Changes in Masticatory Muscle Activity Over Time by Facial Skin Temperature Area During Gum Chewing

Hidetaka Nakamura1*, Kazuyoshi Hashimoto2, Takeshi Seki3, Kei Takahashi1 and Hideto Matsuda2

1Department of Health and Nutrition, Faculty of Health and Human Life, Nagoya Bunri University, Japan.
2Department of Fixed Prosthodontics, School of Dentistry, Aichi Gakuin University, Japan.
3Department of Information and Media Studies, Faculty of Information and Media Studies, Nagoya Bunri University, Japan.

Citation: Nakamura H, Hashimoto K, Seki T, et al. Changes in Masticatory Muscle Activity Over Time by Facial Skin Temperature Area During Gum Chewing. Oral Health Dental Sci. 2021; 5(5); 1-6.

ABSTRACT

Aim: The purpose of this study was to quantify the change in facial skin temperature during mastication, and analyze the two aspects of habitual masticatory side and masticatory ability, and to clarify the change of masticatory muscle activity over time.

Method: Subjects were 23 healthy women (21.3±0.4 years old). An infrared thermography camera was used to measure the left and right facial skin temperatures at rest and when chewing gum. The subjects were given dental xylitol gum and freely chewed it at a rate of once per second for 15 minutes. Skin temperature was measured 5, 10, and 15 minutes after the start of chewing. The facial reference area was measured between 30 to 36°C with a resolution of 1°C per pixel. The habitual masticatory side was determined by the stopping method, and from the 2 minute rest facial skin temperature area of the habitual non-masticatory side, and two groups were formed according to chewing strength.

Results: There were 13 subjects in the weak chewing group and 10 in the strong group, with no significant difference in age, height, weight, BMI, and body fat percentage. The skin temperature increased with chewing, but the increase was less on the habitual non-masticatory side than on the masticatory side. Although there was no difference in muscle activity between the habitual masticatory side of the strong and weak chewing group, the muscle activity on the non-masticatory side was less than on the habitual masticatory side in the weak chewing group.

Conclusions: The amount of masticatory muscle activity at rest was classed as either strong or weak chewing ability, and muscle activity was examined on both the habitual masticatory side and the habitual non-masticatory side. This significant difference suggests that using thermography was useful for determining masticatory ability on the chewing muscle activity at rest. Furthermore, being able to determine muscle activity by measuring changes in the skin temperature area by thermography, suggests that the method used in this study was viable.

Keywords
Thermography, Gum chewing, Facial skin temperature area, Habitual masticatory side, Chewing ability.

Introduction
Mastication is carried out by the activity of the masticatory muscles, and is accompanied by changes in muscle potential and heat produced due to the contraction and relaxation of these muscles. Methods for evaluating the activity of the masticatory muscles are the electromyogram [1-4], deep body thermometer [5-7], and thermography [8-10]. Measurements using electromyograms or a deep body thermometer, involve attaching a sensor directly to the measurement site. Consequently, subtle differences in positioning of the sensors can cause the data to be...
There was a functional difference between mastication on the main occluding area, and the habitual masticatory side and bitten at an arbitrary position. This was done 5 times to determine the main occluding area was determined using stopping [13]. Test food used as stopping was placed on the subject's tongue and the facial skin temperature when at rest (0 minutes) and while chewing gum. The subject was given Dental xylitol gum (Lotte) to chew, and freely chewed the gum at a rate of once per second for 15 minutes. The main occluding area was determined using stopping [13]. Determination of habitual masticatory side

The main occluding area was determined using stopping [13]. Test food used as stopping was placed on the subject's tongue and bitten at an arbitrary position. This was done 5 times to determine the main occluding area, and the habitual masticatory side and the habitual non-masticatory side. According to Tochikura et al. [14], there was a functional difference between mastication on the main masticatory side and the non-main masticatory side, and the main masticatory side chewing time was reported as having more efficient and had more stable movement with a stronger force than on the non-main masticatory side. From this, the habitual non-masticatory side was considered functionally inferior, and there was a big difference in chewing ability on the habitual non-masticatory side. Therefore this study analysed the habitual non-masticatory side.

Determination of masticatory ability

The strong masticatory ability group and weak masticatory ability group were formed from the 2 minute rest facial skin temperature area of the habitual non-masticatory side.

Statistical analysis

Using statistical analysis software SPSS (IBM), the physical status and skin temperature area of each subject were tested with a significance level of 5%. The skin temperature area of each masticatory side of the two groups were tested at 0, 5, 10, and 15 minutes using the Wilcoxon signed rank-sum test. To determine muscle activity, the skin temperature area was measured in the range 31 to 36°C.

Result

Subjects

Table 1 shows the physical status of the subjects. There were 13 people in the weak chewing group and 10 in the strong group. There was no significant difference between the groups in age, height, weight, BMI, or body fat percentage.

Comparison of muscle activity by masticatory side and ability of each group

1) Habitual masticatory side

Table 2 shows the results for the habitual masticatory side. The 32°C area at 5 to 10 minutes (p= 0.011), and 5 to 15 minutes (p= 0.002) significantly increased in both cases.

2) Habitual masticatory side of the strong chewing group

Table 3 shows the results for habitual masticatory side of the strong chewing group. The 32°C area significantly increased from 5 to 15 minutes (p= 0.022).

3) Habitual masticatory side of the weak chewing group

Table 4 shows the result for habitual masticatory side of the weak chewing group. The 32°C area significantly increased from 5 to 10 minutes (p= 0.039), and 5 to 15 minutes (p = 0.028). The 33°C area significantly increased from 10 to 15 minutes (p= 0.023).

4) Habitual non-masticatory side

Table 5 shows the results for the habitual non-masticatory side. The 35°C area increased significantly from 0 to 5 minutes (p= 0.047), and significantly decreased from 5 to 15 minutes (p=0.020). The 36°C area significantly decreased from 10 to 15 minutes (p= 0.046).
### Table 1: Clinical characteristics of the 23 subjects.

| Masticatory ability group | n  | Age (year) | Body height (cm) | Body weight (kg) | Body Mass Index (BMI) (kg/m²) | Body fat (%) |
|---------------------------|----|------------|------------------|------------------|-------------------------------|--------------|
| Weak                      | 13 | 21.2 ± 0.7 | 157.9 ± 3.7      | 53.7 ± 7.9       | 21.5 ± 3.1                    | 30.8 ± 5.9   |
| Strong                    | 10 | 21.2 ± 0.4 | 155.8 ± 4.7      | 57.2 ± 10.5      | 23.6 ± 4.5                    | 31.4 ± 8.6   |
| Total                     | 23 | 21.3 ± 0.4 | 157.0 ± 4.2      | 55.2 ± 9.1       | 22.4 ± 3.8                    | 31.1 ± 7.0   |

The data are expressed as the mean ± standard deviation (SD). There were 13 people in the weak chewing group and 10 in the strong group. There was no significant difference between the groups.

### Table 2: Comparison of muscle activity by habitual masticatory side (n=23).

| Facial skin temperature | Facial skin temperature area (Rest (0 minutes)) | After the start of chewing gum (5 minutes) | 10 minutes | 15 minutes |
|-------------------------|-----------------------------------------------|------------------------------------------|------------|------------|
| 36℃                     | 0.107 ± 0.230                                 | 0.165 ± 0.427                           | 0.094 ± 0.239 | 0.058 ± 0.188 |
| 35℃                     | 3.153 ± 4.071                                 | 4.563 ± 6.364                           | 4.141 ± 5.410 | 4.068 ± 8.080 |
| 34℃                     | 16.563 ± 16.734                               | 18.076 ± 16.681                         | 18.111 ± 17.115 | 15.249 ± 15.564 |
| 33℃                     | 27.898 ± 17.896                               | 26.547 ± 16.771                         | 24.902 ± 13.224 | 25.337 ± 13.324 |
| 32℃                     | 21.214 ± 10.930                               | 19.676 ± 11.400                         | 23.817 ± 14.331 | 27.353 ± 15.031 |
| 31℃                     | 18.690 ± 16.490                               | 18.974 ± 16.052                         | 18.623 ± 16.863 | 20.458 ± 17.627 |

The data are expressed as the mean ± SD. Skin temperature area indicates muscle activity. a* indicates significant difference between a and a. There were significant differences in 32 ℃ value (a: p=0.011, b: p=0.002).

### Table 3: Comparison of muscle activity by habitual masticatory side of the strong chewing group (n=10).

| Facial skin temperature | Facial skin temperature area (Rest (0 minutes)) | After the start of chewing gum (5 minutes) | 10 minutes | 15 minutes |
|-------------------------|-----------------------------------------------|------------------------------------------|------------|------------|
| 36 ℃                    | 0.084 ± 0.242                                 | 0.016 ± 0.057                           | 0.014 ± 0.052 | 0.013 ± 0.045 |
| 35 ℃                    | 0.936 ± 1.863                                 | 1.219 ± 2.467                           | 0.943 ± 1.835 | 0.622 ± 1.238 |
| 34 ℃                    | 4.791 ± 6.429                                 | 6.748 ± 6.989                           | 7.095 ± 8.178 | 5.778 ± 6.701 |
| 33 ℃                    | 16.274 ± 12.747                               | 16.966 ± 13.858                         | 17.821 ± 12.647 | 20.159 ± 12.560 |
| 32 ℃                    | 26.435 ± 7.686                                | 24.459 ± 10.903                         | 27.352 ± 11.710 | 30.172 ± 8.268 |
| 31 ℃                    | 30.083 ± 13.101                               | 30.450 ± 11.839                         | 29.890 ± 14.198 | 31.675 ± 15.515 |

The data are expressed as the mean ± SD. Skin temperature area indicates muscle activity. a* indicates significant difference between a and a. There was significant difference in 32 ℃ value (a: p=0.039, b: p=0.028) and 33 ℃ value (c: p=0.023).
5) Habitual non-masticatory side of the strong chewing group

Table 6 shows the results for the habitual non-masticatory side of the strong group. The 32°C area significantly increased from 5 to 15 minutes (p=0.028).

6) Habitual non-masticatory side of the weak chewing group

Table 7 shows the results of the habitual non-masticatory side masticatory group. The area of 33°C area significantly increased from 5 to 10 minutes (p= 0.039).

**Considerations**

**Determination of habitual masticatory side**

In this study, the main occluding area was determined using stopping and was used to determine the habitual masticatory side. Christensen et al. [15] and Kazazoglu et al. [16] chewed gum and observed the chewing strokes to determine the habitual masticatory side. Pond et al. [17] and Delport et al. [18] used the side of the initial chewing movement and reported that side as the habitual masticatory side, and that initial movement correlated with wide on which chewing continued. In this study, the authors [19] determined the habitual masticatory side using the same method, and after 2 minutes of chewing, a relationship was found between chewing ability and exercise tolerance. From our previous study, the method of determining the habitual masticatory side from the main occluding area by stopping is considered appropriate for this study.

**Determining masticatory ability by facial skin temperature using thermography**

Chewing ability was evaluated from the facial skin temperature at 0 minutes on the habitual non-masticatory side, tested on the habitual

---

**Table 5:** Comparison of muscle activity by habitual non-masticatory side (n=23)

| Facial skin temperature | Facial skin temperature area |
|------------------------|-----------------------------|
| Rest (0 minutes)       | After the start of chewing gum |
| 36 °C                 | 0.039 ± 0.139               |
| 35 °C                 | 2.929 ± 3.991               |
| 34 °C                 | 17.020 ± 17.579             |
| 33 °C                 | 27.904 ± 17.945             |
| 32 °C                 | 21.200 ± 11.801             |
| 31 °C                 | 19.430 ± 16.640             |

The data are expressed as the mean ± SD. Skin temperature area indicates muscle activity. a* indicates significant difference between a and a.

There were significant differences in 35 °C value (a: p=0.047; b: p=0.020) and 36 °C value (c: p=0.046).

**Table 6:** Comparison of muscle activity by habitual non-masticatory side of the strong chewing group (n=10).

| Facial skin temperature | Facial skin temperature area |
|------------------------|-----------------------------|
| Rest (0 minutes)       | After the start of chewing gum |
| 36 °C                 | 0.024 ± 0.063               |
| 35 °C                 | 5.395 ± 4.219               |
| 34 °C                 | 32.985 ± 14.825             |
| 33 °C                 | 43.603 ± 13.166             |
| 32 °C                 | 13.919 ± 8.849              |
| 31 °C                 | 3.401 ± 1.603               |

The data are expressed as the mean ± SD. Skin temperature area indicates muscle activity. a* indicates significant difference between a and a.

There was significant difference in 33 °C value (a: p=0.022).

**Table 7:** Comparison of muscle activity by habitual non-masticatory side of the weak chewing group (n=13).

| Facial skin temperature | Facial skin temperature area |
|------------------------|-----------------------------|
| Rest (0 minutes)       | After the start of chewing gum |
| 36 °C                 | 0.050 ± 0.180               |
| 35 °C                 | 1.032 ± 2.623               |
| 34 °C                 | 4.739 ± 5.093               |
| 33 °C                 | 15.827 ± 9.848              |
| 32 °C                 | 26.801 ± 10.883             |
| 31 °C                 | 31.761 ± 11.263             |

The data are expressed as the mean ± SD. Skin temperature area indicates muscle activity. a* indicates significant difference between a and a.

There was significant difference in 33 °C value (a: p=0.022).
masticatory side and masticatory ability were obtained. The amount of masticatory muscle activity was significantly different. Methods for determining chewing ability, include chewing gum [20] color changing gum [21], gummies [22], peanuts [23], and raw rice [24]. However, these evaluation methods involve multiple factors such as bite, salivation volume, the ability to mix with saliva, and tongue movement. In this study, skin temperature due to masticatory muscle activity was measured by thermography, and the facial reference area was corrected. Therefore, masticatory muscle activity is measured quantitatively and comprehensively compared to previous research. In patients with craniomandibular disorder, masticatory muscle activity was significantly lower than in normal people, and treatment produced a significant increase in muscle activity [25,26]. Since there is a correlation between masticatory efficiency and craniomandibular disorder [27], masticatory efficiency and muscle activity are considered to be closely related. This study suggests that the masticatory muscle activity obtained from thermography was useful in determining masticatory ability.

Changes in muscle activity

Habitual masticatory side and habitual non-masticatory side

The 32°C area on the habitual masticatory side significantly increased from 5 to 10 minutes and from 5 to 15 minutes. After a significant increase in the 35°C area in the habitual non-masticatory side from 0 to 5 minutes, it decreased significantly from 5 to 15 minutes, and the 36°C area area decreased significantly from 10 to 15 minutes. The skin temperature increased when chewing, which gave results similar to previous studies. However, the skin temperature increase was less on the habitual non-masticatory side compared to the habitual masticatory side. Nimura et al. [28] performed a study to clarify the difference in masticatory movement during chewing on the habitual masticatory side and non-masticatory side. They reported that the stability of both the motor pathway and the movement rhythm in the masticatory movement during chewing is greater on the habitual masticatory side than the other side. The smaller increase in skin temperature on the habitual non-masticatory side was considered to be due to reduced muscle activity on that side.

Strong chewing group and weak chewing group

The habitual masticatory side of the strong chewing group had a significant increase in the 32°C area from 5 to 15 minutes, and the 32°C area on habitual non-masticatory side also significantly increased from 5 to 15 minutes. The 32°C area of the habitual masticatory side for the weak chewing group significantly increased from 5 to 10 minutes, 5 to 15 minutes, and the 33°C area significantly increased from 10 to 15 minutes, and from 5 to 10 minutes on the habitual non-masticatory side. The muscle activity of the strong chewing group showed no difference between the sides, while the muscle activity on the habitual non-masticatory side was less than on the habitual masticatory side in the weak chewing group. The muscle activity on the habitual masticatory side is considered to be less involved in mastication due to the high load on the masticatory muscles in the strong chewing group due to the amount of chewing they do on a daily basis. Suzuki et al. [29] reported that for 5 types of chewing gum with different hardness, significantly increased the total carotid blood flow on the right hand side during chewing for 10 minutes, and that the blood flow is greater when chewing food of moderate hardness than soft or hard foods. The masticatory muscles on the habitual non-masticatory side of the weak chewing group are poorly developed. The gum used in this study is not considered to have increased blood flow any more than moderate hardness gum would have done for the weak chewing group. Yamamura [30] examined the effect of persistent mastication on masticatory movements only on the habitual non-masticatory side for 15 days. They reported that the stability and smoothness of the masticatory movement on the masticatory side increase daily. The effect of strengthening the habitual non-masticatory side for evaluating masticatory ability will be examined in the future.

Limitations of research

This study only examined the activity of masticatory muscles while chewing gum in young women, but different sex, age, and chewing samples may produce different results.

Conclusion

The facial skin temperature was measured by thermography, and the subjects were placed into either the strong or weak chewing group according to chewing muscle activity at rest, and the transition of muscle activity over time was examined on the habitual masticatory side and the habitual non-masticatory side. As a result, it was suggested that using thermography to measure the masticatory muscle activity at rest was useful for determining masticatory ability, due to a significant difference in muscle activity. Furthermore, since the muscle activity level could be determined from changes in the skin temperature area measured by thermography, the method used in this study is considered to be useful.

Acknowledgments

Funding for this investigation was provided in part by Nagoya Bunri University. The authors have no conflicts of interest directly relevant to the content of this article. We would like to thank Konan Translation Service (www.konan-tr-s.com) for English language editing.

Clinical Trial Registry or Grant Details

Since this study is not a clinical trial, no clinical study registration has been made, but the ethics committee was obtained. Ethical approval was obtained from the Research Ethics Committee of Nagoya Bunri University (No. 44). The authors have no conflicts of interest directly relevant to the content of this article.

References

1. MacDougall JDB, Andrew BL. An electromyographic study of the temporalis and masseter muscles. J Anat. 1953; 57: 37-45.
2. Jarabak JR. An electromyographic analysis of muscular behavior in mandibular movements from rest position. J Pros Den. 1957; 7: 682-710.

3. Lammie GA, Perry HT, Crumm BD. Certain observations on a complete denture patient Part II Electromyographic observations. J Pros Den. 1958; 8: 929-939.

4. Hiromichi Tsuru, Yoshinori Hirota, Takao Maruyama, et al. Electromyographical Observations on the Behavior of Masticatory Muscles during Chewing Various Foods Part 1. Normal Occlusion. J Jpn Prosthodont Soc. 1966; 10: 163-172.

5. Masahiro Tanaka, Ikuhisa Maeno, Kinnosuke Yamashita, et al. Changes in the Deep Temperature of Masticatory Muscles Part 1. Right and Left Masseter Muscles in Normal Subjects. J Jpn Prosthodont Soc. 1984; 28: 218-223.

6. Tetsuji Kusumoto, Masahiro Tanaka, Lin Ming-Huei, et al. Changes in the Deep Temperature of Masticatory Muscles Part 2. Continuous Monitoring through 24 hours of Masseteric and Forehead Temperatures. J Jpn Prosthodont Soc. 1984; 28: 650-657.

7. Lin Ming-Huei. The Skin and Deep Temperatures of the Masseter Muscles. J Jpn Prosthodont Soc. 1986; 30: 267-278.

8. Berry DC, Yemm R. Changes in facial skin temperature associated with unilateral chewing. Oral Rehabil. 1974; 1: 127-129.

9. Hiroyuki Hijiya, Kenji Takada, Yoshitaka Yasuda, et al. A thermographic study on gum chewing effort. Jpn J Oral Biol. 1990; 32: 93-102.

10. Kenichirou Sadamitsu. Analysis of Facial Skin Temperature by Thermography. J Jpn Prosthodont Soc. 1994; 38: 548-559.

11. Takahashi K, Hashimoto K, Nakamura H, et al. The Study of the Facial Skin Temperature by Thermography after Gum Chewing - The Differences between Insulin Secretion Types. Journal of Japanese Society for Masticatory Science and Health Promotion. 2018; 28: 11-18.

12. Takahashi K, Hashimoto K, Nakamura H, et al. Thermography-Measured Facial Temperature Affects Masticatory Ability. Oral Health Dental Sci. 2019; 3: 1-5.

13. Hitoshi Kato, Yuzuru Furuki, Shigeo Hasegawa. Observations on the main occluding area in mastication. J Jpn Soc Stomatognath Funct. 1996; 2: 119-127.

14. Tochikura J, Shiga H, Kobayashi Y. Functional differences between chewing on habitual chewing side and chewing on non-habitual chewing side - Masticatory movement function, masticatory muscular activity, and masticatory efficiency when chewing gumi-jelly. Journal of Japanese Society for Masticatory Science and Health Promotion. 2000; 9: 57-64.

15. Christensen LV, Radue JT. Lateral preference in mastication: a feasibility study. J oral Rehabil. 1985; 12: 461-467.

16. Kazazoglu E, Heath MR, Muller F. A simple test for determination of the preferred chewing side. J Oral Rehabil. 1994; 21: 723-724.

17. Pond LH, Barghi N, Barnwell GM. Occlusion and chewing side preference. J Prosthett Dent. 1986; 55: 498-500.

18. Delport HP, De Laat A, Nijs J, et al. Preference pattern of mastication during the first chewing cycle. Electromyogr Clin Neurophysiol. 1983; 23: 491-500.

19. Nakamura H, Hashimoto K, Takahashi K, et al. Mastication and Bone Density of Young Women and the Relationship with Tolerance to Exercise Analysis with thermography and a Bicycle Ergometer. Oral Health Dental Sci. 2020; 4: 1-8.

20. Matsuda H, Takada K, Hashimoto K, et al. Examination of measuring the masticatory ability using gum. Journal of Japanese Society for Masticatory Science and Health Promotion. 2001; 10: 95-100.

21. Hayakawa I, Watanabe I, Hirano S, et al. A simple Method for evaluating masticatory performance using a color-changeable chewing gum. Int J Prosthodont. 1998; 11: 173-176

22. Tanaka A, Shiga H, Kobayashi Y. Quantitative Evaluation of Mandibular Movements and Masticatory Muscular Activities by Analyzing the Amount of Glucose Discharge during Gumi-jelly Chewing. The Journal of the Japan Prosthodontic Society. 1994; 38: 1281-1294.

23. Manly RS. Factors affecting masticatory performance and efficiency among young adults. J. Dent. Res. 1951; 30: 874-882.

24. Ishiwar T. Masticatory Efficiency and Particle Size Distribution of Masticated Raw Rice. J Stomatol Soc Jpn. 1995; 22: 207-255.

25. Mohl ND, Lund JP, Widmer CG, et al. Devices for the diagnosis and treatment of temporomandibular disorders Part II: Electromyography and sonography. J Prosthet Dent. 1990; 63: 332-336.

26. Naeije M, Hansson TL. Short-term effect of the stabilization appliance on masticatory muscle activity in myogenous Craniofacial Disorder Patients. J Craniomandib Disord Facial Oral Pain. 1991; 5: 245-250.

27. Agerberg G, Carlsson GE. Chewing ability in relation to dental and general health: Analysis of data obtained from a questionnaire. Acta Odontol Scand. 1981; 39: 147-150.

28. Hideyuki Nimiura, Yoshinori Kobayashi. The Difference in Masticatory Movements between Habitual Chewing Side and Non-Habitual Chewing Side. J Jpn Prosthodont Soc. 1990; 34: 1127-1139.

29. Suzuki M, Ishiyama I, Takiguchi T, et al. Effects of gum hardness on the response of common carotid blood flow volume, oxygen uptake, heart rate and blood pressure to gum-chewing. Journal of Japanese Society for Masticatory Science and Health Promotion. 1994; 4: 51-62.

30. Yamamura Y. The Influence of Mastication with Non-habitual Chewing Side on Masticatory Movements. J Jpn Prosthodont Soc. 1994; 38: 1281-1294.

© 2021 Nakamura H, et al. This article is distributed under the terms of the Creative Commons Attribution 4.0 International License