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Salivary Effects of Facial Vibrotactile Stimulation in Patients with Sjogren's Syndrome and Poor Salivation

Koichiro Ueda, Kanako Gora, Masaru Yamaoka,
Takako Sato, Kimiko Abe, Enri Nakayama,
Mituyasu Sato, Yumiko Tunoda, Sumiko Akatuka,
Sayaka Fukui, Akinari Hayashi, Teruyuki Hirai,
Sayako Ohnishi, Mayumi Hayata and Hisao Hiraba

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Abstract

We examined the effect of vibrotactile apparatus in patients with Sjögren's syndrome and others with reduced salivation in comparison to normal subjects. The most effective salivation in normal subjects was produced by 89 Hz vibrotactile stimulation with 9.8 μ m amplitude on the parotid or submandibular glands vibrotactile stimuli. First, we examined by measuring the weight of dental cotton rolls positioned at the opening of the secretory duct for total salivation 3 min during resting, and then after 5-min intervals, the weights were measured every 3 min of vibrotactile stimulation on salivary glands. Furthermore, we measured facial temperature around vibrators after 2 min of vibration. We investigated 10 poor salivation patients with Sjögren's syndrome (8 patients) defined by examinations (contrast study or scintigraphic test) and others (2 patients). About 50% of patients with poor salivation gained recognition for good results, although they had periods of short-term (3 months) and long-term effects (6–7 years) during recuperation. Furthermore, facial skin temperatures on both sides of parotid glands were decreased in Sjögren's syndrome after vibration, although their temperatures were increased following recovery. Although the mechanism is not clear, we think that vibrotactile stimulation gives activation to salivary glands under the rising facial temperature.

Keywords: vibrotactile stimulation, facial skin temperature, parotid and submandibular glands, poor salivation, Sjögren's syndrome

1. Introduction

When we treat patients with reduced salivation (hyposalivation), we provide treatments such as artificial saliva, humectant, massage on the salivary glands, and so on [1]. However, treatment *with* the artificial saliva and humectant is the symptomatic treatment, and patients with handicaps *experience difficulties when they do massage*. We previously reported about *the relationship between facial vibratory effects in normal subjects and promotion of salivation*. We *performed this method* for facial vibratory effects on Sjögren's syndrome patients with poor salivation. We focused on *increase of salivation with the use of facial vibrotactile stimulation*, as reported by Hiraba et al. [2, 9, 10].

When patients continuously utilize the apparatus in future *the decrease or increase of salivation is examined from this result* [3]. In this experiment, it was necessary to make a comparison between the resting and *stimulated* salivations and to investigate the most effective frequency for increasing the salivary secretion. We examined the amount of salivation during vibrotactile stimuli with one vibrating motor (1.9 μm amplitude) on the bilateral masseter muscle belly (on the parotid glands), and in patients of Sjögren's syndrome, we asked twice practice during 15 min of morning and night. Furthermore, *the amount of salivation was explored by using a dental cotton roll positioned at the opening of the secretory duct for 3 min*. After this experiment was performed, *we made a comparison between the resting and stimulated salivations and investigated the most effective frequency for increasing salivary secretion*. When we examined normal subjects, *the effect of the increased salivation determined the difference between the resting and stimulated salivations*. We think that total salivation after the resting phase shows conditions of day-to-day salivation, and they after the stimulating are effects of vibrotactile stimulation.

We defined 5-min intervals as the recovery time between the resting and *stimulated* salivations from the previous pre-examinations. Furthermore, we examined temperature effects on patients with poor salivations (affected by Sjogren's syndrome) and others by the use of facial vibrotactile stimuli. Increased facial temperature by the vibrotactile stimulation showed changes of metabolism around facial skins. We will discuss the effects of vibrotactile stimulation based on these results.

2. Material and methods

2.1. Vibrotactile stimulation apparatus

The vibrotactile stimulation apparatus consists of an oscillating body and control unit, as shown in **Figure 1A** [2]. The oscillating body is composed of the headset equipped with vibrators as a substitute for positions of the bilateral microphones and vibrators utilizing the vibration electric motor (VEM) (Rekishin Japan Co., LE12AOG), as shown in **Figure 1A**. The VEM is covered in silicon rubber (polyethyl methacrylate, dental mucosa protective material, Shyofu Co.) for conglobating the parts under stimulation and preventing the warming of the VEM's temperature produced by the vibration of long periods [2]. The control unit consists

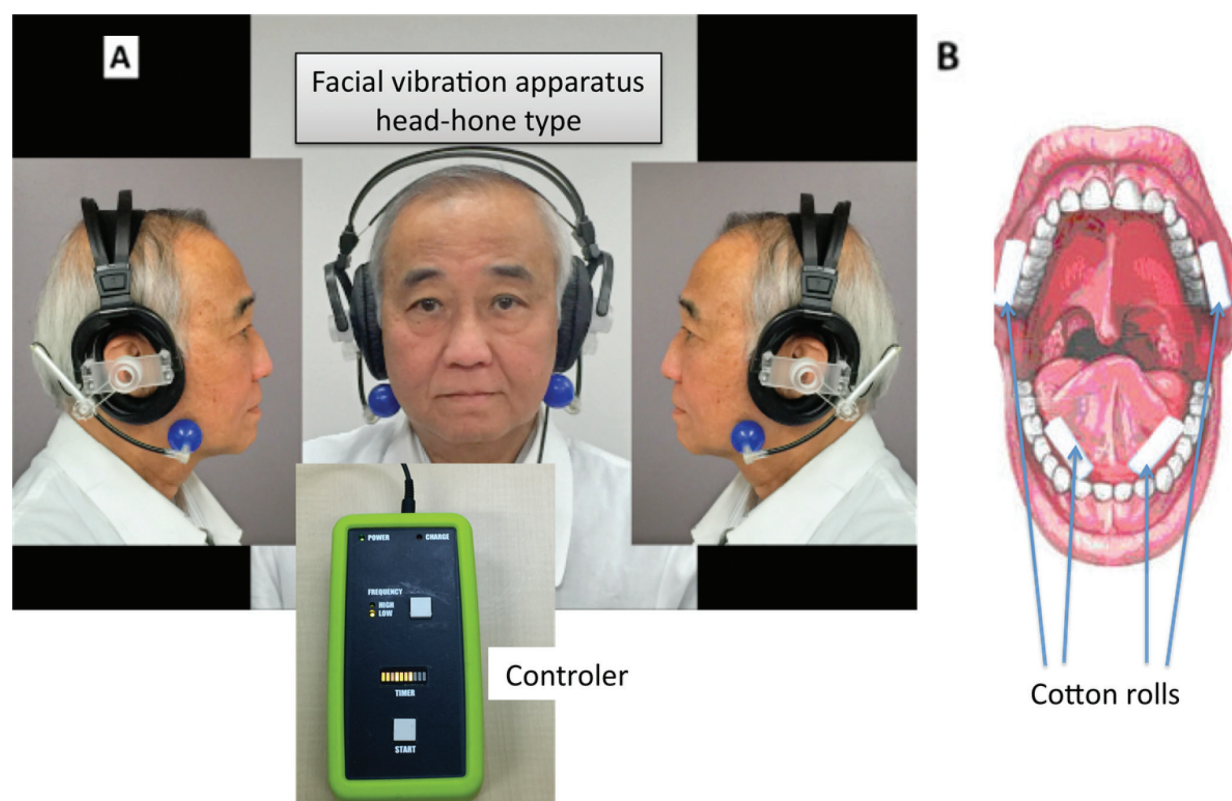


Figure 1. (A) Apparatus for facial vibration and (B) position of cotton rolls.

of three parts: the pulse width modulation (PWM) circuit, LCD monitor circuit and power supply circuit, and *interfaces* with a PWN electric motor, *delivers* vibration frequencies in the 60–182 Hz range [4].

As shown in **Figure 1**, we examined the amount of salivation during vibrotactile stimuli by two kinds of methods: on the bilateral masseter muscles belly (parotid glands) and on the bilateral parts of submandibular angle (submandibular glands). We examined the amount of salivation using a dental cotton roll (1 cm across and 3 cm length) positioned at the opening of the secretory ducts (right and left sides of parotid glands and right and left sides of submandibular and sublingual glands), during the vibrotactile stimuli on the bilateral parotid and submandibular glands, and wet cotton rolls measured for 3 min. These weights were then compared to their initiatory weights, as shown in **Figure 1B** [2].

2.2. Estimation of the stimulating salivation in normal subjects

First, we use three different frequencies, 89, 114 and 180 Hz as the vibrotactile frequency from the character of the oscillating body on the parotid glands. **Figure 1** shows the apparatus and position of rolls. To begin with, we put an exercise into practice for avoiding foreign-body sensation on the cotton rolls while setting for 3 min. Next, after 5 min of resting, we examined the amount of salivation during the 89 Hz vibrotactile stimulation for 3 min. Furthermore, after every 5 min of rest, we examined next amount of salivation during the 114 and 180 Hz vibrotactile stimuli for 3 min, respectively. We decided on 3 min for the measurement of salivation and 5 min for recovery

time from the previous experiment [2]. We carried out the examinations and used 19 normal subjects (male: 6 and female: 13, average age 22) for the resting-stimulating examination. This experiment was performed between 3 and 5 pm in a temperature-controlled room.

Second, as shown in **Figure 2**, we used three different frequencies (89, 114 and 180 Hz) and two different amplitudes (1.9 and 3.5 μm) on the parotid and/or submandibular glands. Amplitudes of vibrotactile stimuli were measured by the CCD laser displacement gauge (LK-G3000, KEYENCE Co.). After three different frequencies were attempted on the parotid glands, we explored the most effective frequency, and we arrived at a frequency of 89 Hz. We examined the frequency of 89 and 114 Hz and we used also oscillating bodies added as the frequency with double motors (one motor is 1.9 μm amplitude and double motors is 3.5 μm amplitude). Namely, the second experiment was practiced by 89 and 114 Hz with one motors (1.9 μm amplitude), and 89 and 114 Hz with double motors (3.5 μm amplitude). We examined the amount of salivation in four different trials, as shown in **Figure 2**. We carried out the examinations and used 17 normal subjects (male: 15 and female: 2, average age: 22) for the resting-stimulating examination. This experiment was performed between 3 and 5 pm in a temperature-controlled room.

Finally, as shown in **Figure 2**, since the most effective salivation by vibrotactile stimuli was at 89 Hz frequency with one motor (1.9 μm amplitude), we examined salivations on 89 Hz vibrotactile stimulation continuously for 4 or 5 days. As patients continuously utilized the apparatus, we examined if adaptation develops with everyday usage and whether or not the decrease of salivation arises. We investigated the adaptation of periods with the continuous use of vibrotactile stimuli for 4 continuous days in the same subjects. We carried out this examination and used 26

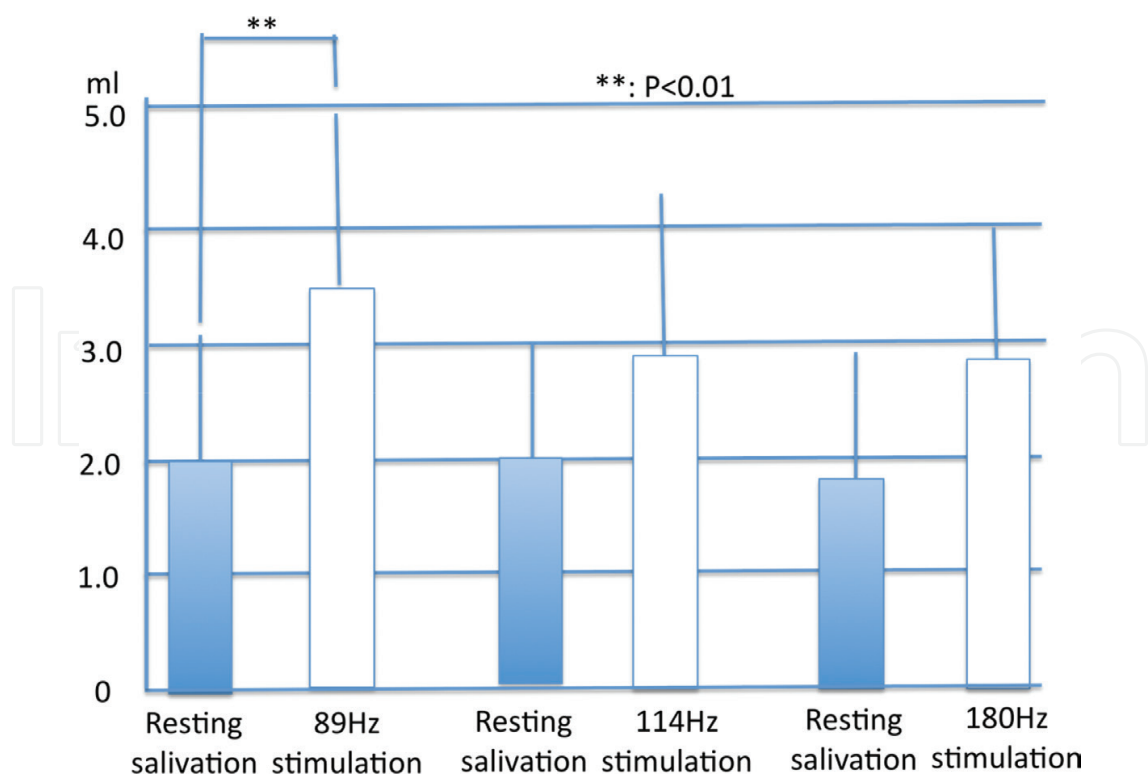


Figure 2. Salivations in each vibration frequency.

normal subjects (male: 11 and female: 15, average age 25) for the resting-stimulating examination. This experiment was performed between 3 and 5 pm in a temperature-controlled room. *In particular, we find that 89 Hz frequency and 1.9 μ m amplitude is most effective for salivation.*

2.3. Vibrotactile stimuli on the parotid and submandibular glands

As shown in **Figure 1**, we examined the difference between vibrotactile stimuli on the parotid glands and the submandibular glands. First, we tried three different vibrotactile stimuli, 89, 114, and 180 Hz, on the parotid glands and explored the frequency for the most effective salivation, as shown in **Figure 2**. Next, we inferred the most effective salivation of 89 Hz with the one motor depending on vibrotactile stimuli on the parotid or submandibular glands [2]. Furthermore, we investigated the most effective salivation depending on the difference of amplitudes (1.9 and 3.5 μ m amplitudes). We inferred the most effective salivation of 89 Hz with the one motor (1.9 microm amplitude) on the submandibular glands (significant difference $P < 0.05$, 89 Hz with 1.9 μ m amplitude and 114 Hz with 1.9 and 3.5 μ m amplitude), as shown in Hiraba et al. [2].

2.4. Total salivation after the vibrotactile stimulation on the parotid or submandibular and sublingual glands

In 89 Hz vibrotactile stimulation with 1.9 μ m amplitude on the parotid glands, we observed the most effective salivation in each gland, the right parotid, left parotid, right submandibular and sublingual, and left submandibular and sublingual glands. *Vibrotactile stimuli on the parotid or submandibular glands in any case showed that at 89 Hz more effective salivation in the right and left parotid and in the left and right submandibular and sublingual glands happened in comparison with the resting salivation in each gland.* On the other hand, vibrotactile stimuli with 1.9 μ m (89 and 114 Hz—1) or 3.5 μ m amplitudes (89 and 114 Hz—2) on the parotid or submandibular glands were examined. The 89 Hz with one motor, was the most effective salivation in the parotid, and the submandibular and sublingual glands, and the 89 Hz with double motors, was the more effective salivation in the parotid, and submandibular and sublingual glands, as shown in Hiraba et al. [2]. From these reasons, we suggested that vibrotactile stimulation at 89 Hz with 1.9 μ m amplitude showed the most effective salivation in many glands.

Finally, we assumed that 89 Hz with 1.9 μ m amplitude vibrotactile stimulation *produced the most effective salivation*, and then the vibrotactile stimuli on the parotid and submandibular glands *showed* hardly any difference. We then decided to use the apparatus to patients affected by poor salivation.

2.5. Information of patients with poor salivation affected by Sjögren's syndrome and others

In **Figure 3**, we showed information of patients: eight women were *diagnosed with Sjögren's syndrome* and two women's symptoms were unexplained. *Patients with Sjögren's syndrome were diagnosed by contrast and/or scintigraphic studies. In particular, the patients with indefinite complaints were not given a definite diagnosis; nevertheless, they had poor salivation as their chief complaint.*

	<u>Name</u>	<u>Definite diagnosis</u>	<u>Saligren Dose level</u>	<u>Passed years</u>	<u>Actual condition</u>
1.	MZ	contrast study	dispense medication (3 drugs/day)	8 years	continued investigation
2.	AS	contrast study	dispense medication (3 drugs/day)	5 years	break up for myalgia
3.	NI	contrast & scintigraphic study	dispense medication (3 drugs/day)	5 years	vibration disamenity
4.	KM	contrast study	dispense medication (3 drugs/day)	3 years	ope of brain cancer
5.	TO	scintigraphic study	dispense medication (3 drugs/day)	6 years	contiued investigation
6.	YA	contrast & scintigraphic study	dispense medication (3 drugs/day)	1.5years	cured patient
7.	NA	scintigraphic study	no drug	6 years	continued investigation
8.	UJ	indefinite complaint	no drug	4 years	break up for change residence
9.	SG	indefinite complaint	dispense medication (3 drugs/day)	2 years	ope of brain cancer
10.	KN	contrast study	dispense medication (3 drugs/day)	3 years	vibration disamenity

Figure 3. Information of subjects. Patients in 8 and 9 showed only poor salivation. Others are Sjögren's syndrome patients.

3. Results

3.1. Variation per day of the effective salivation on the continuous vibrotactile stimulation

We examined whether or not the effective salivation occurred continuously when the vibrotactile stimulation was carried out every day. Normal subjects (26, males 15 and females 11, average age 25) used this apparatus continuously 4 or 5 days *at the same time and place* [8]. Since patients with *decreased* salivation (hyposalivation) had the psychiatric disorder in daily life, we conducted the experiment to realistically approximate the natural condition. In particular, we produced the analysis following the 89 Hz vibrotactile stimulation with 1.9 μm amplitude from the previous experiment, because this frequency produced the most effective salivation. *No gland (right and left parotid glands, and right submandibular and sublingual glands) showed a decreasing tendency with use day after day* [8].

3.2. Facial skin temperature and heart rate in normal subjects

As shown in **Figure 4A**, facial temperature under vibration apparatus was increased about 0.5°C in 2 or 3 min, and then after 15 min of *continuous stimulation*, it was up by about 0.5°C, too. *Namely, a rise in facial temperature and an increase in RR intervals (decreasing heart rate) by vibration were affected by period of stimulating time. On the other hand, by raising about 200 ms of RR intervals after 15 min an increase in heart rate was observed when the vibration was over. The reason was thought to be parasympathetic activation recoil by vibration stimulation.*

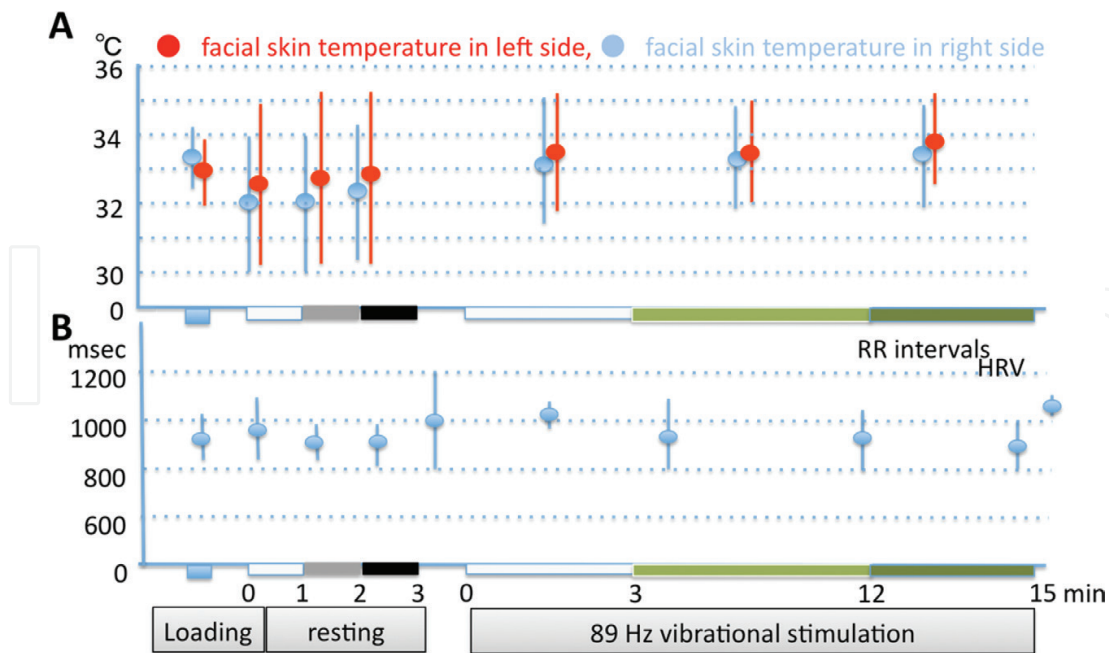


Figure 4. Facial skin temperature (A) and heart rate (B) in normal subjects.

3.3. The relationships between affected and unaffected patients after the vibrotactile stimulation

In Figure 5A, we showed changes to saliva production (Figure 5A-a) and facial temperature (Figure 5A-b) in the patients who were affected followed the vibrotactile stimulation. On the other hand, in Figure 5B, we showed changes to saliva production (Figure 5B-a) and facial temperature (Figure 5B-b) in patients who were not affected followed the vibrotactile stimulation. As shown in Figure 5A, the saliva production (elevated state from avg. 0.2 to 1.5 ml) was exponentially increased after about 5 years. The finding was shown as changes to increased face temperature (in a positive direction). However, as shown in Figure 5B, the saliva production and facial temperature remained static.

3.4. The affected and unaffected patients on the vibrotactile stimulation

In Figures 5 and 6, affected patients were divided into apocatastasis for a long period and for a short period. Affected patients with a long period were exponentially increased after about 6 (A), 5 (B) and 1.5 (D) years. Ones with a short period were exponentially increased after about 2 months (E). Facial temperature was increased with increased saliva production. On the other hand, in Figure 7, in unaffected patients, the saliva production and facial temperature remained static.

3.5. Questionnaire data

In Figure 8, we showed a survey and patients with satisfaction (good) or non-satisfaction (no/yes or bad) were examined. Patients with satisfaction had many good tendencies, but ones with non-satisfaction had many no/yes and bad.

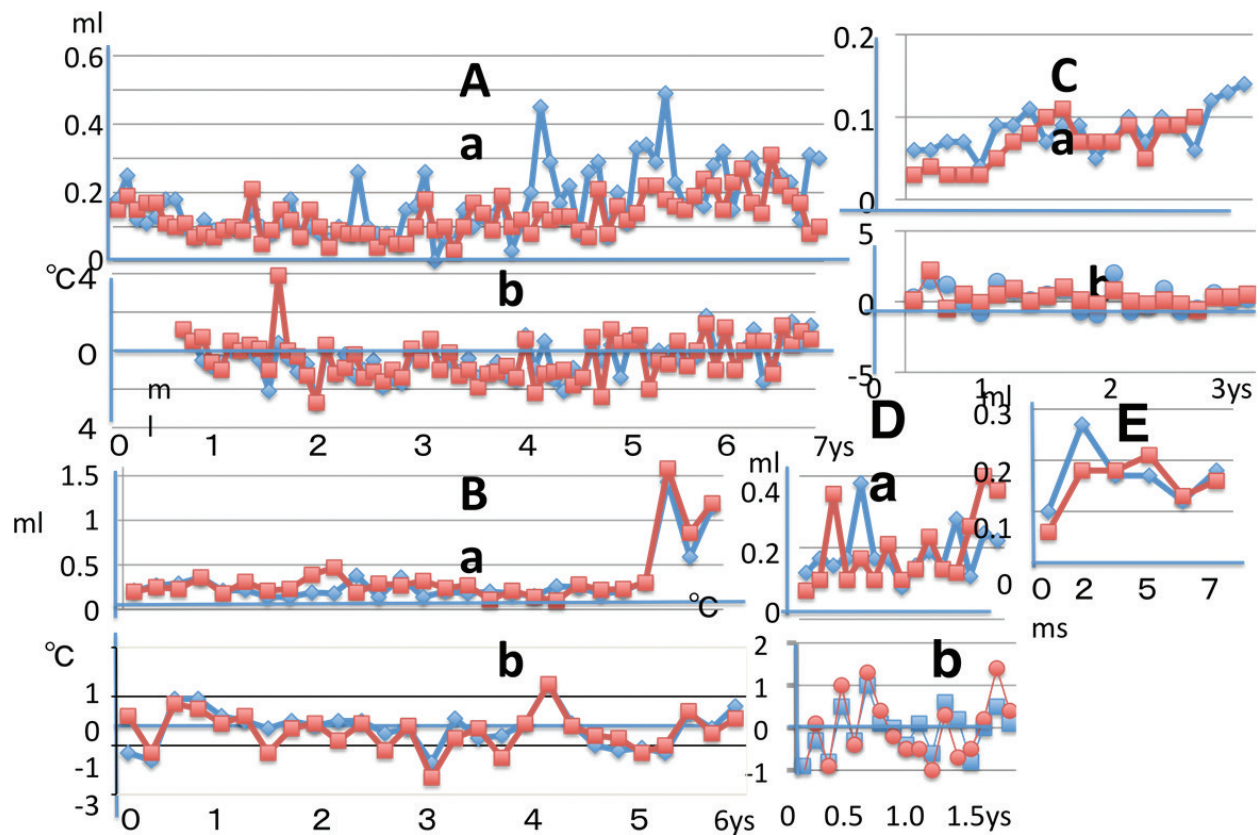


Figure 5. Patients affected by a facial vibration. A: salivation gradually increased, and temperature changed to plus tendency near 7 years. On the other hand, patients in B rapidly increased, and temperature changed to plus tendency near 6 years. Patients in C, D and E gradually increased.

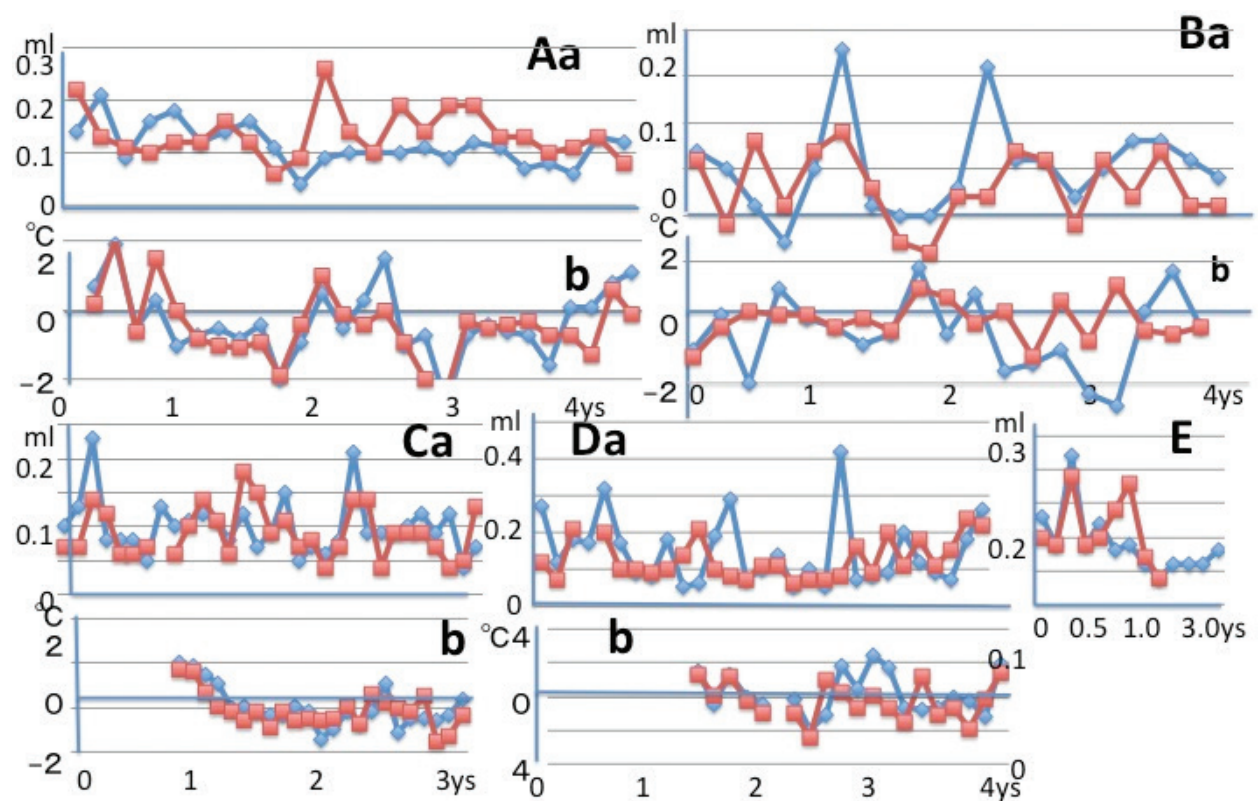


Figure 6. Patients unaffected by a facial vibration.

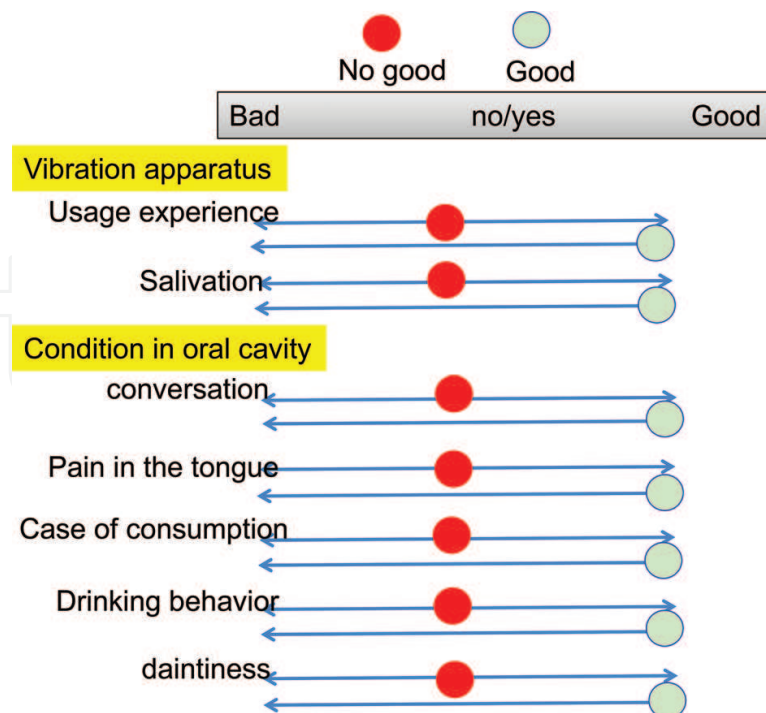


Figure 7. Typical examples of questionnaire data. We divided into three types (bad, no/yes and good) during effects of vibration apparatus and condition in oral cavity after vibration. Effect example is good (blue circles), and no-effect one is no/yes (red circles).

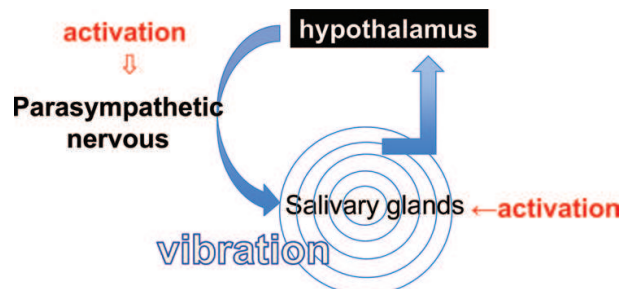


Figure 8. Summary of vibration effects. Facial vibration produces revitalization of cells of salivary glands. Furthermore, stimulation of vibration is activated at hypothalamus, and parasympathetic nerve is activated again. In particular, double activation shows 89 Hz frequency and 1.9 μ m amplitude is the most effective vibration.

4. Discussion

The continuous use of various sensory stimuli has been known to induce an adaptation [3, 7]. So we examined *the effects of vibrotactile stimulation and the adaptation in normal subjects, when the patients continuously used this apparatus every day. The patients' first desire is not to have an increase in salivary secretion from all salivary glands. However, the increase of total secretion quantities is necessary.* So, we first investigated changes in the total secretion quantities of normal subjects with the vibrotactile stimulation using a cotton roll indwelling each duct of each gland.

On parotid glands, 89 Hz vibrotactile stimuli were shown *to result in* the more effective salivation in the right and left parotid glands and submandibular and sublingual glands,

as shown in **Figure 2**. On the other hand, on the submandibular glands, 89 Hz vibrotactile stimuli with one motor were shown *to result in* the more effective salivation in all the glands. The findings suggest the 89 Hz vibrotactile stimuli with one motor may be the most effective salivation, and glands stimulated by vibrotactile stimuli have the tendency *for* the most effective salivation. Namely, on the parotid gland and on the submandibular gland vibrotactile stimuli shows the submandibular and sublingual gland, the place of stimulating portions may be the body of the mandible.

Burdette and Gale studied the effects of treatments in myofascial pain dysfunction patients [5]. Furthermore, Vrijama and Vanharantra [6] reported that discographically painful discs always produced painless feeling in the vibration examination. These facts assume that peripheral stimuli provided by vibration arrive at the central nerve (in the spinal cord and brain stem) and that these effects were exercised by the depressant effect in the cerebral cortex depending on the somatosensory information. Namely, we think that the vibration stimuli may promote the parasympathetic effects by the inhibition of sympathetic effects elicited by the pain, and so on. On the other hand, we know that the production of salivation only induces the parasympathetic effects. Furthermore, the production of salivation will be at a specific frequency and amplitude. This phenomenon may be directly produced by the vibrotactile stimulation of 89 Hz with one motor on the parotid and submandibular glands.

On the other hand, we *examined* the physiological characteristics of the adaptation to the vibrotactile stimulation, whether *it caused decreased salivation or not. A continuous examination was performed for 4 or 5 days on 26 normal subjects [8]. Since patients with the decreased salivation (hyposalivation) are not exclusively happy in every day of their daily life, we conducted the experiment to realistically approximate the natural conditions. We did not show decreased adaptation* depending on the continuous using of this apparatus, as shown in **Figure 4**. The result suggests that 89 Hz vibrotactile stimulation of the facial skin on the masseter belly may be appropriate for patients with the *decreased* salivation. Furthermore, we imagined mechanism of salivary production following facial vibration in **Figure 8**. Facial vibration directly activates the poor salivation of glands and then it indirectly parasympathetic nerve via hypothalamus.

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Appendices and nomenclatures

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Author details

Koichiro Ueda¹, Kanako Gora¹, Masaru Yamaoka², Takako Sato³, Kimiko Abe¹,
Enri Nakayama¹, Mituyasu Sato¹, Yumiko Tunoda⁴, Sumiko Akatuka⁴, Sayaka Fukui⁴,
Akinari Hayashi¹, Teruyuki Hirai¹, Sayako Ohnishi¹, Mayumi Hayata¹ and Hisao Hiraba^{1*}

*Address all correspondence to: hiraba.hisao@nihon-u.ac.jp

1 Department of Dysphasia Rehabilitation, Nihon University, School of Dentistry, Tokyo, Japan

2 Department of Basic Science, Nihon University, School of Dentistry, Tokyo, Japan

3 Department of Oral Surgery, Nihon University, School of Dentistry, Tokyo, Japan

4 Department of Dental Hospital at Surugadai, Nihon University, School of Dentistry,
Tokyo, Japan

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