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ORIGINAL RESEARCH

Clinical Evaluation of Dental Metal Hazards and Therapeutic Effects of Shortwave Diathermy in Dental Medicine

Chisato Mukai, Tetsuji Nakamoto, Yusuke Kondo, Chihiro Masaki, Atsumi Ohta, Ryuji Hosokawa

ABSTRACT

Objective: Shortwave diathermy causes increase in temperature from deep inside the body, results in upregulation of metabolism, and has analgesic effects. In this study, we explored the potential application of shortwave diathermy in the maxillofacial region by monitoring internal and external temperature changes, changes in blood flow, and resting saliva secretion under shortwave diathermy for subjects with and without dental metal restorations (MR) to confirm the safety and the limitation of shortwave diathermy for dental medicine.

Materials and methods: Twenty young healthy subjects were recruited (10 subjects with MR and 10 subjects without MR). Shortwave exposure was achieved with condenser-type probes placed on the bilateral mandibular angles, and the intraoral temperature was monitored. For functional analysis, unstimulated whole saliva before and after exposure was collected. The temperature and blood flow distributions of the exposed areas were then monitored by thermography and two-dimensional (2D) laser Doppler flowmetry.

Results: Shortwave exposure for 20 minutes induced significant temperature increases in all groups ($p \leq 0.05$). The subjects reported no discomfort. When subjects without MR held gold or titanium crowns in their mouths, the thermal effect by shortwave diathermy was reduced. Resting saliva upon exposure only increased significantly in metal-free subjects, and amylase concentration was also increased, but the level of the salivary stress biomarker chromogranin A was unchanged. Furthermore, thermography showed that shortwave diathermy significantly increased the surface temperature for cheek skin and the buccal mucosa; however, this increase failed to elevate surface blood flow.

Conclusion: Shortwave diathermy induces temperature increases in the maxillofacial region. MR did not cause excessive heating, on the contrary, reduce the thermal effect of shortwave radiation. The temperature rise maintains upregulation in salivary function, which could be utilized safely in dental medicine.

Keywords: Shortwave diathermy, Metal restorations, Thermograph, Laser Doppler, Saliva secretion.

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INTRODUCTION

The goal of thermotherapy is to increase the body temperature, resulting in increased metabolism, activation of the sympathetic or parasympathetic nervous system, pain relief, dilation of blood vessels and other effects. Hot packing and infrared irradiation are commonly used in thermotherapy; these treatments very effectively increase the surface temperature, but are less effective in terms of deeper body temperature increases.[1] On the other hand, the thermal effect of shortwave diathermy can reach deep into the body and directly increase the body temperature in 1 minute;[2-4] shortwave diathermy is commonly used, and has been reported to be effective in increasing blood flow and pain relief.[1,5,6] In particular, shortwave diathermy is used for middle ear infections and tonsil inflammation in otolaryngology to relieve pain and induce anti-inflammatory effects. It is also effective in joint pain, neuralgia and muscle pain in orthopedics.[7-9] These physiological effects may be useful for problems in the maxillofacial region, such as healing of extraction sockets, oral inflammation, periodontitis, implantitis and temporomandibular joint disorders.

However, in general, use of shortwave diathermy on metal objects is contraindicated.[10] Therefore, studies of shortwave diathermy have been left far behind in dentistry, although no otolaryngological adverse effects have been reported near the oral cavity, where metal restorations (MR) are very common. In the present study, we examined the effects of shortwave diathermy in the oral cavity and compared the results between subjects with and without MR by monitoring oral temperature during shortwave diathermy and elucidating its functional effects.

MATERIALS AND METHODS

Subjects

This study was approved by the Ethical Committee of Kyushu Dental University (No. 09-33). Twenty young healthy subjects were recruited into this clinical study with written informed consent (14 men and 6 women, mean age: 27.9 years). The subjects were divided in two groups: 10 subjects with MR and 10 subjects without MR (metal-free, MF). MRs were all nonmagnetic, and made of gold alloys, platinum alloys, gold-silver-palladium alloys, cobalt chrome alloys, or dental amalgam alloys. Each subject had a single restoration up to 13 restorations.

Shortwave Exposure

Shortwave exposure was performed with a shortwave diathermy device (SW-201; Ito Co Ltd, Tokyo, Japan). Prior to the *in vivo* experiment, we confirmed the absence of overheating with condenser-type probes, even in the presence of metal. Condenser-type probes were set on both sides of the mandibular angle, and shortwave diathermy was then applied with a frequency of 27.12 MHz and power of 44 W for 20 minutes in accordance with the manufacturer's instructions. Shortwave exposure was first performed in MF subjects, who were then asked to put gold or titanium crowns in the oral vestibule during shortwave exposure, which was then applied to the MR subjects to ensure safety. Oral temperature was monitored every 1 minute with an alcohol thermometer placed beneath the tongue from the beginning of exposure until 5 minutes after completion of exposure (Fig. 1A).

Unstimulated saliva was also collected for 2 minutes[11] before exposure and immediately after completion of the temperature measurement. The volume of collected saliva was measured and stored at –86°C until analyzed. The amylase concentration was measured with a blood sample analyzer (Dri-Chem 7000; Fuji Film Medical, Tokyo, Japan). The level of chromogranin A, a stress biomarker, was measured with an ELISA kit (Yanaihara Institute, Shizuoka, Japan) and then standardized according to the protein concentration with a BCA Protein Assay Kit (Pierce, Rockford, IL).

Surface Temperature and Surface Blood Flow Analysis

Five subjects from both the MF and MR groups were selected at random, and their two-dimensional (2D) surface temperature and surface blood flow images were collected with a thermograph (G120; NEC Avio, Tokyo, Japan) and with a 2D Doppler flowmeter (OZ-1; Omegawave, Tokyo, Japan). Three points were set on the captured images, and the average values were used for further analysis.

Statistics

The paired t-test was used to compare the difference between before and after shortwave exposure. One-way analysis of variance (ANOVA) with Tukey's post hoc test was used for multiple comparisons between the experiments. In all analyses, $p < 0.05$ was taken to indicate statistical significance.

RESULTS

Temperature Changes in Response to Shortwave Diathermy

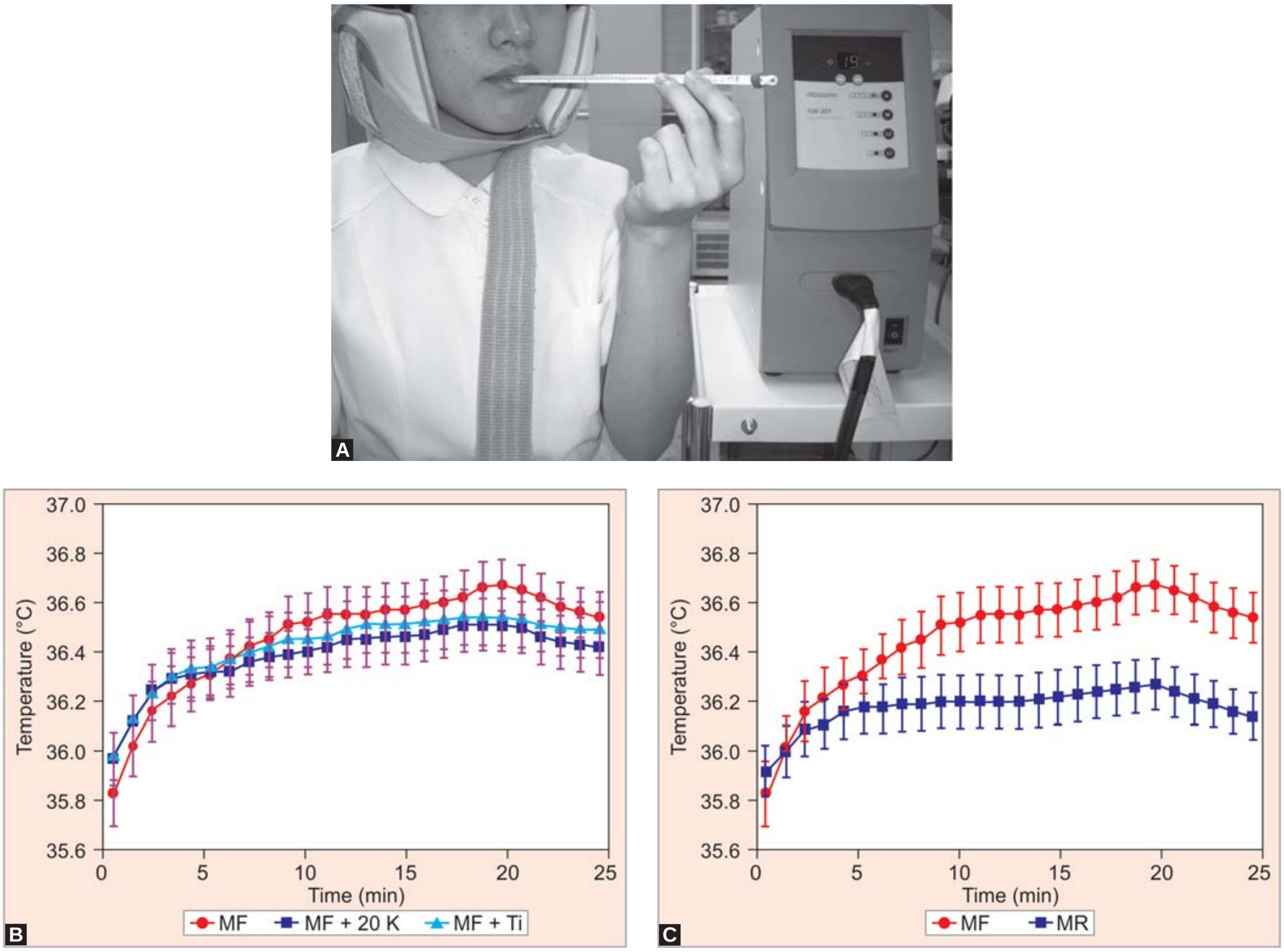
Increases in temperature were seen in most subjects after completion of 20 minutes of shortwave diathermy. The MF group showed an increase of 0.84 ± 0.07°C ($p < 0.001$, paired t-test) after completion of shortwave exposure. Subjects were then asked to hold metal crowns made of gold (MF+20K) or titanium (MF+Ti) in the oral vestibule, and shortwave diathermy was applied (Fig. 1A). The MF+20K group showed an increase of 0.54 ± 0.33°C ($p < 0.001$, paired t-test), whereas the MF+Ti group showed an increase of 0.56 ± 0.36°C increase ($p = 0.03$, paired t-test) (Fig. 1B). However, the differences among these three groups were not significant. The subjects reported no discomfort. We then applied shortwave diathermy to subjects with MR. Significant oral temperature increases were also seen after completion of exposure in the MR group (0.35 ± 0.07°C, $p = 0.03$, paired t-test). When compared with the MF group, the temperature increase in the MR group was significantly lower ($p < 0.001$, nonpaired t-test) (Fig. 1C).

Unstimulated Whole Saliva Collection

We observed temperature increases in response to shortwave diathermy, and then attempted to elucidate the functional up- or downregulation associated with this thermal effect. Unstimulated whole saliva volume was significantly increased for 2 minutes in the MF group (increased by 0.51 ± 0.50 ml, $p < 0.01$, paired t-test), but no significant effects were seen in the other groups (Fig. 2—left panels). In addition, the concentration of amylase in the secreted saliva was only significantly higher in MF subjects ($p = 0.02$, paired t-test); no changes were seen in the MF+20K ($p = 0.21$), MF+Ti ($p = 0.13$), or MR ($p = 0.97$) groups (Fig. 2, center panels). The amylase concentration was used as a stress biomarker in previous reports, and a higher concentration of amylase was reported to be secreted by the parotid gland compared with the two other major salivary glands. We measured the levels of the putative stress biomarker, chromogranin A, in secreted saliva, and the results indicated no changes between before and after exposure (Fig. 2—right panels). Furthermore, no changes were seen when the samples were compared among the oral restorations.

Surface Temperature and Blood Flow Upon Shortwave Exposure

We first observed an increase in oral floor temperature, but did not know the temperature distribution. We also hypothesized that the temperature increase may lead to an increase in blood flow. Therefore, we chose five subjects at random from both the MF and MR groups, and performed thermography and 2D Doppler flowmetry. Representative captured images are shown in Figure 3. The surface temperature was significantly increased for cheek skin (1.24 ± 0.56°C, $p = 0.04$), buccal mucosa (2.14 ± 0.25°C,



Figs 1A to C: The application of shortwave diathermy with condenser-type probes in maxillofacial regions and intraoral temperature changes during shortwave exposure. (A) Example of maxillofacial application of shortwave diathermy, (B) intraoral temperature change during shortwave exposure in subjects without metal restorations. Shortwave diathermy was applied for 20 minutes and the temperature was monitored until 5 minutes after completion of exposure. MF: Metal-free subjects; MF+20 K: Metal-free subjects with 20 karat gold crown in the oral vestibule and MF+Ti: Metal-free subjects with pure titanium crown in the oral vestibule. Significant temperature increases from baseline were seen in all subjects ($p < 0.05$, paired t-test). (C) Intraoral temperature change during shortwave exposure in subjects with metal restorations. MR: Subjects with metal restorations; MF: Metal-free subjects. Significant temperature increases from baseline were seen in both groups (before *vs* after exposure, $p < 0.05$, paired t-test). When groups were compared, MR was significantly lower than MF ($p < 0.05$, nonpaired t-test); n = 10 for all experiments

p = 0.005), and buccal gingiva around the first molar (1.38 ± 0.30°C, p = 0.04) for MF (Fig. 4, upper panels). MR showed significant increases in temperature in cheek skin (1.62 ± 0.24°C, p = 0.01) and buccal mucosa (0.76 ± 0.27°C, p = 0.02), but not in the gingiva (0.78 ± 0.44°C, p = 0.38) (Fig. 4, lower panels).

Then, we performed blood flow imaging, which revealed no changes in all areas measured (Fig. 5).

DISCUSSION

Thermotherapy devices can be classified into two groups from the viewpoint of heat transfer: The first is superficial heat transfer, such as hot packing, whirlpools, paraffin baths, and infrared heat, and the other is deep heat transfer, such as ultrasound, ultra shortwave and shortwave exposure.[1,12,13] Shortwave diathermy uses a radiation frequency of 27.12 MHz, which induces vibration of the molecules once it reaches the target, resulting in frictional heat. Shortwave diathermy can apply its thermal effect deeper than other physical stimulation therapy methods; it can penetrate through a depth of 3 to 5 cm[13] and increase the temperature by 4°C.[14] This temperature increase can induce extension of collagen fibers and inhibit the sympathetic nervous system.[15] In addition, it can improve the range of motion in joints, and it has been extensively used in orthopedic rehabilitation in Japan.[4,10,16-18]

The device used in the present study has two different probes: A dipole condenser type and monopole coil type. The condenser type probe is more effective when applied to a wide area, while the coil type probe is more suitable to warm deeper areas, and the skin surface and muscle temperatures can become higher than when using a

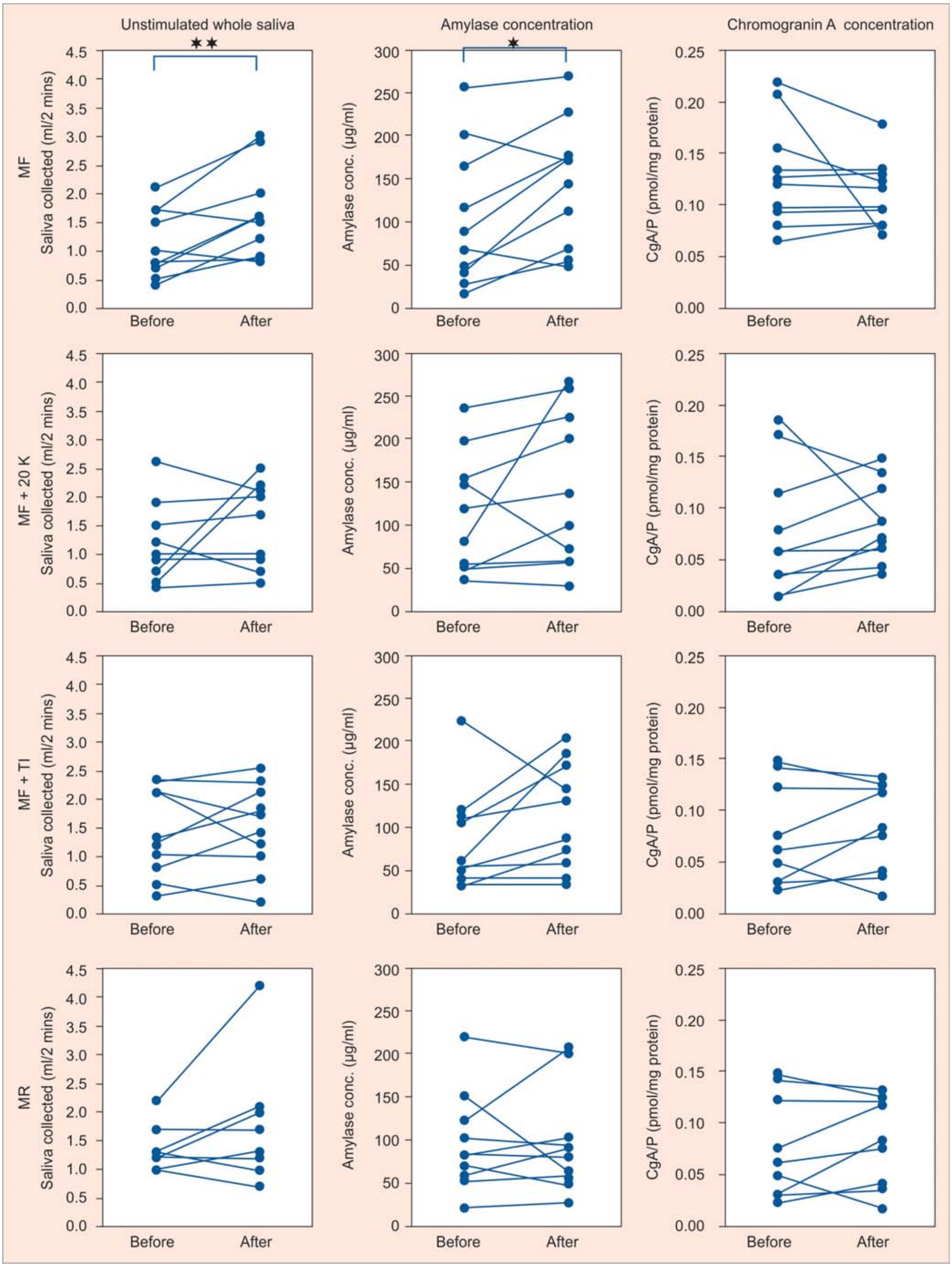


Fig. 2: Effects of shortwave diathermy on unstimulated whole saliva amount and amylase and chromogranin A concentrations. Unstimulated whole saliva was collected before and after completion of the temperature measurement. The first column shows saliva amount over a 2-minute collection period, and the second and third columns show levels of amylase and the stress biomarker, chromogranin A. *$p < 0.05$ and ***$p < 0.001$; t-test; n = 10 for all experiments

condenser-type probe.[19-21] We first used both probes in an *in vitro* experiment (exposure of an agar block made with physiological saline to shortwave diathermy), which revealed no overheating with the condenser-type probe even when metal crowns were placed in the agar, whereas extreme overheating (~80°C) was observed with a thermograph when shortwave diathermy was applied with the coil-type probe (data not shown). Therefore, we chose the condenser type probe for further measurements although it is cumbersome to place two probes in the maxillofacial region.

We found an increase in the amount of flow and amylase concentration in unstimulated whole saliva after shortwave exposure in MF subjects, but no changes were observed in the psychological stress marker chromogranin A. We hypothesized that the flow increase may have been induced by activation of the parasympathetic nervous system, which plays an important role in salivary fluid secretion. However, an increase in amylase was observed upon shortwave exposure, which is inconsistent with this suggestion because amylase is mainly secreted by exocytosis, which is in turn regulated mainly by the sympathetic nervous system. Amylase is also used as a psychological stress biomarker[22] along with chromogranin A[23] and cortisol.[24,25] The increase in amylase was not linked to the chromogranin A (Fig. 2) or cortisol concentrations (data not shown). In addition, if the amylase increase was due to activation of the sympathetic nervous system, the ion composition would have changed, but Na^+, Cl^-, and K^+ levels in secreted saliva were unchanged (data not shown). The above data suggested that the amylase increase was not due to sympathetic activation. The other possibility is a glandular-specific effect. The level of amylase secretion is much higher in parotid saliva than in submandibular and sublingual saliva.[26] To confirm the possible thermal effect on specific glands, we measured the surface temperature as shown in Figures 3 and 4. Comparison of the values between Figures 1 and 4

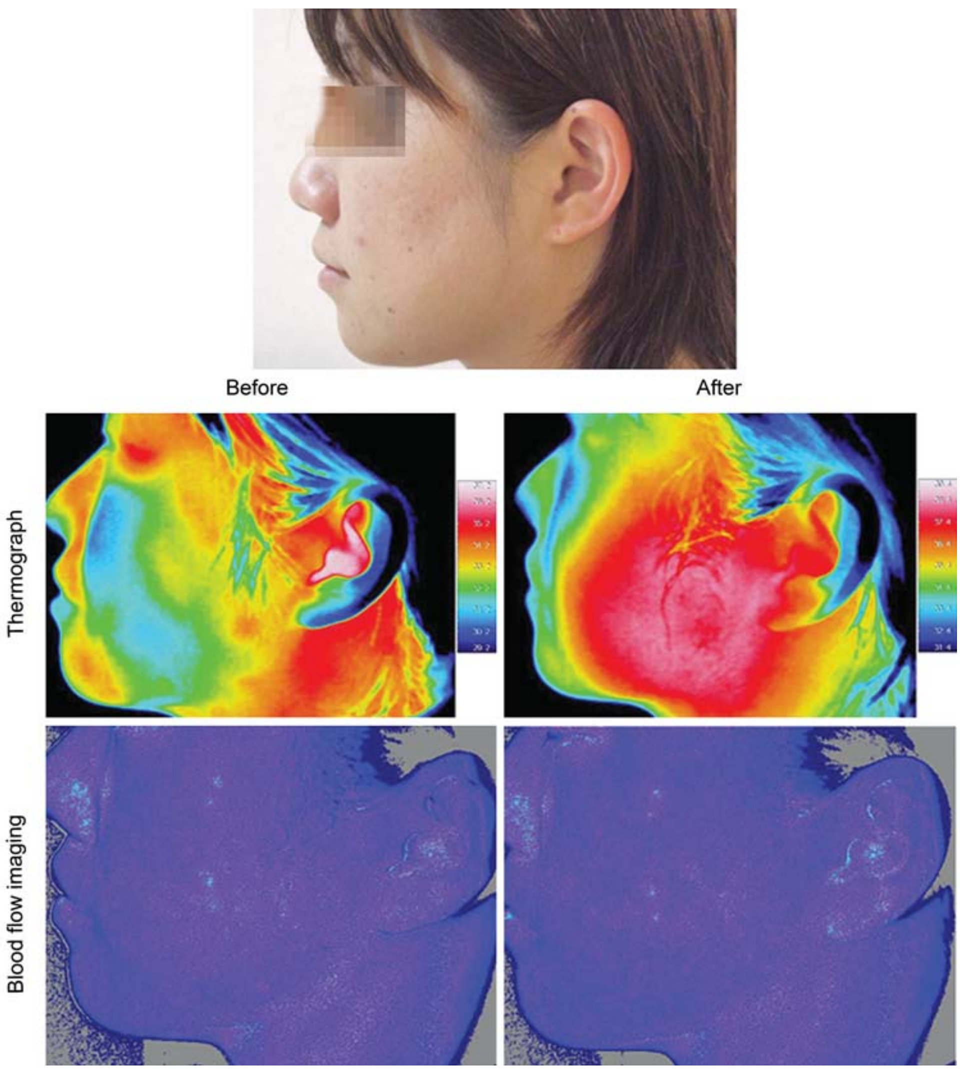


Fig. 3: Example of captured thermography and blood flow imaging before and after shortwave exposure. 2D images before and after shortwave exposure are shown. Captured images were superimposed with a digital camera image (top), and then ROIs were set at a position as similar as possible between images

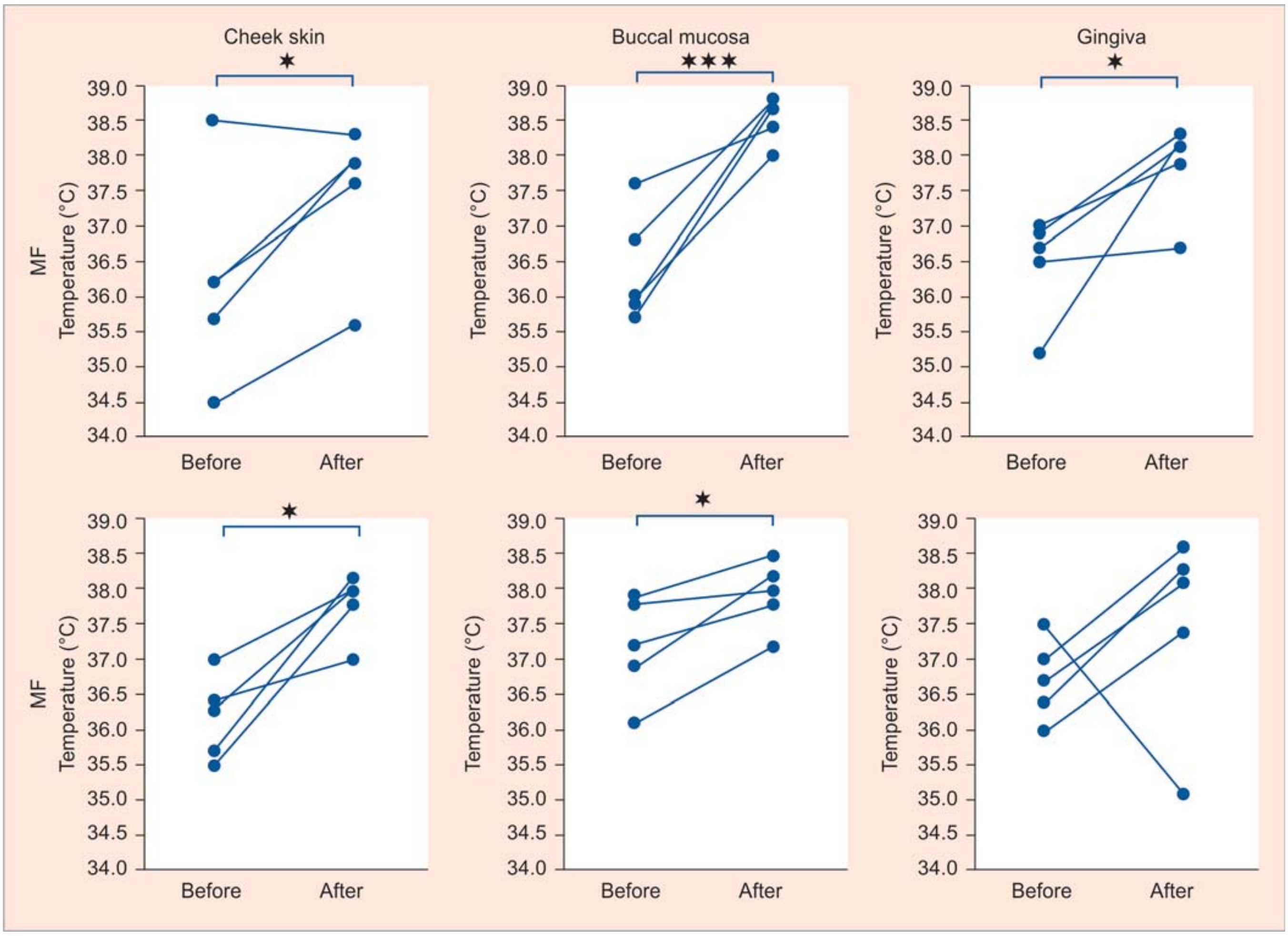


Fig. 4: Surface temperature in response to shortwave exposure. Captured thermographs (Fig. 3) were analyzed for cheek skin, buccal mucosa, and gingiva for MF and MR groups. Most of the area showed significant increases except MR-gingiva. *p < 0.05 and ***p < 0.001, t-test; n = 5 for all experiments

indicated that the surface temperature increase was much more evident in cheek skin. This also suggests that the thermal effect is much more potent in the parotid salivary gland than in the submandibular and sublingual glands. Further, we investigated the effects of shortwave exposure on the surface blood flow. The surface (~1 mm) blood flow did not change even where the surface temperature increase was more than 3°C (see Figs 4 and 5).

Exposure of intravital metal to shortwave diathermy is currently prohibited or not recommended. However, there have been no reports of accidents or injuries during its otolaryngological use adjacent to the oral cavity. There were also no accidents or injuries with use of condenser-type probes. In contrast, we showed that MR had a negative effect on shortwave diathermy-induced thermal effects. Therefore, further studies are required to characterize this negative effect to ensure the proper application of this method.

According to our results of this study, shortwave diathermy might also be effective for those with xerostomia.[27] As a matter of course, additional clinical studies should be needed prior to its clinical use for xerostomia because we only investigated the effects in young healthy subjects in the present study. In addition, shortwave diathermy could have the potential to treat oral and maxillofacial diseases, such as temporomandibular joint disorders, chronic periodontitis and taste disorders; therefore further well-organized clinical trials should be conducted to obtain the evidence.

CONCLUSION

The application of shortwave diathermy with condenser-type probes can significantly increase intraoral temperature with or without MR. The application of shortwave diathermy to MF subjects from bilateral mandibular angles effectively increases salivation.

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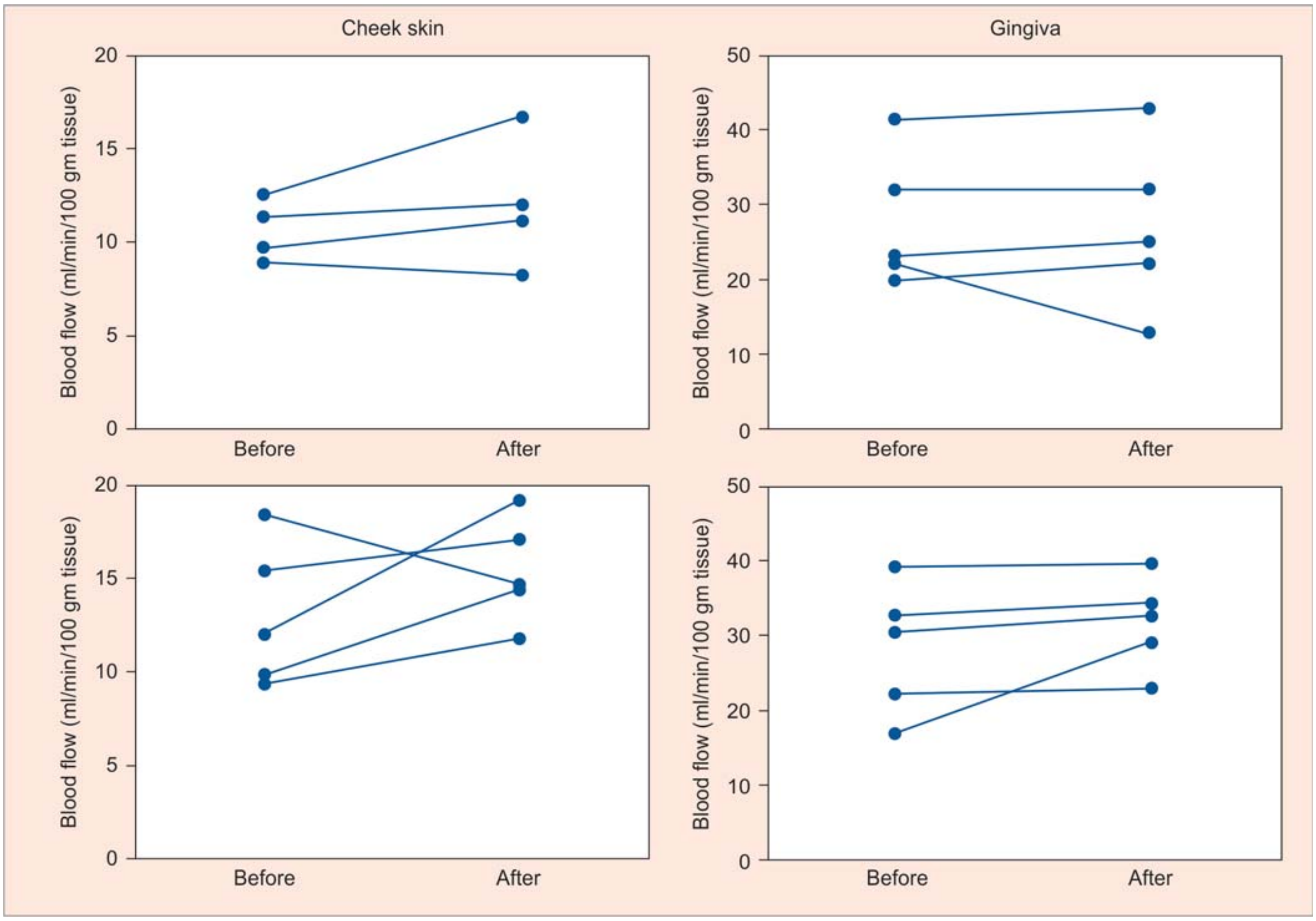

Fig. 5: Surface blood flow in response to shortwave exposure. Captured blood flow images (Fig. 3, lower panels) were analyzed for cheek skin and gingiva in MF and MR groups. No significant differences were detected; n = 5 for all experiments

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