

## Evolution of Theory on Oral Appliances and Exercises for Sleep Apnea and Snoring

By Allen J. Moses, DDS

### Introduction

Patient exercises have been shown in two randomized controlled studies to be effective for reducing both the symptoms and severity in patients with moderate obstructive sleep apnea syndrome. A study by Puhan,<sup>1</sup> et. al. involved lessons to practice and play the didgeridoo, a wind instrument that involves voice control as well as breath control. Regularly playing the didgeridoo, 5.9 days per week for an average playing time of 25.3 minutes per day, for a four month period of time reduced the average Apnea/Hypopnea Index (a measure of severity) by almost 50% (22.3 to 11.6) and lowered the sleepiness (symptom) from an average Epworth Sleepiness Scale score of 11.8 to 7.4.

Guimares,<sup>2</sup> et. al. showed in a randomized controlled trial that oropharyngeal exercises developed for the treatment of OSAS significantly reduced the AHI (severity) and subjective symptoms as well. The exercises, derived from speech therapy, consisted of isometric and isotonic involvement of muscles of the tongue, soft palate, and lateral pharyngeal wall. The exercise set consisted of activities simulating suction, swallowing, chewing, breathing and speech. The target effects are soft palate elevation, tongue protrusion and mandibular elevation to keep the lips together. This study was not designed to explore the exact mechanism by which the signs and symptoms were improved. It does demonstrate that daytime exercises alter muscle tone during sleep.

### Reflex Activity

The oral cavity, the tongue and the pharynx are functionally integrated to perform such vital and complex life functions as breathing, drinking, masticating, swallowing, and speaking. The sensory receptors that innervate these parts are constituents of reflex systems that reflect a huge range of complexity. These oropharyngeal reflexes are in fact critical to maintaining life. Reflexes in the upper airway are protective by preventing aspiration, facilitating vocalization, transporting boluses of food and water and protective of breathing by maintaining a patent airway.

Genioglossus, the main tongue muscle, is a protruder. It has an important role in airway protection and maintenance of airway patency, especially in patients with obstructive sleep apnea. Styloglossus and hyoglossus are tongue retruders. Activation of genioglossus under hypoxic and hypercapnic conditions brings about tongue protrusion and pharyngeal airway dilation.<sup>3,4</sup> In a study by Mateika,<sup>5</sup> et. al. the styloglossus and hyoglossus were also coactivated in response to hypoxia

and hypercapnia. This coactivation is the response of complex reflex activity between tongue protruders, tongue retruders and chemical sensors in the central nervous system.

A reflex is defined as the sum total of any particular involuntary activity.<sup>6</sup> Specific sensory inputs can subconsciously induce motor responses that have reciprocal effects on different motoneuron pools. Reflexes provide relatively hard wired circuits through the central nervous system to control a set of often antagonistic muscles for co-ordination of a given response, such as a swallow. The motor neurons and the Golgi tendon system are part of a neurologic feedback loop for maintaining muscle tone.

A reflex reaction is conditioned not by one reflex arc but many. Coordination is part of the reflex. According to Sherrington,<sup>7</sup> "the main secret of nervous coordination lies in the compounding of reflexes". Learning is involved in establishing many reflexes. Reflexes elicited from stimulating the oral region alter recruitment of lip, tongue and jaw muscles. The type of sensory stimulus determines the type of reflex elicited – from simple reflexes to complex behavior affecting oral and pharyngeal regions. Motor neurons responsible for the reflex activity of the head and neck are located in the brainstem – medulla, pons and midbrain.

The tongue is a complex muscular organ. Extrinsic tongue muscles attach to at least one bone and function to alter the shape of the tongue. Intrinsic tongue muscles have both their origin and insertion in muscle. They protrude, retrace and move the tongue laterally. The chief tongue protruder, the genioglossus muscle is extrinsic.

The electromyographic activity of genioglossus has been shown to be in phase with respiration when awake or in a resting state.<sup>8</sup> Changes in mandibular posture have a direct effect on tongue activity and may relate to the role of the tongue in airway maintenance.<sup>9</sup> Reflexes elicited from stimulating the oral region alter recruitment of lip, tongue and jaw muscles. The type of sensory stimulus determines the type of reflex elicited – from simple reflexes to complex behavior affecting oral and pharyngeal regions.

An important part of the research of A. J. Miller<sup>10</sup> has been description and study of reflexes controlling orofacial function. Relative to tongue protrusion Miller has identified five tongue reflexes. Tongue reflexes are activated from motoneurons from three cranial nerves: hypoglossal, trigeminal and glossopharyngeal.

### Jaw-Hypoglossal Reflex<sup>7</sup>

The hypoglossal nerve (XII) is the only motor nerve to the genioglossus muscle. Stimulation of the medial branch of the hypoglossal nerve causes genioglossus protrusion. The jaw-hypoglossal reflex is that stimulation of the inferior alveolar

Assistant Professor, Rush University College of Medicine, Chicago IL, USA Department of Sleep Disorders.

nerve ( $V_{III}$ ) causes firing of hypoglossal motoneurons, a phenomenon that could not be activated by direct stimulation of the hypoglossal nerve. The hypoglossal motoneurons in this reflex protrude the tongue. Passive opening of the mandible by a sleep appliance increases the activity of genioglossus muscle. The position of the mandible in a sleep appliance affects tongue posture and the amount of protrusion. Forward protrusion of the tongue helps maintain a patent airway. Oral appliances for sleep apnea should be conceived to facilitate this reflex by a non-restrictive, open anterior design.

### Masseter-Hypoglossal Reflex<sup>7</sup>

Direct stimulation of the masseteric nerve ( $V_{III}$ ) contracts the masseter muscle. The masseter-hypoglossal reflex is that masseteric nerve stimulation also *inhibits* polysynaptic firing of hypoglossal motoneurons to *retrusive* tongue muscles. A passive jaw opening beyond rest position stimulates the masseter to shorten, eliciting reproducible inhibition of tongue muscle retrusion that lasts as long as the jaw is open. Stimulation of this reflex can be easily incorporated into oral sleep appliances to inhibit tongue retrusion while the appliance is worn in the mouth.

### Lingual-Hypoglossal Reflex<sup>7</sup>

The lingual nerve is a branch of the third and largest division of the trigeminal nerve ( $V$ ) with a mostly sensory function. Mechanical stimulation of the surface of the tongue by light probing or scraping can induce multiple reflexes involving such functions as opening the jaws, closure of the glottis, elevation of the palate and some degree of tongue retrusion, but mostly tongue protrusion. The lingual-hypoglossal reflex, triggered by tongue stimulation, depends on the site of the sensory input. Stimulation of the medial branch of the hypoglossal nerve innervates intrinsic tongue muscles and brings about protrusion. The lingual-hypoglossal reflex can be facilitated by a prior conditioning reflex and thus trained by exercise. Stimulation of this reflex can also be incorporated into oral appliance design.

### Glossopharyngeal-Hypoglossal Reflex<sup>7</sup>

The glossopharyngeal nerve contains sensory fibers that innervate the lateral border of the posterior  $\frac{1}{3}$  of the tongue. Stimulation of the lateral border of the posterior  $\frac{1}{3}$  of the tongue induces reflex discharges in hypoglossal motoneurons that cause the tongue to protrude and that also inhibit retrusive hypoglossal motoneurons.

### Tongue-Tongue Reflex<sup>7</sup>

The lingual nerve provides sensory innervations to the tip of the tongue. The tongue-tongue reflex is that touch or stroking on the tip of the tongue stimulates hypoglossal motoneurons that cause the tongue to orient toward the stimulus.<sup>11</sup> The more intense the stimulation, the higher the probability of tongue movement toward the source. Mechanical stimulation of the dorsal surface of the tongue will induce the same reflex as direct stimulation of the lingual sensory nerve. Coordination of the tongue-tongue relies heavily on exteroceptors on the tongue surface. Stimulation of this reflex can be incorporated into the design of oral sleep apnea appliances.

## Discussion

Studies by Isono,<sup>12</sup> Miki,<sup>13</sup> Edmonds,<sup>14</sup> Decker,<sup>15</sup> Guilleminault<sup>16</sup> and Schwartz<sup>17</sup> have demonstrated that electrical stimulation directed at hypoglossal motoneurons stiffen the retroglossal airway. As a therapeutic approach electrical stimulation has failed to obtain satisfactory results. Too often the electrical stimulation caused cortical arousal resulting in poor sleep quality. The dilation effect only lasted as long as the electrical stimulation was on. Placement of the electrodes often caused pain.

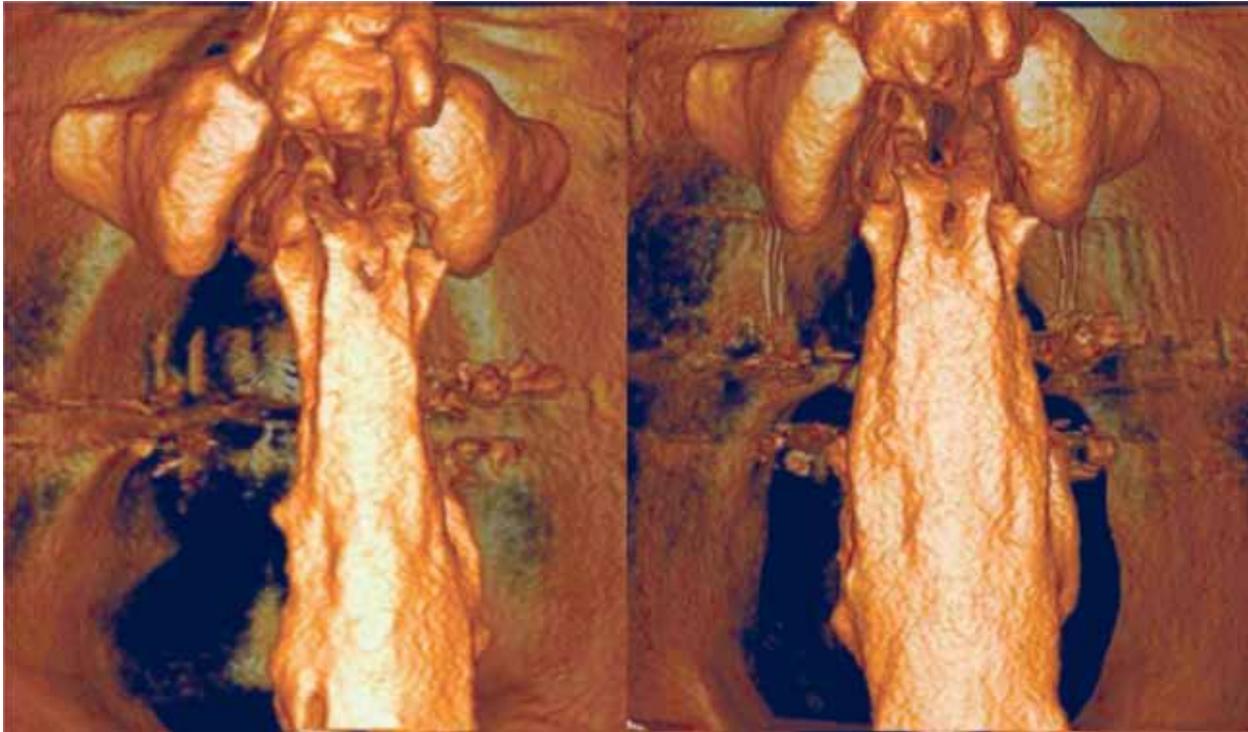
A previous study by Moses<sup>18</sup> demonstrated visually the effect of an oral appliance (Figure 1) to actually achieve airway dilation. Placing that oral device in the mouth gives the appearance of airway dilation similar to the splinting effect of CPAP (Figure 2). The dilation from the appliance however, occurred downstream from the actual site of the appliance in the mouth. Note in Figure 2 (right) the enlargement of the airway in the area of the pharyngeal constrictors. The pharyngeal constrictors are not attached to either the tongue or the mandible. The effect of the oral appliance sitting in the mouth is not as simple as tongue and/or mandibular advancement. It has a more complex effect on the entire airway, more closely resembling inflation of a balloon.



**Fig. 1.** The Moses™, an open anterior, adjustable, FDA cleared oral airway dilator.

It would seem to be a reasonable assumption based on the Moses study and the cited studies on exercises that the operative mechanism by which airway dilation works in both cases is stimulation of hypoglossal reflexes. Reflex training during the day by exercises has a carryover effect during sleep. The reflex effect of oral appliances works as long as the appliance remains in the mouth. Hypoglossal reflexes operate at a site apart from the origin of the stimulus.

The effectiveness of oral appliances at treating OSA is well documented in the scientific literature.<sup>19,20,21,22,23</sup> The effectiveness of exercise training is well demonstrated in the two articles cited.<sup>1,2</sup> Neither methodology alone appears to be better than CPAP when using PSG measures; however, in a recent paper, Chan & Cistulli<sup>24</sup> presented data that patient compliance, acceptance and comfort is better with oral appliances than CPAP.



**Fig. 2.** Left image above is a posterior view of a three dimensional volumetric reconstruction of the patient's airway without MAD. Right image is a posterior view of a three dimensional reconstruction of the patient's airway with MAD properly positioned in the mouth. The increase in size of the airway is substantial and obvious. The appliance used in the figure on the right is The Moses™.

### Evolution

The old idea that oral appliances are merely mandibular advancement devices, moving the tongue forward to prevent its collapse on the airway is an oversimplification. It does not account for the dilation of the sides and back of the pharynx visible on the 3-D computerized cone beam image with The Moses™ in place. The multidimensional airway dilation cannot be accounted for solely by active anterior movement of the mandible and the attendant passive pull-forward of the tongue base. Consideration and testing of oral appliance therapy in terms of their effect on airway dilation by reflex stimulation is warranted.

It would seem that there is no downside or risk to a clinical strategy of a treatment protocol combining the two methodologies of oropharyngeal exercises and oral appliance therapy. It would also seem that future controlled trials to objectively evaluate the combined effects of oral appliances and exercises is warranted.

### Reference

1. Puhan MA, Suarez A, Lo Cascio C, Zahn A, Heitz M, Braendli O, Didgeridoo playing as alternative treatment for obstructive sleep apnoea syndrome: randomized controlled study. *BMJ*, doi:1136/bmj.38705.470590.55 (23 Dec. 2005).
2. Guimares KC, Drager LF, Genta PR, Marcondes BF, Lorenzo-Filho G, Effects of oropharyngeal exercises on patients with moderate obstructive sleep apnea syndrome. 179: 962-966, 2009.
3. McEvoy RD, Popovic RM, Saunders NA, White DP, Effects of sustained and repetitive isotonic hypoxia on ventilation and genioglossal and diaphragmatic EMGs. *J APPL Physiol*, 81:866-875, 1996.
4. Strohl KP, Hensley MJ, Hallet M, Saunders NA, Ingram RH, Activation of upper airway muscles before onset of inspiration in normal humans. *J Appl Physiol*. 49:638-642, 1980.
5. Mateika JH, Millrood DL, Kim J, Rodriguez HP, Samara GJ, Response of human tongue protrudor and retractors to hypoxia and hypercapnia. *Am J Crit Care Med* 160: 1976-1982, 1999.
6. Dictionary
7. Sherrington C, "The Integrative Action of the Nervous System" Yale University Press, 1906.
8. Sabolsky JP, Butler JE, Fogel RB, Taylor JL, Trinder JA, White DP, Gandevia SC, Tonic and phasic respiratory drives to human genioglossus motoneurons during breathing. *J Neurophysiol*, 95:2213-2231, 2006.
9. Blom S, Afferent influences on tongue muscle activity. *Acta Physiol Scand*. Vol 49 (Suppl 170) 1-97, 1960.
10. Miller AJ, Oral and pharyngeal reflexes in the mammalian nervous system: Their diverse range in complexity and the pivotal role of the tongue. *Crit Rev Oral Biol Med*, 13(5):409-425, 2002.
11. Weiffenbach JM, Discrete elicited motions of the newborn's tongue. In: "Oral sensation and Perception" ed. Bosma JF, US Govt Printing Ofc , p232-243, 1972.
12. Isono S, Tanaka A, Nishino T, Effects of tongue electrical stimulation on pharyngeal mechanics in anesthetized patients with obstructive sleep apnea. *Eur Respir J*, 14:1258-1265, 1999.
13. Miki H, Hida W, Chonan T, Kikuchi Y, Takishima T, Effects of submental electrical stimulation during sleep on upper airway patency in patients with obstructive sleep apnea. *Am Rev Respir Dis*, 140: 1285-1289, 1989.
14. Edmonds LC, Daniels BK, Stanson AW, Sheedy PF, Shepard JW, The effects of transcutaneous electrical stimulation during wakefulness and sleep in patients with obstructive sleep apnoea. 146: 1030-1036 , 1992.
15. Decker MJ, Haaga J, Arnold JL, Atzberger D, Strohl KP, Functional electrical stimulation and respiration during sleep. *J Appl Physiol*, 75:1053-1061, 1993.
16. Guillemainault C, Powell N, Bowman B, Stoohs R, the effect of electrical stimulation on obstructive sleep apnoea syndrome. *Chest*, 107:67-73, 1995.

17. Schwartz AR, Eisele DW, Hari A, Testerman R, Erickson D, Smith PL, Electrical stimulation of the lingual musculature in obstructive sleep apnoea. *J Appl Physiol*, 81:643-652, 1996.
18. Moses AJ, Bedoya JA, Learreta JA, Case study of the anatomic changes effected by a mandibular advancement device in a sleep apnea patient. *Sleep Diagnosis and Therapy* 5:1, 30-34, 2010.
19. Schmidt-Nowara WW, Mead TE, Hayes MB, Treatment of snoring and obstructive sleep apnea with a dental orthosis. *Chest*, 99:1378-1385, 1991.
20. Ichioka M, Tojo N, Yoshizawa M, et.al. A dental device for the treatment of sleep apnea: a preliminary study. *Otolaryngol head Neck Surg*, 104: 555-558, 1991.
21. Eveloff SE, Rosenberg CL, Carlisle CC, Millman RP, Efficacy of a Herbst mandibular advancement device in obstructive sleep apnea. *Am J Resp Crit Care Med* 149: 905-909, 1994.
22. Clark GT, Arand D, Chung E, Tong D, Effect of anterior mandibular positioning on obstructive sleep apnea. *Am Rev Resp Dis* 147: 624-629, 1993.
23. Bonham PE, Currier GF, Orr WC, Othman J, Nanda RS, The effect of a modified functional appliance on obstructive sleep apnea. *Am J Orthod Dentofacial Orthop*, 94: 384-392, 1988.
24. Chan ASL, Cistulli PA, Oral appliance treatment of obstructive sleep apnea: an update. *Current Opinion in Pulmon Med*, 2009, 15: 591-595.