

The effects of electrical muscle stimulation on facial muscles: Volume change of facial muscles measured with magnetic resonance imaging

電気筋肉刺激美顔器の表情筋に与える影響の検討：MR画像による表情筋の体積変化から

NAKAYA Koji¹⁾, MUTO Hiroe¹⁾, MATSUURA Kanae¹⁾, SUDO Shu²⁾, YAMANAKA Aya²⁾

1) Department of Radiological Technology, Faculty of Health Science, Suzuka University of Medical Science

2) Research Dept. Mikimoto Pharmaceutical CO., LTD.

Key words: electrical muscle stimulation, buccinator muscle, masseter muscle, slimming effect on the face

[Abstract]

Purpose: Electrical muscle stimulation (EMS) delivers a low-intensity stimulus to the nerves in the muscle to cause muscle contraction, and can result in a cosmetic effect. In this study, we measured volume changes of facial muscles before and after using EMS facial equipment via magnetic resonance imaging, and investigated the effects of EMS facial equipment on facial muscles.

Methods: Eight sessions of facial treatment were performed on healthy volunteers using EMS facial equipment. T₂-weighted images were acquired before and after using the EMS facial equipment, and volume changes in the buccinator and masseter muscles before and after using EMS facial equipment were measured from the images.

Results: The use of EMS facial equipment caused a decrease in masseter muscle volume in magnetic resonance images.

Conclusion: The results suggested that the use of EMS facial equipment had a clear effect on facial muscles, and that a facial treatment effect could be obtained even with short-term use.

【要旨】

目的：電気筋肉刺激（Electrical Muscle Stimulation：EMS）は筋肉内の神経に低強度の刺激を与え、美容効果が得られる。EMS美顔器の使用前後の表情筋体積変化をmagnetic resonance imagingを用いて測定し、EMS美顔器の表情筋に与える影響を検討した。

方法：健康ボランティアに対しEMS美顔器を用いて8回のフェイシャルトリートメントを施行した。EMS美顔器使用前後においてT₂強調画像を取得し、その画像から頬筋と咬筋の体積変化を計測した。

結果：Magnetic resonance画像から、EMSフェイシャル機器の使用は咬筋の体積が減少した。

結論：EMS美顔器の使用は表情筋に明らかな影響を与え、短期間の使用でも美顔効果が得られることが示唆された。

1. Introduction

Human skin shows the effects of aging over time¹⁾. Many women use cosmetics and medicines to prevent skin aging and rejuvenate the skin^{1,2)}. In recent years, the market for beauty appliances has grown rapidly and demand is increasing³⁾. In addition, many beauty salons offer treatments that attempt to prevent skin aging using beauty equipment. In recent years, beauty appliances and esthetic salons have developed and utilized facial equipment us-

ing electrical muscle stimulation (EMS). EMS involves the application of a low-intensity electrical stimulus to the nerves in the muscle, causing contraction of the muscle⁴⁻⁶⁾ resulting in a cosmetic effect. EMS is also used as an exercise device for muscle training in the sports industry⁶⁾. Furthermore, it has been reported that EMS is effective for dieting⁷⁾. Facial EMS is now widely used for skin anti-aging and dieting purposes, providing a facial treatment that stimulates facial muscles and promotes facial muscle movement⁸⁾. It contracts the muscles of the face and gives a slimming effect on the face.

In the current study, we examined the effects of EMS on facial muscles. Many people regularly perform EMS on their face, reporting beneficial effects on their appearance⁹⁾. How-

中舎 幸司¹⁾, 武藤 裕衣¹⁾, 松浦 佳苗¹⁾, 須藤 秀²⁾, 山中 亜弥²⁾

1) 鈴鹿医療科学大学 保健衛生学部 放射線技術科学科

2) 御木本製薬株式会社研究部

Received January 18, 2021; accepted May 26, 2021

ever, the extent to which EMS affects facial muscles is currently unclear. There are no reports quantifying the effects of EMS as a facial treatment. Therefore, we sought to clarify the effect of EMS by using the volume change of facial muscles. Imaging of facial muscles can be taken by computed tomography (CT) and magnetic resonance imaging (MRI), etc. MRI has better contrast resolution than CT¹⁰⁾. Muscles with a small area can be evaluated more accurately from MR images. Therefore, we thought that the facial treatment effect of EMS could be evaluated if the muscles were activated by EMS and the degree of muscle contraction could be captured by MR images. In addition, there is T₂-weighted imaging (T₂WI) in the MR sequence. It has been reported that this sequence is anatomically easy to see and provides good contrast¹¹⁾. Therefore, we would

like to adopt T₂WI for the MR sequence that images facial muscles. In the current study, we measured changes in the volume of facial muscles before and after using EMS facial equipment via T₂WI of MRI, and investigated the effects of EMS facial equipment on facial muscles.

2. Materials and Methods

2-1. Subjects

The subjects were 10 healthy women, aged 21 to 22 years (mean 21.7 ± 0.5 years), who volunteered to take part. This study was carried out with the approval of the Ethics Committee of Suzuka University of Medical Sciences.

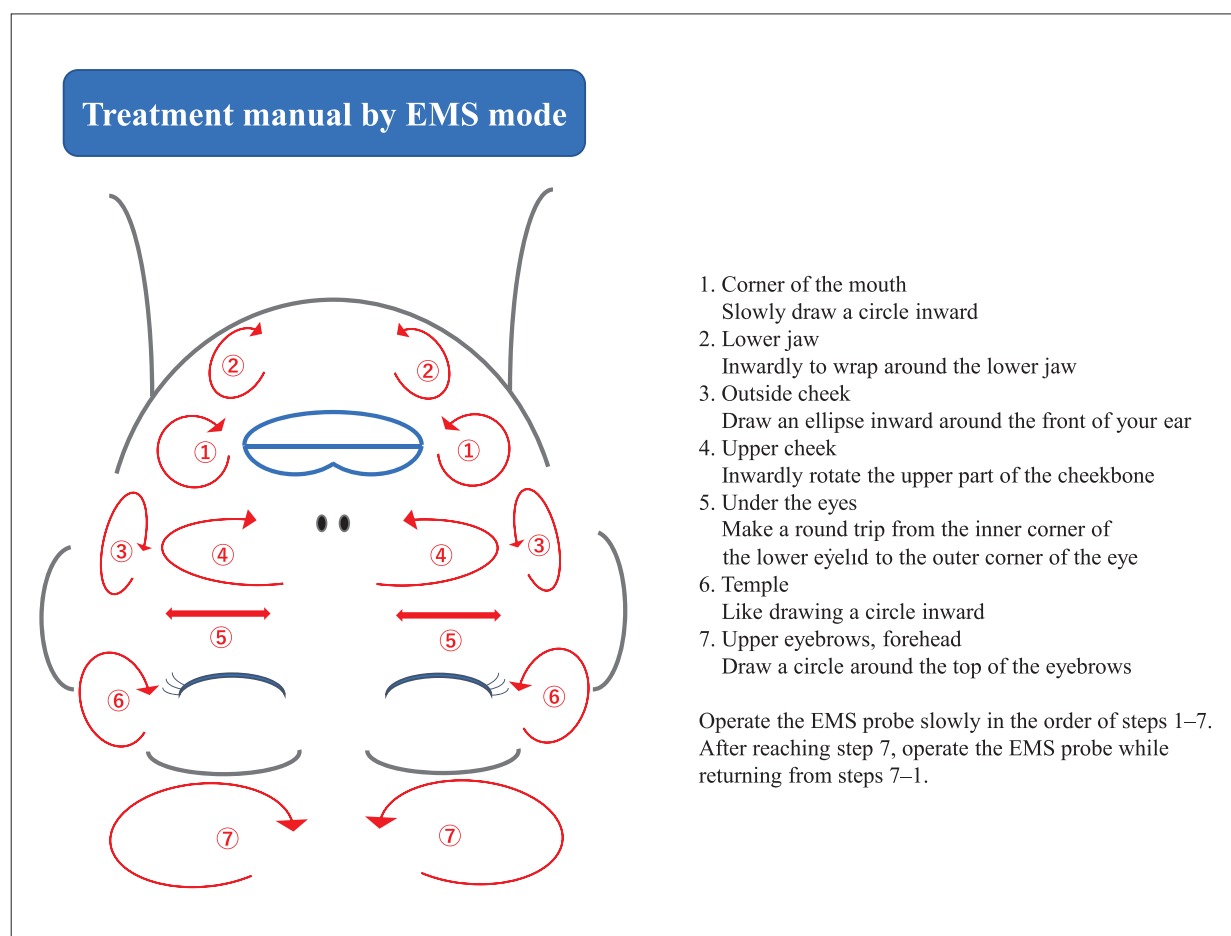


Fig.1 How to use electrical muscle stimulation facial equipment. Instructions provided by Mikimoto Pharmaceutical CO., LTD.

2-2. Use of EMS facial equipment

PEARL FACE ESTHE Sonic EX (ITO CO., LTD., Saitama, Japan) was used as the EMS facial equipment. The method of using the EMS facial equipment is shown in Fig.1. When using the EMS facial equipment, pearly sonic gel (Mikimoto Pharmaceutical CO., LTD., Mie, Japan) was applied to the tip of the probe. The electromagnetic waves of EMS used medium frequencies that affect muscles. Electromagnetic wave output was performed at 13 out of 40 stages. EMS facial equipment was used for 20 minutes per person, and was used twice a week. In total, subjects underwent eight treatment sessions from September 2020 to October 2020. Subjects practiced using the EMS facial equipment, and, after securing an environment in which to do so, operated the EMS facial equipment themselves.

2-3. Acquisition of magnetic resonance imaging

MRI was performed before the use of the EMS facial equipment and within 2 to 3 days after the last day of use. An ECHELON 1.5T scanner (Hitachi, Ltd., Ibaraki, Japan) was used as the MRI device. A head coil was used as the receiving coil. T₂WI was used as the imaging sequence, and the imaging conditions for the T₂WI are shown in Table 1. The imaging cross-section was set so that a cross-section perpendicular to the long axis of the cheek could be obtained.

2-4. Comparison of facial muscle volume before and after using EMS facial equipment

The muscles used for volume measurement were the buccinator muscle, which is involved in facial expression, and the masseter muscle, which is involved in jaw movement and mastication. The masseter muscle is used to open and close the mouth and is also an important muscle for facial expression^{12, 13}. Also, these muscles are the parts where the EMS probe is

Table 1 Imaging conditions for T₂-weighted images

Parameters	
TR (ms)	3,000
TE (ms)	84
FOV (mm)	200
Matrix	320 × 320
FA	90
IR Pulse	off
Thickness (mm)	3
Interval	3
Multi slice	40
E. Factor	12
NSA	2
Bandwidth (Hz/pixel)	147.5

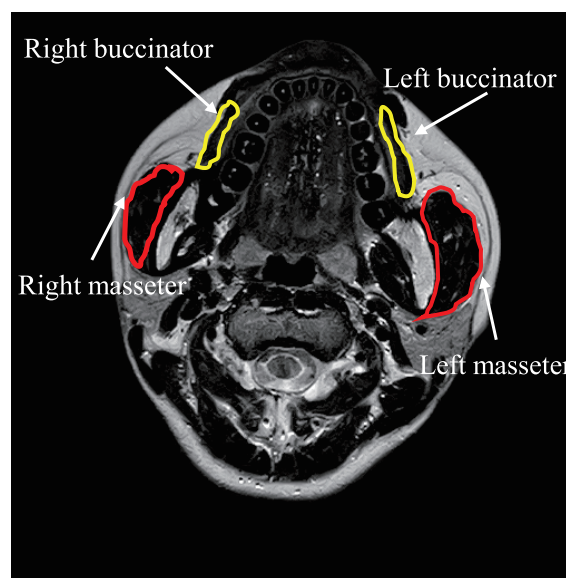


Fig.2 Buccinator and masseter muscles region of interest settings

in close contact, and it was the subject of evaluation. For measuring the volume of both muscles, the region of interest (ROI) tool attached to the workstation of the MR device was used. MR images were acquired by 2-dimensional scan (3 mm slices at 3 mm intervals). The ROI was surrounded by both muscles in all slice cross-sections where both muscles were depicted (Fig.2). Add up the muscle areas of all cross sections, and the volumes of both left

and right muscles were measured. Volumes of the buccinator and masseter muscles were compared before and after the use of the EMS facial equipment. The ROI was set by a radiological technologist with 10 years of experience in MRI work.

2-5. Statistical analysis

Wilcoxon signed-rank test was used for statistical analysis of volume changes in the buccinator and masseter muscles before and after use of the EMS facial equipment. Statistical

significance was defined as a P -value < 0.05 . We analyzed using Statistical Package for the Social Sciences (SPSS), version 26.0 (SPSS Inc., Chicago, IL, USA) for statistical analysis.

3. Results

3-1. Volume change of buccinator muscle

Fig.3 shows the volume of the right buccinator muscle before and after using the EMS facial equipment. The volume of the right buccinator muscle before and after using the

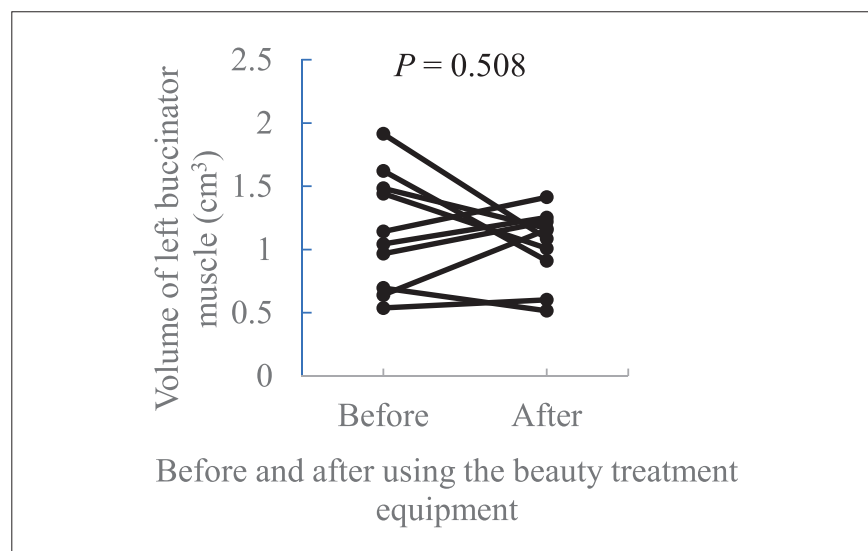


Fig.3 Volume of the right buccinator muscle before and after using electrical muscle stimulation facial equipment

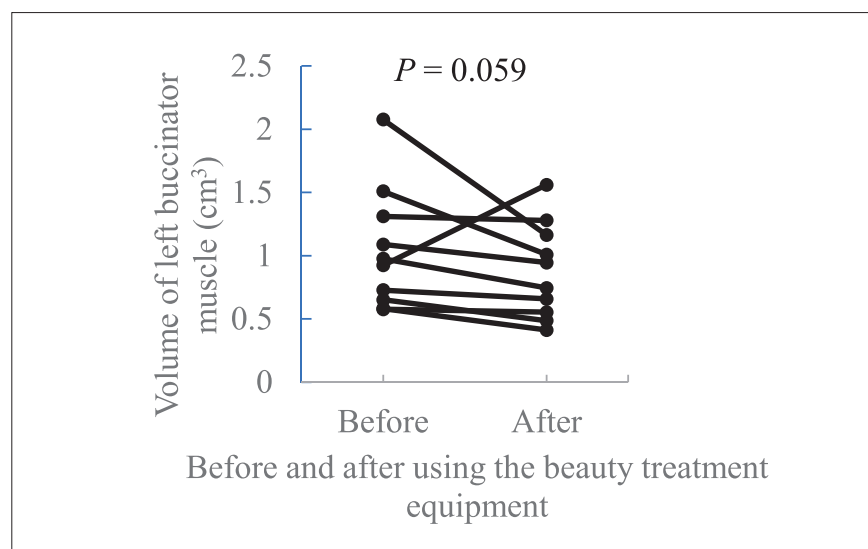


Fig.4 Volume of the left buccinator muscle before and after using electrical muscle stimulation facial equipment

EMS facial equipment was $1.15 \pm 0.43 \text{ cm}^3$ and $1.03 \pm 0.27 \text{ cm}^3$, respectively. There was no significant difference in the volume of the right buccinator muscle before and after using the EMS facial device ($P = 0.508$). Fig.4 shows the volume of the left buccinator muscle before and after using the EMS facial equipment. The left buccinator muscle volumes before and after using the EMS facial equipment were $1.04 \pm 0.45 \text{ cm}^3$ and $0.88 \pm 0.36 \text{ cm}^3$, respectively. There was no significant difference in the volume of the left buccinator muscle before

and after using the EMS facial equipment ($P = 0.059$).

3-2. Volume change of masseter muscle

Fig.5 shows the volume of the right masseter muscle before and after using the EMS facial equipment. The volume of the right masseter muscle before and after using the EMS facial equipment was $19.70 \pm 5.86 \text{ cm}^3$ and $18.13 \pm 4.73 \text{ cm}^3$, respectively. There was a significant decrease in the volume of the right masseter muscle after the use of the EMS facial device

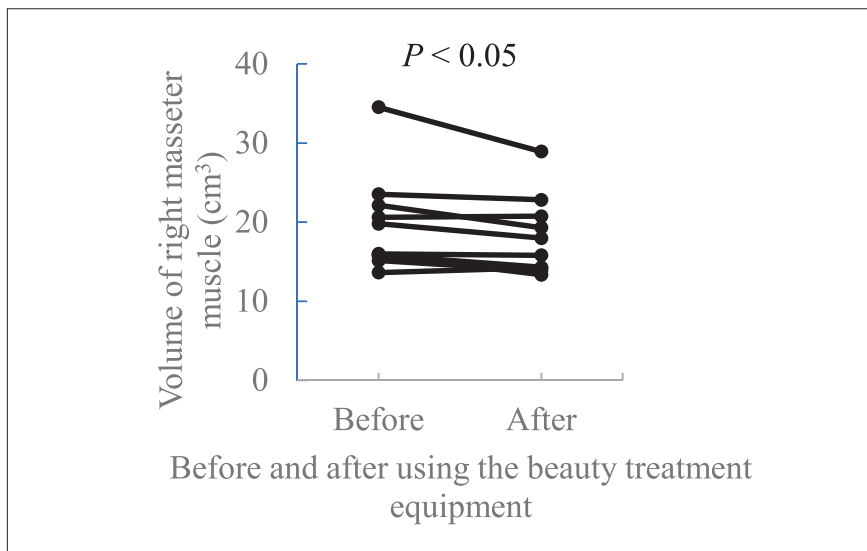


Fig.5 Volume of the right masseter muscle before and after using electrical muscle stimulation facial equipment

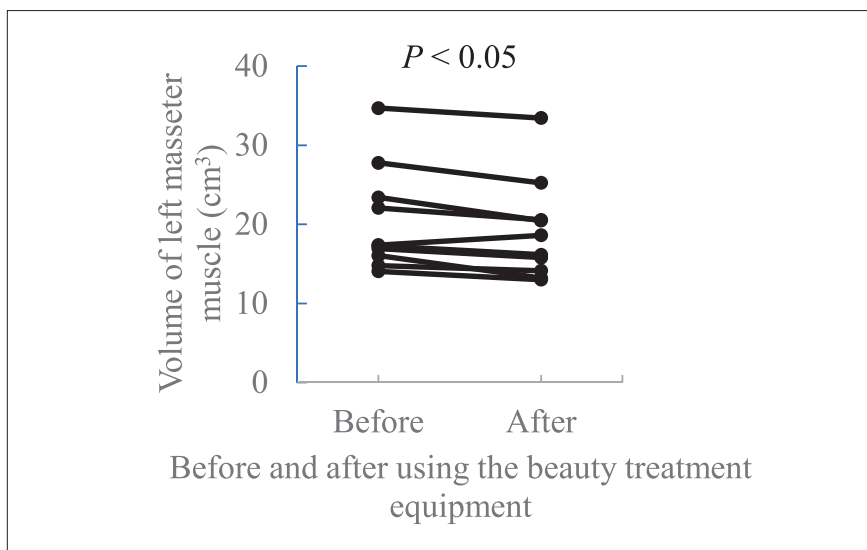


Fig.6 Volume of the left masseter muscle before and after using electrical muscle stimulation facial equipment

compared with before ($P < 0.05$). Fig.6 shows the volume of the left masseter muscle before and after using the EMS facial equipment. The left masseter muscle volume before and after using the EMS facial equipment was $20.44 \pm 6.26 \text{ cm}^3$ and $19.06 \pm 6.04 \text{ cm}^3$, respectively. There was a significant decrease in the volume of the left masseter muscle after the use of the EMS facial device compared with before ($P < 0.05$).

4. Discussion

We measured the volume change of facial muscles from T_2 WI of MRI before and after using the EMS facial equipment, and examined the effects of the EMS facial equipment on the facial muscles.

In the current study, the buccinator and masseter muscles were targeted to induce changes in the volume of facial muscles. The buccinator and masseter muscles were selected because they provided suitable contact with EMS facial equipment, and it was relatively easy to set an effective ROI than other muscles in the MRI images. Regarding the buccinator muscle, there were no changes in the volume of the left and right buccinator muscles following the use of EMS facial equipment. This finding may have occurred for several reasons. First, the volume of the buccinator muscle is small, and no significant volume change was observed. Furthermore, the EMS facial equipment was used by the subjects themselves. Using the EMS facial equipment took exactly 20 minutes. However, because the procedure was performed by the subjects themselves, there were individual differences in the effects, and some subjects did not exhibit an effect on the buccinator muscle, which has a small volume. In addition, there may have been limited reproducibility, because the ROI for measuring volume was set manually. However, the average volume decreased after using the EMS facial equipment. Thus, the results suggest that a signifi-

cant decrease in volume may be obtained by continuing to use the EMS facial equipment. In contrast, there was a marked effect of the EMS facial equipment on the masseter muscle, with the volume of the left and right masseter muscles significantly decreasing after using the EMS facial equipment. The masseter muscle has a larger volume than the buccinator muscle and came into contact with the EMS facial equipment more often. Therefore, the masseter muscle volume was significantly reduced, even though the equipment was controlled by the subjects themselves. However, there were cases in which the volume of the masseter muscles after EMS did not decrease. As with the buccinator muscle, the cause of the cases where the volume reduction was not obtained after EMS was that the subjects themselves used EMS. Therefore, it is considered that there were cases in which the probe could not stimulate the muscles well and the facial treatment effect could not be obtained. In the future, we would like to implement it after sufficient training on how to use the probe. Thus, only the masseter muscle gained volume reduction after using EMS. The muscle that most closely adheres to the skin and the largest of the facial muscles is the masseter muscle. The reduction in masseter volume after using EMS makes the face slimmer. Therefore, it is considered that the use of EMS provided a facial treatment effect. In addition, the loss of muscle volume after EMS is not a loss of muscle mass itself. As mentioned in the introduction, EMS promotes muscle movement and contracts muscles. Muscle activation also has the benefit of enriching facial expressions. Therefore, although the muscle volume is reduced, there is no health problem in using EMS and it can be used for beauty.

In this study, the EMS facial equipment was used only eight times in total. The volume of the masseter muscle was reduced with this relatively small number of uses, suggesting that this EMS facial equipment may be suitable

for use as a cosmetic device, inducing facial treatment effects in a relatively short period of time. However, when use of the EMS facial equipment is discontinued, muscle contraction is likely to return to its original state, leading to the disappearance of the facial treatment effect. Thus, it is likely to be necessary to use the EMS facial equipment on a regular basis to continue the facial treatment effect. Importantly, some facial muscle rollers, cosmetics, and pharmaceuticals have been reported to affect facial expression. One previous study reported that the use of facial muscle roller devices must consider the facial muscles, and that training is required for safe use¹²⁾. In addition, rough skin and other side effects are induced by some cosmetics and pharmaceuticals. Because the EMS facial equipment does not have a risk of these negative effects, facial treatment effects can be obtained efficiently.

Overall, the current results revealed that the EMS facial treatment device induced a facial treatment effect in a relatively short period of time. We describe future research topics below. The number of subjects in this study is 10 cases. Since the number of cases is small in this study, we would like to increase the number of cases and obtain credible data when conducting further research. In addition, the volume data used this time is the one that sets the ROI for one person. Originally, it is appropriate to evaluate with a few people and perform calculation of intra-class correlation coefficient. However, it was too difficult to set the ROI for muscles, so the ROI setting was for one person. We would like to create a manual for muscle ROI setting and build a system that can be evaluated by multiple people. In addition, there is also fat in the muscle. EMS may also be given the ability to burn fat. Therefore, we would like to pursue a method that can evaluate facial treatment from the viewpoint of fat using short TI inversion recovery images. The current study targeted young women in their twenties. In the future, we plan to evalu-

ate whether the treatment effect varies across age groups. In addition, we plan to investigate changes in the thickness of facial muscles using an ultrasonic device, and to measure changes in muscle hardness using shear wave elastography. At the end, in this study, one EMS device is used for evaluation. However, other manufacturers are also developing devices with EMS function. Since the principle of EMS effect is the same even if the device is different and the treatment procedure is different, it is considered that the same facial treatment effect can be obtained. It is also necessary to examine the effects of facial treatments on various devices.

5. Conclusion

The use of EMS facial equipment induced a decrease in masseter muscle volume measured using T₂WI of MRI. Therefore, it was suggested that the use of EMS facial equipment promotes the movement of facial muscles, reduces muscle mass, and has the effect of slimming the face. In addition, a facial treatment effect could be obtained even with short-term use.

Acknowledgments

We would like to express our deep gratitude to Soichi Tatsutani of Hitachi, Ltd. Health care Chubu/Hokuriku Branch, Nobuyuki Arai of Suzuka University of Medical Science, students of Muto Laboratory, and volunteers for their cooperation in this research. We thank Benjamin Knight, MSc., from Edanz Group (<https://en-author-services.edanz.com/ac>) for editing a draft of this manuscript.

Conflicts of Interest

This research was supported by joint research funding from Mikimoto Pharmaceutical CO., LTD.

References

- 1) S. Zhang, et al.: Fighting against Skin Aging: The Way from Bench to Bedside. *Cell Transplant*, 27; 729-738, 2018.
- 2) A. Kazanci, et al.: Analyses of changes on skin by aging. *Skin Res Technol*, 23; 48-60, 2016.
- 3) T. Kaneko, et al.: Effect of Improving Skin Quality by Facial Equipment Using Radio Waves. *Shinryo to Shinryaku (Med Cons New-Remed)*, 55; 787-793, 2018.
- 4) V. Esteve, et al.: The effect of neuromuscular electrical stimulation on muscle strength, functional capacity and body composition in haemodialysis patients. *Nefrologia*, 37; 68-77, 2017.
- 5) N. A. Maffiuletti, et al.: Neuromuscular adaptations to electrostimulation resistance training. *Am J Phys Med Rehabil*, 85; 167-175, 2006.
- 6) General incorporated foundation Institute of Japan Therapeutic Apparatus. http://nihondenshi.xsrv.jp/hp/?page_id=964. Accessed November 15, 2020.
- 7) E. J. Choi, et al.: Effects of Electrical Muscle Stimulation on Waist Circumstance in Adults with Adbominal Obesity: A Randomized, Double-blind, Sham-Controlled Trial. *JNMA J Nepal Med Assoc*, 56; 904-911, 2018.
- 8) ITO CO., LTD. Instruction manual for PEARL FACE ESTHE Sonic EX.
- 9) Beauty Eos Inc. Kireinosensei. <https://kireinosensei.com/1300113/>. Accessed January 12, 2021.
- 10) K. Yamada, et al.: Difference of the Contrast between CT and MRI: the Selection of the Alternative Imaging. *Journal of Animal Clinical Research Foundation*, 12; 27-29, 2003.
- 11) K. Yamada, et al.: Technical parameters affecting image characteristics in in vivo MR microscopy of the mouse. *Vet Radiol Ultrasound*, 43; 518-527, 2002.
- 12) R. Nishime, et al.: Effects on Face Caused by the Face Roller. *Bulletin of Nagoya Future Culture College*, 43; 13-19, 2018.
- 13) Y. Matsuoka: HYOJOKIMMASSAJI SEJUTSU TEKUNIKKU. 46-58, FRAGRANCE JOURNAL LTD., 2011.