of the tongue to move forward [12] and it changes the pharyngeal structures [13]. Early studies related to the effect of RME on the nasal cavity and on breathing patterns date back to 1886 [14]. Several studies on the same topic were published later. Postero-anterior cephalometry [7,8,15,16], latero-lateral cephalometry [17,18] and tomography [11,19-22] have been used to estimate the changes in shape and size of the nose. Acoustic rhinometry [7,8,23-25] and rhinomanometry [7,8,26,27] have been used to adequately assess the airflow. The former provides anatomical information about the nasal airways (minimal cross-sectional area—MCA, minimal cross-section volume—MCV), while the latter measures the nasal resistance to airflow (nasal air resistance—NAR), an essential parameter for a functional assessment. In addition, in some studies, patients were asked to respond to special questionnaires in order to determine their perceptions on changing their breathing [28-30]. Hershey et al. [28] performed a comprehensive evaluation of the nose-breathing parameters mentioned above and it reported positive changes in the amplitude of the nasal cavities and a reduction in the values of NAR after RME to levels comparable to those of physiological nasal breathing. Those values would remain almost unchanged in the post-expansion contention months mentioned in the study. Additionally these Authors did not find any significant variations between the values of NAR in subjects who reported a subjective improvement in breathing and those reported no improvement. In later decades, other Authors analyzed changes in one or more of the parameters described above, which in most cases, caused dimensional and volumetric expansions of the nasal cavity, in particular of its lower part, and a decrease of the NAR. The stability effect achieved by RME and its role in actually changing breathing patterns remains a subject of debate. This debate is still ongoing despite evidence of anatomical and functional changes in the nasal complex after RME, as reported in the orthodontic literature, and notwithstanding the enthusiasm among some Authors who support the hypothesis that it is a means to eliminate or reduce the problem of mouth breathing. Clinical practice presents many cases in which, in spite of orthodontic treatment recovery of all the dental and skeletal conditions for a restoration of physiological nasal breathing, oral breathing persists. Cases of children who underwent tonsillectomy or adenectomy, did not experience an adequate functional recovery despite a clear airway are also common. Hershey et al. [28] confirmed the thesis of Watson et al. (1968—cited in Hershey et al. [28]) pointing out that the reduction of the NAR does not necessarily coincide with a disappearing of mouth breathing in a child. He concluded that RME, although it could potentially result in the recovery of the respiratory function also in the case of nasal stenosis, does not guarantee a resolution of all cases of oral breathing. According to Warren et al. [31] the enlargement of the nasal cavity is not sufficient to modify breathing patterns, in particular in cases of nasal obstruction. An analysis of recent reviews of the literature [9,10,32] has shown that a change in breathing after RME does not represent a predictable result to the point that mouth breathing does not seem to be a primary reason for an expansion procedure. Compradetti et al. [8] also report that a certain

percentage of children, in spite of having structurally adequate nasal airways, do not change their breathing pattern from oral to nasal, which would lead to the need to 'learn' how to breathe properly. In order to promote the restoration of physiological breathing, it might be helpful to associate the expansion of the palate to myofunctional rehabilitation practices. Several articles in orthodontic literature highlight the need to combine orthodontic treatment with myofunctional therapeutic procedures [33-36]. Several procedures are meant to correct the position and the abnormal function of the tongue [34,37], while less emphasis is put on specific breathing exercises included in an orthodontic treatment plan [1,2,3,38-42]. Cozza et al. [40] describe a myofunctional rehabilitation program supporting the traditional orthodontic therapy in patients affected by breathing problems. The program involves exercises for the proprioception of the primary breathing apparatus, a costo-diaphragmatic training and respiratory exercises. The Authors underline that this rehabilitation program is advised to patients diagnosed with chronic mouth breathing, i.e. without any mechanical obstruction of the upper respiratory tract. Villa et al. [39] treated a group of children with nasal chronic obstruction with a myofunctional therapy aimed to re-establish a physiological nasal breathing and lip seal as well as to modify an abnormal swallowing pattern. Their protocol includes nasal exercises for the mobility of alar cartilages, labial exercises to straighten orbicularis oris muscles, tongue exercises to improve swallowing and breathing body exercises. Nasal irrigations using a hypertonic saline solution was added to the myofunctional therapy. The results showed that both myofunctional rehabilitation and nasal irrigation improve significantly nasal obstruction, oral breathing and chronic snoring in 5-10 years old children. A physical therapy program for mouth breathing children was adopted by Correa and Bérzin [41]: muscular stretching and strengthening exercises using a Swiss ball were combined to nasodiaphragmatic re-education. However, the study focuses on the effectiveness of this therapeutic program on cervical muscle activity and body posture which would have seemed to be impaired in the patients in question. No evaluations were made with regards to changes that occur in the respiratory pattern. Guimarães et al. [42] use a myofunctional approach consisting of oro-pharyngeal exercises derived from the traditional speech therapy techniques; it involves the soft palate, the tongue and mandibular and facial muscles. These exercises, combined with insufflation ones, would eventually lead to an improvement in adult patients affected by obstructive sleep apnea (OSA) as an outcome of the upper airway remodeling and its subsequent increase of patency. In a randomized placebo-controlled study Diáféria [43] evaluates the effects of speech therapy on clinical and polysomnographic parameters in obstructive sleep apnea syndrome (OSAS) patients and concludes that speech therapy could reduce OSAS symptoms and increase the adherence to the treatment with continuous positive airway pressure (CPAP). The speech therapy consists of muscular endurance exercises aimed at toning the oropharynx muscle groups, optimizing muscle tension mobility and adjusting the position of the soft tissues and the suitability of the chewing, sucking, swallowing and breathing orofacial functions, according to previously

standardized protocols [44–50]. In a later study Diaféria et al. [51] confirm that speech therapy, alone as well as in association with CPAP, leads to an improvement of quality of life in patients with OSAS. Dantas et al. [52] focuses on the genesis of the upper airway collapsibility in adult patients with OSAS. The Authors suggest that an increased collagen type I in the pharyngeal muscular wall in patients with OSAS could delay the contractile-relaxant responses of the pharyngeal muscles during the transition from inspiration to expiration, increasing pharyngeal collapsibility. Exercises that target the oropharynx region increase the strength of the oropharynx muscles, thus repositioning the tongue under anteroposterior stress, could help to reduce the collapse of the pharynx. The increased strength of the tongue and the soft palate related to the speech therapy could explain the improvement of the Modified Mallampati Index (MMI) and the other objective sleep parameters in patients affected by OSAS [43]. Scientific evidences for speech therapy in children affected by OSAS are rare. Schievano et al. [53] reported an enhanced respiratory function experienced by habitual mouth breathing population who underwent a therapeutic program based on facial massages and myofunctional exercises involving mental, labial and lingual area, feeding re-education included. The Authors argue that the muscular and functional alterations were not completely recovered due to the lack of morphological and structural correction during the therapeutic period; thus they underline the need for a multidisciplinary approach to solve the problem. From these considerations, this study aims to present a literature review and a model of orofacial rehabilitation in children with obstructive sleep apnea undergoing treatment with rapid maxillary expansion. Once, speech therapy presents a promising future in the treatment of patients with obstructive sleep apnea and the lack of standardization of rehabilitation exercises of oronasal in different studies, were the main reasons that encouraged the making of this article.

## 2. Respiratory rehabilitation program

Muscular training is the key factor of the respiratory rehabilitation program described in this paper. The exercises are grouped according to the body area of interest into local exercises (involving nose, lips, antigravity muscles of mastication), see Table 1, and general ones (physical therapy), Table 2. These exercises are taught with the cooperation of a speech therapist and they are performed by the patient in a work at home program. Muscular training must be performed for the whole period of active expansion by the maxillary expander and for at least one month during the post-expansion retention period. The patient and their parents must really commit and cooperate to keep the therapy effective. The results achieved would allow to assess whether to continue the therapy for an additional variable period. With regards to the number of the exercises, we suggest to choose two kinds of general exercises and two kinds of local ones for each body area, alternating their prescription in the sessions. The patients are requested to carry out the whole series of the prescribed exercises (local exercises and general ones) twice a day at least; three times a day would be the ideal frequency. Whenever the child successfully completes the whole series he will note it on a chart marking the current date. This would make the child more aware and the operator will be able to monitor patient's compliance with the therapy. In order to promote the restoration of physiological breathing it would be useful to add to the muscular training hygienic and behavior instructions as well as other therapeutic procedures such as rhinosinusal washes. We also suggest a postural re-education (Alexander technique) and, if necessary, a pharmacological treatment aimed to improve nasal obstruction. An otolaryngologist consultancy before the orthodontic-myofunctional therapy is advisable in order to prevent and treat nasal obstruction. The therapeutic program

**Table 1 – Local rehabilitation—work at home program.**

Body area	Therapy	Type of exercise	Number of repetition/ timing for each exercise	Daily frequency
Nasal area	Blow the nose	–	–	At least 3 times per day
	Nasal washes	–	–	At least 2 times per day
	Muscular training	n.2 among the following exercises: wet gauze, siren, foot of the nose, alternate ventilation, piglet, bunny	n.10 or n.5 per nostril	2–3 times per day
	Massages	n.2 among the following exercises: slow circular movements, tap the nose, pinch the nose	–	2–3 times per day
Lips	Muscular training	n.2 among the following exercises: kiss, pencil, button, inflated cheeks, patch, button-bottle, lip massages or upper lip stretching in patients with only upper lip hypotonia	n.10/10 min	2–3 times per day
Jaw elevator muscles	Muscular training	n.2 among the following exercises: count to 10, TIII, CIUUU, peg	n.10	2–3 times per day

**Table 2 – General rehabilitation—work at home program.**

Therapy	Type of exercise	Number of repetitions for each exercise	Daily frequency
Body training	n.3 among the following exercises: breathing awareness, diaphragm mobilization, perception of breathing sensations, sniff-test, diaphragmatic-abdominal mobilization, supine position and extended legs, supine position and flexed legs	n.10	2-3 times per day

is described below, organized following a topographical criteria. It must be customized for each patient, considering their needs and level of collaboration.

### 3. Local rehabilitation of the nose

#### 3.1. Instructions to blow the nose

The breathing re-education concerning the nose district consists of a first phase in which the operator explains to the patient the importance of blowing the nose and teaches them how to do it properly. Blow the nose one nostril at a time keeping the head down and the mouth closed. It is helpful to include nasal hygiene in their daily routine in order to establish a habit in the child. This is why we suggest the patient to blow the nose always after brushing teeth: the patient will do this two-three times a day at least, more if necessary. It is really important to use paper towels and replace them frequently. The patient and his parents should be aware about how harmful is to sniff up the nose because of the increased infection risk.

#### 3.2. Nasal washes

Nasal irrigations are considered by literature to be an additional or the only treatment for several sinonasal conditions associated with oral breathing [54–58].

In our program we recommend to wash the nostrils twice a day, before performing breathing exercises. There are several nasal irrigation systems available. Among them there is Fluirespira<sup>®</sup> nasal douche device (Zambon, Italy) which is a certified medical device able to spray aqueous solutions. It comes with a button to activate the spray, a suction valve for minimizing the noise level and two adjacent chambers, one designed to atomize the solution, the other one to recover the solution. It is easy to handle and, once charged it can be used wireless. Fluirespira comes with nasal adapters in three different sizes. As an alternative we suggest to use a nasal cup, also known as 'neti pot'. The technique described by Rabago and Zgierska [57] and proposed herein consists of the following passages: lean over a sink looking into the basin with the head down; gently insert the spout of the nasal irrigation pot into a nostril, without pressing the spout against the nose; rotate the head slightly so that the spout is placed into the upper nostril. Breathe through the mouth and lift the container to let the solution into the nostril where the spout is placed; the solution will drain soon through the lower nostril. At the end of the wash, exhale through both nostrils to clear them removing the mucus and the remainder solution; then blow the nose. Repeat this procedure for the other nostril.

A variety of sterile solutions are commercially available. However, another option could be preparing the saline solution at home using non-iodized salt. The literature does not provide consistent data inherent the adequate temperature and concentration that should be used. We suggest a warm saline solution to obtain an additional antimicrobial effect. The first times the irrigation is done it is better to use a lukewarm solution; afterwards the temperature could be increased, compatibly with patient's tolerance. Obviously really high temperatures should be avoided because they might cause nasal irritation and burns. As per solution's concentration, we would prefer a hypertonic one on the assumption that, despite its greater irritation potential, the hyper-tonicity enhances the mucociliary function proven by the increase of the ciliary beat frequency (Marchisio et al.) [58]. In case of mucosal irritation, the sodium chloride concentration should be adjusted. As already stated by other Authors, nasal irrigations can be performed with safety on children of any age and they are compatible with all pharmaceutical therapy.

#### 3.3. Nasal exercises

The nasal respiratory rehabilitation involves the following nasal exercises which will be explained and shown by the operator. Each exercise is described by its name followed by its description in the paragraph below. Alternate these exercises and exhort the patient to perform the series two-three times per day.

##### 3.3.1. Wet gauze

Wet a folded gauze with cold water, squeeze it and inhale several times through the gauze keeping the mouth closed. Not only there will be a muscular benefit derived from the forced inspiration but also a positive effect on the mucosal membrane. The benefits are linked to the airway humidification caused by the cold water particles in the gauze. Ten repetitions.

##### 3.3.2. Siren

Breathe through both nostrils, close one of them with a finger, then exhale forcefully through the previous nostril to produce a sound comparable to a ship's siren. Perform five repetitions per nostril and then other five repetitions emitting a louder sound.

##### 3.3.3. Foot of the nose

Put the thumb under one of the nostril, like it is its foot. Exhale forcefully through the previous nostril, then move the thumb under the other nostril and inhale. During the exercise the child must check they are performing a thoracic-abdominal breathing by placing a hand on the abdomen. Because of inhalation

and exhalation are always performed through the same nostril, carry out five repetitions, then invert the role of the nostrils during the further five repetitions.

#### 3.3.4. Alternate ventilation

Put the thumb of the left hand on the left nostril being careful not to bend the cartilage of the nose and inhale through the right nostril; put the left index finger on the right nostril and exhale through the left nostril. Five repetitions per nostril.

#### 3.3.5. Piglet

While keeping the mouth half-opened, inhale wrinkling the nose, dilating the nostrils to emit a noise like a grunt; then relax the involving muscles and exhale. This exercise allows the elevator muscle of the nose and the dilator muscle of the nostrils to train and it also has an effect on pharyngeal muscles. Ten repetitions.

#### 3.3.6. Bunny

Keeping the mouth closed, inhale imitating a rabbit sniffing, then relax the muscles and exhale causing the nostrils opening. Ten repetitions.

### Nasal massages

- Assuming that rubbing the region of the nasal wings improves ventilation, we suggest to perform the following exercises. Each kind of nasal massages is described by its name followed by its description in the paragraph below.
- *Slow circular movements*: Massage the wings of the nose using the tip of the index finger in slow circular movements, then inhale.
- *Tap the nose*: Gently tap the wing of the nose from the top downwards with the index.
- *Pinch the nose*: Pinch the nose with two fingers for a second and inhale.
- Choose a type of massage to be performed two-three times per day, then switch.

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## 4. Local rehabilitation of the lips

The myofunctional local therapy of our program is also aimed at improving lips function and tone, often found deficient in mouth breathing children [1,2]. For children showing hypotonia of both lips and not affected by hypertonia of the mental muscle a considerable improvement can be achieved by performing the following exercises. Each exercise is described by its name followed by the description of the exercise in the paragraph below. Perform the chosen exercises two-three times a day.

*Kiss*: Strongly push the lips forward like kissing, then bring them upwards trying to almost touch the nose; afterwards, pull them to the right before then to the left. Five repetitions.

*Pencil*: Hold a pencil between nose and upper lip, so that it does not fall down, even tilting the head down.

*Button*: Hold a button between upper lip and lower lip.

*Inflated cheeks*: Keep the mouth closed and inflate the

cheeks, then try to push all the air in the mouth against the lips. Five repetitions.

*Patch*: Put a paper patch that can be easily removed on the lips, then try to remove it just using the lips, no hands or tongue. Five repetitions.

*Button-bottle*: With the head downwards-facing, hold, between lips and teeth, a button fixed to a string which is tied to a plastic bottle (500 mL) filled with water. The exercise must be 10 min long; the amount of water will be gradually increased up to fill the entire bottle.

*Lip massages*: Lift the lower lip to the point that it covers the upper lip, then massage it with thoroughly.

In oral-breathing children the functional failure is often limited to the upper lip [59]; in these patients the only practice to perform is the stretching of the upper lip.

*Upper lip stretching*: Stretch the upper lip downward using one hand and pull down the lower lip with the other hand to avoid the contraction of the mental muscle, if it has an increased tone.

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## 5. Local rehabilitation of the tongue

When the child becomes able to breathe with the nose and achieve the lip seal, he becomes able to activate a physiological deglutition scheme too. However, in the treatment of some patients affected by oral-breathing and visceral swallowing, it may be helpful following a specific re-education therapy for the tongue, aimed at normalizing its altered perception and posture.

The purpose of the tongue exercises is to maximize the mobility of the muscles styloglossus, genioglossus, hyoglossus, palatoglossal muscle superior longitudinal and transverse. The patient is requested to move the tongue tip in clockwise and counter clockwise directions within the vestibule of oral cavity for 20 times in each direction, three times a day, in the morning, afternoon and night, every weekday [60].

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## 6. Exercises of the muscles velopharyngeal sphincter

Exercises of the muscles velopharyngeal sphincter: executed to maximize the mobility (isothonic exercise) and to increase the tension (isometric exercise) of the muscles *uvula, palatopharyngeo, tensor and levator soft palate*. The patient was oriented to emit a /ra/ syllable extending the /r/ consonant, with change of head position to facilitate the muscles mobility, that is, the patient could hold his head straight up or bend it down or up as he wished to facilitate the proper movement of the cited muscles, while producing the syllable. Three series of 10 repetitions were executed, three times a day, in the morning, afternoon and night every day of the week [49].

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## 7. Exercises of the muscle suprahyoides and tongue

Exercises for muscles suprahyoides and tongue: were executed with the purpose to increase mobility (isothonic exercise) and

tension (isometric exercise) of muscles suprahióideos (mylohioid, genyohioid, digastric tyroid) and the tongue genioglossus, hyoglossus, palatoglossus, styloglossus superior longitudinal and transverse. Description: the patient position the tip of the tongue at *papilla incisive*, and then open and close his oral cavity forcing the tongue, but not projecting the jaw forward, while maintaining his head bent backwards. Repetition: 30 times interleaving with swallows keeping the head at the same position, three times a day, in the morning, afternoon and night, every day in the week [61].

## 8. Exercises of the soft palate

Exercises for soft palate has the purpose to work mobility (isotonic exercise), tension (isometric exercise) and resistance (isokinetic exercise) of the muscles *palatopharyngeo*, uvula, tensor and the levator *soft palate*. The patient was oriented to: a) open wide his oral cavity, position the tongue against mouth floor and produce abrupt sounds of open vowel /a/, generating the elevation of the soft *palate* (isotonic exercise), in a rate of 3 series of 10 repetitions; and b) emit a sustained /a/ vowel, to keep the velum raised and contracted, while keeping the tongue in the mouth floor, making 10 repetitions, three times a day, in the morning, afternoon and night, every day in the week [60,42].

## 9. Local rehabilitation of the jaw elevator muscles

This training task targets jaw elevator muscles which appear to be hypotonic in mouth-breathers [62]. Changes in tone and strength of the muscles in question are the outcomes of these exercises. Each exercise is described by its name followed by its description in the paragraph below. Alternate the listed exercises according to the prescription and carry out the whole series of the chosen exercises two-three times a day.

*Count to ten*: Tighten the teeth with the lips in a half-closed way and keep this position counting to ten; at the same time place the index and middle finger on the posterior area of both of the cheeks in order to feel the muscular contraction, then relax. Ten repetitions, each one for 10 s.

*Tiii*: With tightened teeth and half-closed lips, pronounce strongly the sound TIII, exhaling across the teeth. Ten repetitions.

*Ciuuu*: With tightened teeth and half-closed lips pronounce the sound 'CIUUUU' and move, by blowing out air, a piece of paper placed on the palm of the hand. Ten repetitions.

*Peg*: Open and close a wooden peg by tightening and relaxing the teeth. Ten repetitions.

With the same purpose of the previous exercises we would suggest to use chewing gums as an effective means for the voluntary development of the muscular strength. It could be useful to stick the gum on the palate roof, then pinch it with the back of the tongue. This exercise is meant to improve

self-perception of tongue's peristalsis, as well as to tone up its muscles.

## 10. General rehabilitation

The ventilation model of the lower airway appears to be often impaired in mouth-breathers [1,2,39]. The procedure to restore the respiratory function via body training exercises has been known for many years; the purpose is to ease the cost-diaphragmatic breathing by finding out the right balance of the muscles involved. The program presented consists of the following exercises a speech therapist would have to teach to the patient. Perform two-three series a day of the chosen exercises, then switch them.

### 10.1. Breathing awareness

Place the hand on the abdomen, just below the chest, and slide it upwards during inhalation, downward in exhalation. Ten repetitions.

### 10.2. Diaphragm mobilization

Supine position, lay one hand on the upper chest and the other one on the abdomen; slowly breathe through the nostrils imagining that the hands are placed on the plates of a scale and are alternatively raised and lowered during breathing. Ten repetitions.

### 10.3. Perception of breathing sensations

While sitting, slowly inhale, then stop breathing for two-three seconds and slowly exhale, perceiving the warm air flow incoming and the cold one outgoing. Ten repetitions.

### 10.4. Sniff-test

Exhale three times quickly and as many times slowly paying attention to the movement of the diaphragm. Ten repetitions.

### 10.5. Diaphragmatic-abdominal mobilization

While sitting with crossed legs, perform a total exhalation, then expand the chest in apnea contracting the muscles of the rib cage; voluntarily contract the belly, slowly let the air through the lips, then slowly relax. Ten repetitions.

### 10.6. Supine position and extended legs

Supine position with extended legs and the arms along the body, exhale by blowing and retracting the abdomen or, in other words, by pressing the lower back against the floor, then relax the muscles, inhale and inflate the abdomen, making sure to detach the back from the floor. Ten repetitions.

### 10.7. Supine position and flexed legs

Supine position with flexed apart legs, the soles well flat on the floor and the feet in contact with each other, exhale

closing the knees and pressing the back against the floor. Then let the air in, dropping the knees toward the outside and slightly lifting the pelvis off the floor, meanwhile the abdomen and the chest are inflating. Ten repetitions.

Since we treat young patients we think that using pictures to explain the correct movement of the chest is useful. The lower chest that expands due to the movement of the rib is comparable to lift a bucket handle, while the upper chest movement, i.e. the sternum that lifts, can be pictured as the lever of a pump [63].

In order to learn the perception of respiratory muscles and to set a correct breathing dynamic, our therapeutic program involves breathing exercises which derive from the ancient yoga technique of pranayama, where this term means the control of life energy through breathing [64].

The 'square breath' is the basic exercise we refer to. The four phases of breathing, namely inhalation, retention of breath, exhalation and retention of emptiness, are bonded in a rhythmic form. This breathing scheme can be viewed as a square: the patient ideally follows the left vertical side of the square from the bottom upwards (inhalation), the upper horizontal side from the left to the right (retention of breath), the right vertical side from the top downwards (exhalation), the lower horizontal one from the right to the left (retention of emptiness). One must start the exercise emptying the lungs completely, then go ideally along each side of the square with the right rhythm, keeping open the vocal cords for the whole exercise timing. It is important to underline that the break between inspiration and expiration phases are different from the state of apnea, during which the glottis is involuntarily closed. Progressively it will be possible to add some variants within the same exercise such as the contraction of the abdominal wall during the breathing retention. The deep and slow breath of pranayama seems to modify the autonomic control of breathing by increasing the vagal tone and reducing the sympathetic activity [65].

Scientific literature shows the decrease of the breathing dead space and the increase of the vital capacity of the lungs when pranayama exercises are performed by young adults in good health conditions [66]. The same exercises are practiced, particularly in India, as a non-pharmacological treatment of respiratory diseases, such as the bronchial asthma, with proven positive effects on the patient's symptoms [67,68].

In our program we suggest to integrate the mentioned breathing exercises with the so-called 'Alexander technique'. This technique, introduced by Alexander more than a hundred years ago, is a form of physical therapy aimed at the correction of posture by keeping head, neck and trunk in their natural alignment. It does not involve exercises, rather these are lessons of musculoskeletal proprioceptive education during which an adequately trained instructor teaches the learner, via explanations and hand contact, to adjust their posture; the instructor modifies patient's movement habits and their body response to external stimuli [69].

Early evidence in literature state that the Alexander Technique may positively influence the lung function [69,70]. Austin [71] assumes that the subjective breathing improvement experimented by healthy young adults involved in his study is linked to the following steps: reduction of cervical lordosis, increase of the muscular strength of the abdominal

wall, decreased muscular tension of the chest wall with greater expansion of the rib cage, reduction of musculoskeletal interferences in the respiratory movement coordination. These effects would justify the use of the Alexander technique in mouth-breathing children, who often present postural alterations as well [72-74].

## 11. Conclusion

If RME is supported by an adequate functional rehabilitation, the possibility to change the breathing pattern is considerably amplified. The physical exercises (local and general ones) and the nasal washes represent the crucial points of our program that should be customized for each patient. Awareness, motivation and collaboration of the child and their parents, as well as the cooperation among specialists, such as orthodontist, speech therapist, pediatrician and otolaryngologist, are necessary conditions to achieve the goal.

## REFERENCES

- [1] Levrimi A. *Terapia miofunzionale. Rieducazione neuromuscolare integrata*. Milano: Masson; 1997.
- [2] Cozza P, Polimeni A, De Toffol L. *Manuale di terapia miofunzionale*. Milano: Masson; 2002.
- [3] Villa MP, Brunetti L, Bruni O, Cirignotta F, Cozza P, Donzelli G, et al. Gruppo di Studio Interdisciplinare Disturbi Respiratori nel Sonno. Guidelines for the diagnosis of childhood obstructive sleep apnea syndrome. *Miner Pediatr* 2004;56(3):239-53.
- [4] Peltomäki T. The effect of mode of breathing on craniofacial growth—revisited. *Eur J Orthod* 2007;29(5):426-9.
- [5] Giuca MR, Pasini M, Galli V, Casani AP, Marchetti E, Marzo G. Correlations between transversal discrepancies of the upper maxilla and oral breathing. *Eur J Paediatr Dentist* 2009;10(1):23-8.
- [6] Haas AJ. Rapid expansion of the maxillary dental arch and nasal cavity by opening the midpalatal suture. *Angle Orthod* 1961;31:73-86.
- [7] Enoki C, Valera FC, Lessa FC, Elias AM, Matsumoto MA, Anselmo-Lima WT. Effect of rapid maxillary expansion on the dimension of the nasal cavity and on nasal air resistance. *Int J Pediatr Otorhinolaryngol* 2006;70(7):1225-30.
- [8] Compadretti GC, Tasca I, Bonetti GA. Nasal airway measurements in children treated by rapid maxillary expansion. *Am J Rhinol Aller* 2006;20(4):385-93.
- [9] Ramires T, Maia RA, Barone JR. Nasal cavity changes and the respiratory standard after maxillary expansion. *Braz J Otorhinolaryngol* 2008;74(5):763-9.
- [10] Kiliç N, Oktay H. Effects of rapid maxillary expansion on nasal breathing and some naso-respiratory and breathing problems in growing children: a literature review. *Int J Pediatr Otorhinolaryngol* 2008;72(11):1595-601.
- [11] Ballanti F, Lione R, Baccetti T, Franchi L, Cozza P. Treatment and post-treatment skeletal effects of rapid maxillary expansion investigated with low-dose computed tomography in growing subjects. *Am J Orthod Dentofacial Orthop* 2010;138(3):311-7.
- [12] Ozbek MM, Memikoglu UT, Altug-Atac AT, Lowe AA. Stability of maxillary expansion and tongue posture. *Angle Orthod* 2009;79(2):214-20.

- [13] Buccheri A, Dilella G, Stella R. Rapid palatal expansion and pharyngeal space. *Cephalometric evaluation. Prog Orthod* 2004;5(2):160-71.
- [14] Haas SA. The treatment of maxillary deficiency by opening the midpalatal suture. *Angle Orthod* 1965;35(3):200-17.
- [15] Baccetti T, Franchi L, Cameron CG, McNamara Jr. JA. Treatment timing for rapid maxillary expansion. *Angle Orthod* 2001;71(5):343-50.
- [16] Cameron CG, Franchi L, Baccetti T, McNamara Jr. JA. Long-term effects of rapid maxillary expansion: a posteroanterior cephalometric evaluation. *Am J Orthod Dentofacial Orthop* 2002;121(2):129-35.
- [17] Tecco S, Festa F, Tete S, Longhi V, D'Attilio M. Changes in head posture after rapid maxillary expansion in mouth-breathing girls: a controlled study. *Angle Orthod* 2005;75(2):171-6.
- [18] Monini S, Malagola C, Villa MP, Tripodi C, Tarentini S, Malagnino I, et al. Rapid maxillary expansion for the treatment of nasal obstruction in children younger than 12 years. *Arch Otolaryngol Head Neck Surg* 2009;135(1):22-7.
- [19] Palaisa J, Ngan P, Martin C, Razmus T. Use of conventional tomography to evaluate changes in the nasal cavity with rapid palatal expansion. *Am J Orthod Dentofacial Orthop* 2007;132(4):458-66.
- [20] Garrett BJ, Caruso JM, Rungcharassaeng K, Farrage JR, Kim JS, Taylor GD. Skeletal effects to the maxilla after rapid maxillary expansion assessed with cone-beam computed tomography. *Am J Orthod Dentofacial Orthop* 2008;134(1):8-9.
- [21] Zhao Y, Nguyen M, Gohl E, Mah JK, Sameshima G, Enciso R. Oropharyngeal airway changes after rapid palatal expansion evaluated with cone-beam computed tomography. *Am J Orthod Dentofacial Orthop* 2010;137(4 Suppl):S71-8.
- [22] Cordasco G, Nucera R, Fastuca R, Matarese G, Lindauer SJ, Leone P, et al. Effects of orthopedic maxillary expansion on nasal cavity size in growing subjects: a low dose computer tomography clinical trial. *Int J Pediatr Otorhinolaryngol* 2012;76(11):1547-51.
- [23] Doruk C, Sökücü O, Sezer H, Canbay EI. Evaluation of nasal airway resistance during rapid maxillary expansion using acoustic rhinometry. *Eur J Orthod* 2004;26(4):397-401.
- [24] De Felipe NL, Da Silveira AC, Viana G, Kusnoto B, Smith B, Evans CA. Relationship between rapid maxillary expansion and nasal cavity size and airway resistance: short- and long-term effects. *Am J Orthod Dentofacial Orthop* 2008;134(3):370-82.
- [25] De Felipe NL, Bhushan N, Da Silveira AC, Viana G, Smith B. Long-term effects of orthodontic therapy on the maxillary dental arch and nasal cavity. *Am J Orthod Dentofacial Orthoped* 2009;136(4):136(4) (490.e1-8; discussion 490-1).
- [26] Hartgerink DV, Vig PS, Abbott DW. The effect of rapid maxillary expansion on nasal airway resistance. *Am J Orthod Dentofacial Orthoped* 1987;92(5):381-9.
- [27] Monini S, Malagola C, Villa MP, Tripodi C, Tarentini S, Malagnino I, et al. Rapid maxillary expansion for the treatment of nasal obstruction in children younger than 12 years. *Arch Otolaryngol Head Neck Surg* 2009;135:22-7.
- [28] Hershey HG, Stewart BL, Warren DW. Changes in nasal airway resistance associated with rapid maxillary expansion. *Am J Orthod* 1976;69(3):274-84.
- [29] Timms DJ. Rapid maxillary expansion in the treatment of nasal obstruction and respiratory disease. *Ear, Nose Throat J* 1987;66(6):242-7.
- [30] Doruk C, Bicakci AA, Basciftci FA, Agar U, Babacan H. A comparison of the effects of rapid maxillary expansion and fan-type rapid maxillary expansion on dentofacial structures. *Angle Orthod* 2004;74(2):184-94.
- [31] Warren DW, Hershey HG, Turvey TA, Hinton VA, Hairfield WM. The nasal airway following maxillary expansion. *Am J Orthod Dentofacial Orthoped* 1987;91(2):111-6.
- [32] Baratieri C, Alves Jr M, de Souza MM, de Souza Araújo MT, Maia LC. Does rapid maxillary expansion have long-term effects on airway dimensions and breathing? *Am J Orthod Dentofacial Orthoped* 2011;140(2):146-56.
- [33] Howland J. The winning team: orthodontics and myofunctional therapy. *Int J Oral Myol* 1979;5(3):13-4.
- [34] Picchioni P, Soli P, Pirini D. Treatment of orofacial musculature imbalance. *Mondo Ortodontico* 1990;15(1):71-90.
- [35] Padovan BA. Neurofunctional reorganization in myo-osteodentofacial disorders: complementary roles of orthodontics, speech and myofunctional therapy. *Int J Orofacial Myol* 1995;21:33-40.
- [36] Saccomanno S, Antonini G, D'Alatri L, D'Angelantonio M, Fiorita A, Deli R. Causal relationship between malocclusion and oral muscles dysfunction: a model of approach. *Eur J Paediatr Dentist* 2012;13(4):321-3.
- [37] Giuca MR, Pasini M, Pagano A, Mummolo S, Vanni A. Longitudinal study on a rehabilitative model for correction of atypical swallowing. *Eur J Paediatr Dentist* 2008;9(4):170-4.
- [38] Levrini A, Caprioglio A, Levrini L. Rieducazione respiratoria: esercizi miofunzionali. *Dent Cadmos* 1994;17:17-48.
- [39] Villa MP, Bertarini AM, Pagani J, Paggi B, Montesano M, Alterio A, et al. Terapia mio funzionale in bambini con ostruzione delle alte vie respiratorie. *Rivista Italiana di Pediatria* 2001;27:229-36.
- [40] Cozza P, D'Aversa L, Mascolo F, Mucedero M, Rosignoli R. Riabilitazione respiratoria nella terapia miofunzionale. *Dent Cadmos* 2000;17:55-9.
- [41] Corrêa EC, Bérzin F. Efficacy of physical therapy on cervical muscle activity and on body posture in school-age mouth breathing children. *Int J Pediatr Otorhinolaryngol* 2007;71(10):1527-35.
- [42] Guimarães KC, Drager LF, Genta PR, Marcondes BF, Lorenzi-Filho G. Effects of oropharyngeal exercises on patients with moderate obstructive sleep apnea syndrome. *Am J Respir Crit Care Med* 2009;179(10):962-6.
- [43] Diaféria G, Badke L, Santos-Silva R, Bommarito S, Tufik S, Bittencourt L. Effect of speech therapy as adjunct treatment to continuous positive airway pressure on the quality of life of patients with obstructive sleep apnea. *Sleep Med* 2013;14(7):628-35.
- [44] Diaféria G. Speech therapy as adjunct treatment with the use of continuous positive airway pressure in patients with obstructive sleep apnea syndrome. *Dissertação (Mestrado)*. São Paulo:- Universidade Federal de São Paulo—Escola Paulista de Medicina. Programa de Pós-Graduação em Psicobiologia; 2012.
- [45] Fujii M, Logemann J. Effect of a tongue-holding maneuver on posterior pharyngeal wall movement during deglutition. *Am J Speech Lang Pathol* 1996;5:23-30.
- [46] Logemann JA, Pauloski BR, Rademaker AW, Colangelo LA. Speech and swallowing rehabilitation for head and neck cancer patients. *Oncology* 1997;11(5):651-64.
- [47] Krakauer LH, Di Francesco RC, Marchesan IQ. *Respiração oral: abordagem interdisciplinar*. Pulso: São José dos Campos; 2003.
- [48] Ferraz MCA. *Manual Prático de Motricidade Oral: Avaliação e tratamento*. [Practical Manual of Oral Motor Function: Evaluation and treatment.]. Rio de Janeiro: Revinter; 2001.
- [49] Furkin AM, Santini CS. *Disfagias orofaríngeas*. [Oropharyngeal dysphagia. São Paulo: Pró Fono; 1999.
- [50] Carvalho GDSOS. *Respirador bucal—uma visão funcional e clínica da amamentação*. São Paulo: Editora Lovise; 2003.
- [51] Burger RCP, Caixeta EC, Dininno CQMS. A relação entre apnéia do sono, ronco e respiração oral. [Relationship between sleep apnea, snoring and oral respiration.] *Rev. CEFAC [online journal]* (<http://www.cefac.com.br>) 2004.



- [52] Dantas DAS, Mauad T, Silva LFF, Lorenzi-Filho G, Formigoni GGS, Cahali MB. The extracellular matrix of the lateral pharyngeal wall in obstructive sleep apnea. *Sleep* 2012;35(4):483-90.
- [53] Schievano D, Rontani RMP, Berzin F. Influence of myofunctional therapy on the perioral muscles. *Clinical and electromyographic evaluations. J Oral Rehab* 1999;26:564-9.
- [54] Georgitis JW. Nasal hyperthermia and simple irrigation for perennial rhinitis. Changes in inflammatory mediators. *Chest* 1994;106(5):1487-92.
- [55] Bernkopf E, Broia V, Bertarini AM. Il lavaggio della mucosa rinosinusale con soluzione idrosalina calda. *Il Medico Pediatra* 1998;7(3):156-9.
- [56] Papsin B, McTavish A. Saline nasal irrigation: its role as an adjunct treatment. *Can Family Phys* 2003;49:168-73.
- [57] Rabago D, Zgierska A. Saline nasal irrigation for upper respiratory conditions. *Am Family Phys* 2009;80(10):1117-9.
- [58] Marchisio P, Varricchio A, Baggi E, Bianchini S, Capasso ME, Torretta S, et al. Hypertonic saline is more effective than normal saline in seasonal allergic rhinitis in children. *Int J Immunopathol Pharmacol* 2012;25(3):721-30.
- [59] Ambrosio AR, Trevilatto PC, Martins LP, Santos-Pinto AD, Shimizu RH. Electromyographic evaluation of the upper lip according to the breathing mode: a longitudinal study. *Braz Oral Res* 2009;23(4):415-23.
- [60] Furia CLB. Reabilitação fonoaudiológica das resseções de boca e orofaringe. In: Carrara-de Angelis E, Furia CLB, Mourão LF, Kowalski LP, A atuação da fonoaudiologia no câncer de cabeça e pescoço. São Paulo: Lovise; 2000.
- [61] Gurfinkel, VK. Respiração oral: Propostas de terapias. In: Motricidade orofacial: Como atuam os especialistas. Comitê de Motricidade Orofacial—SBFa. São José dos Campos: Pulso; 2004.
- [62] Ferla A, Silva AM, Corrêa EC. Electrical activity of the anterior temporal and masseter muscles in mouth and nasal breathing children. *Braz J Otorhinolaryngol* 2008;74(4):588-95.
- [63] Le Huche F, Allali A. La voce. Volume I: anatomia e fisiologia degli organi della voce e della parola, 2a ed.. Milano: Masson; 1993.
- [64] Magnani S. Curare la voce. Diagnosi e terapia dei disturbi della voce. Milano: Franco Angeli; 2005.
- [65] Bhargava R, Gogate MG, Mascarenhas JF. Autonomic responses to breath holding and its variations following pranayama. *Indian J Physiol Pharmacol* 1988;32(4):257-64.
- [66] Sivakumar G, Prabhu K, Baliga R, Pai MK, Manjunatha S. Acute effects of deep breathing for a short duration (2-10 min) on pulmonary functions in healthy young volunteers. *Indian J Physiol Pharmacol* 2011;55(2):154-9.
- [67] Nagarathna R, Nagendra HR. Yoga for bronchial asthma: a controlled study. *Br Med J (Clinical Research edition)* 1985;291(6502):1077-9.
- [68] Saxena T, Saxena M. The effect of various breathing exercises (pranayama) in patients with bronchial asthma of mild to moderate severity. *Int J Yoga* 2009;2(1):22-5.
- [69] Woodman JP, Moore NR. Evidence for the effectiveness of Alexander technique lessons in medical and health-related conditions: a systematic review. *Int J Clin Pract* 2012;66(1):98-112.
- [70] Dennis JA, Cates CJ. Alexander technique for chronic asthma. Available through: *Cochrane Database Syst Rev* 2012;12(9):CD000995.
- [71] Austin JH, Ausubel P. Enhanced respiratory muscular function in normal adults after lessons in proprioceptive musculoskeletal education without exercises. *Chest* 1992;102(2):486-90.
- [72] Silveira Wd, Mello FC, Guimarães FS, Menezes SL. Postural alterations and pulmonary function of mouth-breathing children. *Braz J Otorhinolaryngol* 2010;76(6):683-6.
- [73] Okuro RT, Morcillo AM, Sakano E, Schivinski CI, Ribeiro MÂ, Ribeiro JD. Exercise capacity, respiratory mechanics and posture in mouth breathers. *Braz J Otorhinolaryngol* 2011;77(5):656-62.
- [74] Fokkens WJ, Lund VJ, Mullol J, Bachert C, Alobid I, Baroody F, et al. EPOS 2012: European position paper on rhinosinusitis and nasal polyps. *Rhinol Suppl* 2012;23(3):1-298.