

THE CLINICAL APPLICATION OF ACOUSTIC ANALYSIS TO EVALUATION OF TONGUE POSITION

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ABSTRACT. *Tongue thrust is a habit in which the tongue protrudes between the upper and lower anterior teeth and causes malocclusion. Oral myofunctional therapy (MFT) is used to eliminate the habit of tongue-thrust swallowing. In the present study, we investigated changes in the tongue position before and after MFT using acoustic analysis. Twelve patients with tongue thrust who underwent MFT were enrolled. The first formant (F1) and the second formant (F2) of the consonant /s/ were analyzed. To revise individual differences, F1 and F2 were divided by the fourth formant (F'4) of the vowel /i/. As a result, F1/F'4 and F2/F'4 were significantly lower after MFT than before MFT. Our results suggest that the tongue moves superiorly and posteriorly after MFT, which restores normal swallowing in patients with the tongue thrust habit.*

Keywords: Formant, Tongue position, Myofunctional therapy, Tongue thrust

1. Introduction. Tongue thrust is an oral habit in which the tongue protrudes between the upper and lower anterior teeth, primarily during swallowing. The anterior teeth are inclined forward by the pressure of the tongue; therefore, tongue thrust can result in malocclusions such as an open bite [1,2]. A protruded tongue can also cause relapse after orthodontic treatment.

Oral myofunctional therapy (MFT) is an exercise-based treatment to eliminate the habit of tongue-thrust swallowing and restore normal swallowing [3]. However, a practical, objective method for evaluation of the effects of MFT has not been established. Generally, the effects of MFT are confirmed by naked eye observation, and it is important to establish a method for the objective evaluation of the tongue position for the prevention and treatment of malocclusion.

Conventionally, modalities for the analyses of tongue function, such as palatography [4] and X-ray cinematography [5], have been used. However, palatography may prevent physiological tongue movements, while X-ray cinematography causes radiation exposure.

Some recent studies used speech analysis to evaluate the position of the tongue [6,7]. Clinically, an acoustic analysis is advantageous because it is noninvasive. In previous studies, we focused on the formant frequency and investigated the acoustic characteristics of orthodontic patients [8,9]. The first formant represents the vertical position of the tongue, while the second formant represents the horizontal position of the tongue [10]. We believe that the formant frequency can be applied for evaluation of the effects of MFT. However, there are few reports on the use of acoustic analysis to evaluate changes in the tongue position after MFT.

Therefore, in the present study, we investigated changes in the tongue position after MFT using acoustic analysis based on the formant frequency.

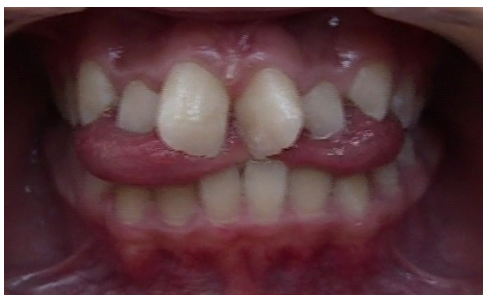


FIGURE 1. Open bite caused by tongue thrust

2. Subjects and Methods. Twelve patients (four men and eight women) at Nihon University Hospital were included in this study. The mean age of patients at the initial visit was 9.3 ± 1.0 (range: 9-11) years. All patients were diagnosed with the tongue-thrust swallowing habit and underwent MFT.

Table 1 shows the recording conditions. A condenser microphone was placed 20 cm away from subject's mouth. The sampling frequency and resolution were 22.05 kHz in 16 bits. Each participant pronounced the word /i/i/ three times. The voice was recorded before and after MFT.

TABLE 1. Recording conditions

Recording location	Consultation room at hospital
Microphone	Audio Technica ATM31a
Audio interface	Roland EDIROL UA-25EX
Condition	22.05 Hz, 16 bits

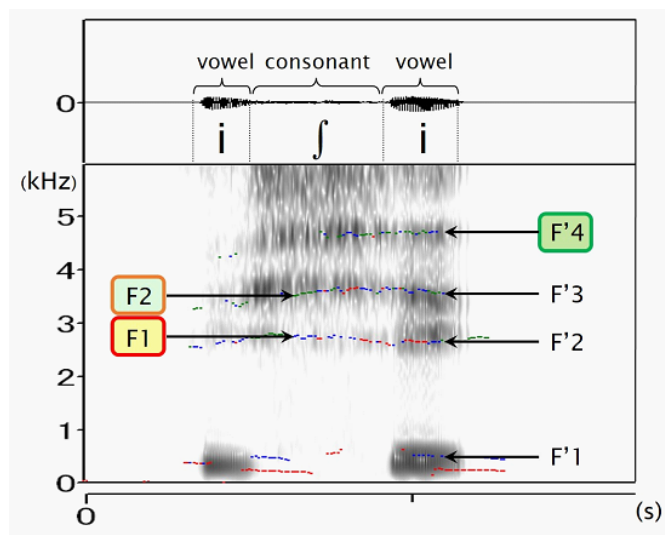


FIGURE 2. Sound spectrograph

The frequencies of the first formant (F1) and the second formant (F2) of the postalveolar fricative consonant /f/ were analyzed. To revise individual differences, F1 and F2 were each divided by the fourth formant (F'4) of the vowel /i/. $F1/F'4$ and $F2/F'4$ after MFT were compared with those before MFT [7].

Student's *t*-test was performed for comparison of data before and after MFT.

3. Results. As shown in Table 2, $F1/F'4$ and $F2/F'4$ were significantly lower after MFT than before MFT. Figure 3 shows the changes in $F1/F'4$ and $F2/F'4$ in each subject.

TABLE 2. Changes in F1/F'4 and F2/F'4 after MFT

	Before MFT		After MFT		<i>t</i> -test
	Mean	S.D.	Mean	S.D.	
F1/F'4 (%)	60.2	5.1	57.7	3.1	**
F2/F'4 (%)	81.8	3.7	78.1	3.1	**

***p* < 0.01 (paired *t*-test)

S.D.: standard deviation

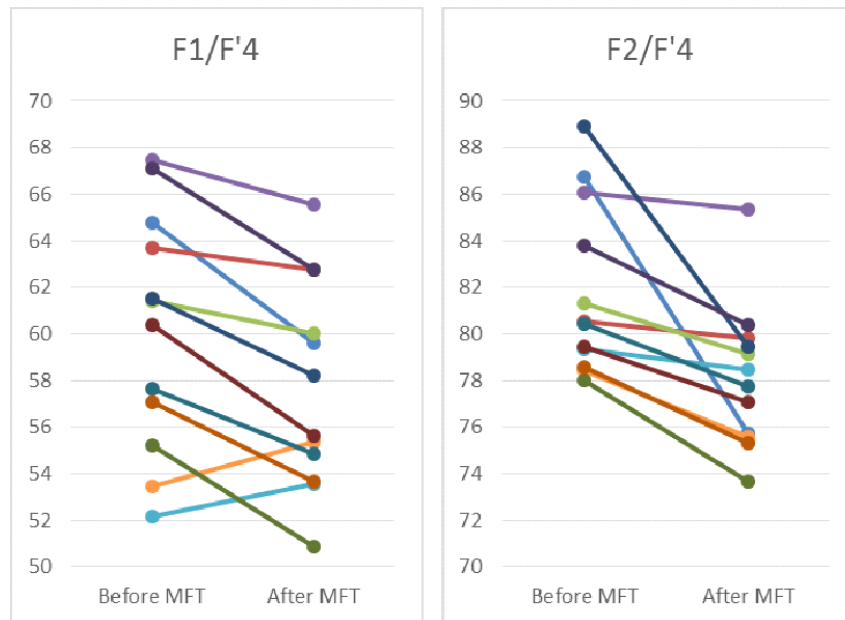


FIGURE 3. F1/F'4 and F2/F'4 before and after MFT in each subject

4. **Discussion.** In patients with the tongue-thrust swallowing habit, the tongue is low and protruded during swallowing. On the other hand, the tongue closely touches the palate during normal swallowing [11]. Therefore, the tongue position during normal swallowing is superior and posterior compared with that during tongue-thrust swallowing.

The postalveolar fricative consonant /*f*/ was chosen in this study because the articulation point of /*f*/ is influenced by the tongue position. The lisping sound of /*f*/ is characteristic of individuals with tongue-thrust swallowing, who protrude the tongue between the upper and lower anterior teeth even while speaking.

F1/F'4 represents the vertical position of the tongue, while F2/F'4 represents the horizontal position of the tongue [10]. When the articulation point is low, F1/F'4 becomes high. When the articulation point is anterior, F2/F'4 becomes high.

MFT is used for the elimination of tongue thrust. In the present study, we investigated changes in F1/F'4 and F2/F'4 after MFT. According to the results, F1/F'4 and F2/F'4 were significantly lower after MFT than before MFT. These results indicate that the tongue position changed superiorly and posteriorly after MFT, resulting in the restoration of normal swallowing.

5. **Conclusions.** The findings of our study suggest that acoustic analysis is an effective technique for evaluation of the effects of MFT with regard to changes in the tongue position. In addition, this technique is feasible for use in clinical practice, because voice recording does not require much time and is noninvasive.

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