Clinical significance
Low-level laser treatment for patients with chronic temporomandibular disorders reduces joint pain. This study evaluated the blood flow changes of a superficial temporal artery before and after low-level laser irradiation applied to the temporomandibular joint (TMJ) area of healthy subjects.

Abstract
Purpose: The aim of this study was to evaluate the blood flow changes of a superficial temporal artery before and after low-level laser irradiation was applied to the TMJ area of healthy subjects.
Methods: Right TMJ areas of six healthy subjects were irradiated with a CO₂ laser. Variation of diameter, blood flow rate, and blood flow volume of the vessel, on both the irradiated side and opposite side, before and after irradiation on the TMJ were evaluated by using a Doppler flowmeter.
Results: The diameter and blood flow volume of the vessel after irradiation increased significantly compared to that before irradiation.
Conclusion: Low-level laser irradiation applied to the right TMJ area caused an expansion of blood vessels and an increase in blood flow volume. The same result on the contralateral side may be caused by the vasodilator reflex via the hypothalamic thermostat.

Key words: blood flow, superficial temporal artery, low-level laser irradiation, temporomandibular joint

Introduction
With regard to the treatment effect on orofacial pain involving temporomandibular disorders (TMD), Bjordal et al. reported that low-level laser treatment (LLLT) with the suggested dose range significantly reduced pain and improved the health status in patients with chronic joint disorders. Pinheiro et al.² and Simunovic³ maintain that LLLT is an important tool that has brought many benefits in the treatment of many disorders of the maxillofacial region. Although it is not necessary to understand theory to establish benefit, lack of knowledge complicates the evaluation of clinical results. We evaluated the thermographic changes in facial temperature before and after low-level CO₂ laser irradiation on the temporomandibular joint (TMJ) area of healthy subjects, and found that facial temperature increased by irradiation not only on the irradiated area, but also on the whole face, including the contralateral side. This result suggested that the CO₂ laser was useful for LLLT as physiotherapy. The reason for the increase in whole facial temperature was thought to be that the increase in facial temperature and blood temperature in the stimulated region by continuous laser irradiation caused an expansion of blood vessels and an increase in blood flow volume, and this process was the mechanism that also caused the increase in facial temperature in the unstimulated region. In addition, the increase in facial temperature on the contralateral side may be caused by the vasodilator reflex via the central nervous system.⁴

The aim of the present study was to evaluate the blood flow changes of a superficial temporal artery (STA) before and after low-level laser irradiation applied to the TMJ area of healthy subjects to examine the above hypothesis.

Materials and Methods
Six healthy subjects (four male, two female; mean age 25.5±2.81 years) were enrolled in the study...
and were evaluated using a Doppler flowmeter. None had symptoms relating to TMD, inflammation, or pain in the orofacial region. They were post-graduate students and dentists at Kyushu Dental College Hospital. Informed consent was obtained from each participant. The experiment was obtained the ethic committee of Kyushu Dental College. They understood the purpose of this study and agreed to participate in the experiment.

All subjects underwent low-level laser irradiation over the right TMJ area with a CO₂ laser (Ople laser 03, Yoshi Co. Ltd, Tokyo, Japan) for 10 minutes with a continuous wave setting and a power output of 1.0 W. The laser tip was positioned 10 cm above the skin and moved in an elliptical pattern over the right TMJ. The actual fluence on the facial surface was 7.64 J/cm². All subjects were kept in the supine position during this experiment.

A Doppler flowmeter (Ultra sound equipment model SSA-370A, Toshiba, Tokyo, Japan) was used to measure the change in diameter and blood flow rate of the vessel. The probe type of this equipment was PLM-703AT and the central frequency was 7.5 MHz. This equipment was used to evaluate the change in diameter, blood flow rate, and blood flow volume of STA located about 10 mm above the superior border of the zygomatic-orbital arch, before the zygomatic-orbital artery branches off. All subjects were marked with a measuring point on their skin using a felt-tip pen to measure the same point at all times. The diameter and the blood flow rate of STA of each subject were measured on the irradiated side and the opposite side before irradiation and 10 minutes after stopping irradiation. The diameter and the blood flow rate were measured automatically. The variation of blood flow volume was calculated according to the following formulas:

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\text{Blood flow volume (ml/s)} = \text{(diameter/2)}^2 \times \text{blood flow rate.}
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The laboratory where this experiment was performed had a constant room temperature of 25°C. Statistical analysis was performed with regard to the change in the diameter, the blood flow rate, and the blood flow volume of STA before and after irradiation using a paired t-test.

Results

The diameter changes in STA on the irradiated side are shown in Fig. 1. The mean diameter of the STA in the six subjects was 1.45 ± 0.50 mm before irradiation and 2.33 ± 0.59 mm, 10 minutes after stopping irradiation. The diameter 10 minutes after stopping irradiation increased significantly compared to that before irradiation (\(p < 0.01\)). The changes in blood flow rate on the irradiated side are shown in Fig. 2. The average blood flow rate of the six subjects was 33.5 ± 12.36 cm/s before irradiation and 30.0 ± 9.21 cm/s, 10 minutes after stopping irradiation. A significant difference was not found between before and 10 minutes after stopping irradiation (\(p = 0.5080\)). The changes in blood flow volume on the irradiated side are shown in Fig. 3. The average blood flow volume of the six subjects was 0.71 ± 0.80 ml/s before irradiation and 1.46 ± 1.00 ml/s, 10 minutes after stopping irradiation. The blood flow volume 10 minutes after stopping irradiation increased significantly compared to that before irradiation (\(p < 0.05\)).

The diameter changes in STA on the opposite side are shown in Fig. 4. The mean diameter in the six subjects was 1.82 ± 0.57 mm before irradiation and 2.50 ± 0.72 mm, 10 minutes after stopping irradiation. The diameter 10 minutes after stopping irradiation increased significantly compared to that before irradiation (\(p < 0.05\)).
Blood Flow Changes of LLL Irradiation

The changes in blood flow rate on the opposite side are shown in Fig. 5. The mean blood flow rate in the six subjects was 26.1 ± 8.18 cm/s before irradiation and 34.78 ± 9.05 cm/s, 10 minutes after stopping irradiation. A significant difference was not found between before and 10 minutes after stopping irradiation (p = 0.1246). The changes in blood flow volume on the opposite side are shown in Fig. 6. The mean blood flow volume in the six subjects was 0.73 ± 0.41 ml/s before irradiation and 1.81 ± 1.18 ml/s, 10 minutes after stopping irradiation. The blood flow volume 10 minutes after stopping irradiation increased significantly compared to that before irradiation (p < 0.05).

Discussion

Generally, near-infrared sources in the 810–905 nm range have been used for LLLT and physiotherapy-type treatment strategies. As the wavelength of the CO₂ laser is 10.6 μm, it may be better to use it as HLLT. However, the CO₂ laser has been used by many general practitioners in Japan and is used not only for HLLT, but also for LLLT.

Therefore, we decided to apply the CO₂ laser as an LLLT device.⁴

An STA is one of the end branches of an external carotid artery and runs along the lateral side of a TMJ. This vessel was thought to be the most affected vessel when the laser irradiated the TMJ area. Furthermore, an STA that runs along the lateral side of osseous tissue is suitable for measuring blood vessels with a Doppler flowmeter because the rate of absorption of ultrasonic wave energy is the highest in tissue of high density such as osseous tissue. For these reasons, we chose this vessel in this study. As it was difficult to measure blood flow volume directly, it was calculated from the diameter of the blood vessel and blood flow rate.

In this study, the diameter and blood flow volume of STA on the irradiated side 10 minutes after stopping irradiation increased significantly compared to that before irradiation (p < 0.05).
Continuous laser irradiation caused an expansion of blood vessels and an increase in blood flow volume, and this process was the mechanism that also caused the increase in facial temperature in the unstimulated region.

In addition, the diameter and blood flow volume of STA on the irradiated side 10 minutes after stopping irradiation also increased significantly compared to that before irradiation. Nicotra et al⁶ also reported that local heating evokes an increase in skin blood flow. Minson et al⁷ suggested that the initial rise in skin blood flow is a neurogenic phase mediated by axon reflexes, and the secondary rise is mediated by local production of endothelial nitric oxide.

Furthermore, the diameter and blood flow volume of STA on the opposite side 10 minutes after stopping irradiation also increased significantly compared to that before irradiation. The body keeps its core temperature constant at about 37°C by physiological adjustments controlled by the hypothalamus (thermostat center) where there are neurons sensitive to changes in skin and blood temperatures. The temperature-regulating centers are found in the preoptic area (the anterior portion of the hypothalamus). This area receives input from temperature receptors in the skin and mucous membranes (peripheral thermoreceptors) and from internal structures (central thermoreceptors), which include the hypothalamus itself. The temperature sensory signals from the preoptic area and those from the periphery are combined in the posterior hypothalamus to control the heat-producing and conserving reactions of the body. The hypothalamic thermostat works in conjunction with other hypothalamic, autonomic, and higher nervous thermoregulatory centers to keep the core temperature constant. When the body is exposed to heat, body temperature rises. Skin warmth receptors and blood convey these changes to the hypothalamic thermostat. The thermostat inhibits the adrenergic activity of the sympathetic nervous system, which controls vasoconstriction and the metabolic rate, thus causing cutaneous vasodilation and reducing the basal metabolic rate.⁸⁻¹⁰ For example, the warming of one side of a lower limb causes improvement in the circulation of the opposite side and of the same-side upper limb. This phenomenon is called the vasodilator reflex.⁶,⁷ Therefore, the same mechanism as that mentioned above may cause the phenomenon of the expansion of the diameter and the increase in the blood flow volume on the contralateral side. To examine this hypothesis we will evaluate the change in activity of the hypothalamus using a functional MRI.

Conclusion

The diameter and blood flow volume of STA 10 minutes after stopping irradiation increased significantly compared to that before irradiation. In addition, the diameter and blood flow volume of STA on the contralateral side 10 minutes after stopping irradiation also increased significantly compared to that before irradiation.

References