A PDA-BASED MEASUREMENT SYSTEM OF TONGUE FORCE FOR CLINICAL APPLICATION

R.Tsuji*, M.Matsumura**, K.Nohara***, T.Tachimura****, and K.Chihara*

* Nara Institute of Science and Technology, Graduate School of Information Science, Nara, Japan
** Osaka Electro-Communication University, Graduate School of Biomedical Engineering, Osaka, Japan
*** Osaka University, Osaka University Dental Hospital, Osaka, Japan
**** Osaka University, Graduate School of Dentistry, Osaka, Japan

matumura@amlab.osakac.ac.jp

Abstract: We measured linguopalatal contact pressure during production of the consonant /t/ and succeeded in measuring tongue force (amount of force exerted by the tongue against the palate) and its action point (center of contact pressure) in both individuals with articulation disorder and those without. By comparing palatal shape with the spatial relationship of the action point of tongue force, both factors were found to be important for normal articulation. We then created the tongue force measurement system to aid clinicians in measuring tongue force simply in patients with articulation disorder and for use in medical treatment. This system conveniently utilizes a personal digital assistant (PDA). The advantages of our system include that it is wireless and can be operated with one hand. It is possible for the clinician to assess the patient's linguopalatal contact force immediately, to feed back the information to the patient, and to use it during medical treatment. We expect this system to contribute to the advancement of treatment for articulation disorders.

Introduction

Articulation is a function of the oral cavity. The tongue plays a particularly important role in articulation, and its motor function has been measured and estimated using various techniques, including radiography[1], magnetic resonance imaging (MRI)[2], ultrasonic tomography[3], electropalatography[4] and the use of magnetometer sensors[5]. However, since these techniques are limited to measurement of movement of the tongue, movement of the jaw and shape of the lips, a number of researchers have investigated methods of making the distributed contact points sensitive to linguopalatal contact pressure[6][7].

Previously we described our successful measurement of linguopalatal contact pressure distribution using a small cantilever-type force sensor, which enabled us to measure tongue force (amount of force exerted by the tongue against the palate) and its action point (center of contact pressure)[8][9][10]. We then developed a PDA - based measurement system of tongue force to measure tongue force in articulation disorder.

The present paper describes the difference between the action point of tongue force during normal articulation and in articulation disorder. We discuss the usefulness of our system to the medical treatment of articulation disorder.

Use of the force sensor mounted palatal plate in subjects without articulation disorder

We previously developed the force sensor mounted palatal plate. This plate has small, high sensitivity sensors to measure linguopalatal contact pressure distribution. Tongue force (force applied by the tongue to the palate) can be presumed by integrating with distribution, and the action point of tongue force can be found by calculating the weighted mean of distribution.

Figure 1 shows the force sensor and Table 1 shows the performance of the force sensor. Figure 2 shows the force sensor mounted palatal plate.

We measured the linguopalatal contact pressure distribution during production of the consonant /t/ in 6 subjects without articulation disorder using the force sensor mounted palatal plate and measured tongue force and the action point of tongue force. The measurement conditions are shown in Table 2.

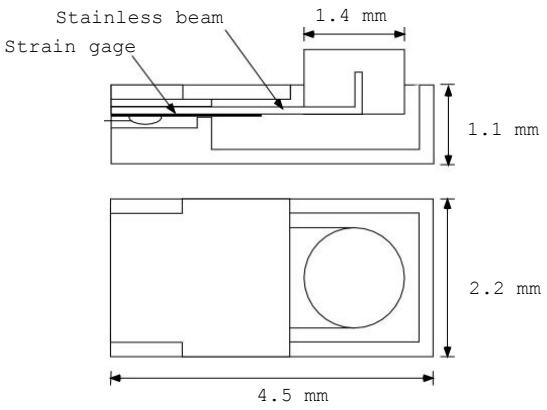

Figure 1: Force Sensor.

ISSN: 1727-1983 © 2005 IFMBE

Table 1: Performance of the Force Sensor.

Size	W: 2.2 mm L: 4.5 mm H: 1.1 mm
Active area	1.54 mm^2 (0.7 mm in radius)
Static characteristic	1.7 % (In saline: 1.9 %)
Dynamic characteristic	0.22 ms (In saline: 0.19 ms)

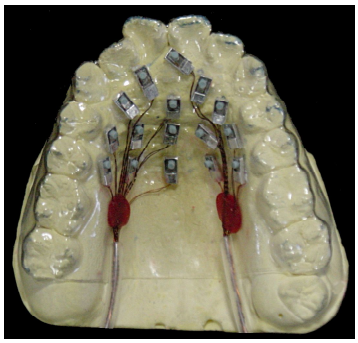

Figure 2: Force Sensor Mounted Palatal Plate.

Table 2: Measurement Conditions for Subjects without Articulation Disorder.

Subjects	Adult; 3 males, 3 females without articulation disorder
Test words	/ta/,/ti/,/tu/, /te/,/to/
Inputs	16 ch force sensor
Sampling	Sampling rate: 10 kHz Quantization: 12 bit
Measurement time	/ti/: 3 sec Others: 1 sec

Use of the PDA-based tongue force measurement system in subjects with articulation disorder

Next, we measured tongue force in 3 subjects with articulation disorder, who use palatal augmentation prosthesis (PAP) for medical treatment[11][12]. Since using the force sensor mounted palatal plate for medical treatment is difficult in individuals with an articulation disorder, we developed the tongue force measurement probe. The tongue force measurement probe comprises one force sensor attached to a stainless plate. The probe cannot measure linguopalatal contact pressure distribution, but the action point of tongue force can be measured from the coordinates and pressure at a measurement position. Measurement was taken at three locations: the lingual center of the maxillary anterior teeth and bilateral lingual gingiva between the second premolar and first molar.

Figure 3: PDA-based Tongue Force Measurement System.

Table 3: Measurement Conditions for Subjects with Articulation Disorder.

Subjects	Adult; 3 males with articulation disorder
Test word	/ta/
Inputs	1 ch force sensor
Measurement position	Lingual center of maxillary anterior teeth Bilateral lingual gingiva between second premolar and first molar
Sampling	Sampling rate: 100 Hz Quantization: 12 bit
Measurement time	10 sec

Thus we developed the tongue force measurement system using the tongue force measurement probe and personal digital assistant (PDA). Tongue force measurement system is shown in Figure 3. The system can record tongue force at 100 Hz. The probe has a functional button where the system begins recording tongue force when the button is pushed. Recording is stopped when the button is pushed again. Measurement conditions are shown in Table 3.

The advantages of using this system are as follows. The fact that it is portable, being small and based on neither a place nor a situation. And it has a display that can show a measurement result. Moreover, it is possible to operate with one hand. It mean this system include the ability to measure tongue force and to check the measurement result easily.

ISSN: 1727-1983 © 2005 IFMBE

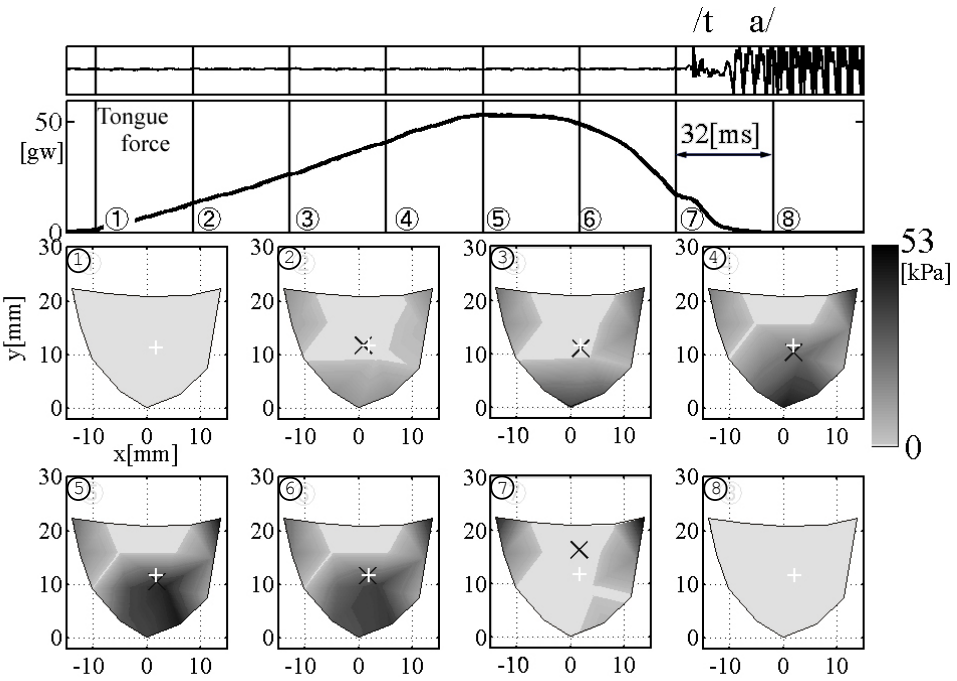

Figure 4: Transition of Linguopalatal Contact Pressure Distribution.

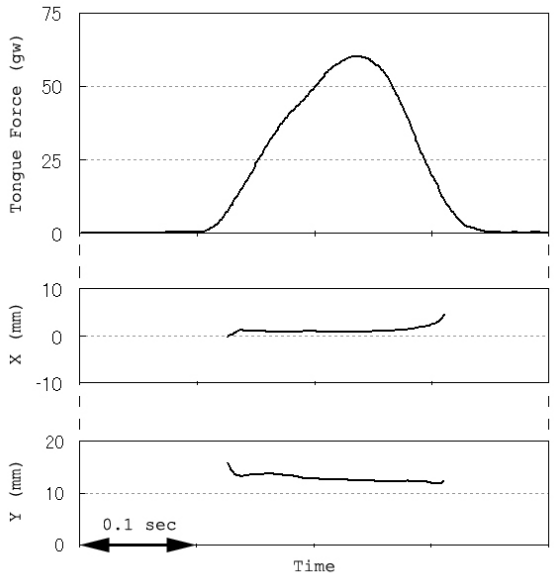

Figure 5: Transition of the Action Point of Tongue Force.

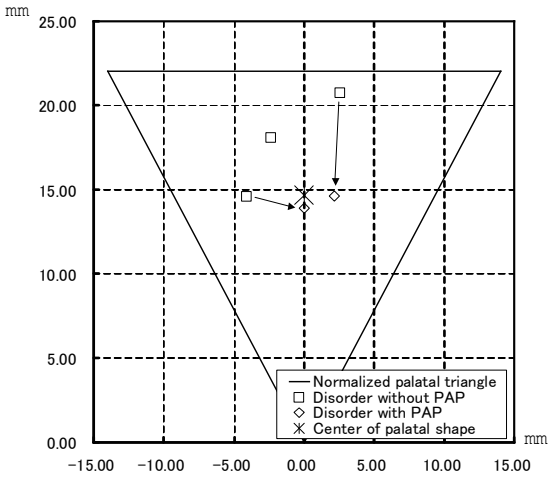

Figure 6: Measurement Results for Subjects with Articulation Disorder.

Tongue force in subjects without articulation disorder

The transition of linguopalatal contact pressure distribution is shown in Figure 4, and the transition of the action point of tongue force is shown in Figure 5. The results showed that the action point of tongue force was consistently in the same position during production of consonant /t/ utterances. Moreover, the position was in agreement with the center of gravity of the palatal shape.

Tongue force in subjects with articulation disorder

Using the PDA-based tongue force measurement system we measured and compared the action point of tongue force for the time when PAP was not being used with the time it was used. Measurement results are shown in Figure 6. We found that the action point of tongue force when not using the PAP is far from the center of gravity of the palatal shape, and that the action point of tongue force when using PAP was in agreement with the center of gravity of the palatal shape. These results indicate that our device is capable of measuring the location of tongue force pressure, data for which can be provided for patient feedback in the treatment of articulation disorder.

ISSN: 1727-1983 © 2005 IFMBE

Conclusions

Measurement of linguopalatal contact pressure distribution in subjects without articulation disorder during the production of the consonant /t/ and measurement of the action point of tongue force revealed that the action point of tongue force exists near the center of the palatal shape.

Based on this result, the PDA-based tongue force measurement system was developed to measure the tongue force of an individual with articulation disorder. We discovered that the action point of tongue force in articulation disorder was far from the center of the palatal shape. However, when measuring tongue force while the subject wore a PAP, we found that the action point of tongue force was closer to the center of the palatal shape, as in normal articulation

Our measurement system of tongue force appears to be of importance to the medical treatment of articulation disorder. The clinician can measure tongue force simply, can check the result immediately and can provide more accurate directions to the patient to modify articulation. Moreover, the patient is able to pracice with the device outside the hospital setting. The data captured can be transferred to a PC using a memory card or a wireless LAN, which allows the clinician to monitor the patient's condition remotely, where the patient takes a measurement at home, transmits the data via e-mail to the clinican, who can then provide advice by e-mail. Since the patient becomes more conscious of the action point of tongue force during use of our system in real time, our system appears to be a promising tool for speech therapists treating articulation disorders.

References

[1] O.FUJIMURA, S. KIRITANI, and H. ISHIDA (1973): 'Computer controlled radiography for observation of movements of articulatory and other human organs', *Computers in Medicine and Biology,* **3**, pp. 371-384

[2] M. MATSUMURA, AND A. SUGIURA (1992-7): 'Measurement of Vocal Tract Shapes Using Magnetic Resonance Imaging', *Trans. IEICE A*, **J75-A**, No.7, pp. 1115-1123

[3] C. B. SONIES, T. H. SHAWKER, T. A. HALL, L. H. GERBER, AND S. B. LEIGHTON (1981): 'Ultrasonic observation of tongue motion during speech', *J. Acoust. Soc. Am.*, **70**, pp. 683-686

[4] W. HARDCASTLE (1972): 'The use of electro-palatography in phonetic research', *Phonatica*, **25**, pp. 197-215

[5] K. OGATA, AND Y. SONODA (1976): 'Articulatory Measuring System Using Magnetometer Sensors —Studies of Sensor Arrangements for Reducing Errors Caused by Tilting and Lateral Movements of a Magnetic Pellet—', *T. IEE Japan*, **144-C**, No. 3, pp. 386-392

[6] Y. ICHINOSE, M. WAKUMOTO, K. HONDA, T. AZUMA, AND J. SATOU (2003): 'Human Interface Using a Wireless Tongue-Palate Contact Pressure Sensor System and Its Application to the Control of an Electric Wheelchair', *Trans. IEICE D-II*, **J86-D-II**, pp. 364-367

[7] TIEDE M, PERKELL J, ZANDIOUR M, MATTHIES M, AND STOCKMANN E (2003): 'A new approach to pressure sensitive palatography using a capacitive sensing device', Proc. of 15th International Congress of Phonetic Sciences, Barcelona, 2003, p.3149-3152

[8] M.MATSUMURA, Y.YAMASAKI, R.TSUJI, T.NIIKAWA, K.NOHARA, T.TACHIMURA AND T.WADA (2002): 'Measurement of palatolingual contact pressure and tongue force using a force-sensor mounted on a palatal plate' in THE SOCIETY OF BIOMECHANISMS JAPAN: 'Biomechanisms 16: Looking for physical and motion features of living things', (University of Tokyo Press, Tokyo), pp. 75-85

[9] R. TSUJI, M. MATSUMURA, K. NOHARA, T. TACHIMURA, AND T. WADA (2003): 'Analysis of Tongue Force Adaptation Based on Palatolingual Contact Pressure', *Trans. JSMBE*, **41**, pp.410-418

[10] R. TSUJI, M.MATSUMURA, K. NOHARA, T. TACHIMURA, AND T. WADA (2004): 'Analysis of tongue force adaptation to the change of palatal shape based on measurement of palatolingual contact pressure', Proc. of 18th International Congress on Acoustics, Kyoto, 2004, p.1331-1344

[11] WHEELER R.L., LOGEMANN J.A., AND ROSEN M.S. (1980): 'Maxillary reshaping prostheses: effectiveness in improving speech and swallowing of postsurgical oral cancer patients', *J Prosthet Dent*, **43**, 3, pp.313-319

[12] ROBBINS K.T., BOWMAN J.B., AND JACOB R.F. (1987): 'Postglossectomy deglutitory and articulatory rehabilitation with palatal augmentation prosthesis', *Arch Otolaryngol Head Neck Surg*, **113**, pp.1214-1218

[13] K. NOHARA, T. TACHIMURA, T. WADA, T. NIIKAWA, AND M. MATSUMURA (2003): 'Fabrication of palatal augmentation prosthesis using small force sensor', *Jpn. J. Logop. Phoniatr*, **44**, p.49

ISSN: 1727-1983 © 2005 IFMBE