Advancements in the Treatment of OSDB for Conventional Medical Practice

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Forward

The role of dental appliance therapy in the treatment of sleep disordered breathing is now defined. Research has demonstrated an efficacy which, for selected patients, confirms dental appliance therapy as a viable treatment alternative. Combination therapy is often advantageous. A trial dental appliance may be used to identify a treatment of choice. This publication addresses the need for a clear and concise pattern of case selection. Another important contribution is an analysis of how and why dental appliances function to relieve the symptoms of sleep apnea and snoring. This presentation is a valuable tool in advancing an understanding of dental appliance therapy for all disciplines involved in diagnosing and treating sleep disordered breathing.

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Dental Appliance Therapy for Obstructive Sleep Disordered Breathing

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INTRODUCTION

Obstructive Sleep Disordered Breathing (OSDB) is a term that encompasses several conditions. Primary Snoring (PS) and Obstructive Sleep Apnea (OSA) are the most common and affect 30% and 5% of the adult population, respectively (1,2,3). Two other partial forms of OSA have only recently been described. They are Upper Airway Resistance Syndrome (UARS) and REM-Specific OSA and their prevalence is less well established (4,5,6).

The health effects of OSA are well recognized and include impairment of daytime function (due to the disruption of normal sleep) and cardiovascular complications (7).

Although PS is generally believed to be a benign condition, a small percentage of patients also exhibit impairment of daytime function that is indistinguishable from that seen in OSA (8,9). Significant impairment of daytime function is also seen in patients with UARS or REM-Specific OSA, however, findings on standard polysomnography are normal in this population (4,5,6).

The economic impact of OSDB is substantial. Increased health care costs, lost productivity, and increased likelihood of motor vehicle and workplace accidents contribute to an estimated annual cost in the tens of billions of dollars (10, 11).

Traditional management of these conditions has included CPAP and surgery, however, each of these treatment modalities has limitations. Patient compliance is a major problem with CPAP, and the results of surgery to the upper airway are difficult to predict (7).

Although the medical community has been slow to accept dental appliance therapy as an effective treatment for OSDB, it is gaining increased recognition as a viable alternative to CPAP and surgery in this patient population (12). In fact, used in conjunction with CPAP and surgery, this treatment modality can result in successful outcomes for a much broader spectrum of OSDB than would otherwise be possible.

THE ORIGINS OF OSDB [13,14]

When a person goes to sleep, the upper airway collapses as a result of a decrease in muscle activity and a blunting of protective reflexes. In most instances snoring is the only problem to develop, however,

in a significant proportion, airway collapse triggers arousal and is accompanied by significant drops in oxygen saturation.

The following conditions are likely to cause clinically significant upper airway collapse during sleep:

* there is excessive narrowing of the airway by edema, tissue infiltration, or inflammatory changes

* the soft palate and uvula are too long and/or too thick

* the space behind the soft palate is too wide or not wide enough

* the space behind the soft palate is too shallow

* the space between the base of the tongue and the back of the pharynx is too shallow (front to back) or too deep (vertically)

* the muscles in front of the cervical spine are thickened

* the tonsils and adenoids are enlarged

* the nasal airway is obstructed causing the individual to breathe with their mouth open

* protective reflexes are blunted by alcohol, drugs, or damage to the central nervous system

* the neuromuscular function is compromised by diseases such as ALS and muscular dystrophy

In any given patient with OSDB, several of these factors will be present.

These anatomic factors contribute to airway collapse and instability in several different ways. Narrowing in any segment of the upper airway leads to a drop in the pressure distally. Irregular narrowing of the airway also causes the airflow to be turbulent which increases the resistance to airflow and generates rapid fluctuations in the pressure at different points along the airway. These changes lower the pressure in the airway and cause the tissues to vibrate. Although all the tissues in the airway will vibrate to some extent, the soft palate, because it has a free edge, will vibrate the most.

This vibration of the tissues brings opposing surfaces closer together and complete airway collapse may result if there is sufficient narrowing and laxity in the tissues, such as may occur behind the soft palate or at the base of the tongue. Under these conditions, apnea will result. A partial collapse can result in a significant decrease in the airflow (hypopnea), or in a significant increase inairway resistance that is not reflected by a measurable change in the airflow. The body defends itself against airway collapse by activating reflexes that are triggered by airway sensations and by changes in blood gas concentrations. These defense mechanisms are often compromised in patients who have OSDB. Ironically, it may be the activation of these defensive mechanisms which causes the repeated arousal that destroys the continuity of sleep in patients with OSDB.

This process is very dynamic. In any given patient, collapse can occur at different points in the airway, at different times, and to different degrees. This is why the spectrum of disease for OSDB includes PS, OSA and the partial forms of OSA such as UARS and REM-Speci~c OSA.

Traditional Therapies

CONTINUOUS POSITIVE AIRWAY PRESSURE [CPAP]

In CPAP, a pump is used to keep the pressure in the upper airway high enough to prevent the tissues from collapsing and vibrating. This treatment is highly effective (15) and nightly use may reverse some of the airway changes associated with OSDB (16). Unfortunately, many patients are not compliant with this modality because of discomfort, inconvenience, or embarrassment over their appearance when they are hooked up to the CPAP device. (17)

UPPER AIRWAY SURGERY [18] Tracheostomy, a surgical procedure which bypasses the upper airway, is 100% effective, but is generally considered a last resort in the treatment of OSDB. Other, less drastic surgical treatments are based on the following principles:

* removing obstructing tissues such as the tonsils, portions of the soft palate, and portions of the tongue

* increasing the dimensions of the upper airway by lengthening the mandible, repositioning the hyoid bone, or advancing the soft palate

Some of this surgical remodelling of the airway may result in tightening of loose tissues. Studies looking at the collapsibility of the upper airway before and after surgery are now being undertaken to try to determine precisely how these surgeries work (19,20).Predicting which patients will respond to any of these surgical procedures has proven difficult and the patients may undergo two or more operations before achieving the desired results. There may be lasting side effects such as nasal regurgitation. Surgery may make the OSDB worse (21) or compromise the efficacy of CPAP (22). Finally, the beneficial effects of surgery (with the exception of tracheostomy) appear not to be as permanent as previously believed (23).

THE LITERATURE ON DENTAL, APPLIANCE THERAPY FOR OSDB

There are three basic kinds of dental appliances are used in the treatment of OSDB:

* tongue-retaining devices which may be useful in select patients,

* devices that use a flange at the base of the tongue to hold the tongue out of the pharynx,

* devices that advance the mandible (which are the most effective).

New information has emerged since the publication of the ASDA guidelines for the use of dental appliance in the treatment of OSA (24). It arises from controlled studies of dental appliance therapy versus CPAP in the treatment of OSA and from investigations into how the upper airway changes when the mandible is advanced.

There have been three controlled trials comparing dental appliances to CPAP in the treatment of OSA. Each trial used a different type of dental appliance, however, all three appliances use the principle of mandibular advancement.

Clark et al (25) used the AMP (Anterior Mandibular Positioner) which consisted of two custom-fitted acrylic appliances joined by a Herbst attachment on each side to allow for adjustable protrusion, jaw opening and limited side-to-side motion. Twenty-one of twenty-three patients with OSA (mean apnea-hypopnea index (AHI) before treatment 33.86ñ 14.30) completed the crossover study comparing AMP with CPAP. Although CPAP (mean AHI on CPAP of 11.15+3.93) was more effective than AMP (mean AHI with AMP of 19.94+12.75) in eliminating OSDB in all patients (particularly those with severe OSA), there was no difference between the two treatment modalities in terms of improvement in daytime sleepiness. Following the crossover phase of the study, the patients chose one treatment for continuation of use. After three to ten months, 17 reported using the AMP nightly, two reported using the AMP most nights, one reported using CPAP, and one was not using either treatment.

Ferguson et al (26) used a device also referred to as an AMP but which is better known as the Silencer. This device uses an elastomeric material and mandibular advancement is achieved with a special titanium "Halstrom Hinge[tm]" which allows stepwise advancement of the mandible and side-to-side motion. This study also used a crossover design. Twenty-four patients with OSA (mean AHI before treatment of 26.8+11.9) were recruited to the study of which 20 completed all phases. Three patients refused to cross over from the Silencer to CPAP. One patient dropped out of the study. Again CPAP (mean AHI of 4.2+2.2) was found to be more effective than the dental appliance (mean AHI of 13.6+ 14.5) in eliminating OSDB (particularly for those with the highest AHIs). Seventeen of the patients using the Silencer showed a reduction of their AHI below 20, fourteen to below 10. All 20 patients showed a reduction of their AHI to below 10 while on CPAP, however, one patient could not tolerate the Silencer, whereas six could not tolerate CPAP. Patient satisfaction was greater with the Silencer than with CPAP. There was no difference between the two treatments in terms of improvement in daytime sleepiness.

Fleetham and Lowe et al (27) conducted a two year randomized controlled trial of a third dental appliance, the Klearway, versus CPAP. The Klearway uses an advancement mechanism that consists of a worm screw in a fiat metal plate that is suspended over the tongue by a wire frame. Fifty-nine patients were recruited, but only fortytwo completed the study. Nine patients dropped out because they could not tolerate the Klearway, eight patients dropped out because they could not tolerate CPAP. For patients completing the CPAP therapy, the mean AHI before treatment was 41+28 and during treatment was 5+3. For patients using the Klearway the mean AHI before treatment was 35+ 14; 13+ 12 while on treatment. There was no difference between the two treatments in terms of improvement in daytime sleepiness.

These studies demonstrate that a dental appliance which advances the mandible can be effective in the treatment of mild to moderately severe OSA, however, comfort and compliance are issues. Less intrusive appliances such as the Clark AMP and the Silencer may be better tolerated than more bulky appliances such as the Klearway (which had the same dropout rate as CPAP in its recent trial). Further studies are needed to measure long-term compliance to these devices. Of note, in an earlier study, only 50% of patients treated with the Clark AMP were still using it after one year. Patients who tolerate dental appliances early on may continue to use them for extended periods. A recent study by Loube et al (28) showed that 70% of patients who were initially compliant with dental appliance use were still compliant at 3.4+0.7 years. Follow-up sleep studies were not conducted.

How Do Dental Appliances Work?

The simple and incomplete explanation is that advancing the mandible pulls the tongue forward, however, recent studies have shown that changes occur in the upper airway at several levels when the mandible is pulled forward. Isono et al (29) used video endoscopy to examine the effects of advancing the mandible on the pharyngeal airway of thirteen patients with OSA who were under general anaesthetic with total muscle paralysis. They found that advancing the mandible widened the retropalatal airway as well as that at the base of the tongue. They applied negative pressures to the airway and demonstrated that a more negative pressure was required to induce collapse in the airway when the mandible was advanced. In their discussion, they postulated that one of the mechanisms by which mandibular advancement stabilizes the soft palate and retropalatal airway is through tension transmitted along the palatoglossus muscles to the soft palate.

Schwab et al (30) used MRI on awake snorers to show that advancing the mandible resulted in a greater increase in the lateral than the AP dimension of the airway. CPAP produces a similar change (33).

Wearing an appliance also prevents the mouth from falling open during sleep. Meurice et al (31) showed that upper airway collapsibility was increased in normal awake subjects when their mouths were open. They postulated that mouth opening narrows the upper airway and reduces the efficiency of upper airway dilator muscles.

Therefore, wearing a dental appliance that advances the mandible may stabilize the upper airway by:

* pulling the base of the tongue forward

* pulling the soft palate forward and placing the walls of the upper airway under tension

* preventing the mouth from falling open during sleep.

These primarily passive mechanical effects can be explained by applying simple physical principles to the anatomy of the upper airway.

HOW DOES MANDIBULAR ADVANCEMENT STABILIZE THE UPPER AIRWAY?

It is an oversimplification to state that the airway can be opened by simply pulling the mandible forward to move the base of the tongue out of the back of the throat. The tongue is part of a complex muscular apparatus that participates in speech, swallowing, and breathing and there fore cannot be considered in isolation of its anatomic relationships to surrounding structures in the upper airway.

The critical anatomic relationships are as follows:

* insertion of the tongue into the mandible anteriorly

* linkage of the soft palate to the tongue by insertion of the palatoglossus muscles into the sides of the tongue

* linkage of the palatopharyngeus muscles to the palatoglossus muscles through the palatine aponeurosis

* linkage of the superior and middle pharyngeal constrictors to the mandible via ,their insertion on the pterygomandibular raphe, a fibrous band that extends from the inferior hamulus of the pterygoid to the medial surface of the angle of the mandible.

As a result of these linkages, as the mandible is pulled forward, the following occurs:

* the base of the tongue is pulled forward * the soft palate is pulled forward by tension developed along the palatoglossus muscles

* as the soft palate comes forward, tension is transmitted along the palatopharyngeus muscles to the back wall of the pharynx

* the pharyngeal constrictors are elevated off the cervical spine and anterior paraspinous muscles (longus capitis and cervicalis) because of their insertion on the pterygomandibular raphe

* tension is developed in the side walls of the pharyngeal constrictors by splaying of the arch formed on each side of the orophyarynx by the palatoglossus and palatopharyngeus muscles

It is very important that the mouth be kept closed. If the mouth is opened, tensile forces that are produced by advancing the mandible are directed downwards instead of forwards. This increases the longitudinal tension in the pharynx and promotes collapse.

The following sequence of events can be observed endoscopically as the mandible is advanced:

* elevation of the base of the tongue which increases the A-P dimension of the hypopharynx

* advancement of the soft palate which increases the A-P dimension of the velopharynx

* forward and sideway movement of the palatopharyngeus folds which widen and flatten the back of the pharynx

* an increase in the lateral dimension of the upper airway at several levels

The net result is dilation and splinting of the velopharynx, oropharynx, and hypopharynx.

It is tension that stabilizes the structures in the upper airway. When a patient is awake, upper airway muscles are activated to produce this tension. During sleep, these muscles become less active and tensionislost. CPAP restores this tension by applying an intraluminal pressure. When the anatomy is favourable, mandibular advancement can be as effective as CPAP in tensing and stabilizing the structures of the upper airway. It is not necessary to invoke reflexes to explain how CPAP and mandibular advancement stabilize the upper airway during sleep although reflexes may augment the effects of these treatments.

This explains how pulling the mandible forward increases the A-P dimension and helps to stabilize the upper airway by putting tension into the tissues. However, the upper airway also gets wider side-toside. CPAP achieves this effect by applying an intraluminal pressure that stretches the tissues of the upper airway. This intraluminal pressure also acts as a counter-pressure to the pressure exerted by the tissues surrounding the upper airway. Advancing the mandible decompresses these same tissues by lifting the weight of the mandible and the attached structures such as the tongue off of the tissues surrounding the pharynx. Either way, the net pressure in the tissues surrounding the upper airway is lowered and this is what allows the upper airway to widen side-to-side. In fact, mandibular advancement may be superior to CPAP in some instances because it can produce greater increases in the A-P dimensions behind the soft palate and at the base of the tongue.

This model also explains why dental appliances that advance the mandible work better than tongue-retaining devices and devices that push the tongue forward by placing a flange at the base of the tongue. Tongue-retaining devices do pull the tongue and soft palate forward (32). Devices using a flange probably push the base of the tongue forward but the presence of the flange may actually increase the narrowing at the level of the soft palate. Neither type of device decompresses the tissues around the pharynx because they do not advance the mandible.

HOW DYNAMIC NASOPHARYNGOSCOPY CAN HELP DETERMINE IF A PATIENT CAN USE A DENTAL APPLIANCE FOR TREAMENT OF THEIR OSDB

In performing dynamic nasopharyngoscopy, it is best to try and simulate the conditions that exist when the patient is sleeping. The patient is examined while lying on their back with their soft palate and nasal passages anaesthetized with topical Lidocaine.

A flexible endoscope is introduced through one of the nasal passages and advanced into the pharyngeal airway. The pharyngeal airway is examined along its entire length extending from the suprapharyngeal recess to the vocal cords. The patient is asked to perform two manoeuvres during the examination.

In the first manoeuvre, the patient is asked to try and take a breath in while keeping their lips sealed and having their nostrils pinched shut. This generates a negative pressure inside the pharynx. Patients with OSDB show one or more of the following responses to this manoeuvre:

* lateral collapse of the velopharynx

* collapse of the soft palate against the back of the pharynx

* concentric collapse of the velopharynx (which invariably indicates Severe OSA)

* increased concealment of the epiglottis and glottis by the base of the tongue

In the second manoeuvre, the patient is asked to slowly advance their mandible to its most forward position. An airway that can be stabilized by mandibular advancement shows the following changes as the mandible is advanced:

* the soft palate moves forward and the velopharynx widens side-to-side

* the base of the tongue lifts off the epiglottis and the glottis is fully exposed.

The following findings are absolute contraindications to the use of a dental appliance:

* the soft palate completely seals off the velopharynx in the awake patient

* the velopharynx is completely or nearly closed off by tissue swelling

* advancing the mandible causes the velopharynx to become more narrow side-to-side

* the epiglottis and glottis are concealed by the base of the tongue and advancing the mandible does not bring them into view

Advancing the mandible will not create a satisfactory sleeping airway in patients with these findings.

An example of a borderline endoscopic finding is that of a partially occluded velopharynx that shows some dilation as the mandible is advanced. The dilation indicates that tension is being developed in the tissue by advancing the mandible. In this situation, the results of a sleep study are quite helpful in determining if the patient can safely use a dental appliance for treatment of their OSDB. An appliance can be used if the sleep study shows PS or mild to moderately severe OSA. If it shows severe OSA, the treatment of choice remains CPAP.

Up to this point, much of what has been described applies mainly to patients with PS or OSA. In theory, however, these concepts should apply equally well to UARS and REM-Specific OSA.

THE POTENTIAL IMPACT OF DENTAL APPLIANCE THERAPY ON THE MANAGEMENT OF OSDB

Dental appliances should be considered the treatment of choice for Primary Snoring, and patients with mild to moderately severe OSA generally prefer dental appliances to CPAP. Dental appliances are very likely to be effective for REM-Specific OSA. Their use for the treatment of UARS is still under investigation.

When used appropriately, dental appliances, like any health care technology, can produce enormous benefits for the patient and society. But their use must be guided by a clear understanding of how the technology works to achieve the desired outcomes.

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