Original Article

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# A Study of the Electrical Properties of the Buccal Area using Facial Surface Electromyography※

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## [Abstract]

**Objectives :** The purpose of this study was to determine the electrical properties of the buccal area using facial surface electromyography (sEMG).

**Methods :** This research was conducted on 44 healthy participants irrespective of their sex. Surface electrodes were attached to the midpoints of three imaginary lines connecting ST4 (Dicang) to ST6 (Jiache), ST4 to SI18 (Quanliao), and ST4 to the center point of SI18 and ST6. Then, the participants were trained in the movement that included a comprehensive action of buccal area. While the participants were performing the motion, sEMG values ($E_1$, $E_2$, $E_3$) and the distance change of the three imaginary lines ($D_1$, $D_2$, $D_3$) were measured. The data were statistically analyzed using SPSS ver. 22.0.

**Results :** Significant differences were observed in the distance changes ($D_1 > D_3$, $D_2 > D_3$) and sEMG values ($E_1 < E_2 < E_3$). Moreover, there were positive correlations between $D_1$ and $E_1$, $D_2$ and $E_2$.

**Conclusion :** We suggest that the measurement at ST4 to the center point of ST6 and SI18 with this motion would be adequate to check the electrical characteristics of the buccal area.

**Key words :**
Surface electromyography;
Surface EMG;
sEMG, Buccal area;
ST4

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# Ⅰ. Introduction

Electromyography (EMG) is a diagnostic test used to detect and quantify the electrical signals generated by muscle activity. Electrical signals transmitted from the neurons are expressed as the potential difference generated by the ion exchange between the inside and outside of the cell membranes[1]. Electromyography is a diagnostic method that distinguishes physiological and pathological characteristics by recording the potential difference through attachment of surface electrodes or insertion of intramuscular electrodes[2].

Electromyography can be classified according to the type of electrode used. Needle EMG is an invasive method using fine-wire or intramuscular needle. In contrast, surface EMG (sEMG) is a non-invasive and painless method using skin adhesion of surface electrodes. Due to the relative simplicity of its measurement process, sEMG has the advantages of repetitive measurement and follow-up. However, since the electrodes are attached to the surface of the body, it is necessary to be careful while interpreting results in cases of fine muscles, muscles located in the deeper parts, or broader parts where the muscles overlap.

The facial area is characterized by the distribution of various facial muscles in three dimensions, although the area is relatively small compared to the trunk and limbs. Unlike needle EMG, which measures the electrical activity of a single muscle, surface EMG is useful for evaluating the facial function by analyzing the synergistic activity of motor units as it measures the potential at the body surface.

However, there is little consensus on the clinical use of facial sEMG as a measuring method. The aim of this study was to investigate the relationship between the real-motion and sEMG in the buccal area, which occupies a large part of the face, as a part of the development of facial electro-diagnostic systems. We report the results of the measurement method, which can reflect the electrical properties of the buccal area more significantly.

# Ⅱ. Materials and Methods

## 1. Subjects

With an approval of the Institutional Review Board (IRB), we recruited healthy adult men and women, aged 19 to 40 years, who had no neurological abnormalities and medication use that could affect their measurements (WSOH-IRB approval No.1510-04). Forty-four adult men and women (22 men and 22 women), who gave voluntary consents

Table 1. Exclusion Criteria

| No. | Exclusion Criteria |
|---|---|
| 1 | People who suffer from a stroke. (past and present) |
| 2 | People who have the facial palsy or related diseases. (past and present) |
| 3 | People who have other facial problem |
| 4 | People who have a systemic disease that affect the facial activity. |
| 5 | People who have difficulty in facial activity by plastic surgery or facial surgery |
| 6 | People who had activities that affects the measurement within a week |
| 7 | People who take medications that affects the measurement within a week |
| 8 | People who have a constant use of facial muscles in their profession and have a deviation (such as a brass player) |
| 9 | People who already have facial asymmetry of grade 2 by House-Brackmann scale |
| 10 | People who judged inappropriately with other reasons by the clinical research |

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after hearing the precautions and details, participated in the experiment. The exclusion criteria are described in Table 1.

## 2. Materials

Surface Electromyography equipment used in this study was QEMG-4XL (LAXTHA Inc., Daejeon, Korea), which has four simultaneous channels of measurement. The active electromyography sensor that connects the output parts and electrodes was AM530 (LAXTHA Inc.). We used dual surface electrodes (Product #272S) produced by Noraxon U.S.A. Inc.(Scottsdale, AZ, USA). In general, the use of wet-gel electrodes improves conduction and reduces resistance[2]. The center point to center point distance is generally less than 2 cm. We used the smallest surface electrode available in the market as the facial muscles are very fine and the attachment sites were narrow.

## 3. Methods

### 1) Preparation and recording of the distance between the markers during motion

All procedures were performed by two examiners who were proficient in measuring facial sEMG. After providing a written voluntary consent and undergoing screening, the participants were trained using detailed pictures of the action. The tester confirmed the movement several times and marked four points on the face (Fig. 1). The patient was seated on a fixed chair and his/her facial region was photographed from the front and the side to check the markers. Before the measurement of sEMG, the distances of the three imaginary lines were measured during rest and motion by a measuring tape. The first line was the connecting line between ST4 and ST6. The second line connected ST4 and the center point of SI18 and ST6, and the third line connected ST4 and SI18. For accuracy, the male participants underwent measurements after shaving and the female participants underwent the measurements without makeup. Each point was wiped with cotton dipped in alcohol to reduce skin resistance before attachment and it was confirmed to have a slight red light[2]. Surface electrodes were attached to the center of the three imaginary lines (Fig. 2).

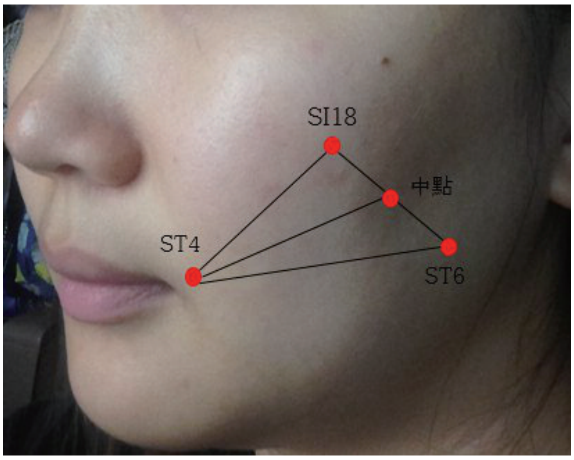


Fig. 1. The four important points

Fig. 2. Site of attachment of electrodes

### 2) Selection of motion, training, and confirmation

The subjects were orally trained with a picture of the action (Fig. 3). This movement was composed of two motions, moving the corner of mouth laterally and upwards at the same time. It is considered to represent the movement of the major facial muscles in the buccal area, i.e., the risorius muscle and zygomaticus major and minor muscles. In addition, the subjects were instructed to lift the cheekbones up. The examiner confirmed that the section between the cheekbones and the nose was moving, and completed the movement training.

### 3) Measurement of sEMG

The ground electrode was attached to the right ear TE17 (Yifeng) to minimize electrical interference. The sEMG measurement was repeated thrice, including 3 seconds of tension time and 5 seconds of relaxation time. Between each action, the subject had enough rest and the examiner reconfirmed the correct motion. The sEMG values were recorded using the Root Mean Square (RMS) and the repetitive results were averaged.

Fig. 3. Facial motion

## 4. Statistical analysis

The results from one participant were excluded due to the random measure conversion of the RMS value caused by the mechanical properties. Thus, a total of 43 measurements were statistically processed. The data were analyzed using SPSS 22.0 for Windows. The general characteristics of the participants and the RMS value were expressed as Mean ± SD. In the Shapiro-Wilk test, the distance changes and sEMG value were not found to be normally distributed. A non-parametric Friedman test was used to compare the mean differences in sEMG and the distance changes between the three measurement points during the motion, and a post-test was performed using the Wilcoxon signed-rank test. However, the significance of the post test was defined as $p$-value $<0.017$ by the Bonferroni method.

Secondly, the correlation between the surface distance change and the sEMG value was analyzed using Pearson's correlation test. Statistical significance was set at $p<0.05$ and the result of the correlation analysis was expressed using Pearson's correlation coefficient 'r'.

# Ⅲ. Results

## 1. General Characteristics

Of the total 43 subjects, 22 were men and 21 were women. The average age was 24.19 ± 1.83 years, body temperature was 36.43 ± 0.34 °C, body weight was 61.00 ± 11.59 kg, and height was 167.46 ± 7.35 cm. In addition, the 43 subjects did not use neurological drugs that could affect the test (Table 2).

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**Table 2.** General Characteristics of the Participants

| | Mean | SD | Minimum | Maximum |
|---|---|---|---|---|
| Sex (%) | | Male 21 (48.83%) | | |
| | | Female 22 (51.16%) | | |
| Age (years) | 24.19 | 1.83 | 21.00 | 29.00 |
| Body Temperature (℃) | 36.43 | 0.34 | 35.80 | 37.20 |
| Body Weight (kg) | 61.00 | 11.59 | 44.50 | 90.50 |
| Height (cm) | 167.46 | 7.35 | 156.00 | 185.60 |
| Drug History | | N/S* | | |

* N/S: Non Specific

## 2. Symbolization and meaning of variables

The main variables of this study are the distance change and sEMG value during motion. For convenience, the letter D and the letter E were used to symbolize the distance change and sEMG RMS, respectively, as shown in Table 3.

## 3. Detailed Analysis

### 1) Distribution of distance change for each part (Table 4)

In this motion, the distance change value of each part was calculated using the average and standard deviation. $D_1$ was 0.56 ± 0.30 cm, $D_2$ was 0.54 ± 0.28 cm, and $D_3$ was 0.31 ± 0.26 cm. The Friedman test showed statistically significant difference in the distance between the two sites during the motion ($\chi^2$ (2) = 23.031, $p < 0.001$). The post-hoc test was performed and $D_1$ ($p$ = 0.523 > 0.017) was not statistically significant. However, the difference between $D_3 < D_1$ ($p < 0.001$) and $D_3 < D_2$ ($p < 0.001$) was statistically significant.

### 2) Distribution of sEMG value for each part (Table 5)

In this motion, the sEMG value of each part was calculated by the average and standard deviation. $E_1$ was 44.26 ± 22.28 mV, $E_2$ was 111.40 ± 66.24 mV, and $E_3$ was 137.30 ± 72.65 mV. In Friedman's test, there was a statistically significant difference between the three sEMG measurements ($\chi^2$ (2) = 65.275, $p < 0.001$). In the Wilcoxon signed-rank test, $E_1 < E_2$ ($p < 0.001$), $E_1 < E_3$ ($p < 0.001$), and $E_2 < E_3$ ($p < 0.001$) were statistically significant.

**Table 3.** Codes and their Meanings used in this Study

| Code | Meaning |
|---|---|
| $D_1$ | Distance Change of ST4 – ST6 |
| $D_2$ | Distance Change of ST4 – Center point of ST6 and SI18 |
| $D_3$ | Distance Change of ST4 – SI18 |
| $E_1$ | sEMG* RMS† of ST4 – ST6 |
| $E_2$ | sEMG* RMS† of ST4 – Center point of ST6 and SI18 |
| $E_3$ | sEMG* RMS† of ST4 – SI18 |

* sEMG: Surface electromyography, † RMS: Root Mean Square

**Table 4.** Means of Distance Change During Motion

| Code | Mean | SD | Friedman test *p*-value | Ranking by Wilcoxon test |
|---|---|---|---|---|
| $D_1$ | .56 | .30 | | b |
| $D_2$ | .54 | .28 | <0.001 | b |
| $D_3$ | .31 | .26 | | a |

The same letters of 'Ranking' indicate non-significant difference between groups based on Wilcoxon signed-rank test. $D_1$: Distance Change of ST4 - ST6, $D_2$: Distance Change of ST4 - Center point of ST6 and SI18, $D_3$: Distance Change of ST4 - SI18

**Table 5.** Means of Surface Electromyography Root Mean Square Value During Motion

| Code | Mean | SD | Friedman test *p*–value | Ranking by Wilcoxon test |
|---|---|---|---|---|
| $E_1$ | 44.26 | 22.28 | | a |
| $E_2$ | 111.40 | 66.24 | $<0.001$ | b |
| $E_3$ | 137.30 | 72.65 | | c |

$E_1$: Surface Electromyography Root Mean Square of ST4 - ST6, $E_2$: Surface Electromyography Root Mean Square of ST4 - Center point of ST6 and SI18, $E_3$: Surface Electromyography Root Mean Square of ST4 - SI18

### 3) Correlation between distance change and sEMG value (Table 6)

There was a significant correlation between $D_1$ and $E_1$ (r = 0.378, p = 0.013), and between $D_2$ and $E_2$ (r = 0.519, $p < 0.001$); however, there was no significant correlation between $D_3$ and $E_3$ (r=0.079, $p$=0.614).

**Table 6.** Correlation between Distance Change and Surface Electromyography Root Mean Square

| EMG \ Distance | $D_1$ | $D_2$ | $D_3$ |
|---|---|---|---|
| $E_1$ | r=.378* ($p$=.013) | r=.473* ($p$=.001) | r=.014 ($p$=.927) |
| $E_2$ | r=.449* ($p$=.002) | r=.519* ($p$=.000) | r=–.191 ($p$=.221) |
| $E_3$ | r=.549* ($p$=.000) | r=.553* ($p$=.000) | r=.079 ($p$=.614) |

The shaded cells are the correlation between distance change and surface electromyography on each part. r=Pearson's Correlation Coefficient. $p$=$p$–value. * $p<0.05$, $D_1$: Distance Change of ST4 - ST6, $D_2$: Distance Change of ST4 - Center point of ST6 and SI18, $D_3$: Distance Change of ST4 - SI18, $E_1$: Surface Electromyography Root Mean Square of ST4 - ST6, $E_2$: Surface Electromyography Root Mean Square of ST4 - Center point of ST6 and SI18, $E_3$: Surface Electromyography Root Mean Square of ST4 - SI18

# Ⅳ. Discussion

One nerve ending stimulates several groups of muscle fibers at the same time. This is called a motor unit (MU), which includes the anterior column, nerve, axon, and muscle fibers. At the time of motion, negative potential appears inside the cell membrane, maintaining a resting membrane potential of −70 mV for the nerves and −80 mV for the muscle fibers. When the muscle activity is represented as the electrical signal of the nerve and the threshold is exceeded, the stable potential changes to a depolarized state, in which a strong positive potential appears. Then, it changes to a repolarized state, following which, the resting membrane potential is recovered[3]. Surface electromyography is a diagnostic method that mechanically recognizes, amplifies, and quantifies the current flow caused by muscle movement on the body surface.

Considering the existing studies, A. Frigerio et al.[4] proposed a measurement method especially for the orbicularis oculi muscle. N. P. Schumann et al.[5] analyzed the movement of the muscles during a specific facial expression by examining the sEMG of 48 channels. The SENIAM (Surface Electromyography for the Non–Invasive Assessment of Muscles) project is a concerted European action as a part of the Biomedical Health and Research Program of the European Union. The SENIAM group has recommended sensor locations and placements in various muscles. However, we could only find few consensuses in the facial muscle groups. Lee et al.[6] reported that less than 10 studies were conducted on surface electromyography among the papers published in Korea, China, and Japan until 2012. In particular, there was only one clinical study related to facial nerve palsy. In Korea, Lee et al.[7] described the effectiveness of the surface EMG in patients with facial nerve palsy. Kim et al.[8] used sEMG for the diagnosis of facial asymmetry in patients, and the relationship between EMG and malfunction of the masticatory muscles was measured using surface electromyography. However, in most studies, there was no definite evidence or preliminary study on the position and direction of the electrode, and therefore, it is difficult to perform systematic studies because of the different posi–

tions and measurement methods that are used in each study.

This is a preliminary study for the efficient clinical use of surface electromyography. In the first step, we studied the electrical properties of the buccal area with dynamic movement.

One of the important anatomical indicators for the origin and insertion of the buccal muscle group is the modiolus. It is an important location for estimating the movement of facial muscles because seven muscles (i.e., the orbicularis oris, buccinator, levator anguli oris, depressor anguli oris, zygomaticus major, risorius, platysma, and levator labii superioris) insert at the modiolus. As a result, the modiolus could be a specific point to trace the movements of the muscles.

In addition, in the perspective of meridian and acupuncture, there are three meridians passing through the face, foot yang brightness stomach meridian, hand yang brightness large intestine meridian, and hand greater yang small intestine meridian. Moreover, major acupoints related to the buccal area are as follows: ST3 (Juliao), ST4 (Dicang), ST6 (Jiache), ST7 (Xiaguan), LI20 (Yingxiang), and SI18 (Quanliao). Acupoints belonging to the stomach meridian were the most common.

ST4 was chosen as an important point in this study as it is locally similar to the modiolus and is the insertion point of various buccal muscles. To reflect various movements of the buccal muscles, ST6 was chosen on the front and SI18 was chosen laterally. In addition, considering the broad area of the cheek, the middle point of SI18 and ST6 was also added.

Finally, we drew three imaginary connecting lines between ST4 and each of the three points. Then, we checked the distance changes and surface electromyography values according to the motion of the buccal muscles, and analyzed their correlation.

The motion conducted in this study resulted in the activation of the broad area of the cheek, especially between the nose and zygomatic arch. We expected to find a clear correlation between $D_3$ and $E_3$ during the motion. The measured $D_3$ values were statistically significantly lower than those of the other sites. However, $E_3$ values were significantly higher than $E_1$ and $E_2$. Moreover, the correlation between the distance change and the sEMG value was the highest ($D_2$ and $E_2$, $r = 0.519$, $p<0.001$). Although there was no significant correlation between the measured values of $D_3$ and $E_3$, it is meaningful that the broad motion in the measurement area should be performed to improve the accuracy of sEMG of the face. As a conclusion, we suggest that the measurement at ST4 to the center point of ST6 and SI18 with this motion would be adequate to check the electrical characteristics of the buccal area.

In future research, efforts to reduce individual differences in motion are needed. Moreover, it will be meaningful to try a more accurate evaluation of distance change of the facial surface by using three-dimensional motion tracking and depth sensing cameras, such as Microsoft's Kinect or Google's Tango, rather than one-dimensional distance measurement using a measuring tape.

This study started with questions about the electrical properties of the facial, especially the buccal area. As the buccal area is anatomically present in three dimensions of fine facial muscles, the precise palpation of the muscles may affect the reliability of the needle electromyography. Therefore, if the electrical characteristics of the buccal area can be mapped through the surface electrode, surface electromyography can be a more effective and economical diagnostic method in various diseases such as facial nerve paralysis, facial spasm, muscle atrophy, etc.

# V. Results

In November 2015, 44 healthy men and women were subjected to surface electromyography of the buccal area. The surface electrodes were attached to three imaginary lines (ST4 - ST6, ST4-center point of ST6, and SI18, ST4-SI18). Then, the distance changes ($D_1$, $D_2$, $D_3$) and surface electromyography ($E_1$, $E_2$, $E_3$) during motion were measured and the results were compared with each other to obtain the following conclusions.

1. There was a significant difference between $D_3 < D_1$, $D_3 < D_2$, and $E_1 < E_2 < E_3$.

2. The correlation between the surface distance change value and surface electromyography in motion was positive at $D_1$ and $E_1$, $D_2$ and $E_2$.

3. As a conclusion, we suggest that the measurement at ST4 to the center point of ST6 and SI18 with this motion would be adequate to check the electrical characteristics of the buccal area.

## Ⅵ. Acknowledgement

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