Nighttime Biofeedback as a Tool for the Reduction of Habitual Bruxism Activity and Related TMD Symptoms.
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Introduction:

The National Institutes of Health estimates that 10.8 million people suffer from temporomandibular disorders (TMD) in the United States, and 90 percent of those sufferers are women in child-bearing years. In a recent study done at Tufts involving 504 TMD patients, about 70% of patients self-reported that they attributed their TMD symptoms to bruxism [1]. It has long been known that bruxism is one of the main causes of TMD, but until the recent advent of wearable, quantitative EMG measurement equipment, it had been difficult to measure the correlation between various TMD symptoms and the quantity of bruxism that a patient exhibits. The advent of the first EMG measurement headband in 2001 made quantitative assessment of bruxism easy and economical.

One of the most challenging things about bruxism to both patients and clinicians is that in many cases even if the initial cause of bruxism can be identified and eliminated, the bruxism behavior may have become habitual and thus the behavior may not be eliminated by the elimination of the cause. The habitual nature of bruxism is one of the reasons that all treatment modalities to date (including splints, drugs, Botox, chiropractic techniques, acupuncture, etc.) have achieved only limited success. In a survey of 300 habitual bruxers conducted through Google [2], less than 15% of those surveyed rated any of these treatments highly effective.

There has been a large body of research to support the use of biofeedback to aid in treatment of TMD pain [3], with dental cotreatment [4-10], for temporomandibular joint (TMJ) muscle tension [11-15], and bruxism [16,17]. These studies were all done using tabletop biofeedback units that connect to the patient with wired adhesive electrodes.

In this study patients provided with a self-contained biofeedback headband which was worn at night to provide biofeedback during sleep. We examine the efficacy of nighttime use of the biofeedback headband in the reduction or elimination of habitual bruxism. Efficacy was measured through quantitative EMG measurements made during sleep. Many patients who participated in this study additionally self-reported reduction or elimination of symptoms.

Therapeutic Intervention:

The SleepGuard biofeedback headband (shown below) is a self-contained biofeedback device worn on the head, which measures electromyographic signals (EMG) from the temporalis muscles. No adhesive electrodes are required.

The headband can be worn either in silent mode (to measure baseline bruxism) or in biofeedback mode. In both modes it measures two things over the course of a night: a count of bruxism events, and the total accumulated clenching time of those bruxism events. It also includes a piezoelectric tone generator that contacts the forehead and can produce an acoustic biofeedback tone, which is heard through bone conduction in both ears. The tone starts at a low volume when clenching starts, and ramps up in volume as clenching continues. As soon as clenching stops, the tone stops.

Clinical Trial Results

The first round of clinical trials to test the efficacy of using a biofeedback headband to reduce bruxism was completed on October 10, 2010. There were 92 patients in the trial. The total clenching time recorded by the biofeedback headband each night was logged on a daily basis. The first three days of data for each participant were baseline data. The remaining 27 days of data were data taken with the biofeedback turned on. Running the data through a statistical analysis package yielded a p value for the data of $2x10^{-16}$.

One illuminating way to view the data is to divide the clinical trial patients into four groups (quartiles), ranked by overall end reduction in nightly bruxism at the end of the trial versus the beginning. The four graphs below represent efficacy quartiles (23 patients each, with each graph representing the average of the normalized data from the 23 patients in the quartile). The most responsive quartile is shown first and the least responsive quartile is shown last. Average nightly reduction in bruxism time was measured as the difference between the normalized average nightly clenching time during the three days of initial baseline measurement (this average was normalized to 1 for all patients), and the normalized average nightly clenching time during the last three days of the trial.

 The best performing quartile (23 patients) results are shown below.

Top 25% (23 patients)
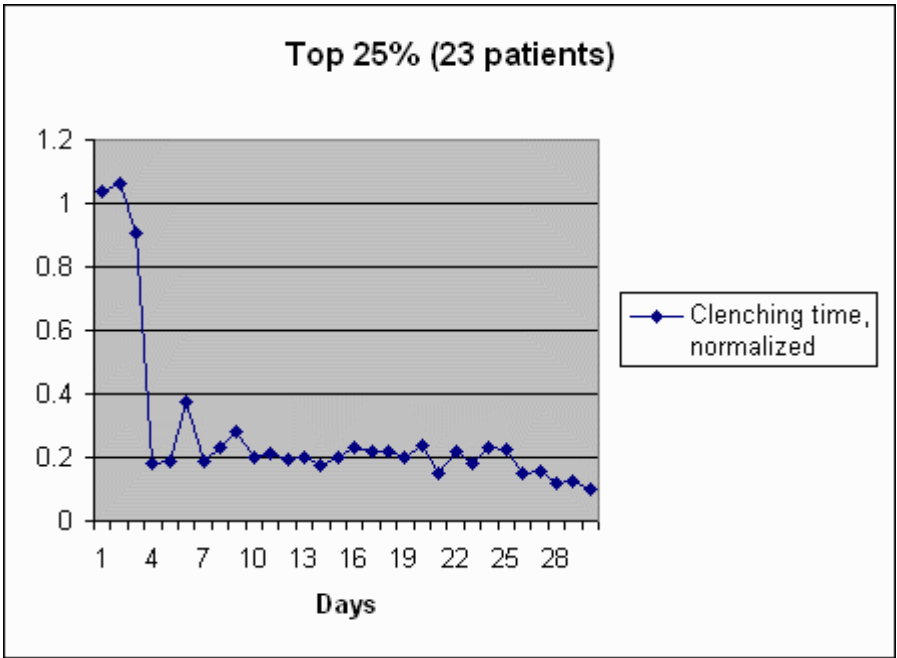
These patients showed an average initial reduction in bruxism time of 80% in one day after turning on the biofeedback, and by the end of the month they had a nightly bruxism time reduction of 90%. Also taking into account the probable average reduction of clenching force of 50% to 90%, gives a probable 95% to 99% reduction in nightly damage. Most patients in this quartile report substantial reduction or complete elimination of pain such as jaw pain, migraines, TMJ pain, etc..

The next best performing quartile (23 patients) is shown below.


Upper Mid 25% (23 patients)
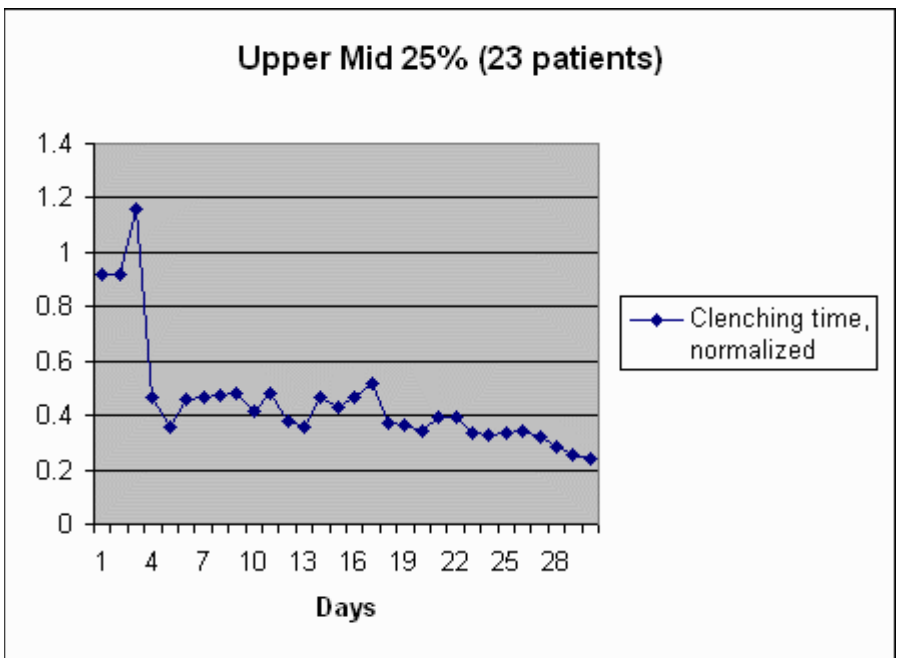
These patients' "remaining bruxism" is about twice the top group, but still very low.

As can be seen in both of the upper quartiles above, nightly clenching time was trending down steadily toward the end of the month, perhaps indicating that these patients are on the average training themselves out of their bruxism habit. This theory is supported by anecdotal evidence in follow-up interviews several months later, where a number of patients said that after using the biofeedback for between two and four months, they were able to go for long periods (over a month) without using the headband before any daily pain returned.

Most patients in this second quartile, like the first quartile, report substantial reduction or complete elimination of pain such as jaw pain, migraines, TMJ pain, etc..

The average of the data from the lower mid quartile (23 patients) is shown below.
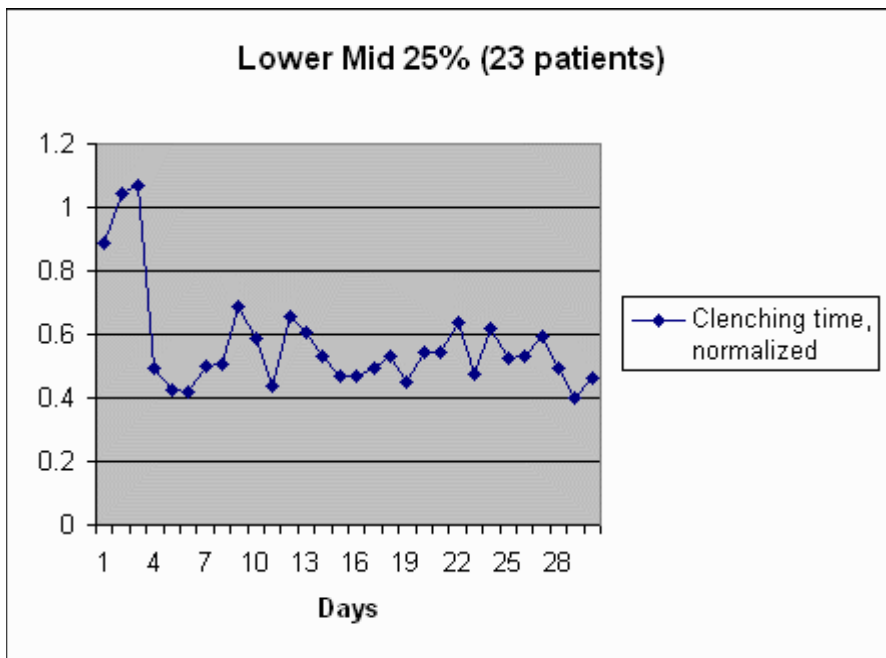
These patients experience approximately a 60% initial reduction in nightly clenching time when the biofeedback is turned on, and their nightly clenching times remain at roughly this level for the rest of the month. In addition to the reduction in clenching time, it is estimated that this group experiences a reduction in clenching force by about 50%.

There is no obvious trending downward toward the end of the month for this group, so there is no evidence that they are training themselves out of their bruxism habit, but continued use of the biofeedback appears to be a viable tool in ongoing mitigation of bruxism damage and pain. Some patients in this quartile reported a complete elimination of pain symptoms, including TMJ pain and migraines.

The data from the worst-performing quartile (excluding one outlier, whose data is included in the whole group average) is shown below.
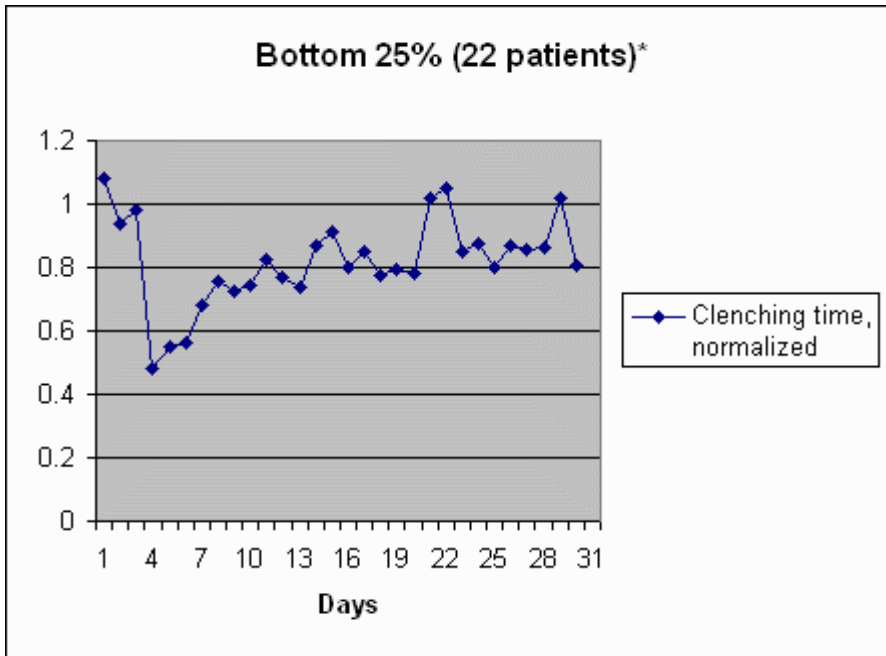

These patients respond well to the biofeedback at first, and then over time, their nightly bruxism times came back to a level close to their baseline levels.

One way to interpret why this may happen is that each person may be thought of as being of "two minds". One part of the mind wants to learn to relax and end the bruxism habit. This part of the mind hears the biofeedback tone as a caring reminder about something important.

The other part of the mind wants to learn to ignore any sound heard during sleep. For this group, this second part of the mind appears to win out, and patients return to near-baseline levels of clenching (though there is some reduction in clenching time and some reduction in clenching force, so they still benefit).

A follow-on study is under way with the majority of patients in the lower quartile. In the follow-on study, the biofeedback headbands given to these patients have been equipped with earphones which enable the biofeedback sound to be adjusted to a significantly louder level. The theory here is that when the sound is louder, the part of the mind that wants to sleep through everything will have less chance to succeed, and the part of the mind that wants to respond by learning to relax rather than clench will have more of a chance to succeed. Initial results of this follow-on study indicate that with a louder biofeedback sound, the majority of patients in the last quartile move into one of the first three quartiles.

Averaging the data from all 92 patients in the clinical trial, the overall average clenching time graph is shown below.

Overall Average of 92 Patient Data Sets
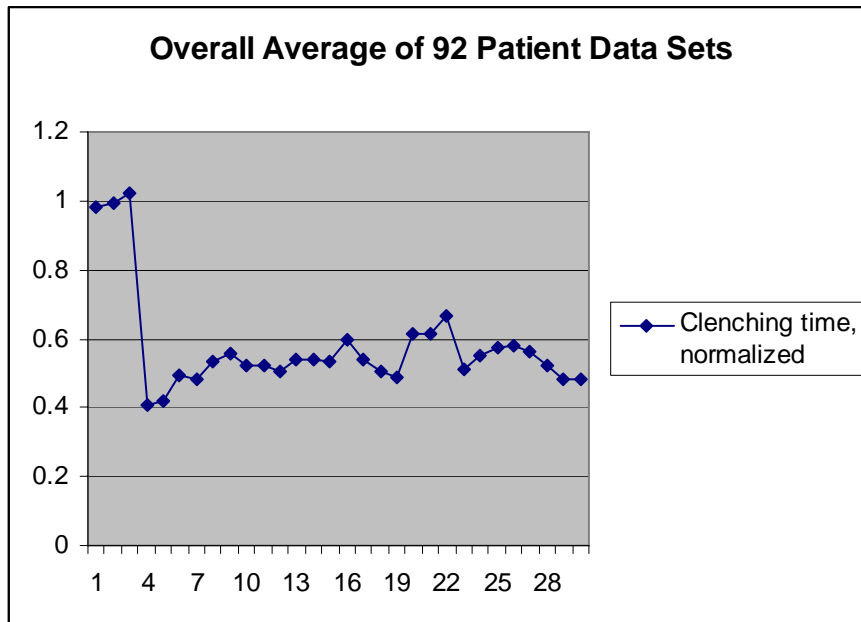
As can be seen by comparing the "overall average" graph above to the four quartile graphs, the overall average is only representative of a small percentage of people in the trial.

Discussion:

To place the results of this study in proper context it is important to understand the neurological nature of habit formation and habit modification and their relationship to biofeedback and bruxism. Below we will first present a modern neurological model of habit formation and modification, which form the basis for the design of this study. After that premise is shared, we will discuss other treatments and how they fit within this neurological model of habit formation and modification. We will then present key differences between nighttime biofeedback and daytime biofeedback in the treatment of nighttime bruxism.

The Habitual Nature of Bruxism

How nighttime clenching becomes a habit

Let's take a look at how we human beings build habits. One of the key functions of the neocortex (the part of the brain that makes humans different from animals) is the formation and execution of habits. Habits enable us to do many things subconsciously and simultaneously, while our conscious attention can only handle doing one or two things. Recent brain research [18] has shown that the basic function of the neocortex is to

memorize, recognize, predict, and replay patterns. Habit formation and the triggering of habitual actions (such as stepping on the brake when the brake lights of a car in front of you go on) are subsets of these basic neocortex functions of memorizing, recognizing, predicting, and replaying patterns.

We survive by building thousands of such "good" habits, all of which are triggered by associated feelings or situations. Once a recognition sequence (of a feeling or situation) and the appropriate response action sequence have been learned, that recognition and those responses can (and do) become subconscious, in that the recognition of circumstances and the acting out of the response both happen without us thinking about it. There are many such recognition and action sequences involved in being able to do something like play a sport, or drive a car. Once a given recognition neuron has been wired up to trigger an action sequence neuron, it takes non-trivial re-training to prevent that triggering from happening, or to mitigate the action once it has been initiated. The perception patterns we learn to recognize to trigger a motor sequence (habit) can include all our senses, plus emotional states, plus imagined situations and emotions.

When we learn a habit such as bruxism, both an action sequence (clenching), and the resulting sensation sequence are stored in our brains through repetition, in the form of strengthened neural connections, and later either imagining the sensation sequence or something associated with it (or experiencing an associated emotion) can trigger the action subconsciously.

As we first develop a habit where there is no initial tendency, the (non-conscious) neural pathway from sensation sequence to desired action sequence could be thought of as a meandering pathway (sequence of neurons that fire) through an uncut jungle to a destination (an action).

For habits where there is an initial tendency, a jungle with a path through it may be a better initial analogy.

Each time a particular neural pathway gets used, it gets strengthened. This happens physically at the synapses between neurons. So as the habit gets more entrenched, that path through the jungle may begin to look more like a road (which is easier to go down than a path).
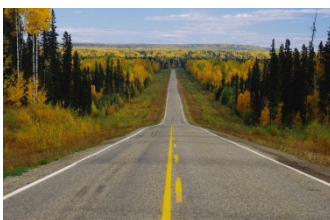
When the habit becomes still more entrenched, it may look more like a highway.

The structure of breaking a habit

If we have a habit (a neural highway toward a particular action sequence such as bruxism) and we want to stop using that highway for a while, so it can become "overgrown with trees and look more like a jungle," how might this be accomplished?

With habits like fingernail biting or thumb-sucking, the answer may seem obvious. A way to change the habit is to develop awareness of the onset of the behavior, and then substitute a different behavior. Repeated conscious intervention is the key to modifying any habit. But how can a habit be modified if it occurs during sleep?

The key to modifying a habit that occurs during sleep is to provide some level of conscious awareness of the onset of the habitual action, so the sleeping person can substitute a different action sequence. Nighttime biofeedback can provide a signal at the onset of an action but a challenge has been how to recognize and respond to such a signal when sleeping. Most parents will realize through their own experience that if they hear a sound in the house that could indicate his or her child is in danger, the parent will usually suddenly awake. This sudden awakening happens when a subconscious process in the neocortex recognizes (for instance) a sound sequence that could indicate a child is in danger. If a signal is recognized during sleep, this signal could be effectively used to change a habit, particularly if it can occur without awakening the patient.

Bruxism Habit Formation

The stages of habit formation as they relate to bruxism could be modeled as follows:

1) Neurologically Intense Thought/Emotion   --------------->   Initial Action
   (for instance stress, traumatic memory of   (Clenching and/or
   car accident, allergic reaction to a food,   grinding of teeth)
   or reaction to a drug)

2) Action Sequence (in presence of thought/emotion) ------>   Nerve Sensation
   Clench with force ramping up, then stop   Sequence from teeth

3) Thought/Emotion -> Predictive memory of sequence -> Habitual Muscle/Sensation
   sequence

While in the beginning it may take an exceptional circumstance (such as a traumatic event, or a very stressful period of time, or a drug or nutritional situation that throws the patient's system into imbalance) to trigger bruxism, once bruxism becomes a habit, it only takes a subconscious memory to trigger the previously memorized bruxism action sequence in sleep. As the bruxism happens, neural associations are built between emotions, physical sensations, and muscle actions. Additionally, memories are formed of

those emotional states and physical sensations, and later recalling of those memories can trigger the associated muscle action sequences.

Detecting and Interrupting Bruxism

The muscles involved in typical bruxism are the temporalis and masseter muscle groups. Typically these two muscle groups fire together during normal chewing and bruxism. There are exceptions to this, but those exceptions are relatively uncommon.
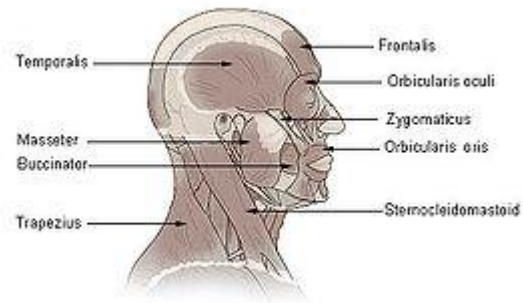
Increasing Probability of Efficacy through Daytime Pavlovian Conditioning

About a year after the biofeedback headband first became available, interviews were conducted with 100 patients who had used the headband for bruxism reduction for at least a couple of months. Anecdotal reports from those interviews indicated that patients who spent wakeful time training themselves to relax when they heard the biofeedback tone did better than patients who did not. Thus within the clinical trial presented herein, all participants were instructed to spend at least a few minutes per day in the first few days doing "Pavlovian training," to train themselves to relax when the tone was heard. The intent is for this training to carry over into sleep, and increase the patient's ability to respond (by relaxing his or her jaw) in sleep without waking when the biofeedback tone is heard.

Conclusion:

This clinical trial showed that about 75 percent of patients are able to reduce their nightly clenching substantially through ongoing use of the biofeedback headband. On the average, the bulk of the benefit in nightly clenching time reduction is realized from the day the biofeedback is turned on. Reduction in pain or elimination of pain usually follows within several days. About 25% of patients appear to remain at the initially reduced level ongoingly, and there are indications that about 50% of patients are able to continue to steadily reduce their nightly clenching times beyond the initial reduction. Future research will include a follow up trial that is 60 days long instead of 30 days long, and includes 3-day baseline measurements after 27 days and after 57 days, as well as at the beginning of the trial. Another clinical trial is being designed for a migraine reduction study to be run by a neurologist in Buffalo, New York. Other partnering opportunities for future clinical trials are currently being explored.

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