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Fundamental Study on Monitoring System of Masseter Muscle Condition Using SWE

Tomohisa Funakura[1†], Takuma Hoshino[1], Masahiro Tsuchiya[2], Noriaki Shoji[3], Shinnosuke Hirata[4], and Marie Tabaru[1] ([1]IIR, Tokyo Tech; [2]Tohoku Fukushi Univ. Department of Nursing; [3]Tohoku Univ. Grad. School of Dentistry; [4]Center for Frontier Medical Engineering, Chiba Univ.)

1. Introduction

In recent years, the number of patients with temporomandibular disorder (TMD) has been on the rise[2)]. However, the onset mechanism of TMD is unknown. The symptoms of TMD include stiffness and pain in the muscles around the jaw[2)]. A monitoring system of such muscle conditions will be useful to reveal the mechanism. The goal of our study is establishing a monitoring system of condition of masseter muscle using ultrasound.

This report investigates the relationship between the bite force and shear wave speed of masseter muscle measured by shear wave elastography (SWE) technique.

2. Fabrication and evaluation of bite force sensor

2.1 Prototype of bite force sensor

A film-type pressure sensor (FlexiForce, 440 N) was use as a bite force sensor as shown in **Fig. 1**. Sensor output changes by electrical resistance of a thin-film resistor. The output voltage was amplified using an inverting amplifier circuit. The pressure-sensitive area was bonded with a nitrile rubber (hardness: 50) of 9 mm in diameter and 1 mm in thickness, so that the sensor output was not affected by load shape.

Figure 2(a) shows the different shapes of the load connectors to investigate the sensor output. A digital force gauge (FGJN-50, Nidec-Simpo) was used to apply load from 100 to 400 N with the connectors, and the relationship between the load and the sensor output was measured. The result shown in **Fig. 2(b)** shows that the sensor was not affected by the connector shape.

2.2 Mouthpiece integrated bite force sensor

Because the sensor is easily broken if it is chewed directly with the teeth. Therefore, the sensor was sandwiched by two mouthpieces (AoLiGei, Professional Fit Mouthpiece) and plastic plates (thickness: 1 mm). Mouthpieces were molded to fit the teeth. The cross-sectional configuration from the top to the bottom is mouthpiece - plastic plate - sensor - plastic plate – mouthpiece. **Figure 3** shows the sensor outputs increase almost linearly with the load. Therefore, we decided to use the mouthpiece integrated sensor in the measurement with SWE.

funakura.t.aa@m.titech.ac.jp

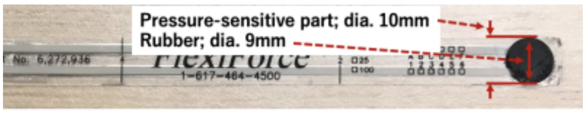
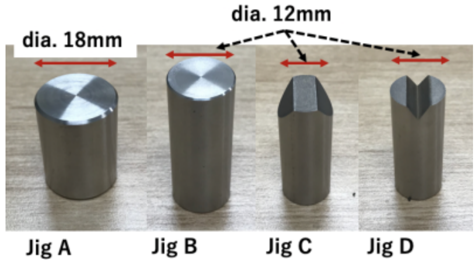
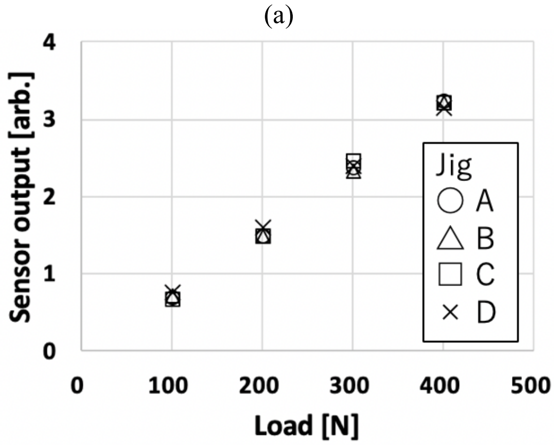


Fig. 1 Rubberized pressure-sensitive sensor.



(a)



(b)

Fig. 2 (a) Pictures of load connectors. (b) Sensor output with different connector shapes.

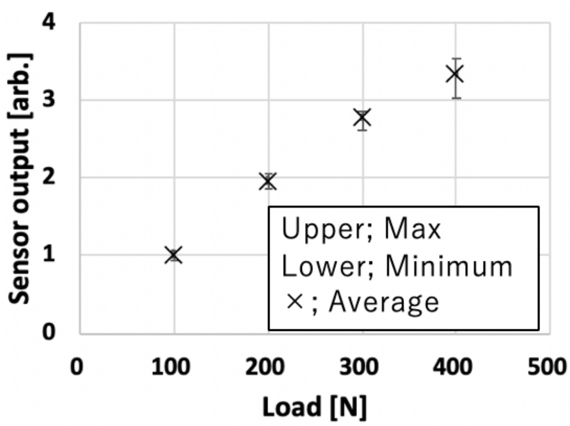


Fig. 3 Mouthpiece integrated sensor output.

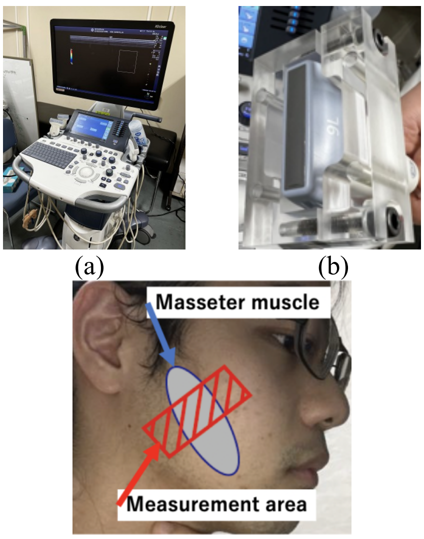
3. Elasticity measurement of masseter muscle

3.1 Experimental system and method

SWE is an ultrasound-based technique that characterizes elastic properties of human tissue such as shear wave speed based on the propagation of shear waves[3]. In this report, an ultrasonic diagnostic device (LOGIQ S8, GE) (**Fig. 4 (a)**) and a linear array probe (9L, GE) (**Fig. 4 (b)**) were used to measure the shear wave speeds of masseter muscle. An acrylic jig was attached to the probe to provide stability the measurement position (**Fig. 4 (b)**). An experiment is conducted with one healthy male (age: twenties). The measurement area of SWE is illustrated in **Fig. 4(c)**. The ultrasonic probe was placed so that the longitudinal direction and the muscle fiber direction were perpendicular to each other. Since the position of the masseter muscle is near the skin surface, an acoustic coupler of 2 cm in thickness was put between the jig and the skin. B-mode and SWE image were obtained by increasing bite force. Ultrasonic jelly was also applied.

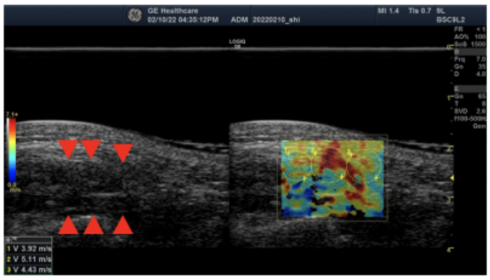
3.2 Experimental results

Figures 5(a) and **(b)** show the B-mode and SWE images, respectively, when bite force was 90 N. The masseter muscle thicknesses were measured from B-mode image. The averaged shear wave speeds inside the region of interest of SWE image were also calculated. Results in **Fig. 6** show that shear wave speed increases as bite force increases. The results indicate that the masseter muscle became stiffer with the increase of bite force. The thickness of the masseter muscle also increased as bite force increases, however did not continuously increase.



(c)

Fig. 4 (a) Ultrasonic diagnostic device. (b) Linear array probe with jig. (c) Area of masseter muscle measurement.



(a) (b)

Fig. 5 (a) B-mode and (b) SWE images of masseter muscle when the bite force was 90 N.

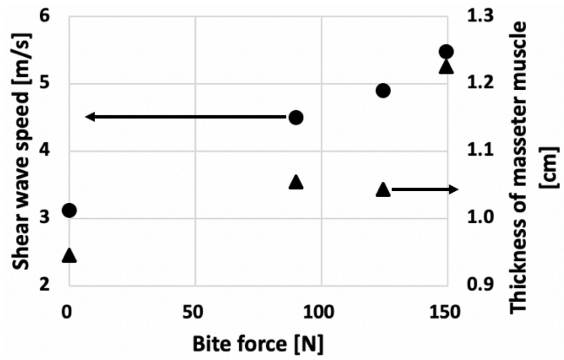


Fig. 6 Shear wave speeds and thickness of masseter muscle vs. bite force.

4. Summary and future plan

Through the experiments, we confirmed that it was possible to measure the condition of elasticity of masseter muscle by SWE. As to simulate TMD, we will fatigue the masseter muscle and measure the elastic property of the masseter muscle before and after fatigue in future study. For the measurement, the bite force sensor should be improved to be able to measure up to 1000 N to measure of maximum bite force.

Acknowledgment

This work was supported by JSPS KAKENHI Grant Number 22K04134 and the Cooperative Research Project of Research Center for Biomedical Engineering.

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