DEVELOPMENT OF A WIRELESS AUTONOMOUS BRUXISM MONITORING DEVICE

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Abstract: A wireless pressure sensing bite guard has been developed for monitoring the progress of bruxism (teeth grinding during sleep. The pressure sensor was fabricated from carbon-polymer composite which was encapsulated into a conventional prescription bite-guard; together with a built in-house microcontroller-based electronics circuit for data collection and data transmission. A low power approach was configured to maximize the working life-time of the device to several months. The device can provide real-time tooth grinding profile through wireless communication. This device is anticipated to be a useful tool for understanding the progress of bruxism treatment.

1 Introduction

Bruxism is a movement disorder of masticatory system that results in involuntary grinding of the teeth and the clenching of the jaw during sleep as well as wakefulness. It is estimated that about 10% of the population suffer from the disease. [1-3] Tooth clenching or grinding during sleep can result in abnormal wear patterns of the occlusal surface, fractures in the teeth, morning headaches and facial muscle pain. [4] The most common method of bruxism management is based on minimizing the abrasion of tooth surfaces by wearing a bite-guard [5, 6]. Currently, there is no definitive clinical diagnostic method for assessing bruxism.

Evaluation of existing tooth wear does not provide evidence of current bruxism. Generally, bruxism diagnosis is to monitor masticatory muscle activities by using the surface Electromyography (EMG) . [7-9] However, the surface EMG signal is affected by factors such as electrode position, posture and skin resistance. In addition, it is not easy to attach multiple electrodes on the face without causing unease or disrupting sleep. An alternative way to diagnose bruxism is to measure bruxism activity directly in situ using pressure sensitive transducer. Several researchers have measured sleep bruxism activity directly using an intra-oral appliance. Nishigawa et. al. measured the bite force using strain-gauge transducer incorporated bite guard. This device was an analogue pressure sensor with electric wires connected out of the mouth during sleep. [10] Takeuchi et. al. proposed a pressure sensing device by using piezoelectric sensor. However, piezoelectric transducer has very limited force range. [11] Despite the number of techniques being developed to detect bruxism, a practical method is still not available to monitor the progress of the symptom.

We propose a wireless wearable pressure sensing device which offers continuous monitoring of suspected grinding over a time period to allow the diagnosis of the problem. The concept envisages a pressure sensor integrated into a normal prescription bite-guard. This type of pressure-sensitive composite has been investigated as force sensor [12-15]. The proposed device will have all electronic components encapsulated into the body of the bite-guard which will detect and wirelessly transmit in real time the grinding events to a computer. It is envisages that the device will identify patients with an active problem; monitor the progress of the symptom and to access the effectiveness of the treatment.

2 Method

The configuration of the proposed system used for monitoring bruxism activities is shown in Figure 1. It is composed of four main parts: (1) A bite-guard, (2) a pressure sensor with (3) control electronics (microcontroller and wireless transmitter module) incorporated within a bite guard and (4) a separate RF receiver module which is connected through USB to the host computer for logging data.

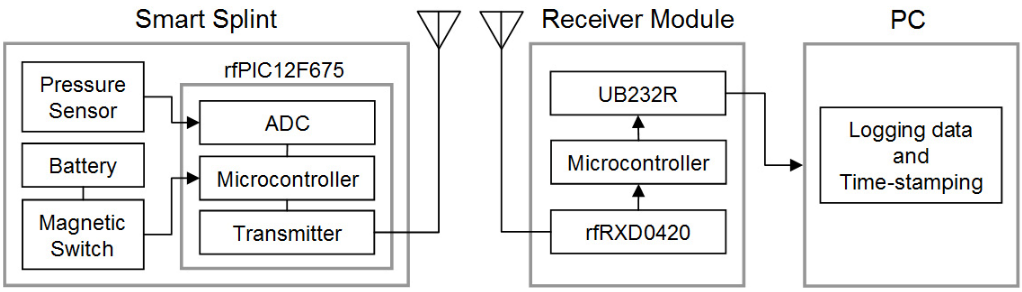

Fig. 1. System Configuration: pressure sensing bite guard with wireless transmitter, receiver module and host computer.

Fabrication of pressure sensor: Conductive carbon black powder (Carbot Corp, Rozenburg, Netherlands) was mixed with PDMS pre-polymer (Polydimethylsiloxane: Dowcorning, Sylgard 184) prepared by mixing 10:1 ratio (base : curing agent). The mass ratio of carbon black to PDMS mixture was 17-19 wt%.

Electronic Circuitry**:** An 8 bit CMOS microcontroller rfPIC12F675 (Microchip Technology Inc.) with built-in UHF ASK/FSK transmitter (20 pin SSOP package: 7.85 mm x 7.20 mm x 1.85 mm) was used. It has a 2 digital I/O and 10 bit A/D converter with 4 analog inputs. Therefore, 4 signals can be read from different sensors and transmitted with a 433.92 MHz carrier. In order to make the electronic circuitry small enough to be incorporated into the bite-guard, it was designed into two modules connected via flexible wirings as shown in Figure 2. The receiver module was fabricated using radio frequency receiver module (rfRXD420) and microcontroller (PIC12F675) from Micro Chip Inc. The microcontroller detects radio signal using interrupt routine and checks received data for errors. And the receiver module sends one byte containing sensor ID and a second byte containing data to the PC through the USB cable at 9600 baud rate and this module is powered by PC through USB 5V supply.

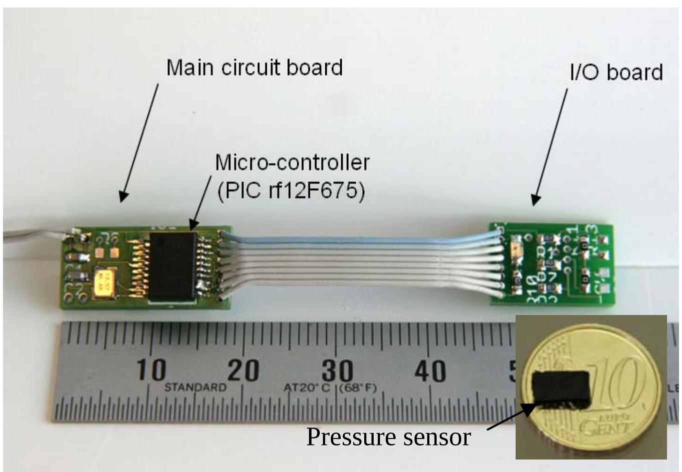

Fig. 2. Photograph of fabricated microcontroller board and I/O board. Inset is the carbon-

polymer composite pressure sensor.

The finished pressure sensing bite guard prototype has microcontroller circuit board with wireless transmitter module and 2 button batteries (Silver oxide battery, SR43) integrated as shown in Figure 3. The pressure sensors were incorporated into two cavities fabricated on both sides of the molar teeth area of the bite guard. The thickness of pressure sensor and acrylic cover was 0.6mm and 1.0mm respectively. The integrated bite guard was then calibrated with compression test using Zwick instrument. Known load was applied 5 times repeatedly at 1mm/min speed. The maximum applied force for compression test was 200N.

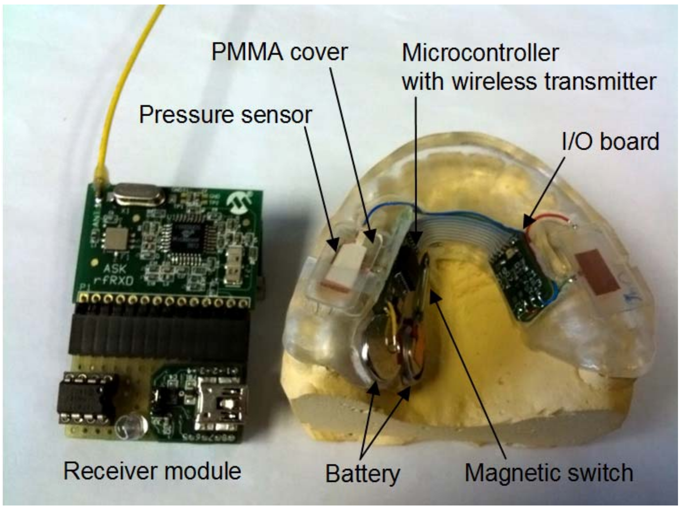

Fig. 3. The integrated wireless pressure sensing bite-guard with receiver module.

3 Results and Discussion

3.1 Calibration of the carbon-polymer composite sensor

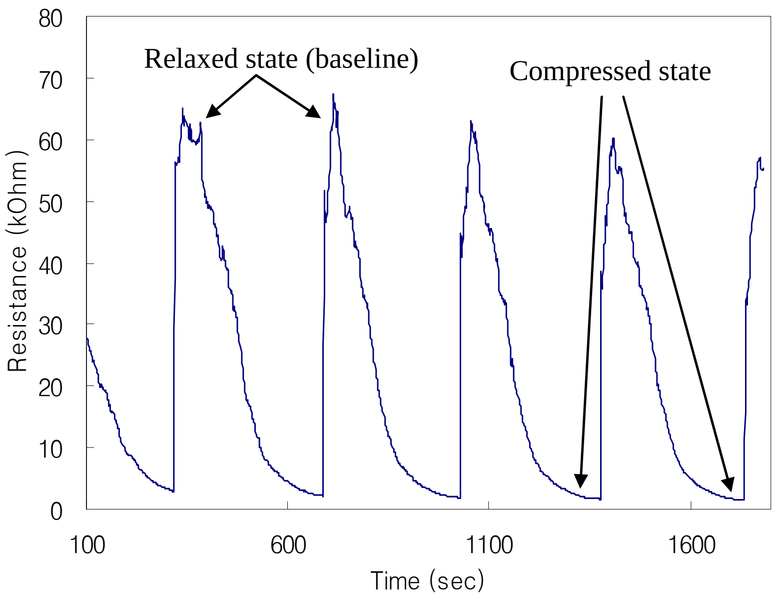

Fig. 4. Zwick loading-unloading test results obtained from a bare carbon-composite pressure sensor showing resistance change on 50% compression. Test speed: 0.1mm/min.

The compression test results obtained from a bare carbon-composite pressure sensor are shown in Figure 4. With the 50% compression range investigated, the measured force was between 0 - 61.8 N, and the range of resistance caused by the compression was between 67.3kOhm and 1.6kOhm. These results have shown that the pressure sensor gave good sensitivity over the applied force range.

3.2 Validation of PMMA cover

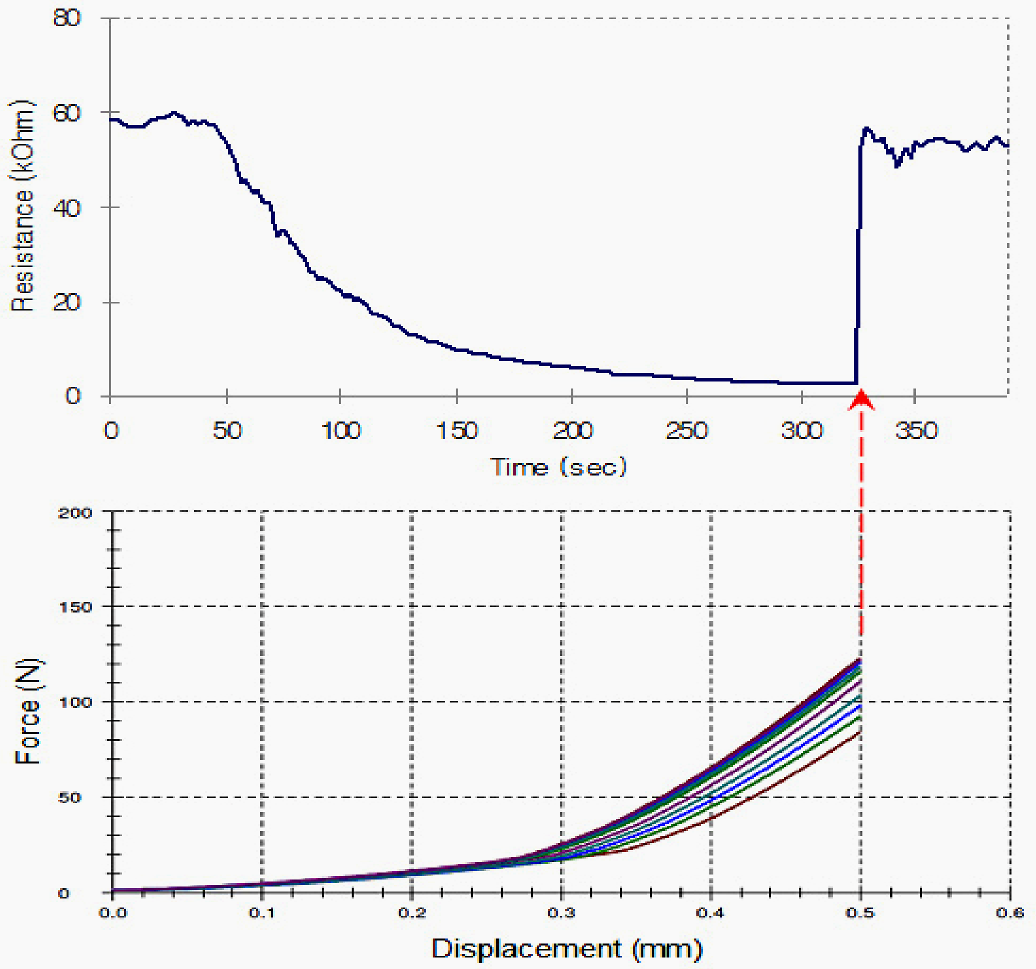

Fig. 5. (a) The change of sensor resistance during (b) compression of sensor under acrylic covers of different thickness.

In the final pressure sensing bite-guard design, the pressure sensor needs to be encapsulated under a acrylic cover to protect it from the saliva and mechanical damages. The pressure sensor would therefore serve as a transducer for the force that bends the acrylic cover. Figure 5 shows the resulting resistance change from the compression test using 0.87 mm - 1.20 mm thick acrylic covers. As expected, the observed sensitivity would be governed by the modulus of elasticity of the cover material. The range of resistance recorded during the compression test was similar to the previous results obtained with bare sensor, but the maximum load required to achieved 50% compression doubled to ca. 120N. These results shows that the sensitivity of the pressure sensing bite-guard can be tuned by the thickness of the covering material.

3.3 Performance of the integrated wireless bruxism monitoring device

The integrated pressure sensing bite-guard has the pressure sensor incorporated into a cavity in the bite-guard protected by a PMMA cover. Also buried inside the bite guard is the microcontroller-based electronic circuit board including wireless module to perform essential functions including sensor control, data logging, data transmission and power management. To reduce power consumption, the device is normally set at sleep mote and would only start to transmit when a threshold value is crossed. Transmission in packets of 8 data points per second is used.

Compression test of the wireless integrated sensing bite-guard was performed with Zwick instrument and the A/D value from the sensor was received wirelessly at the PC through the receiver module.

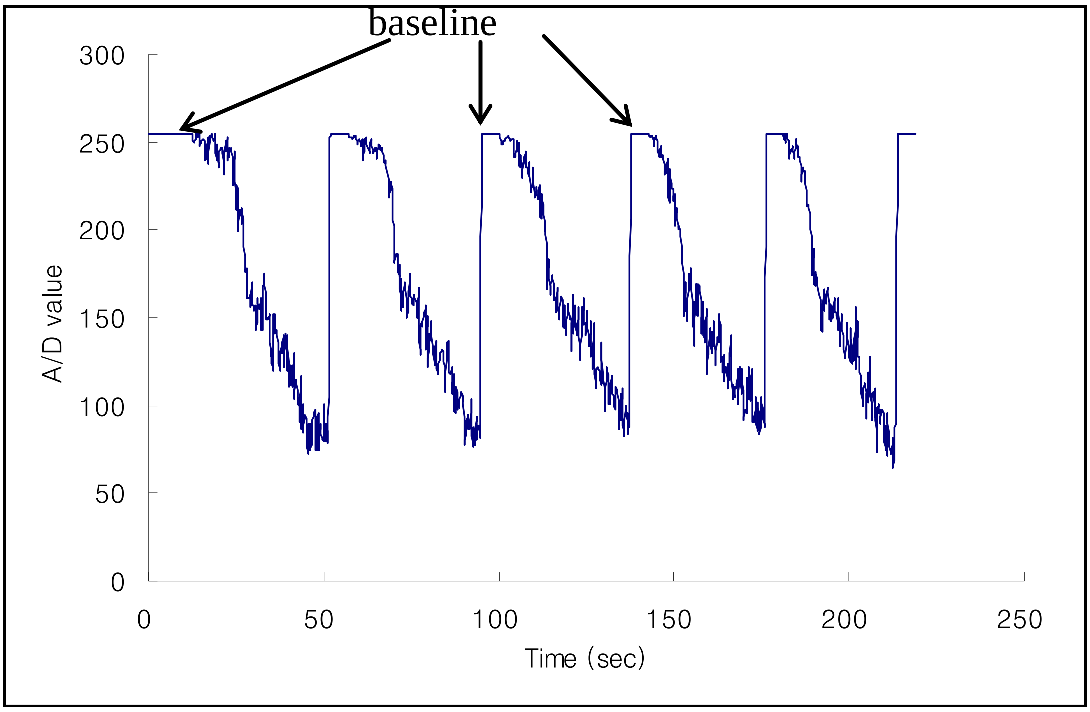

Fig. 6. Output signal (A/D value) obtained from wireless pressure sensing biteguard during a compression test.

As shown in Figure 6, good response range between 250 – 70 unit was obtained with applied load between 0 to 200 N to achieve a 50% compression of the pressure sensor. Very good reproducibility was also observed from as shown from the 5 consecutive compressing tests. The signal seems to be noisier (RSD 10%) than those observed previously before integration. This was due to the experimental setup where the bite-guard had to be fitted onto its corresponding mould from which it was made. Naturally, the teeth was not completely horizontal but inclined inwards with a slope, hence, during compression, the press head was constantly sliding away from the original point of contact, resulting in the observed noisy data. Unfortunately, it could happen in real-life application as there would be no control over the point of contact during tooth grinding. However, the sensor could capture the compression (grinding) event correctly every time. Although we have not perform trials with human at this stage, the results have shown good promise for diagnosing and monitoring bruxism.

The device requires very low power to run with an average current draw at standby mode to be 0.76mA. During RF transmission, the peak current reached ca. 11mA. With a capacity of 120mAh from a 1.55V silver oxide battery (SR43) used in this application, this device was shown to run for over 100 hours continuously with 1 Hz transmission rate (Figure 7). Practically, the total duration of tooth grinding per night is normally less than 30 minutes. Hence, this device could last for several months without changing the battery. The working range of wireless communication is up to 100 meters line of sight. So the patient could locate the host computer anywhere in the house as this device has a wireless range suitable for most residential environments.

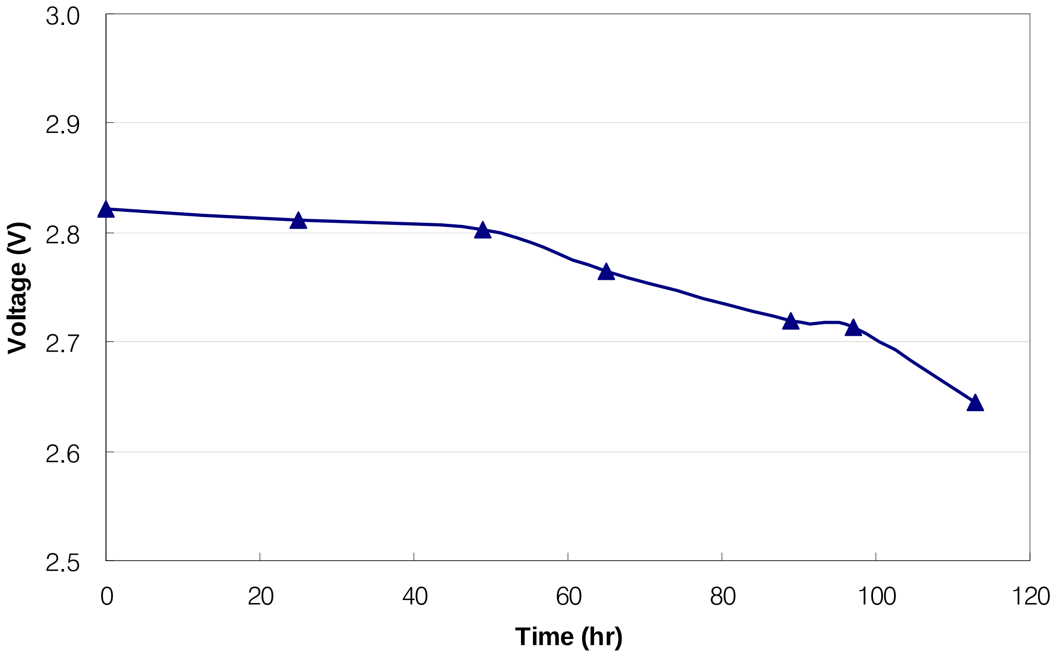

Fig. 7. Voltage drop of battery during operation at transmitting frequency = 1Hz.

4 Conclusions

A wireless pressure sensing bite guard has been developed for monitoring the progress of bruxism. The performance of the device appears to be an excellent methodology for diagnosing and monitoring bruxism.

Acknowledgement

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