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박사학위논문

Thermographic Assessment of Inferior Alveolar Nerve Injury in Patients with Dentofacial Deformity

조 선 대 학 교 대 학 원

치 의 학 과

이　준　길

Thermographic Assessment of Inferior Alveolar Nerve Injury in Patients with Dentofacial Deformity

체열 촬영을 이용한 악교정 수술 환자의 하치조 신경 손상의 평가

2005년 2 월 일

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Thermographic Assessment of Inferior Alveolar Nerve Injury in Patients with Dentofacial Deformity

지도교수 김 수 관

이 논문을 치의학 박사학위신청 논문으로 제출함.

2005년 2 월 일

조 선 대 학 교 대 학 원

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이 준 길

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2004년 12월 일

조선대학교 대학원

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국문초록

체열 촬영을 이용한 악교정 수술 환자의 하치조 신경 손상의 평가

이 준길
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구강악안면외과학 전공

본 연구의 목적은 악교정 수술을 시행한 환자에서 술전, 술후 1주, 술후 4주에 체열 촬영을 시행하여 하치조 신경의 손상과 회복을 평가하는 데 있다.

체열 촬영은 안면부에서 정면 1장, 측면에 좌,우측 각각 1장씩 촬영하였다. 수술 후 1주와 4주에 역시 정면 1장, 측면에 좌,우 각각 1장씩 촬영하였다. 정상군은 수술후 편측이나 양측의 신경 손상을 보인 20명 환자의 수술전 온도를 의미한다.

체열 촬영 후 좌,우측 온도차가 0.3℃를 초과한 경우를 하치조 신경이 손상을 받은 경우로 정의하였다.

통계는 반복측정 분석법으로 시행되었으며, 편측 신경손상 환자에서 정면 사진에서 통계적으로 유의할만한 결과를 나타냈다.

본 연구를 바탕으로 적외선 체열 촬영이 하치조 신경의 손상을 받은 경우 진단할 수 있는 보조적인 진단방법으로 사용할 수 있으며, 이의 객관적인 지표로 적외선 체열 촬영이 사용될 수 있다.

Introduction

Neurosensory deficit is one of the major complications encountered in oral and maxillofacial surgery, and the inferior alveolar nerve (IAN) can be injured in a variety of common oral surgical procedures[1)]. The incidence of IAN dysfunction ranges from 3% after surgical removal of impacted molars to 74% after sagittal osteotomy of the mandible[2-7)]. Permanent decreases in sensory perception are sufficiently distressing to cause a high percentage of these patients (43 to 71%) to contemplate corrective nerve surgery[8)].

Currently, there are few clinical tests for trigeminal nerve function that are objective yet noninvasive and convenient to administer. Conventional neurosensory tests used to define the degree of sensory loss include von Frey's test for tactile discrimination, the Weber two-point discrimination test, and thermal discrimination tests. However, these qualitative tests have low inter-rater reliability in as much as they are sensitive to differences in the examiner's expertise and to the subjective responses of the patient[1)]. If the neurosensory evaluation is based solely on a patient's assessment of symptoms, it is even more difficult to determine whether an expressed complaint of IAN dysfunction is the result of organic nerve damage, psychogenic factors, or even malingering. Coghlan and Irvine underscored this lack of objectivity in a study in which 74% of patients reported normal sensation after sagittal osteotomy, whereas standard neurosensory tests demonstrated normal sensation in only 34% of patients[3)]. This variability and difficulty in assessing the degree of nerve recovery has significant therapeutic implications.

It is difficult to demonstrate the efficacy of a surgical exploration conclusively, or which type of repair to perform, owing to the current lack of a sound scientific basis. A possible solution to these problems involves the development of a protocol for a more objective assessment of IAN injury, including not only current neurosensory tests but also quantitative imaging studies[2)].

Thermography is a generic term describing various methods of identifying and analyzing the skin temperature distribution. Thermography is based on the ability to image heat emissions from the human body. A variety of temperature measurement devices, including thermistors, thermocouples, liquid crystal thermal imaging systems, and infrared detection systems, have been used to measure the amount of heat given off by blood flowing within and beneath the skin. As the circulation within and beneath the skin layers varies, so does the skin temperature. Different disorders affect this blood flow and result in abnormalities in the skin temperature distribution. These thermal abnormalities carry diagnostic information. Conventional medical thermography surveys the body surface and a superficial layer a few mm in depth and can map and record the temperature distribution[9)].

The value of clinical thermography is based on its ability to picture, record, and facilitate the analysis of the body's vascular heat emissions. Electronic thermography (ET) systems are used to image symmetrical thermal patterns in normal subjects and asymmetrical thermal patterns in patients with a variety of physical disorders, including motor and sensory radiculopathies[10)].

With respect to neurosensory deficits, ET has been evaluated in a limited fashion as an alternative technique for recording the normal and pathologic status of nerves with a cutaneous distribution. The rationale is based on the fact that the sympathetic distribution closely parallels the somatic sensory distribution of nerves. Skin temperature, which is a function of sympathetic (not somatic) vasomotor control, reflects disturbances in peripheral nerve function. The loss of sensory tone causes a concomitant loss of sympathetic activity, resulting in vasodilation of the cutaneous blood vessels. In the acute stage of peripheral nerve injury, the affected area loses more heat as a result of vasodilation. As the nerve regenerates (or denervation sensitivity develops), the affected area may lose less heat. Given that these alterations in the skin temperature are an expression of sympathetic vasomotor disturbances resulting from interrupted conduction in primary afferent neurons, the change in heat production recorded on a thermogram can provide insight into the type of nerve injury[10,11)]. Therefore, ET, in conjunction with recent advances in computer image analysis, allows imaging and anatomic mapping of areas with vasomotor changes believed to result from neuropathy of the IAN[12,13)].

The purpose of this study was to evaluate the injury and recovery of the inferior alveolar nerve in orthognathic patients at one and four weeks after surgery using ET.

Materials and Methods

Study populations

This study was approved by IRB Committee of Chosun University. Twenty subjects with class III dentofacial deformity were studied; all completed a medical history questionnaire. For the study, a negative health history (defined as good health without history of facial pain, trauma, skin problems, or blemishes) and a negative clinical examination established normal IAN status. The subjects were not followed clinically over time, nor did we conduct further tests to support our "normal"assessment. All patients underwent bilateral sagittal split ramus osteotomy (BSSRO).

Thermography equipment

The photographic equipment was an IRIS 2000 (Medi-core, Seoul, Korea), which has a sensitivity of 0.5°C and an accuracy of 0.1°C.

Facial (chin) imaging

All subjects were instructed before the thermographic examination. Before the examination, each patient's face was cleared of hair (the hair was tied back), wiped with a damp cloth, and then air-dried with a small electric fan. A 15-min period was allowed for facial temperature equilibration, and then a series of facial thermograms was obtained and stored on computer disk for analysis.

To image the temperature of the face, one anteroposterior view and one lateral view were taken from both the right and left sides. Similar images were taken at 1 and 4 weeks after surgery. The control was the presurgical temperature of the 20 patients who showed unilateral or bilateral nerve damage after surgery.

In this study, a temperature difference exceeding 0.3°C between the right and left sides was considered abnormal.

Statistical analysis

Data analysis included calculating mean values and standard deviations (SD) and using repeated measures analysis, with significance accepted at the $p < 0.05$ level. Reliability measures were calculated as interclass correct correlations (r) at the 95% confidence interval.

Results

Fourteen of the 20 patients had symptoms of unilateral inferior aveolar nerve damage after surgery, and the remaining six patients had bilateral damage.

Before surgery, the temperature differences between the mentum areas on the two sides of the patients (n = 20) were 0.02°C on the anteroposterior views and 0.08°C on the lateral views (Figs. 1-3).

In the patients with unilateral nerve damage (n = 14), on the anteroposterior views, the temperatures of the mentum on the two sides differed by 0.64°C at 1 week after surgery, and the difference decreased to 0.23°C at 4 weeks after surgery. On the lateral images, the differences in temperature between the mentum areas were 0.10°C at 1 week and 0.27°C at 4 weeks after surgery (Figs. 4-9).

In the patients with bilateral nerve injury (n = 6), on the anteroposterior views, the temperatures of the mentum on the two sides differed by 0.20°C at 1 week after surgery and 0.13°C after 4 weeks. On the lateral views, the differences were 0.18°C at 1 week and 0.34°C at 4 weeks after surgery (Figs. 10-15).

Using the repeated measurement analysis method, the anteroposterior view showed statistically significant results in the patients with unilateral nerve damage ($p<0.05$, Tables 1, 2).

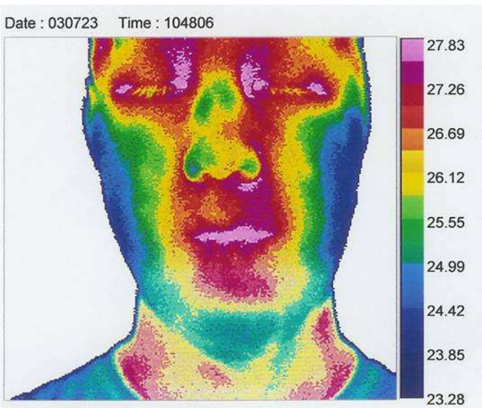


Fig. 1. Preoperative anteroposterior view

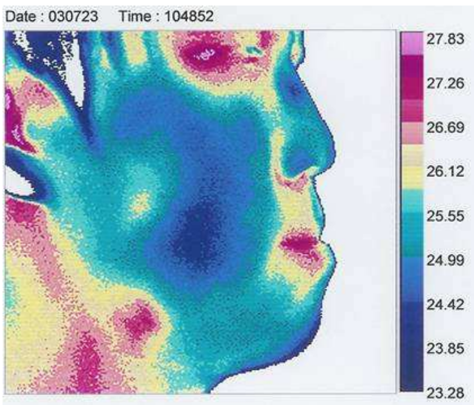


Fig. 2. Preoperative right lateral view

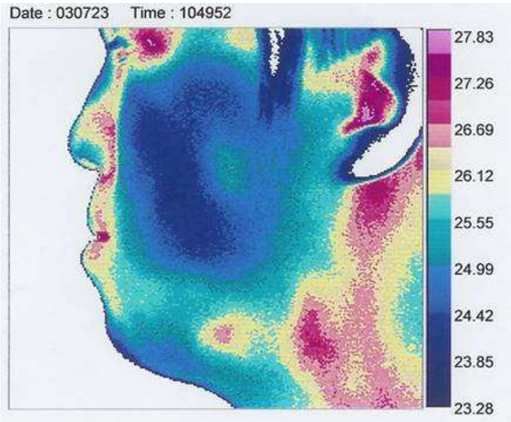


Fig. 3. Preoperative left lateral view

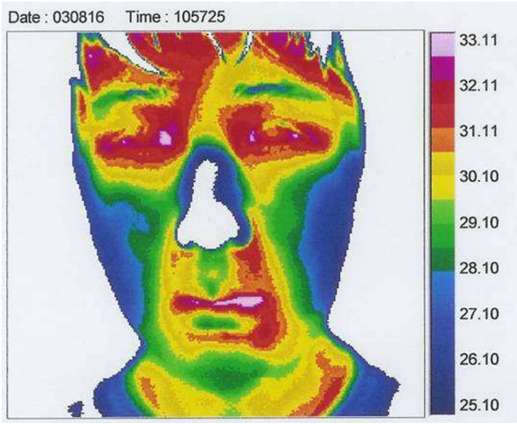


Fig. 4. Unilateral nerve damage; 1 week after surgery

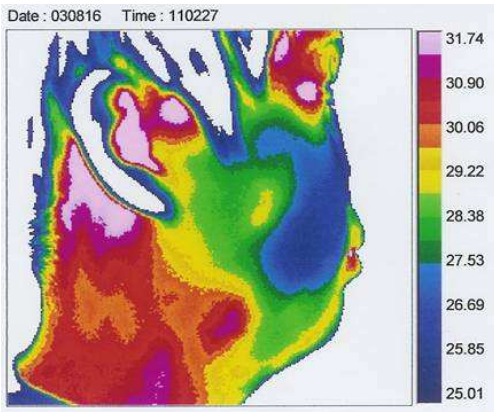


Fig. 5. Unilateral nerve damage; 1 week after surgery

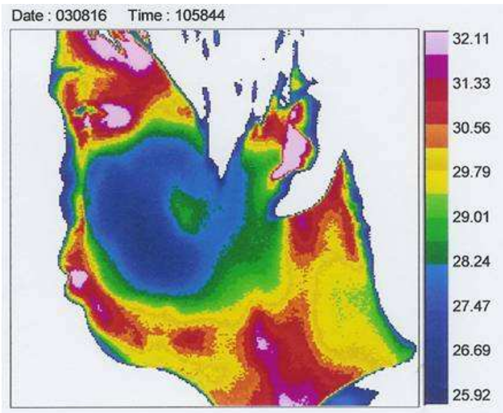


Fig. 6. Unilateral nerve damage; 1 week after surgery

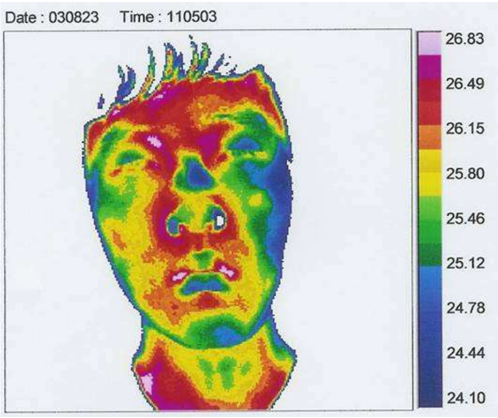


Fig. 7. Unilateral nerve damage; 4 weeks after surgery

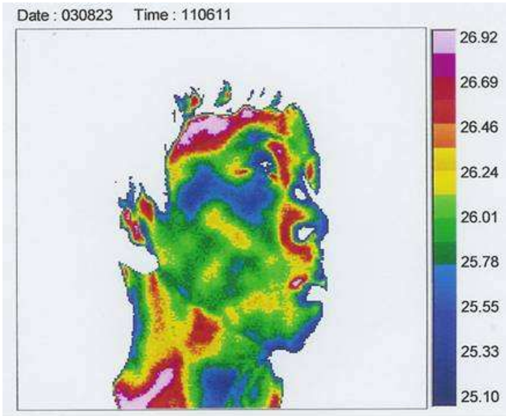


Fig. 8. Unilateral nerve damage; 4 weeks after surgery

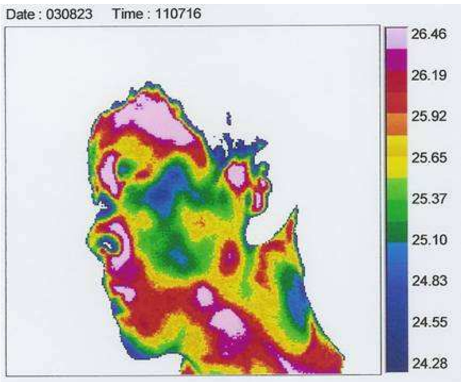


Fig. 9. Unilateral nerve damage; 4 weeks after surgery

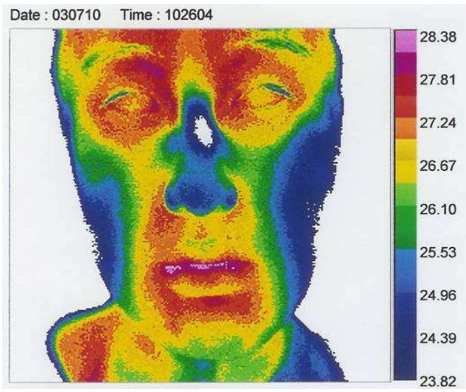
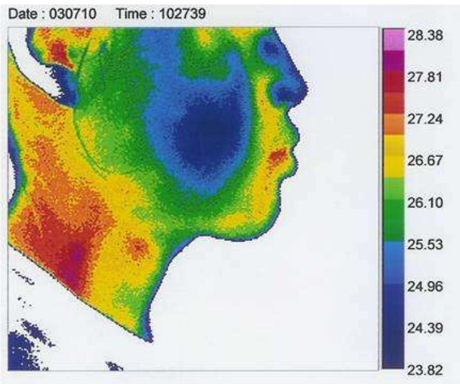


Fig. 10. Bilateral nerve damage; 1 week after surgery



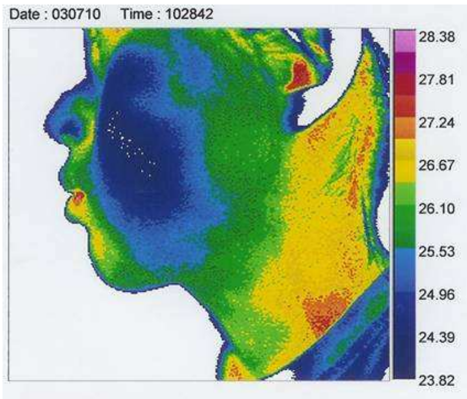
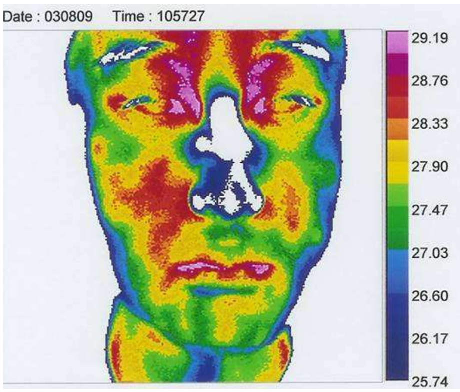


Fig. 11. Bilateral nerve damage; 1 week after surgery

Fig. 12. Bilateral nerve damage; 1 week after surgery



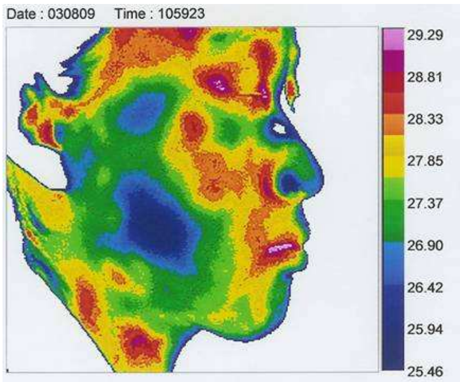


Fig. 13. Bilateral nerve damage; 4 weeks after surgery

Fig. 14. Bilateral nerve damage; 4 weeks after surgery

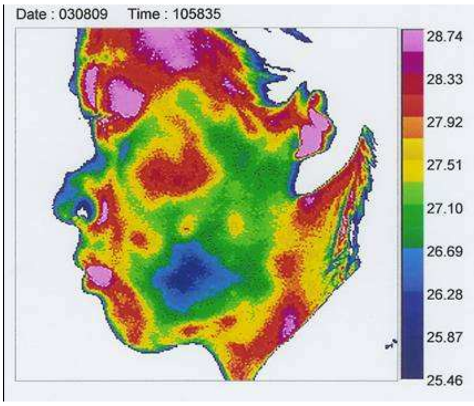


Fig. 15. Bilateral nerve damage; 4 weeks after surgery

Table 1. Temperature Differences in the Patients with Unilateral Inferior Alveolar Nerve Damage at one and four weeks after surgery

	Anteroposterior view (^{0}C)	Lateral view (^{0}C)
Before surgery (n=20)	0.02 ± 0.04	0.08 ± 0.09
One week after surgery (n=14)	0.64 ± 0.76	0.10 ± 0.77
Four weeks after surgery (n=14)	0.23 ± 0.18*	0.27 ± 0.37

*Statistically significant

Table 2. Temperature Differences in the Patients with Biilateral Inferior Alveolar Nerve Damages at one and four weeks after surgery

	Anteroposterior view (^{0}C)	Lateral view (^{0}C)
Before surgery (n=20)	0.02 ± 0.04	0.08 ± 0.09
One week after surgery (n=6)	0.20 ± 0.84	0.18 ± 0.32
Four weeks after surgery (n=6)	0.13 ± 0.53	0.34 ± 0.88

Discussion

As many factors can influence a patient's perception and expression of sensation, the interpretation of the results of a sensory examination may be difficult[11]. Sensation results from the activation of a receptor and the propagation of impulses via the afferent nerves to the central nervous system. The three primary modes of sensation recognized by the peripheral terminal endings of sensory axons are mechanoreception (touch-pressure), nociception (pain), and thermoreception (cold and warmth). These sensations protect the organism from environmental damage[8,14].

Thermal images are the result of heat given off by blood flow within and beneath the skin surface and the surrounding superficial muscles. The skin temperature varies with the amount of blood circulating within these structures. Thermography can only evaluate the body surface and a superficial layer of tissue 6 to 10 mm deep[15].

The skin temperature is easily measured and has been used extensively to evaluate the skin blood flow. The skin temperature varies widely with time and vasomotor changes[11]. As mentioned above, the skin temperature is regulated by the thermoregulatory blood flow, which accounts for the largest part of the total blood flow. The skin temperature also depends on other factors, such as sweating and underlying muscular metabolic activity[16].

Computerized electronic thermography is a rapid, non-invasive, non-ionizing method of obtaining physiological information. The study of the heat emission from facial structures promises to be beneficial in dental care, including in the evaluation of chronic toothache, which usually results in unsuccessful invasive treatment; craniomandibular dysfunction (TM disorders); sinus disease; and headache, which may confound proper dental diagnosis and promote inappropriate dental care. In addition, ET can objectively assess facial nerve function, which may be impaired because of infection or trauma, or after oral surgery. All of these facial problems may be studied by obtaining and analyzing physiological measurements in the form of vascular heat emissions, without using ionizing radiation or invasive techniques[15].

The method of computerized infrared temperature views measures and amplifies the energy released from the skin, showing differences in body temperature as different colors on a monitor. It does not involve irradiation and can be used to diagnose nervous system, vascular, dermatological, and muscular/skeletal diseases; sports injuries; and peripheral nerve damage, as well as in the diagnosis and evaluation of cancer[17,18].

Importantly, it is non-invasive and causes no pain; it is safe, as it passively senses and images the infrared heat released from the body naturally, without irradiation. Repeated application is feasible, and clinical patterns and the progression of disease can be evaluated readily.

The greatest advantage of thermal imaging is that the image can be shown to patients, to improve patient understanding of the condition and progression of a disease. Unlike conventional radiological tests that detect the presence or absence of anatomical abnormalities, it is the only method than can quantitatively assess as well as visualize the physiological and functional condition of pain. Therefore, it may be used to help distinguish true pain from false pain[18)].

Although many studies have examined the diagnostic usefulness of the infrared temperature view, computed tomography, myelography, and electromyography, contradictory results have been reported. Importantly, in infrared body temperature images, the temperature distributions on the right and left sides of normal adults are always symmetrical, and the American Medical Association (AMA) uses this bilateral symmetry as the standard for evaluating infrared views. The normal difference in temperature between the right and left sides averages less than 0.3°C, and a temperature difference exceeding 1.0°C is generally diagnosed as a functional abnormality[19)]. However, various temperature differences have been reported, and the uniform application of these values is not proper, as they vary widely depending on the body area. In this study, a temperature difference exceeding 0.3°C between the right and left sides was considered abnormal.

Owing to the complexity of the normal skin temperature pattern and possible anatomical variation, the sensory examination and thermographic imaging should be evaluated using good clinical judgment. Note that the skin temperature may change as the sympathetic nerve recovers. Initially, the skin supplied by the damaged nerve segment may be warmer (usually for the first few months), and then it becomes colder. Sometimes, after some initial warmness, the temperature rapidly returns to normal[11)].

The temperature of the skin may be influenced by age, gender, height, weight, psychological conditions, etc. The skin temperature is 20% higher in children than in adults and decreases with age; it is lower in women than in men. However, the degree of the effect of such variables on the skin temperature has not been investigated sufficiently. Some studies have argued that the skin temperature is not influenced by age[11,20)]. In addition, there are numerous exogenous and endogenous factors to be considered. After adjusting for such factors, the diagnostic value of thermal imaging might be enhanced.

The vascular structures in the skin are not distributed uniformly[21], and the blood flow is influenced by posture. For example, the flow to the foot while lying down is less than that while standing, so that lying down can prevent edema in the legs.

This study demonstrates the potential of using thermography to assess IAN deficits. This has important clinical implications because an initial loss of sensation is not an indication for IAN surgery unless it is known that the inferior alveolar nerve has been severed (neurotmesis). If nerve dysfunction is complete after 4 to 6 weeks, exploratory surgery to determine the extent of injury is justified, allowing surgical repair if indicated.

As ET is inexpensive, non-ionizing, and noninvasive, it promises to aid in the diagnosis and management of IAN injuries if clinical efficacy can be demonstrated.

With scientific progress, the advances in modern medicine are proportional to the development of diagnostic equipment, and many new diagnostic devices are undergoing clinical testing. Much new diagnostic equipment, such as that for CT and MRI, initially faced much criticism when first applied clinically. Although problems can be expected with new diagnostic equipment, we believe that infrared body temperature imaging warrants further investigation and scientific analysis, leading to clinical trials. We propose that the infrared body temperature method is an objective method that can be applied as a supplemental diagnostic method for inferior alveolar nerve injury.

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