WIRELESS INTRAORAL SENSOR FOR THE PHYSIOLOGICAL MONITORING OF TONGUE PRESSURE

E. Sardini[1], *M. Serpelloni*[1*], *and R. Fiorentini*[2]
[1]Dep. of Information Engineering, University of Brescia, Brescia, ITALY
[2]Dental-Care, Orthodontic Medical Specialists, Brescia, ITALY

ABSTRACT

The tongue has continuously contact with the hard palate during articulation of a syllable or during swallowing. Patients who have had a cerebrovascular accident or other neurological disorders may present language disorders and lack of tongue coordination. In this work, a proposed device with the aim to provide a non-invasive aid to rehabilitation and care of people with language or swallowing disorders is described. The proposed device is designed with the purpose to measure continuously the tongue pressure on the palate and transmit wirelessly the data. The device is minimally invasive, because no cable connects the measuring system placed in the mouth and the readout unit placed outside. A first prototype has been developed and preliminary tests were performed using an experimental setup designed ad hoc. Preliminary experimental results obtained using a testing machine show a wide measurement range of the fabricated pressure sensor, up to 80 kPa. Fields of use of this device are the treatment of people with language or swallowing disorders.

KEYWORDS

Intraoral sensor, implanted sensor, wireless sensor, physiological monitoring, pressure sensor, thick-film sensor.

INTRODUCTION

In recent years, the number of patients who have had a cerebrovascular accident or other neurological disorders (e.g. Parkinson's disease) is increasing. The problems of swallowing and sound articulation are important issues for the treatment, rehabilitation and care of these patients [1-2]. In fact, the motor disorder of language and a lack of coordination of tongue are often diagnosed for these patients. Until now, videofluorography (VF) or videoendoscopy (VE) have been used in the diagnosis of swallowing problems. VF and VE investigations have analyzed qualitatively the tongue coordination and jaw movement in chewing and swallowing [3-5]. However, applying VF extensively and repeatedly is difficult because of the dangers of radiation exposure to patients. The measurement possibility of tongue pressure against hard palate during articulation of a syllable or during swallowing is important, in fact, the tongue contact with the palate is of vital importance for both functions.

In the literature, investigations on the contact of the tongue against the hard palate during swallowing or articulation of sounds have been studied recently. In [6-11], pressure sensors were used for measuring the tongue pressure. These techniques are based on a sensor positioned in contact with the palate and connected via cables to a conditioning electronics positioned outside of the oral cavity. In [9], the authors describe a pressure sensor for measuring the pressure of the tongue on the palate using a palatal plate with seven experimental pressure sensors, which was estimated to be a useful procedure for the qualitative evaluation of the language activities in patients with problems of swallowing and articulation of sounds. However, the presence of wired connections, between oral cavity and readout unit placed outside, can impair normal physiological swallowing or sound articulations. In addition, the presence of cables can be felt invasive by the patient. A solution could be the use of measuring devices that integrate a wireless transmission.

In the literature, devices that transmit information in wireless mode between the inside and the outside of the oral cavity are reported for different applications [12-14]. In [12], the authors describe architecture and principle of operation of a new wireless embedded tongue tactile biofeedback system for balance control for fall prevention and present results of a feasibility study performed on young healthy adults. The device performs the biofeedback, but does not incorporate any pressure sensor. In [13], the purpose was to develop a wireless telemetry method to supplement the shortcomings of existing methods which measure the intra-oral pH. In [14], a prototype system for wireless control of computer interfaces to the internet and other devices is reported. The wireless intra-oral device is activated by the language, the signals are sent to tens of meters to a wireless coordinator that forwards commands from human intra-oral device to computers and other devices. The sensor operates as a switch that transmits the contact information. The pressure of the tongue on the palate is not measured.

In this research work, a wireless intra-oral device for measuring the tongue pressure on the palate is proposed. The presented system is designed to measure continuously the tongue pressure on the palate and transmit wirelessly the data to a readout unit. The implanted device is composed of seven sensors connected to an electronic circuit for conditioning and data transmission. The sensors are fabricated using screen-printing technique over a plastic substrate at low-temperature. The proposed conditioning and transmitting circuit is introduced and the constituent blocks are briefly described. The sensors were manufactured and tested using an experimental setup designed ad hoc. Preliminary experimental results are reported and discussed. Fields of use of this device are the treatment of people with language or swallowing disorders.

SYSTEM DESCRIPTION

In Fig. 1, the proposed device for measuring tongue pressure totally is shown.

The device consists of tactile sensors fabricated over a plastic sheet. The sensors are connected to an implanted circuit for the conditioning of the sensor signals and the transmission of data outside the mouth wirelessly. The thinness of the sheet was considered to be effective to reduce the discomfort in the oral cavity. All the system can be enclosed in a plastic casing of biocompatible material. The casing is thermoformed so as to adapt to the physiognomy of the oral cavity of the individual patient.

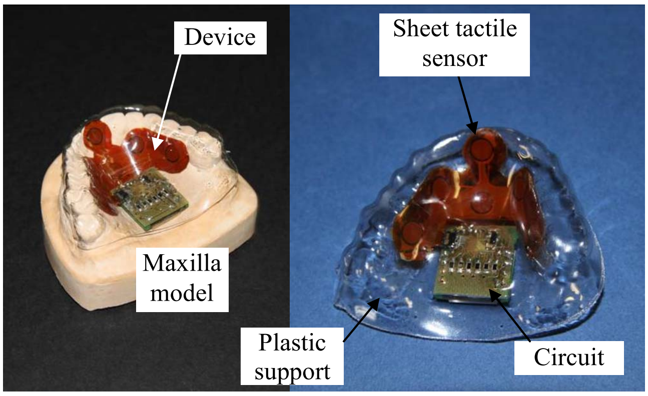

Figure 1: View of the realized device enclosed in a biocompatible plastic support and placed on a maxilla model.

In Fig. 1, a preformed maxilla model of an adult woman was used as reference of real oral cavity for the design of the geometrical characteristics of the sensors. The sensors are placed in specific positions described below, while the sheet on which the sensors are fabricated has a geometry that can be adapted to the curvature of the oral cavity. The circuit has small dimensions (about 18 x 20 x 5 mm) and it is positioned in a part not affected by pressure measurement.

The sensor sheet implements six sensing points called sensor pads (P1-P6), Fig. 2. The sensor sheet with the six measurement points (diameter 3.2 mm) was designed ad hoc; two measurement points (P1-P4) are placed along the midline, two (P5-P6) are in the back-side and two (P2-P3) laterally. Consequently, the sheet sensor has the shape reported in Fig. 2, which has allowed to be easily attached on the curved surface of the hard palate. The positions of the pressure sensors are decided on the basis of the dental arch and anatomical landmarks of a standard subject [9]. The size of the sheet and the distance between the sensors are shown in Fig. 2.

The sensor sheet consists of two sheets of Kapton film (25 μm thick) with copper laminated on it (35 μm thick). Electrodes and connections are obtained using photolithographic technology, and then a material, sensitive to pressure, (CreativeMaterials DS118_44) is deposed on the electrodes (Fig.2).

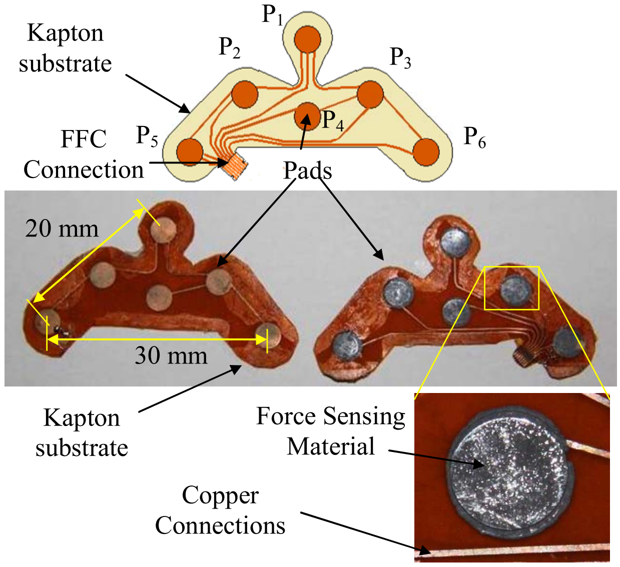

Figure 2: View of sensor layout and fabricated sensor with screen-printed resistive film and a zoom of one pad with the force sensing material deposited.

The material is deposed using screen-printing techniques and cured at low temperature 120 °C for about half an hour. An adhesive is applied to connect together the two sheets, so the thickness of the sensor is approximately 150 μm. The electrical resistance of the sensor in the absence of load is almost infinite, and decreases applying a force.

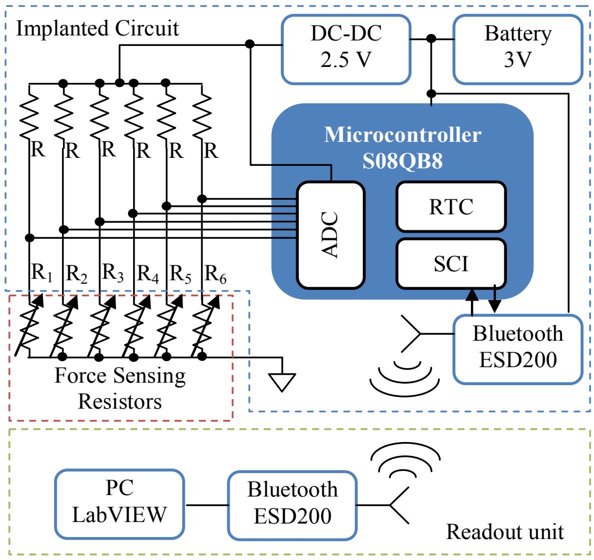

Figure 3: Block diagram of the implanted system and readout unit.

In Fig. 3 the block diagram of the implanted system and readout unit are shown. The conditioning and transmitting circuit is based on a low power microcontroller (FreescaleS08QB8) powered by a 3 V button battery. The battery voltage is stabilized by a DC-DC regulator with output to 2.5 V; this voltage is used as a fixed reference for the analog to digital converter and as reference voltage for the resistive divider. In fact, the principle of resistive measurement of the sensors is based on a measurement of the voltage divider as shown in Fig.3; the resistance R is about 50 MΩ and the sampling frequency is about 70 Hz, but it can be modified using the RTC (real time counter) of the microcontroller. The resolution of the analog to digital converter is 10 bits. The voltage divider is converted by the analog to digital converter and sent via serial communication to the Bluetooth module (ParaniESD210). Thus, the pressure detected by the sensors is transmitted in real time using a Bluetooth to a personal computer in which data are displayed and saved.

EXPERIMENTAL SETUP

In Fig.4, the experimental setup is shown. A machine (Instron3366) was used for the pressure characterization. The machine is equipped with a load cell able to detect the force exerted on the material with a resolution of 0.01 N. The conformation of the machine ensures that the force is exerted in a perpendicular way to the target. The machine is connected to a computer, which allows to control the scrolling speed of the moving beam or the force exerted. Then forces were applied and the divider voltages were detected by means of a Hewlett Packard 34401A multimeter. Each value of force was maintained for a constant time interval. For each test the temperature of the environment to which was made the characterization was measured. Bluetooth-microcontroller connections were tested with an oscilloscope (LecroyLT374M).

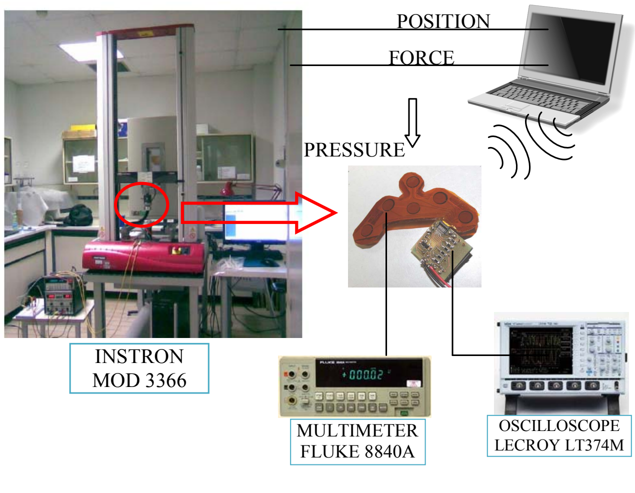

Figure 4: Experimental setup adopted for the characterization of the sensors and circuit testing.

EXPERIMENTAL RESULTS

Preliminary experimental tests were executed to evaluate the sensor outputs. In this paper, two graphs are reported. Fig. 5 shows the average resistance values for the six resistors and the maximum and minimum values measured. As shown in Fig. 5, the measurement of low pressures is associated with high sensitivity, while a measure of high pressures is associated with lower sensitivity. However, the maximum and minimum values for resistance measurement is closer for low values, guaranteeing the possibility of properly discretize the high values of pressure as well. The obtained behavior is in accordance with expectations, in fact, the sensors are designed to have an infinite resistance when no pressure is applied and a decreasing trend of the resistance value when the value of applied pressure increases.

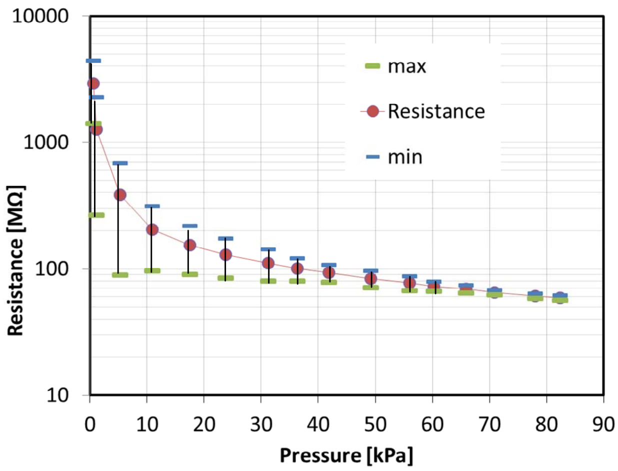

Figure 5: Average resistance, maximum and minimum level measured vs. pressure.

Fig.6 shows the average voltage measured for the six sensors as a function of the pressure exerted and the maximum and minimum values measured. The function is of quadratic type and the interpolating polynomial is shown in the graph. The squared correlation coefficient is about 0.999. Furthermore, as shown in Fig. 6, a nearly linear trend can be observed for values between 80 kPa and 20 kPa, while for lower values, the trend is quadratic.

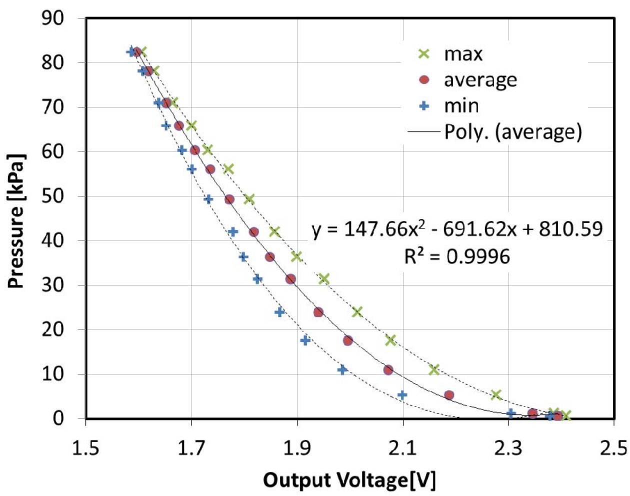

Figure 6: Output voltage measured for different imposed pressures and polynomial interpolation.

CONCLUSIONS

In this work, a wireless intraoral sensor is presented. The proposed device is designed for the monitoring of the tongue pressure on the palate. The proposed device is composed of six sensors and a conditioning and transmitting circuit. The sensor is fabricated using screen-printing technique over a plastic substrate at low-temperature. The proposed conditioning and transmitting circuit is introduced and the constituent blocks are briefly described. The thickness of the sensor and the dimension of the conditioning and transmitting circuit reduce the discomfort in the oral cavity. Preliminary experimental results are reported and discussed. The characterization shows a wide pressure range up to 80 kPa. Experimental results and trials on patients are undergone. Fields of use of this device are the treatment of people with language or swallowing disorders.

REFERENCES

[1] O. Chenu, N. Vuillerme, J. Demongeot, Y. Payan, "A Wireless Lingual Feedback Device to Reduce Overpressures in Seated Posture: A Feasibility Study", *PLOS one 4(10),* 2009, 1-8.

[2] C.M. Steele, G.L. Bailey, S.M. Molfenter, E.M. Yeates, K. G. Martin, "Pressure profile similarities between tongue resistance training tasks and liquid swallows", *Journal of Rehabilitation Research & Development 47(7)*, 2010, 651–660.

[3] H. M. Clark, N. P. Solomon, "Age and sex differences in orofacial strength", *Dysphagia 27(1)*, 2012, 2-9.

[4] T. Ono, K. Hori, KI. Tamine, Y. Maeda, "Evaluation of tongue motor biomechanics during swallowing—From oral feeding models to quantitative sensing methods", *Japanese Dental Science Review* 45(2), 2009, 65–74.

[5] Y.J, Kumakura, K. Hori, KI Tamine, T Ono, "Differences in biomechanical features of tongue pressure production between articulation and swallow", *Journal of Oral Rehabilitation* 39(2), 2012, 118-25.

[6] F. Yoshioka, S. Ozawa, Y.I. Sumita, H. Mukohyama, H. Taniguchi, "The pattern of tongue pressure against the palate during articulationg glossal sounds in normal subjects and glossectomy patients", *J. Medical Dental Science 51*, 2004, 19-25.

[7] M.J. Mcauliffe, E.C. Ward, B.E. Murdoch, "Intra-participant variability in Parkinson's disease: An electropalatographic examination of articulation", *Advances in Speech–Language Pathology 9(1),* 2007, 13 – 19.

[8] J. Yano, I . Kumakura, K. Hori, K.I. Tamine, T. Ono, "Differences in biomechanical features of tongue pressure production between articulation and swallow", *Journal of Oral Rehabilitation 39,* 2012, 118–125.

[9] K. Hori, T. Ono, K. Tamine, J. Kondo, S. Hamanaka, Y. Maeda, J. Dong, M. Hatsuda, "Newly developed sensor sheet for measuring tongue pressure during swallowing", *Journal of Prosthodontic Research* 53(1), 2009, 28-32.

[10] K. Yanagisawa, I. Takagi, K. Sakurai, "Influence of tongue pressure and width on tongue indentation formation", *Journal of Oral Rehabilitation 34*; 2007, 827–834.

[11] C. Jeannin, P. Perrier, Y. Payan, A. Dittmar, B. Grosgogeat, "Tongue pressure recordings during speech using complete denture", *Materials Science and Engineering* C 28, 2008, 835-841.

[12] N. Vuillerme, N. Pinsault, O. Chenu, A. Fleury, Y. Payan, J. Demongeot, "A wireless embedded tongue tactile biofeedback system for balance control", *Pervasive and Mobile Computing 5*, 2009, 268–275.

[13] J.H. Ro, S.Y. Ye, J.H Jung, A.Y. Jeon, Y.-J Kim, I.C. Kim, C.H. Kim, G.R. Jeon, "Development of Indwelling Wireless pH Telemetry of Intraoral Acidity", *World Academy of Science, Engineering and Technology 30*, 2007, 361-365.

[14] Q. Peng, T.F. Budinger, "ZigBee-based Wireless Intra-oral Control System for Quadriplegic Patients", *Proceedings of the 29th Annual International Conference of the IEEE EMBS*, Cité Internationale, Lyon, France, August 23-26, 2007, 1647-1650.

CONTACT

*M.Serpelloni, tel: +39-030-3715915; mauro.serpelloni@ing.unibs.it