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Electrical Stimulation Device as Possible Treatment for Nocturnal Bruxism: Preliminary results

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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. It can cause dental damage and irreversible temporomandibular joint dysfunction. We designed a device that generates electrical stimulation on inhibitory sensory afferents when an EMG signal is measured. This stimulation was applied to the right mental nerve to produce a decrease in the contraction intensity of the mandibular elevation muscles. To measure the intensity of contraction, electromyographic (EMG) signal of the left temporalis anterior (LTa) muscle was used. The results showed that, on average, the percentage decrease in the bruxist group was 30.53% and for the control group was 28.91%. These results indicate that the device implemented generates an important decrease in the muscle contractile activity. Therefore, the device could be useful as a possible treatment to decrease nocturnal bruxism.**

I. Introduction

Nocturnal bruxism (NB) is a temporomandibular disorder that has periodic and stereotyped movements. It is characterized by an excessive grinding and involuntary parafunctional clenching of the teeth during sleep [1, 2]. If left untreated, it causes irreversible damage to the teeth, including the periodontium and joint surfaces [2]. In the short-term, NB produces general fatigue, poor sleep quality, headache and pain in the mandibular elevator muscles (mostly the temporalis anterior and masseter). 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% [3, 4] depending on the age of the patient.

We chose to implement a type of treatment that is based on electrical stimulation to generate electrical potentials. This electrical stimulation induces a decreased contraction of the muscles that elevate the jaw. Theoretically, therefore, it should decrease the intensity of events of NB [5, 6]. Previous studies have shown that electrical stimulation on different locations of the face can induce a decrease of the electrical activity of the jaw elevating muscles [7]. Thus, stimulation tests were performed to patients to define the location where stimulate. Finally, it was decided to stimulate the mental nerve, because it generated more decrease of the EMG activity.

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Additionally, the treatments actually used are not 100% efficient to eliminate the NB. Therefore, an electronic device that uses electrical stimulation on inhibitory sensory afferents is a good option to reduce the NB.

To validate the stimulation device, we performed a study that evaluates the effects induced by electrical stimulation of the right mental nerve. The experiments were conducted in people with and without NB when they were clenching their teeth at maximum voluntary contraction (MVC). We observed electromyography (EMG) changes in people that have been electrically stimulated at MVC.

II. Materials and Methods

A. Electrical Stimulation Device

The stimulation device used the method of electrical stimulation on the right mental nerve to generate a decrease of the intensity of contraction of the mandibular elevating muscles. To measure the level of contraction, the device uses the electromyographic (EMG) signal of the left temporalis anterior (LTa) muscle. The EMG was used because is proportional to the bite force [8, 9].

The diagram of the stimulation device is shown in Fig. 1. In this figure it can be observed that the EMG is registered with surface electrodes, then the signal enters to the device. In the device the signal is amplified with an instrumentation amplifier (INA128). The gain of the amplification is variable to adjust the maximal amplitude of the EMG to the range of entry voltage that allows the microcontroller board (MCU) (0-3.3V).

In the conditioning circuit block, it removes the signal offset and is filtered with a bandpass filter of second order. The bandpass filter has cutoff frequencies of 10-500Hz, which is the bandwidth of the EMG. Then, the signal is rectified and smoothed to obtain the integrated EMG (intEMG). The intEMG was the signal used to detect the events of NB later in the MCU.

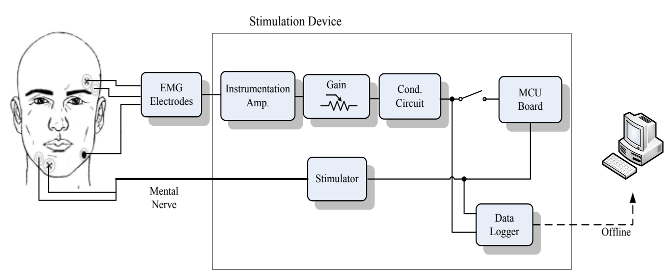

Figure 1. Diagram of the system implemented.

In the MCU board block, the signal enters the MCU when the onset switch was enabled. An algorithm was implemented to detect the events of nocturnal bruxism. The sampling frequency of the digital analog converter (DAC) was 4800Hz. The bruxism detection algorithm detects when the threshold of 25% of the maximal voluntary contraction (MVC) is reached. In that moment, a window of length of 0.52 seconds calculates the cumulative integral of the intEMG to determine if there is presence of bruxism. When this occurs, the MCU send a stimulation signal to the stimulator (control ON/OFF). Stimulation waveform used was a square-wave train with different values of amplitude. Duration of stimulation of 2 seconds was defined. The frequency of the signal was 300 and 500Hz with a pulse width of 1.67ms and 1ms respectively.

The stimulator block receive the stimulation signal sent by the MCU and modulate the amplitude of the stimulation. The stimulator is voltage regulated. Later, it sends the stimulation to the right mental nerve closing the circuit and generating the biofeedback.

Finally, the data logger block registers the intEMG signal and the signal that activates the stimulation in the MCU. Data is stored in an external memory to an offline analysis in a PC. Then, data is analyzed with the software Matlab to obtain the intEMG signal. Additionally, calculates the percentage decrease of the area under the curve (AUC) of the signal that denotes a reduction of the contractile activity of the muscle. The percentage decrease corresponds to how much has decreased the AUC of the intEMG when stimulating with respect to the AUC just before detect the NB event.

B. *Tests Subjects*

28 patients between 18 to 23 years old were selected and divided in two groups. One group with subjects suffering NB (bruxists), and other without it (controls). An informed consent based on the Helsinki protocol was implemented to inform the patients about the experiment.

Thus, 12 subjects were included in the group of bruxism (B) (4 men and 8 women). In the control group (C) were 16 subjects (5 men and 11 women). The mean ages of each group were 21.17 ± 1.80 (bruxists) and 21.13 ± 1.78 (controls). All the patients were evaluated on the basis of mental reflex techniques of Jadidi et al. [5, 6], and EMG activity was evaluated according to the technique of Ferrario et al. [10].

C. *Experimental Procedure*

The experiment consisted in make subjects clench their teeth to MVC. Then, the device detects the bruxism event and applies an electrical stimulation to the mental nerve for 2 seconds. This stimulation allows deprogram the mandibular elevation system and decrease the level of EMG activity that muscles generated.

The equipment used was the stimulation device implemented. The device registers the EMG signal of the LTa and stimulates the mental nerve with surface electrodes. The Fig. 2 shows the position of electrodes, where is positioned the positive (x), negative (white) and reference (black) in the LTa muscle. Also, the positive and negative electrodes of the stimulator were placed on the chin.

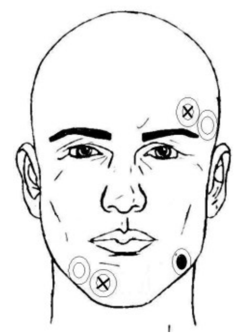

Figure 2. Positioning of electrodes.

Each experiment consisted of five records, where the first record was simply one bite at MVC (pattern). From the second to the fifth record, the stimulus was applied during the last 2 seconds with different combinations of amplitude and frequency (Record 2: 0.1V, 300Hz; Record 3: 0.5V, 300Hz; Record 4: 0.1V, 500Hz; Record 5: 0.5V, 500Hz).

In each record the area under the curve (AUC) was calculated for the intEMG with and without stimulation. Then we compared these values during the interval without stimulation to the interval with stimulation to calculate the change percentage.

III. Results

The Fig. 3 shows the complete system used to measure and detect events of NB. This consists in the device, the signal and stimulation cables, and the surface electrodes. The EMG was measured with the cables attached to a belt in the forehead.

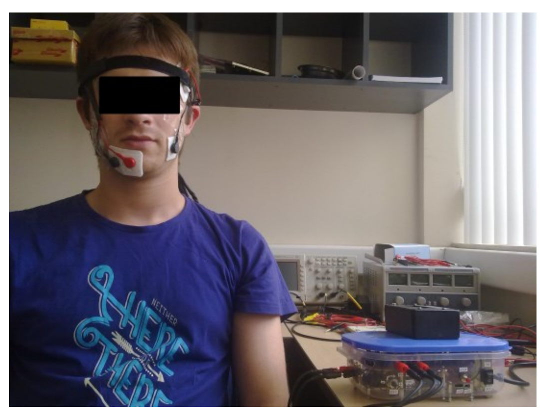

Figure 3. Electrical stimulation device mounted.

Fig. 4 shows a segment of the signals recorded with the device. The signal corresponds to a bruxist subject. In a) is shown the intEMG of a subject clenching the teeth at MVC. In b) is shown the activation stimulation signal that indicates the moments when the stimulator is stimulating. As can be seen, the intEMG starts decrease when stimulation occurs. This indicates that the effect of the stimulation generates a reduction of the electrical activity of the muscle when is contracted.

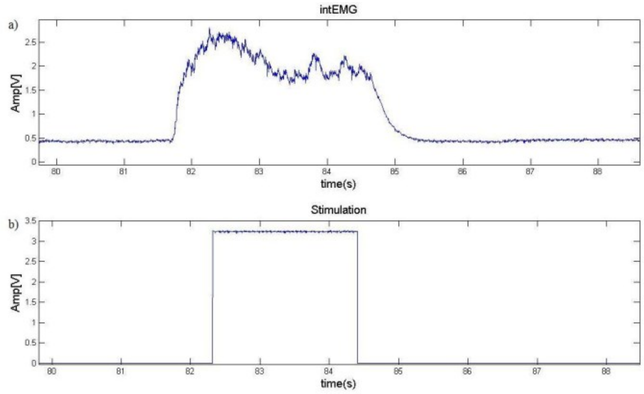

Figure 4. Segment of data recorded with the stimulation device.

a) intEMG, b) activation stimulation signal

Fig. 5 shows the average intEMG percentage decrease in each group considering the muscle measured in record 5. Records 2, 3 and 4 showed the same tendency as record 5. However, the best overall result was found with record 5 (0.5V, 500Hz).

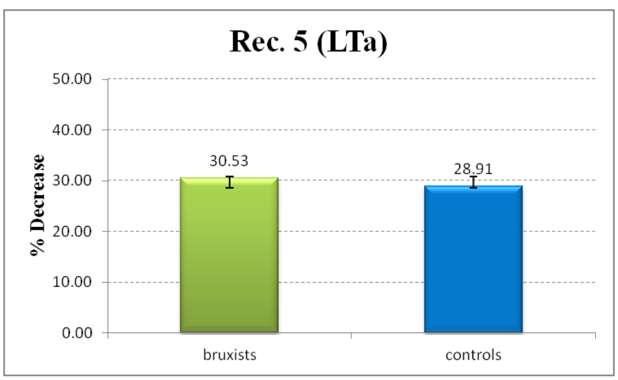

Figure 5. Average percentage decrease of Rec. 5 for each group, mean ± standard deviation.

In Fig. 5 the bruxist group showed a reduction of intEMG of 30.53%, while the control group was 28.91%. The results indicate that a decrease in the AUC of intEMG was generated as seen too in Fig. 4. This means that in both groups the muscles tend to reduce their intensity of contraction when the mental nerve is electrically stimulated with the intensity and duration of stimulation used.

IV. Conclusion

With the stimulation device, the inhibitory mechanism did work in subjects with and without nocturnal bruxism.

The inhibitory mechanism used is physiologically based on the electrical stimulation of the mental nerve with a low voltage (0.1V and 0.5V) and high frequency stimulus (300Hz and 500Hz) stimulating half the period of the stimulating signal. The afferent responses that are generated are directed towards higher nervous centers (brain stem). These afferent signals are processed by neurons that decrease motor responses for the contraction of muscles involved in the elevation of the jaw.

When stimulated with high frequencies, the threshold of stimulus perception increases, making the subject perceive less electrical current [11]. This helps the patient not to notice the stimulation while sleeping.

The decreased activity measured in the LTa muscle indicates that inhibition responses can be generated considering that the temporalis anterior is the major muscle that elevates the mandibule. This is consistent with the results obtained by Jadidi et al. [5, 6].

Therefore, this electronic device is a good start for possible treatment in patients with NB. Further tests and studies in subjects are needed to ensure that the equipment reduces completely the bruxism while sleeping.

Acknowledgment

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