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Application of Thermography in Dentistry —Visualization of Temperature Distribution on Oral Tissues—

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The purpose of this study was to devise and propose appropriate conditions for the photographing of thermal images in the oral cavity and to evaluate which thermography techniques can be applied to dentistry by evaluating the differences in temperature among oral tissues.

Thermal images of oral cavities of 20 volunteers in normal oral condition were taken according to the guidelines of the Japanese Society of Thermography, with five added items for oral observation.

The use of a mirror made it possible to take thermal images of the posterior portion or palate. Teeth, free gingiva, attached gingiva and alveolar mucosa were identified on thermal images. There were differences in temperature between teeth, free gingiva, attached gingiva and alveolar mucosa. These were nearly in agreement with the anatomical view. Thermography need no longer be restricted to the anterior portion using a mirror, and can now be applied to the dental region.

Key words: Thermography, Dentistry, Diagnosis

INTRODUCTION

Measurement of the body temperature is a most basic and important feature of the diagnostic technique, applied when one feels that something is wrong with one's body. The surface temperature of the inflamed area changes when redness, swelling or pyrexia are generated, not only in the whole body but also locally. Visualization by thermography basically reflects the temperature distribution of the body.

The principle of thermography[1)] is as follows: since any object which is higher than the absolute temperature −273℃ emits infrared rays in proportion due to vibrations and rotations of the atoms or molecules which constitute the object, it is possible to measure the temperature of the object by measuring the infrared output.

Thermography is not invasive to the human body, as opposed to x-rays or γ-

rays, and is a non-contact technique through which the temperature distribution of the human body surface can be monitored and recorded. Thermography was introduced in 1968 as a method of diagnostic examination in the medical field[2]. Thermographic inspection for the diagnosis of diseases such as localized inflammation, dermatitis, hematogenous disorder, sensory nerve failure including facial nerve paralysis is already permitted as an inspection for medical treatment in Japan. Thermography is also useful in the management of diseases.

Crandell and Hill[3] were one of the first to publish their findings of infrared thermography and its application in dentistry. They evaluated an incisor with a periapical abscess of the facial surface with the mouth closed. They assumed thermography would become very important in diagnostics, for example in the determination of teeth vitality, although their attempt at an open-mouth thermogram was not successful. Since then, there has been interest in the application of thermographic methods to the study of oral lesions[4-11]. In Japan, many studies regarding the application of thermography to the maxillofacial region have been investigated by Nagasawa *et al.*[12-19] since 1967. However, thermography has not clinically been used in dentistry yet. This is mainly due to high equipment costs, lack of sensitivity and slow image processing. In those studies, thermography was confined to the anterior portion. There are few reports concerning the posterior portion. This might be one of the reasons why thermography has not clinically been used in dentistry yet. Recently, through technical developments and image processing applications, modern thermography equipment is sufficiently sensitive to record changes of 0.1℃, and with dedicated image processing software allows for highly flexible usage in the field of thermology.

The purpose of this study was to apply thermography in the intraoral region, especially in the posterior portion, and to devise and propose appropriate conditions for the photographing of thermal images in the oral cavity which is complicated by lack of space and wetness due to saliva. In this study, thermal images were taken from the maxillary and mandibular portions of not only the anterior teeth but also the posterior teeth of many subjects. This is a report on a preliminary study of the possible use of this method in dentistry.

MATERIALS AND METHODS

This study was approved by the ethical committee of the Tsurumi University School of Dental Medicine. Twenty healthy human subjects, aged 23 to 30, were selected from among the 6th year-dental students, interns and staff in the dental Hospital of Tsurumi University. The procedure was explained to the volunteers and written consent was sought and obtained.

Thermal images were produced by an infrared thermo camera (Neo Thermo TVS-700, Nippon Avionics Co. Ltd., Tokyo, Japan), which detects temperature differences as low as 0.08℃, and analyzed using an imaging system (PE Professional, Nippon Avionics Co. Ltd., Tokyo, Japan). The temperature can be indicated to one pixel.

One pixel was $50\times50\,\mu m^2$ in this study. All subjects underwent the same thermographic protocol.

Since there was no standard for photographing in the oral cavity, five items were added to the guideline of the Japanese Society of Thermology[20]. The first seven items below are the preexisting guideline, and the last five are our additions.

1) Keep the testing room free of wind. Turn off air conditioners.
2) Keep sources emitting high-temperature infrared away from the subject. Place a screen between any heater and the subject.
3) Keep control room temperature at over 25℃. Record room temperature and humidity when taking each thermal image.
4) Stabilize the environment for at least 20 min before examination in the winter.
5) Instruct the subject to refrain from smoking for at least 4 hr before thermographic examination.
6) Note the following items as subject-related information in the medical record. Name, Sex, Age, Chief complaint, History of tobacco use, History of alcohol consumption, Handedness, Painful position, Abnormal position, Region of cold sensitivity, Past medical history, Present clinical history, Presence of medical treatment and detail of medical treatment, Diagnostic entity, Body temperature, Time when the thermal image is taken, Room temperature, Room humidity, Wall temperature
7) Check the first thermal image again at the end of the sequence to confirm the reproducibility of images and changes over time.
8) Judge the inter-oral condition and perform periodontal inspection.
9) Hold the frontal region and chin of the subject and set a thermo camera at a consistent distance from the subject.
10) Instruct the subject to remain seated during image acquisition.
11) Inform the subject to keep water in their mouth for 5 sec before image acquisition.
12) Instruct the subject on edge-to-edge occlusion and on the prohibition of mouth respiration during image acquisition.

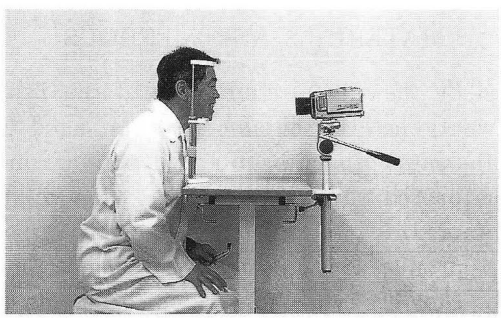

Fig. 1 Individual positioned in front of the thermography camera.

Oral photographs and thermal images were taken using a positioning apparatus as shown in Fig. 1. The subject was seated with the chin resting on a positioning apparatus. The area of interest was isolated to a focal length of 0.28 m. The body temperatures of subjects were measured at their external acoustic meatus using an ear thermometer (Baby's Digital Ear Thermometer C10, Pigeon Corporation, Tokyo, Japan). Oral photographs and thermal images of the anterior portion were taken directly from the front, while those of the posterior portion were taken from the side directly and indirectly, *i. e.* using a dental mirror for photographing in the oral cavity with the usual technique.

RESULTS

Fig. 2 is an oral photograph of one of the subjects who had good alignment and no dental treatment in the anterior portion. His periodontal pocket is 2.0 mm in depth. Free gingiva, attached gingiva and alveolar mucosa are identified in Fig. 2. His body temperature at the time of imaging was 36.4℃.

Fig. 2 Oral photograph of the anterior portion of one of the subjects.

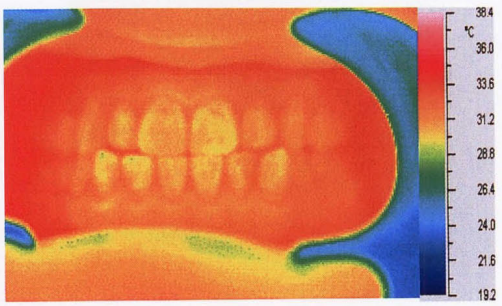

Fig. 3 Thermography corresponding to the oral photograph in Fig. 2.

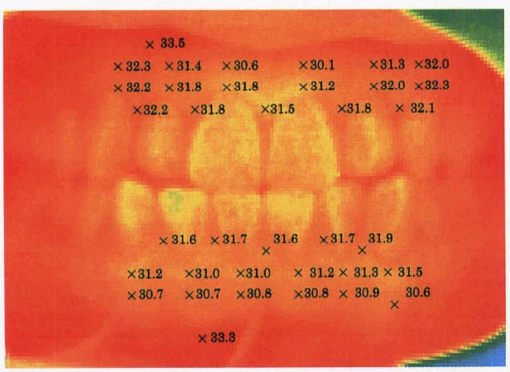

Fig. 4 Magnification of Fig. 3.
The cross marks indicate the temperature measured at those points.

Table Average surface temperature at each anatomical division

Maxilla	AM	32.1(1.5)										
	AG	30.2(1.8)		29.4(1.9)		29.2(2.0)		29.3(2.1)		29.6(2.0)		30.5(1.9)
	FG & IP	30.1(1.8)	29.8(1.8)	29.7(1.9)	29.5(1.8)	29.6(2.0)	29.5(1.7)	29.6(2.0)	29.5(2.0)	29.9(2.1)	30.0(2.0)	30.5(2.1)
		FG	IP	FG	IP	FG	IP	FG	IP	FG	IP	FG
Dental formula		3		2		1		1		2		3
Mandibula	FG & IP	FG	IP	FG	IP	FG	IP	FG	IP	FG	IP	FG
		30.1(1.9)	29.8(1.9)	29.7(1.9)	29.8(1.9)	29.7(2.0)	29.7(1.8)	29.7(2.0)	29.7(1.9)	29.9(1.9)	30.0(1.8)	30.2(1.8)
	AG	30.1(2.2)		29.7(2.2)		29.8(2.2)		29.7(2.1)		29.8(1.9)		30.0(1.8)
	AM	32.2(1.6)										

AM: alveolar mucosa
AG: attached gingiva
FG: free gingiva
IP: interdental papilla

Fig. 5 Oral photograph of the posterior portion taken using a dental mirror.

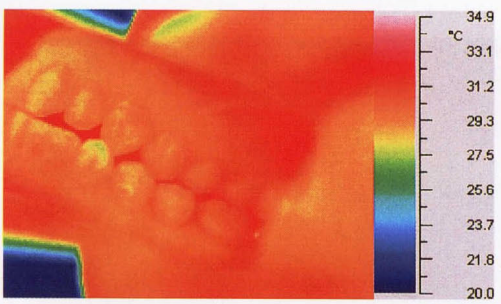

Fig. 6 Thermography corresponding to the oral photograph in Fig. 5.

The thermograph corresponding to the oral photograph in Fig. 2 is shown in Fig. 3. The color-coded gradations (dark blue to pale red) on the scale represent temperatures between 19.2℃ to 38.4℃, encompassing the range recorded in this study. In the thermal images, free gingiva, attached gingiva, and alveolar mucosa can be distinguished clearly. It was apparent that the surface temperatures of each portion were different. The numbers in Fig. 4 indicate the temperatures of free gingiva, attached gingiva and alveolar mucosa.

The average temperatures of free gingiva, attached gingiva, interdental papilla and alveolar mucosa among the subjects are shown in Table. The average body temperature of the twenty subjects was 36.1℃. The average of their alveolar mucosa was 32.2℃, the highest among the portions examined. The temperatures of free gingiva and interdental papillae were higher than that of attached gingiva.

An oral photograph and thermal image of the posterior portion are shown in Figs. 5 and 6, respectively. The color-coded gradations (dark blue to pale red) on the

scale represent temperatures between 20.0℃ to 34.9℃. The free gingiva, attached gingiva, and alveolar mucosa around the second molar could be distinguished clearly in the thermal images, although an image of the third molar could not be taken.

DISCUSSION

There exists a guideline of the Japanese Society of Thermography for measuring body surface temperature in the medical field. However, oral conditions are wet and the oral structure is very complex, making a guideline for oral photographing necessary. Five new items are thus proposed from our experiences.

Thermal images depend on number of functions, not least of which is the ambient environment, in which the evaluated temperature is the relative temperature. Thermal images are thus affected by the atmosphere around the subject. Since infrared radiation behaves according to the inverse square law, moving the object toward the thermovision camera increases the intensity beyond the subject. In this study, the distance from the camera to the subject was a constant 0.28 m. Thermography depicts the relative temperatures of different areas. Therefore thermal images should not be confined to a local portion and should be taken extensively, preferably at the same time as right-versus-left images.

Moisture on the tissue surfaces at times interfered with the picture because of both infrared absorption and limited cooling effects. However, it was obvious that they dried fast enough to make this a small problem[7]. The findings of this study are consistent with this opinion. In this study, thermal images were taken after subjects had kept water in their mouths for 5 sec.

Image quality might also depend on the surface substance and its smoothness among other factors, but it seemed in this study that such influences were small.

The temperatures of free gingiva and interdental papilla were higher than that of attached gingiva. The difference in surface temperature between attached gingiva and free gingiva agreed with the results of Barnett *et al.*[11]. Body temperature is related to the oxygen consumption of an organism. The diameter of the arteries which nurture the gingiva is smaller than that of alveolar mucosa, and the arterial rete formatted in gingiva is small. The temperature of free gingiva might thus be expected to be lower than that of alveolar mucosa since there is less blood flow in the gingiva. On the other hand, it is thought that the temperatures of free gingiva and interdental papilla are higher than that of attached gingiva because the immunological reactions in the gingiva sulcus are strong, so the capillaries in free gingiva and interdental papilla are better spread than those in attached gingiva, and the blood flow joins at the free gingiva and interdental papilla from the oral cavity proper and periodontal membrane which have a high temperature.

Most dental studies regarding thermography have investigated only the anterior portion, with few studies considering the posterior portion. The use of a mirror may enable thermal imaging of the posterior portion using an ordinary technique for taking images of the oral cavity. It is also possible to compare the temperatures at

each portion in a thermal image since thermography determines the relative temperatures of different areas.

The system used here can detect temperature differences as little as 0.08℃, which is considerably less than the differences often associated with cancer (>1℃), graft necrosis (up to 8℃) and burn conditions (2℃) in the medical field[4-6]. In the dental field, periodontal diseases such as gingivitis, periodontitis can cause a temperature rise in the tissue around the gingiva. Thermography is a potentially useful addition to the diagnostic technique which may be used for screening patients for endodontic diseases in the intraoral region. The authors reported that thermography can also be useful in testing for pulp vitality[21].

CONCLUSION

This is a report on a preliminary study of possible uses of thermography in dentistry. Thermography is a potentially useful addition to the diagnostic technique used for screening patients for endodontic diseases in the intraoral region.

Thermography need no longer be restricted to the anterior potion, since the use of a mirror made it possible to take thermal images of the posterior portion. These findings suggest that infrared thermography may have numerous applications in dental research. Thermographic examination will help the clinician identify areas of adequate blood supply and locate surgical margins within them.

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