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Literature Review

Innovative Rehabilitation for Orofacial Praxis

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Abstract

Swallowing rehabilitation is a component to include in our treatment plan. Getting good results discourages many practitioners. We propose a totally innovative approach leading to physiological and biochemical modifications and inhibition of old circuits that do not call upon traditional time-consuming protocols. This new approach has been tested with a clinical study at CHRU University Hospital of Lille, France. The aim of the study was to determine its efficiency towards atypical swallowing in 10 weeks on 40 patients between 5 and 16 yo, all of them diagnosed with atypical swallowing. After 10 weeks of treatment, secondary deglutition was obtained for 80% of the patients including 60% automatization and "a significant decrease in the percentage value of the oral ventilation flow". Then 15 minutes a day during a few weeks is enough to get such results and allow an easy compliance even for young children.

Keywords: *Suction-Swallowing Swallowing-Mastication; Anoetic Network; Connexionism Between Networks*

Foreword

The signs of atypical swallowing are easily visible during the clinical examination. They differ very little from the signs of suction swallowing, which must be remembered as a physiological praxis in young children. When it continues after the establishment of mastication, it becomes dysfunctional and atypical [1].

The lower lip

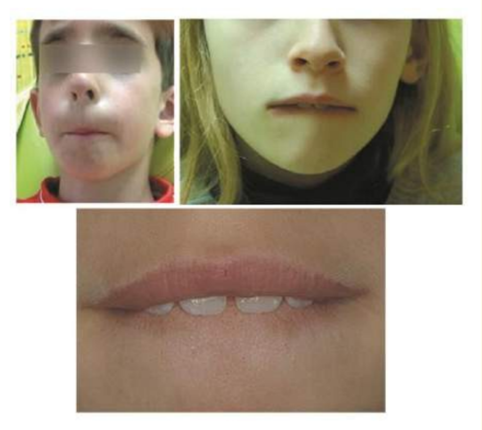


***Figure 1:** Bilabial contact and seal behind the upper incisors.*

Bilabial contact is essential in creating a seal in the anterior mouth and swallowing saliva by means of the pressure difference with the posterior mouth. In severe retromandibular, the seal can be pushed back behind the upper incisors [2].

Chin's muscles

***Figure 2:** Contraction of the chin's muscles to obtain bilabial contact.*

It is often necessary to raise the lower lip towards the upper, which is too short, by contraction of the depressor labii inferioris and the mentalis muscle.

Figure 3: *Change of the pelvic-mandibular angle during atypical swallowing and physiological swallowing.*

The nasal orifices

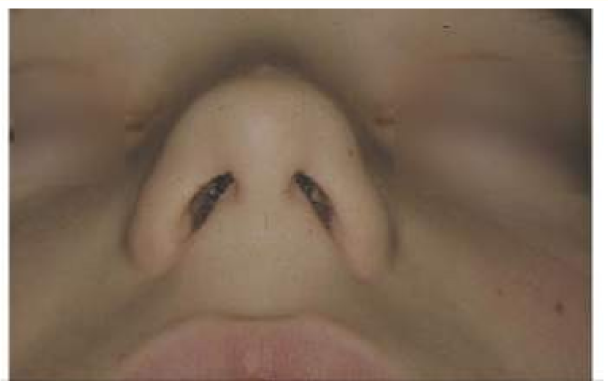


Figure 4: *Non-functional, hypotonic, or congested nasal orifices indicate mouth breathing.*

Buccinator depletion

The quickest and most significant test is to put your little finger against the inner side of the cheek and ask the patient to swallow.

Figure 5: *Perception of the jugal force in suction-type swallowing by the examiner.*

The perception of the force exerted by the cheeks against the dental arches allows us to understand the influence of dysfunctional swallowing on the transverse dimension of the maxillae.

Systematical activation of the facial nerve inhibits the action of the trigeminal nerve, necessary for dental occlusion.

Introduction

These dysfunctional children will need to learn new methods of physiological functioning, unfairly called "swallowing rehabilitation".

"Learning leads to a modification of the strength of the synaptic connections between specific cells in the neural circuits that manage behavior" [3].

This consists in establishing new circuits. This plasticity is achieved either by reorganizing the existing programs or by creating new ones [4].

When the anatomical environment is compatible, this therapeutic phase should take place in three steps: engrammation, automation, inhibition.

Literature Review

The traditional protocol is to use a top-down approach (instructions from the cortex to the motor sites concerned).

Exercises are proposed to patients by speech-language therapists; Exercises are voluntary actions managed by the cortical regions. First, the child needs to be made aware of the gestures he usually performs and then of the gestures he should be performing. This is what the neurosciences call a top-down approach, with instructions going from the cortex to the motor sites involved.

Hebb sensed that our learning memory lies in the synapses [5]. But Eric Kandel proved that in this approach, there is a neurotransmitter stimulation in the synapses, but the neural nuclei is not involved; short-term memory is activated for approximately six hours. This work was rewarded by the Nobel Prize in Medicine in 2000 [3].

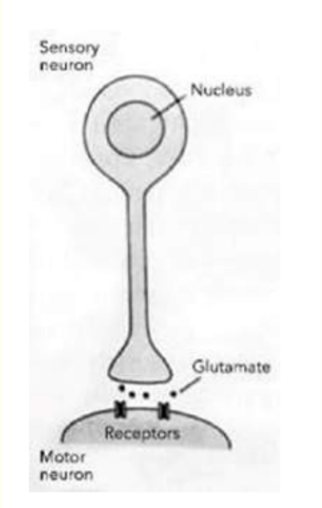


Figure 6: *Short-term memory: increase in the quantity of neurotransmitters.*
Source: Eric Kandel [3].

For short-term memory to be converted to long-term memory, neurons have to reorganize their genomes. This is possible: "neurons are not chained by their genes" [6].

If stimulations are repeated over a short period of time, a dialogue is created between the synapse and the nucleus to activate Cyclic AMP Response Element-Binding Protein (CREB-1)[1], inhibit CREB-2* and produce a new protein that is essential to the passage from short-term memory to long-term memory [7].

This new protein - CPEB[2]- will be present in the synapses and constantly ensures the permanent transmission of the message [8].

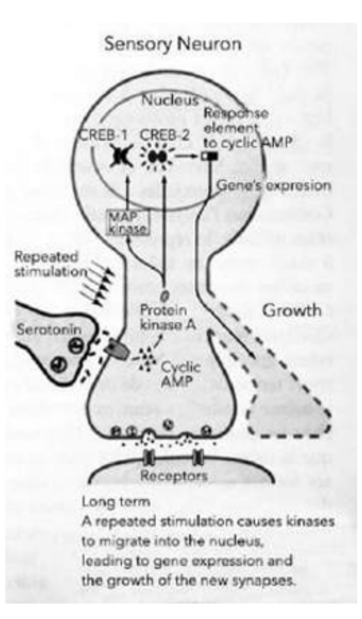


Figure 7: *Dialogue between the synapse and the nucleus Source: Eric Kandel [3].*

Practice makes perfect and needs repetition to be established in the long-term memory.

The most experienced rehabilitation specialists themselves admit that this practice is long and difficult and are not possible for young children which explains the results are often disappointing.

But this action on CREBs can be obtained much more easily: a highly emotional state can short-circuit the normal constraints and produce enough Mitogen-Activated Protein kinase (MAP-kinase)[3] molecules to be sent to the nucleus; this will further deactivate the CREB-2 molecules and facilitate activation of CREB-1 and the direct imprinting of this experience in the long-term memory (located in the basolateral region of the amygdala) [9,10]. This will produce the creation of new synapses and new neuralcircuits.

[1]CREB: Cyclic AMP Response Element-Binding Protein, a protein that activates the genes responsible for long-term memory.
[2]CPEB: Cytoplasmic Polyadenylation Element-Binding Protein.
[3]MAP kinase works in conjunction with protein kinase A to initiate long-term memorization.

If you had a car crash twenty years ago, you still remember - without having to constantly repeat to yourself - that it was a late afternoon in December, that it was raining, that you were wearing a blue raincoat. All of these information were immediately imprinted in your long-term memory.

This notion of facilitator stress was confirmed in studies by Shors and Servatius [11], who demonstrated that rats stressed using electric shocks learn faster and more durably than control animals.

“But stress facilitates memory mechanisms only when it is felt at the moment the patient has to memorize the event, and only when hormones and neurotransmitters activate the same networks as those activated by learning" [12].

A new bottom-up approach: Froggymouth®

The first step is engrammation (biochemical modification)

Froggymouth is a device that is worn fifteen minutes in front of a television screen (a treatment assimilated with a reward by the limbic system), causing the facilitator stress that generates MAP kinase production and forcing the child to find a new swallowing method by an anoetic[4] process.

Indeed, as he cannot close his lips, he cannot use suction to swallow, which causes a sharp, immediate reaction in the brainstem - The child is looking for a different swallowing program. Faced with this new situation, the child calls upon the patterns at their disposal. If he doesn't have a pattern that suits the new situation, the child will have to create new one that will immediately be engrammed in their procedural memory. This is an immediate incidental learning [12].

The simultaneous presence of a television screen is not innocent: placed at a distance from the screen, the child's look will be horizontal and parallel to the lingual plane, facilitating elevation of its posterior part. This would not be the case if the child were reading a book on his knees with his head tipped forward.

"A modifiable connection accompanied or followed by a state of satisfaction is consolidated. The pleasure reinforces the connection more than the annoyance weakens it" [13].

The new program is immediately integrated into the implicit memory, a memory that is not connected to any previous learning, does not require repetition to be retained, and which can be called up without requiring any conscious attention.

Implicit memories are saved in the cerebellum, the striatum, and the amygdala.

Second step: Automation

The first step has been described: engrammation, which is necessary but not sufficient for leading to automation.

"We have to admit that lingual, labial and functional neuromuscular relapse often occurs in rehabilitation. But is it really a question of relapse? That would imply that healing had been achieved. It would rather seem that the goal sought; i.e. automation of the functional posture, had not been achieved. And yet that is what true healing is. We are not sufficiently vigilant in meticulously monitoring that automation has been achieved. We are often happy with just observing the neuromuscular responses to the orders given. On the contrary, it is a matter of obtaining automatism, therefore an unconscious praxis" M. Fournier [14].

The child now has two programs for extra prandial swallowing and, like a computer, when they have two programs, activating one icon or the other will run the desired program.

The sucking-swallowing icon is activated by the facial nerve: "my lips are contracted, my teeth aren't touching each other".

The physiological swallowing icon - "my lips are relaxed, my molars are in occlusion" - is activated by the trigeminal nerve, which not only ensures molar occlusion but also protects the tongue from being bitten, due to the abundance of trigeminal nerve endings in its epithelial lining.

The therapist will have to monitor the posture at rest to obtain peri-oral muscle relaxation and dental occlusion during swallowing.

Trigeminal nerve control, which is solicited in this step, replaces facial nerve control and inhibits it. The trigeminal nerve also controls the respiratory centers in the pontine tegmentum through

[4]Controlled only by the lower brain.

its sensory nucleus, encouraging renewed nasal breathing and allowing the tongue to adopt a high posture in its posterior part. Odor recognition exercises emphasize restoration of nasal breathing, as the sense of smell and breathing use different circuits. This lets the sensory areas become familiar with the nasal pathway and use it for breathing [15].

Thinking that the absence of bilabial contact encourages the continued use of oral breathing is to ignore that the seal that blocks oral breathing is created further back by the lingual dome.

On this subject, R. Bjork has undertaken some interesting experimentations at UCLA. He proposed four learning protocols in which A corresponds to a conventional learning session. In our example the last A corresponds to wearing the Froggymouth, T to a test phase, and E to an evaluation of learning:

1. A.A.A.A.E.
2. A.A.A.T.E.
3. A.A.T.T.E.
4. A.T.T.T.E.

Most of the participants chose protocol 1, whereas the greatest efficacy rewarded protocol 4, which gives more value to the test phases than to the learning phases.

Dehaene confirms this approach "dozens of scientific publications demonstrate its effectiveness... The retrieval practice is one of the most effective teaching strategies. This strategy 4 will be used in game programs managed by artificial intelligence" [16].

The number of speech therapy sessions is therefore not an essential element in facilitating our therapeutic objectives. Wearing the Froggymouth is more than sufficient to integrate new data. This leaves more time to work on automation, since engrammation is almost instantaneous.

The best factor that can truly indicate to us that these new processes have been automated is an attentive study of phonation.

Ask the child to count out loud from 1 to 20 and observe the position of the tongue: if the sounds are formed by the lips, the tongue will not appear outside of the dental arches; when it comes time to swallow the child will only need to clench his teeth and use the new program. If, on the other hand, the therapist can see the tongue between the dental arches, this means that the sounds are being modulated by the tongue. When the time to swallow comes, it will be much more comfortable for the child to use the old program than to clench his teeth (the upper teeth are at a distance from the lower teeth), pull in his tongue to avoid biting it, swallow, open the teeth in occlusion and push his tongue forward to continue speaking.

Two simple exercises can be used to deal with this problem: once a day, have the child count from 1 to 60 through clenched teeth; he will have to use his lips and will understand the importance of this labial dynamic. The following week have him count from 1 to 60, not through clenched teeth, but rather clenching his teeth between each number and while increasing the speed.

The tongue may emerge laterally at first, but very quickly the speaking speed will not leave enough time and the tongue will find its place inside the dental arches.

This exercise will be rounded out by asking the child to suddenly clench his teeth in the middle of a conversation, the aim being to make him feel unsafe for his tongue to get in the way again.

The correlation between swallowing and verbal orality is reinforced by the fact that they use analogous anatomical pathways, but they use them in opposite directions [17,18].

Sucking on words is an expression of the persistence of primary orality in phonation, with the interposition of the tongue between the incisors, producing a lisp.

There is an antagonism between the method of swallowing and expressing oneself. You can't do two different things at the same time with the same organ.

Due to this antagonism, the role of phonation is key, contrary to certain preconceived ideas that consider speaking time to be too limited to have a mechanical effect on the dental arches.

These control sessions can be entrusted to the parents, who must ask their children three times a day whether their lips are in the correct position and correct them three times a day if they observe a contraction of the orbicularis oris muscles.

The third step is “Inhibition”

We have now seen the first two phases in the automation processes, but we have to reach the third step: inhibition of the old circuits.

"Learning is not just a question of the ability to produce a behavior that had been unknown to us, it is also an approach that seeks to inhibit automatic mental processes" [19].

"Learning also means eliminating" [20,21]: learning a new swallowing pattern means eliminating the previous one.

A McGill University research team has discovered at least two distinct processes happening in two cerebral networks when consolidating memory: the exciter neurons networks and the inhibitor neurons ones. Thanks to retroaction loop the latter opens doors normally closed for entering new information inhibiting the habitual network.

Daniel Kahneman, Nobel Prize in Economics in 2002, published in 2012 "Thinking, Fast and Slow," in which he describes two systems of thought in the human brain, "One heuristic, approximative and fast, System 1; the other analytical, exact but slower, System 2" [22].

System 1 dominates our thought through unconscious cognitive automatisms that can be observed in fMRI studies. System 2 is a reflex system that can counteract some of the automatisms in system 1 by taking their place, but at the cost of a slower, conscious effort.

Olivier Houde, in 2019, adds a system 3 that inhibits system 1 whose epicenter is located in the inferior frontal gyrus to enable system 2 to be implemented [23].

In light of these new considerations, we could interpret the question of swallowing rehabilitation as follows: noetic rehabilitation comes through system 2, whereas the sucking-swallowing program is established through the anoetic pathway and managed by system 1. In the case of conventional rehabilitation, there is a conflict between system 2 and system 1. In our approach to rehabilitation, changes to system 1 do not require a deliberate, conscious effort, but rather the establishment of new automatisms in system 1. The notion of comfort is what gives priority to the new program.

But it is especially important to understand that it is not the rehabilitation of a praxis which must be managed; swallowing for us orthodontists, breathing for sleep specialists, drainage of the inner ear for ENTs, speech for speech therapists, but the totality of orofacial praxes to ensure an overall dynamic balance. Fortunately, nature can help us if we respect acquisition processes that are physiological.

It's easy to control your lips. It is much more difficult to control your tongue and even more difficult to control the dynamics of the oropharyngeal or tympanic musculature. The idea is to focus on rehabilitating the lips and thus inducing a change in the associated neural circuits.

Effective rehabilitation concerning the neural circuits managing labial posture and dynamic can have an impact on other neural circuits.

Diffuse transmission exists between the various neural circuits, a form of cross-talk that intervenes in the production of related programs. We will come back to connectionism because we mustn't forget that memory is localized in different areas of the brain.

There are four to five times more glial cells than neurons, and they certainly play a major role in these interactions.

"Our study shows that glial cells are essential to the transmission of signals between neurons. This notably reveals that our species elaborate cognitive capacities. These capacities come not only from our sophisticated neural networks - they also reflect the evolution of our glial cells, which are more abundant, complex and diverse than in any other species" [24].

If we compare the dialogue between two neurons in the synapse to a phone call between two people, the presence of glial cells around the synapse makes it possible to pick up the message transmitted and to spread it to neighboring neural circuits like a transistor radio.

This "connectionist" system reminds us of how falling dominos work. The simple fact of controlling labial posture will activate the swallowing circuit which will activate the control of nasal breathing, and so ensure the rehabilitation of praxes that are difficult to access.

Visualization of Froggymouth effects by fMRI

Magnetic fields are used to detect variations in oxygen consumption and the relationship between oxyhemoglobin and deoxyhemoglobin, which gives a reconstructed view of activity in the different regions of the brain.

We have observed areas of constantly increased signal changes in the caudal sensorimotor cortex, the anterior insula, the premotor cortex, the frontal operculum, the anterior cortex and the prefrontal cortex, the anterolateral and posterior parietal cortex, and the precuneus and medial superior temporal cortex.

Swallowing recruits several cerebral regions, notably the caudolateral sensorimotor cortex, the premotor cortex, the insula and the temporopolar cortex, with varying degrees of hemispheric lateralization. Cerebral activity decreases with practice.

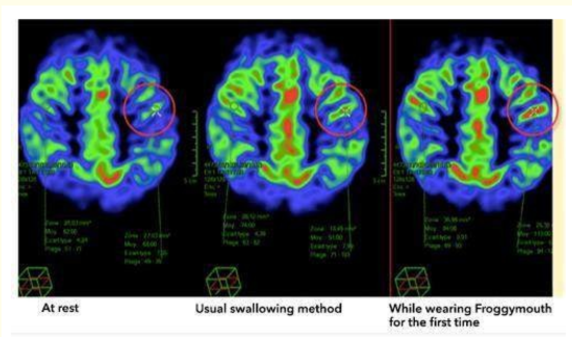


Figure 8: *Viewing of the role of the Froggymouth using fMRI.*

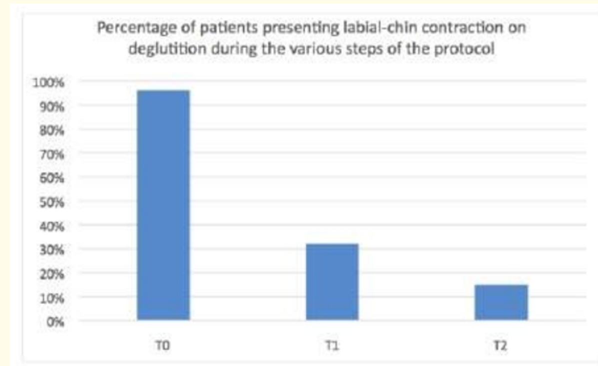
Thus, with an MRI performed in Arterial Spin Labeling, there is an increase in subcortical and sensorimotor cortical activity (at the level of the central sulcus) during swallowing, and in particular a 34% increase in cerebral perfusion at the sensorimotor cortical level.

This increase is 66% larger when using the Froggymouth. Consequently, we see that the use of Froggymouth induces changes in brain activity at the level of the sensorimotor cortex during swallowing. It is those new sensations and the corresponding cerebral modifications that does allow rehabilitation (Gaillard R.).

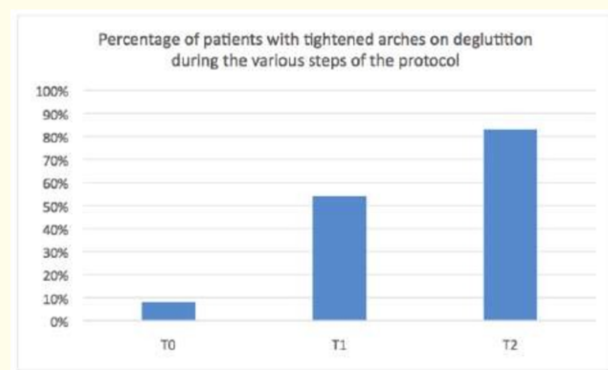
Materials and Methods

A study, carried out by Dr. Pauline Cornut and the Department of Biostatistics at the CHRU University Hospital in Lille, have studied during 10 weeks 40 patients, 25 girls and 15 boys. The patients were at different stages of their treatments. Some had finished, others were still underway and undergoing rehabilitation trials, but all still had atypical swallowing. Twenty patients never received orthodontic treatment, 19 wore functional education devices, 4 were undergoing multi-attachment treatment and 5 had retainers.

At the first visit (T0), more than 95% of patients presented labial-chin contraction on swallowing, which decreased significantly after five and ten weeks of using the froggymouth ($p < 0.0001$).



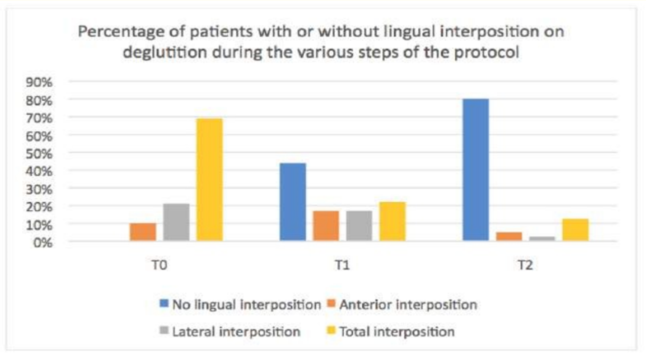
Graph 1: *Percentage of patients presenting labial-chin contraction on swallowing during the various steps of the protocol.*



Graph 2: *Percentage of patients with tightened arches on swallowing during the various steps of the protocol.*

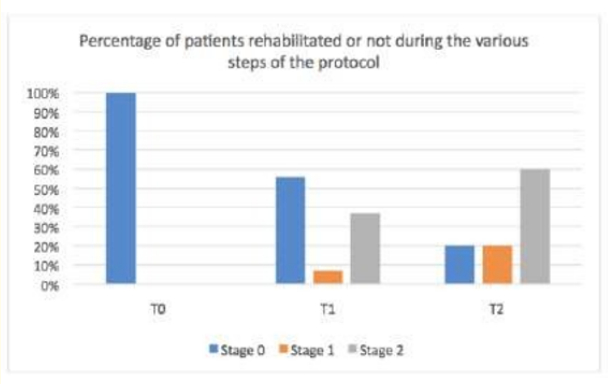
We observe a significant difference ($p < 0.0001$) between the rate of swallowing with tightened arches between the first visit (T0) and the end of the protocol (T2).

A decrease in lingual interposition was observed at ten weeks (T2), whether anterior, lateral or total. At T1, an increase in anterior interposition was seen compared with T0, which could be explained by the hypothesis that some patients with lateral or total lingual interposition go through a stage of anterior interposition.



Graph 3: *Percentage of patients with or without lingual interposition on swallowing during the various steps of the protocol.*

Statistics were not possible for this part because none of the patients with an absence of lingual interposition at T0. However, we can observe that 80% of patients no longer showed any lingual interposition at the end of the protocol.



Graph 4: *Percentage of patients rehabilitated or not during the various steps of the protocol.*

Stage 0 is when swallowing has not been acquired. Stage 1 is when swallowing is undergoing automation. Stage 2 is the stage of rehabilitated swallowing.

At the first visit (T0), all patients are at stage 0 since they all have atypical swallowing.

Results

After ten weeks of treatment with Froggymouth, 20% of patients show no signs of improved swallowing (stage 0), 20% of patients have understood the swallowing-mastication mechanism but have not acquired automation of this new posture (stage 1) and 60% of patients have acquired automatic swallowing- mastication (stage 2).

We thus observe significant rehabilitation of swallowing after ten weeks of using Froggymouth.

Reported cases

Results with Froggymouth only

Figure 9: *Open bite treatment.*

Simply wearing the Froggymouth allowed a near normalization of the open bite in two weeks.

Figure 10: *Dysmorphosis treatment between March 31st (Top left) and October 11 (bottom right) in a 4-year- old patient.*

This four-year-old girl showed an anterior open bite before functional treatment. She was wearing the Froggymouth for two months. The dysmorphic feature continued to correct itself spontaneously after the treatment. The result obtained does let us predict permanent physiological dental occlusion without any orthodontic intervention.

Narcolepsy

Figure 11: *Narcolepsy treated with Froggymouth.*

Narcolepsy-cataplexy is a highly debilitating sleep disorder characterized by uncontrollable sleeping attacks that can occur in the middle of an activity during the daytime, with a sudden loss of muscle strength but no loss of consciousness. It is mainly triggered by emotions: surprise or a funny story).

The symptoms may range from a slackening of the facial muscles that is barely perceivable to a drop of the jaw or head, weakness in the knees or total collapse.

Related attention-deficit disorders make re-education difficult, with a high rate of failure. The bottom-up approach provides immediate results with no constraints for the child. Lymphangioma and multi-cysts in the oropharynx.

An immediate change in his lingual posture can be noticed the first time he used Froggymouth.

Without wishing to predict the future, one notes that the tongue has posteriorized and is often found inside the oral cavity and the apex is less prominent. This stage enabled the healthcare team at Hospital Necker- Enfants Malades to postpone a glossectomy that had been scheduled.

Figure 12: *Lymphangioma and multi-cysts in the oropharynx.*

Results with orthopedic appliance and Froggymouth

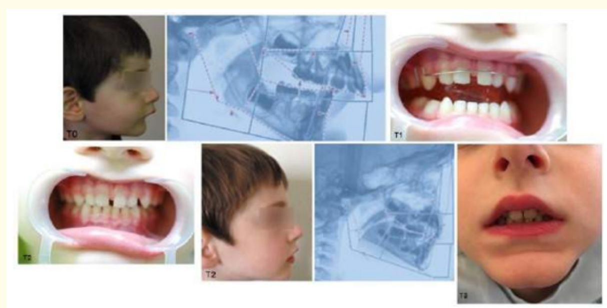


Figure 13: *Correction of severe retromandibular.*

Marc came at 4 with this severe retromandibulia (T0) - He was treated with a “Toboggan” stimulating sagittal growth when swallowing and a Froggymouth (T1). Interrupting the treatment at the age of 5, (T2) he came back at the age of 8 with satisfactory occlusal and dental alignment (T3).

Figure 14: *Lymphatic malformation.*

Results on a patient with lymphatic malformation

Lymphatic malformation (LM), formerly called lymphangioma, is a benign malformation of the lymphatic vessels that is hamartomatous in nature and is caused by the sequestration of lymphatic tissue that maintains its growth potential.

Mandibular prognathism is brought about by an excessive lingual volume at the origin of an overly anterior dysposture.

Wearing Froggymouth repositioned the rear section of the tongue, slowing mandibular growth and the anteriorization of the medium stage of the face.

Discussion and Conclusion

New clinical studies are launched in INSERM (France) University of Louvain (Belgium) and Alquila University (Italy). It seems that the Froggymouth separating the two lips acts as a catalyst and enable only controlling the lips to have an almost global orofacial praxis rehabilitation. New double-blind studies are launched and will determine more precisely the efficiency of the Froggymouth.

When prescribed at around four years old for slight deformities, this device normalizes functions and ensures a return to eumorphic growth without the systematic use of an orthodontic treatment.

At the age of six years, most of the pathologies that will require treatment can be diagnosed. Why wait to correct them a few years later when there is practically no chance that a spontaneous correction will occur?

Early treatment of occlusal abnormalities can thus avoid a worsening of the situation brought on by growth in an unbalanced muscle environment.

But even if it is undertaken later, close to adolescence, treating muscle dynamics will ensure that growth and the mechanics of dental devices work together, leading to shorter treatment times.

Once the malpositions have been corrected, stability can only be obtained if the causes have been eliminated and a functional environment obtained.

The benefits go far beyond the context of dental occlusion: a reduction in bouts of serous otitis (during swallowing-mastication the tensor tympani contracts, which helps ventilate the middle ear by dilating the Eustachian tube), equalizing the pressures on each side of the tympanic membrane. The usual posture will be modified,

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