Electrical Stimulation System to Relax the Jaw Elevation Muscles in People with Nocturnal Bruxism

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Abstract: Nocturnal bruxism (NB) is a temporomandibular disorder characterized by an excessive clenching and involuntary parafunctional grinding of the teeth during sleep. In this paper, we present a device that generates electrical stimulation to produce an inhibitory action of the muscles involved in the elevation of the jaw. The device measures the electromyographic (EMG) signal of the left temporalis anterior (LTa) muscle to determine the intensity of contraction. It then, stimulates the right mental nerve to produce a decrease in the contraction intensity of the jaw elevation muscles. The device was used by one bruxist subject for 12 nights. The results showed that, on average, the percentage decrease of the EMG activity was 43.55% when a bruxism event occurred. The events of nocturnal bruxism appeared mostly one and three hours after going to sleep. In conclusion, the electrical stimulation device generated an important inhibitory action of the LTa muscle when the subject was performing nocturnal bruxism. Thus, this result indicates that the device could be useful as a possible treatment for bruxism.

1 INTRODUCTION

Nocturnal bruxism (NB) is a temporomandibular disorder that has periodic and stereotyped movements. It is characterized by an excessive grinding and involuntary clenching of the teeth during sleep (ASDA, 1998). If left untreated, it causes irreversible damage to the teeth, including the periodontium and joint surfaces (Carlsson, 1999). In the short-term, NB produces general fatigue, poor sleep quality, headache and pain in the mandibular elevator muscles. Chronic effects can include structural periodontium damage, temporomandibular joint dysfunction (TMJ) and severe tooth wear including broken teeth. The prevalence of NB varies between 5% to 36% (Bader, 2000)(Abou-Atme, 2004) depending on the age of the patient.

The treatments currently used for bruxism are only of limited benefit. Therefore, we implemented a device that is based on electrical stimulation to an inhibitory sensory afferent (right mental nerve). When this inhibitory afferent is activated, it induces a decrease of contraction of the muscles that elevate the jaw. Thus, theoretically, it should decrease the intensity of events of NB (Jadidi, 2007)(Jadidi, 2011).

We performed an evaluation of the effects over the masseter and temporalis anterior muscles in 28 subjects with and without bruxism when electrical stimulation is applied to the right mental nerve. The results showed that, on average, the percentage decrease in the bruxist group for the right masseter was 25.02% and for the left masseter 25.87%. These results indicate that the inhibitory system produces an important decrease in the electrical activity of the two muscles, so it is a good starting point for a possible treatment in patients with bruxism and to develop new electronic stimulators (Aqueveque, 2013).

In this paper, we show the experiment that was performed to evaluate if the our electrical stimulation device causes a decrease in the electromyographic (EMG) activity when it is used by a bruxist subject during sleep. The experiment was conducted in one bruxist subject, who used the device for 12 consecutive nights. We observed that the device detects the events of NB and decreases the EMG activity by electrically stimulating the mental nerve.

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2 MATERIALS AND METHODS

2.1 Electrical Stimulation Device

The stimulation device used electrical stimulation on the right mental nerve to generate a decrease in the intensity of contraction of the jaw elevating muscles. To measure the level of contraction, the device uses the integrated EMG (iEMG) signal of the left temporalis anterior (LTa) muscle. The EMG was used because it is proportional to the bite force (Gonzalez, 2011) and is therefore, a good indicator of high and low contractile activity of the muscles that elevate the jaw (Cardenas, 2002).

The diagram of the stimulation device is shown in Fig. 1, where it can be observed that the EMG signal is acquired with surface electrodes. The signal then enters the device where it is amplified with an instrumentation amplifier (INA128). The gain of the amplification is variable and adapts the maximal amplitude of the EMG to the range of entry permitted by the microcontroller unit (MCU). This range of entry is 0V to 3.3V.

In the conditioning circuit block the signal offset is removed and filtered with a bandpass filter of second order. The bandpass filter has cutoff frequencies of 10Hz and 500Hz, which is the bandwidth of the EMG. Thereafter, the signal is rectified and smoothed to obtain the iEMG. The iEMG is the signal used to detect the events of NB in the MCU.

In the MCU block, the signal enters the MCU when the onset switch is enabled. An algorithm is implemented to detect the events of NB. The sampling frequency of the digital to analog converter (DAC) is 4800Hz. The bruxism detection algorithm establishes when the threshold of 25% of the maximal voluntary contraction (MVC) is reached. During a window of 0.52 seconds the cumulative integral of the iEMG is calculated to determine if there is presence of bruxism. When this occurs, the MCU sends a stimulation signal to the stimulator. The electrical stimulation is activated by an ON/OFF control. The stimulation waveform is a square-wave train with different values of amplitude. A duration of 2 seconds was defined for the stimulation. The frequency of the signal was 300Hz with a pulse width of 1.67ms.

The stimulator block receives the stimulation signal sent by the MCU and modulates the amplitude of the stimulation. The stimulator is voltage-regulated. Once the stimulation is modulated, it is sent to the right mental nerve, closing the circuit and generating the biofeedback.

Finally, the data logger block registers the iEMG signal and also the signal that activates the stimulation in the MCU. Data is stored in an external memory to perform an offline analysis in a PC later. The data is analyzed with Matlab to obtain the iEMG signal and calculate the percentage decrease of the area under the curve (AUC) that denotes a reduction of the contractile activity of the muscle. To calculate the percentage decrease in Matlab, the bruxism detection algorithm was used. In this case, we calculated the AUC of the signal before and after the stimulation to obtain it.

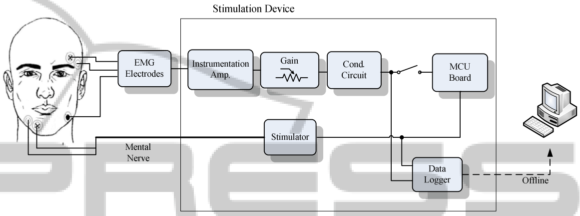

Figure 1: Diagram of the system.

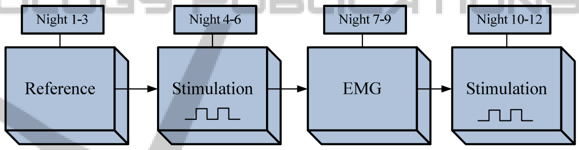

Figure 2: Diagram of the study design.

2.2. Experimental Procedure

To evaluate the proper functioning of the stimulation device, we asked one subject to use the device while sleeping. This allowed us to observe if the device detects the events of NB, stimulates electrically, and if it produces a decrease of the iEMG signal when the subject is performing nocturnal bruxism.

Informed consent based on the Helsinki protocol was implemented to inform the patient a 25 year old male bruxist, about the experiment.

Tests were performed during 12 consecutive nights. The records started once the subject went to sleep at midnight until he woke up. Fig. 2 shows the diagram of the study design. During the first three nights only the iEMG signal was recorded to establish a reference of the subject signal, no stimulation was applied. During nights 4 to 6 stimulation was applied to the mental nerve while the subject was sleeping. During nights 7 to 9 the signals were recorded without stimulating electrically. Finally, during nights 10 to 12 the signals were recorded and electrical stimulation was applied to the mental nerve.

The experiments were performed in the subject's home and the equipment used was the stimulation device described above. The device registers the EMG signal of the LTa and stimulates the mental nerve with surface electrodes. The position of the positive (x), negative (white) and reference (black) electrodes is shown en Fig.3. The positive and negative electrodes of the stimulator were placed on the chin.

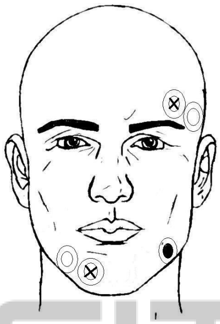

Figure 3: Positioning of electrodes.

Each night the subject had to clean the places where the electrodes were to be positioned. Later he had to place the electrodes and mount a headband with the electrode cables of the device. He then had to turn on the device and adjust the amplification of the EMG signal clenching his teeth at MVC to achieve the maximum voltage accepted by the MCU. Additionally, the amplitude of stimulation had to be at 0.5V with a frequency of 300Hz. These values were defined by previous tests, which were carried out to establish if the iEMG signal decreased when the mental nerve was electrically stimulated.

Once these steps were performed, the onset switch had to be enabled and the device started recording. The subject could then go to sleep. When the subject woke up, he had to turn off the device and take off the headband.

3 RESULTS

Fig. 4 shows the complete electrical system for measuring and detecting events of NB. The system consists of the electrical stimulation device, the signal and stimulation cables, and the surface electrodes.

The data obtained in this study was analyzed to observe the effect of electrical stimulation on the iEMG signal, and to calculate the percentage decrease of the AUC of the iEMG when the mental nerve is stimulated electrically. The length of time recorded each night was 5.71 ± 1.37hrs. The average percentage decrease of the AUC during the six days with stimulation was 43.55 ± 26.07%.

Fig. 5 shows a segment of one record of the iEMG signal acquired with the device: a) display the iEMG of the subjectwith the threshold of detection (25%MVC) and the different intensities of EMG activity recorded. Fig. 5.b) shows the activation stimulation signal that indicates the moments when the stimulator is active. In this segment, the device detected two events of NB when the iEMG activity was high. This means that the activity exceeded the threshold, and the cumulative integral calculated within the window of 0.52s was sufficient to determine it as a bruxism event. In the first high activity, the algorithm did not detect bruxism.

Fig. 6 shows a zoom of the iEMG signal that corresponds to a NB event detected. In a) the iEMG and the activation stimulation signal are shown. The legends Eve-Est and Eve-iEMG indicate the moment when the stimulation was applied, corresponding to the signal stimulation (Est) and iEMG respectively. The iEMG decreases when the electrical stimulation is applied to the mental nerve. Fig. 6.b) shows a NB event detected when electrical stimulation was not applied. The remarkable point when comparing both

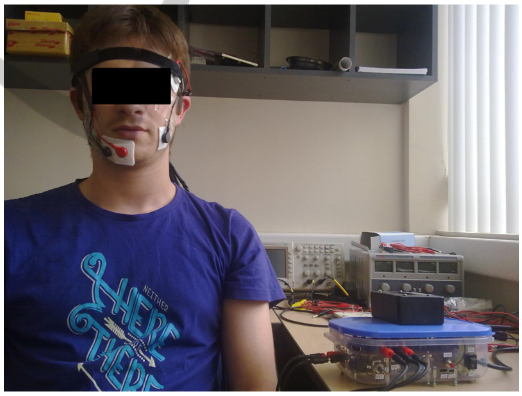

Figure 4: System used for the study.

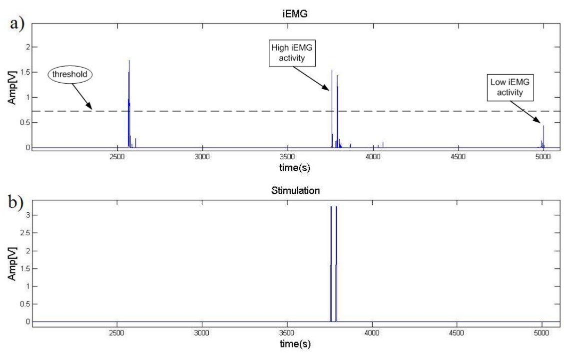

Figure 5: Segment of data recorded with the stimulation device. a) iEMG, b) activation stimulation signal.

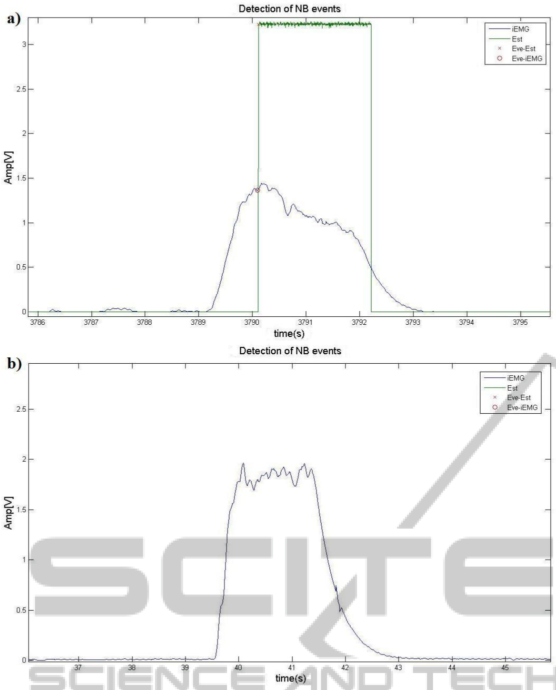

Figure 6: Nocturnal bruxism event with electrical stimulation applied. a) event with stimulation, b) event without stimulation.

records, a) and b), is that the iEMG signal decreases when electrical stimulation is applied. However, when a NB event is performed and no electrical stimulation is applied, the amplitude of the iEMG remains high until the NB event ends.

4 DISCUSSION

During the study the electrical stimulation device recorded the EMG and the stimulation signal. It also detected the activity related to bruxism when the subject was sleeping, and then electrically stimulated the mental nerve.

The percentage decrease of the EMG signal was considerable (43.55%). This is consistent with the results obtained in our previous studies with electrical stimulation of the mental nerve in bruxist and non bruxist subjects. Other studies (Jadidi, 2010) indicate that electrical stimulation to inhibitory afferents of the face can induce an inhibitory action while the bruxist subjects were sleeping.

5 CONCLUSIONS

Electrical stimulation device caused an inhibitory action in the intensity of muscle contraction elevating the jaw. The average percentage decrease of the iEMG signal for the complete study decreased by 43.55 ± 26.07%. This means that when the bruxist was sleeping the stimulation of the mental nerve caused a decrease of the bite force during a NB event.

Although the results of the study were satisfactory, it should be repeated using a larger sample of subjects and extended study time. Additionally, the effectiveness of this electrical stimulation device must be analyzed further.

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