Thermography for the Clinical Assessment of Inferior Alveolar Nerve Deficit: A Pilot Study

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Neurosensory deficit is a major complication encountered in maxillofacial surgery. This study assessed the ability of electronic thermography to identify inferior alveolar nerve deficits in a pilot clinical study. The study population comprised six patients with inferior alveolar nerve deficit and 12 normal subjects. Frontally projected facial thermograms were taken on 18 subjects and measured using an Agema 870 unit and thermal image computer. Mathematical analysis of thermal measurements included temperature and ΔT calculations of the anatomic zone over the mental region of the face. Results included (1) high levels of thermal symmetry of the chin in normal subjects ($\Delta T = 0.1°C$, standard deviation = $0.1°C$); (2) low levels of thermal symmetry in patients with inferior alveolar nerve deficits ($\Delta T = +0.5°C$, standard deviation = $0.2°C$); (3) statistically significant differences in ΔT values ($t = 4.82$, $P > .001$) in patients with inferior alveolar nerve deficit; and (4) absolute temperature variations of the mental region in both groups. This pilot study demonstrated thermal asymmetry in patients with inferior alveolar nerve deficit and suggests that electronic thermography has promise as a simple, objective, noninvasive method for evaluating nerve deficits. However, more extensive studies are needed before thermographic procedures are accepted clinically.

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Neurosensory deficit is a major complication encountered in oral and maxillofacial surgery and is a leading cause of malpractice claims against oral surgeons.[1] The incidence of inferior alveolar nerve (IAN) paresthesia ranges from 3% (following surgical removal of impacted third molars) to 70% (following sagittal osteotomy of the mandible).[2–4] Currently there is no simple objective test to detect and document the cutaneous sensory impairment resulting from IAN injury. Commonly used sensory tests, such as von Frey's tactile sensation, Weber two-point discrimination, and brush directional tests, are mainly qualitative, are not easily reproducible, and have limited utility in the assessment of IAN injury and repair.[5] These sensory examinations are based on the patient's subjective assessment of symptoms and involve uncertainty about whether the individual's expressed complaint is based on organic nerve damage, psychogenic factors, or malingering. Occasionally, patients may choose not to report postsurgical symptoms or findings; in a previously published clinical maxillofacial surgery study, normal sensation was subjectively demonstrated in 74% of patients with sagittal osteotomy of the mandible, but objective tests demonstrated normal sensation in only 34% of patients.[4] Because sensation is predicated on the activation of sensory receptors, which include mechanoreceptors (touch-pressure), nociceptors (pain), and thermoreceptors (cold and warmth), no single test can evaluate the intactness of sensation.[4] Given the variability of current commonly used clinical tests, it is difficult to assess the degree of nerve injury or predict the quality of nerve regeneration following injury to the IAN.

Thermography is a generic term given to various methods of heat pattern identification and analysis. Skin-temperature observations can provide an insight into physiologic problems, especially those concerned with thermoregulation. Clinical thermography provides the ability to picture, record, and analyze the body's vascular heat emissions. Electronic thermography (ET) systems produce symmetric thermal patterns in normal subjects and asymmetric thermal patterns in patients with a variety of physical disorders including myofascial pain syndromes,[6] motor and sensory radiculopathies,[7] herniated disc disease,[8] musculoligamentous disease,[9] and carpal tunnel syndrome.[10] In the case of neurosensory deficits, thermography has been evaluated only in a limited fashion, as an alternative technique for recording the normal and pathologic status of nerves with cutaneous distribution. The technique is based on the observation that the sympathetic distribution closely parallels the somatic sensory distribution of nerves. Skin temperature, which is a function of sympathetic (not somatic) vasomotor control, is known to reflect disturbances in peripheral nerve function. Malfunctioning areas are reliably demonstrated by thermographic imaging of skin-temperature changes.[11]

In a recent study,[12] ET was assessed as a tool for the evaluation of IAN deficit by using a pharmacologic nerve block as a model (2% lidocaine injection). The ET was compared with four common neurosensory tests (pin prick, Minnesota Thermal disks, two-point discrimination, and light touch) for detection of IAN block. The study indicated that ET may be more sensitive (fastest detection rate) in identifying IAN deficit than the other tests. However, the study did not evaluate ET for the assessment of IAN deficit as a consequence of maxillofacial surgery or trauma.

This pilot study was designed to assess the ability of ET to distinguish between normal subjects and patients having clinically evident IAN paresthesia or dysesthesia.

Materials and Methods

Study Population

The study population consisted of two groups: *(1)* all patients presenting at the University Medical Center over a 2-year period having clinically determined IAN deficit, and *(2)* age and sex-matched normal subjects. The study was approved in advance by the authors' Institutional Review Board. Informed consent was obtained from all normal and IAN-deficit subjects.

Normal Subjects. Normal subjects were chosen from adult (aged 20 years and older) patients, students, staff, and faculty at the UCLA Medical Center. Twelve normal subjects were used; two normal subjects were selected for each IAN patient studied. Mean age of the study population was 41.2 years, with a woman-to-man ratio of 2:1. All subjects completed a medical-history questionnaire and those found to be acceptable (12 of 13) received a clinical examination by a dentist (BMG). For study purposes, a negative health history (good health without history of pain, trauma, facial skin problems and blemishes, or third molar extraction) and a negative clinical examination established normal IAN status. The subjects were not followed clinically over time, and further tests were not conducted to support the "normal" assessment.

Patients With IAN Deficit. All six subjects presenting at the clinic with IAN deficit (dysesthesia or paresthesia following IAN insult) were evaluated by a dentist (BMG). Two IAN insults resulted from trauma, two from difficult third molar extractions, one from suboptimal implant surgery, and one from root canal surgery. Age and gender of the patients were recorded to match normal subjects. Mean age of the study population also was 41.3 years, with a female-to-male ratio of 2:1. The duration of each unilateral deficit was also recorded.

Thermography Equipment

Thermography was conducted using an Agema 870 thermovision unit (Agema, Secaus, NY) that included an infrared scanner, a control unit, MEDS 1.02 software, and a thermal image computer TIC-8000 linked to a color monitor that was coupled to a 35 mm camera with color print film. Room conditions for thermographic examinations included a draft-free environment (no windows or open doors), with temperature control (ranging from 20°C to 22°C), variable lighting, a patient-positioning chair, a head-positioning device, and a small hand-held electric fan.

Facial Imaging

All subjects were given prethermographic examination instructions according to the recommenda-

Fig 1 Facial thermogram of the chin in a normal subject. Zones of interest are outlined (white lines) and measured by computer (right side). Boxes 1 and 2 on the right reveal that the right mental region of the chin has a mean temperature of 34.8°C, same as the left side (ΔT value was calculated to be 0.0°C, measured over an area of 162 pixels).

tions of the Academy of Neuro-Muscular Thermography.[14] Facial thermograms were taken of the 18 subjects using frontal projections, at 0.5°C imaging sensitivity (0.1°C accuracy) (Fig 1). Before the examination, each patient's face was cleared of hair (tied back). The face was wiped with a damp cloth and then air dried using a small electric fan. Men with beards were ineligible for participation in the study. A 15-minute period was allowed for facial temperature equilibration. A series of facial thermograms was made and stored on computer disk for analysis.

Computerized Image and Data Analysis

Mathematical analysis was made from electronically generated images using an Agema TIC-8000 computer, software, and a color monitor. Built-in computer programs facilitated individual mapping of any zone of sensory loss on the involved side of the anterior mandible and allowed comparison with the contralateral (control) side. Absolute temperature measurements of individually selected anatomic zones or regions, mirrored comparisons, and mean temperature measurements differences (ΔT values) were facilitated by the advanced anatomically oriented computer software (Fig 2). This represents an advance over previous prototype software used by other investigators of facial thermography.

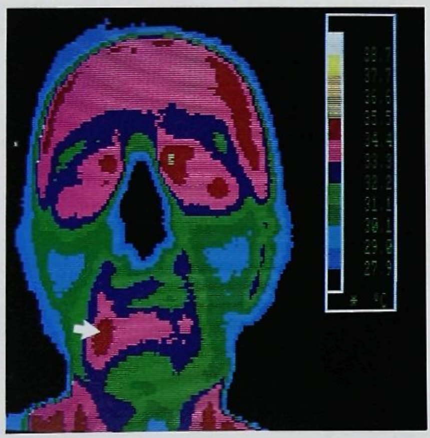

Fig 2 Facial thermogram of the chin in a patient with IAN deficit. The affected area (arrow) appears hotter (red) than the contralateral side (pink-blue).

Table 1 Temperature Measurements and Thermal Differences (ΔT) of 12 Normal Subjects

Subject	Gender, Age (y)	Right side (°C)	Left side (°C)	ΔT (°C)
1	F, 28	35.1	35.2	0.1
2	F, 27	36.0	35.8	0.2
3	F, 56	35.2	35.2	0.0
4	F, 36	34.7	34.6	0.1
5	F, 26	34.8	34.9	0.1
6	F, 31	36.1	36.0	0.1
7	F, 75	34.8	34.7	0.1
8	F, 53	34.3	34.6	0.3
9	M, 42	34.4	34.4	0.0
10	M, 50	36.3	34.2	0.1
11	M, 34	34.4	34.6	0.2
12	M, 28	35.8	35.6	0.2
Mean (SD)	41.2 (14.2)	35.2 (0.7)*	35.0 (0.6)*	0.1 (0.1)

*No statistical significance found using Student's *t* test at $P < .05$.

Data analysis included determinations of mean values and use of Student's *t* test when appropriate, with significance accepted at the $P < .05$ level.

Results

The results of temperature measurements of the right and left sides of the chin (anterior mental region) on 12 normal subjects are shown in Table 1. Measured absolute temperatures over the region of the chin for normal subjects varied from 34.2°C to 36.3°C. Mean temperature values, comparing the left side to the right side, ranged from 35.0°C to 35.2°C (SD 0.6°C to 0.7°C). The mean ΔT calculations were found to be 0.1 °C, (SD 0.1°C).

The results of temperature measurements of the affected and unaffected regions over the chin of the six IAN deficit patients are shown in Table 2. Mean duration of deficit was 49.3 days (SD 67.5 days). Skin temperatures over the chin region varied from 33.1°C to 36.1°C. Mean temperature values, comparing the unaffected side to the affected side, ranged from 34.3°C to 34.7°C (SD 0.8°C to 0.9°C). The ΔT calculations were found to be 0.5°C (SD 0.2°C). A significant difference was found between ΔT values of the six IAN deficit patients (+0.5°C) and the 12 normal subjects (absolute 0.1°C), *t* statistic = 4.65, $P < .001$, using Student's *t* test.

Discussion

The results of this pilot study indicate that ET has promise as a means to assess IAN deficits. In normal subjects, core temperature hemostasis of the body is maintained by feedback mechanisms that operate through a temperature-regulating center in the hypothalamus. Central control of the skin temperature affects both sides of the body uniformly and simultaneously, resulting in symmetry of thermal patterns. In previous ET studies measuring the forehead, body (trunk), and extremities (arms) of normal subjects, the skin temperature difference (ΔT) between sides of the body was 0.2°C.[15] A previous study of 60 normal temporomandibular joint (TMJ) temperature measurements found the skin temperature difference (ΔT) between the right and left TMJ regions to be 0.1°C.[16] Similarly, this study demonstrated a high degree of thermal symmetry for the chin region in normal patients (ΔT = 0.1°C, SD 0.1°C). On the other hand, patients with IAN deficits demonstrated significant temperature differences when comparing similar regions of the affected side to the unaffected side (ΔT = +0.5°C, SD 0.2°C). The difference between normal subjects and patients with IAN deficit was statistically significant, even for the small sample size used in this study.

In patients with IAN deficit, skin temperature is altered in the field of an impaired peripheral nerve due to sympathetic vasomotor disturbance, resulting in a thermal asymmetry between corresponding areas of opposite sides of the body. This thermal asymmetry is indicative of nerve impairment, and the affected sensory segment can be demonstrated in the thermographic image. In the acute stage of peripheral nerve injury, for example, the affected area may demonstrate greater heat loss. As the nerve regenerates or denervation sensitivity of sympathetic nerve fibers develops, the affected area may demonstrate decreased heat loss. Thermal asymmetry is the hallmark of abnormality, and previous studies have shown that a significant temperature difference between corresponding sites on opposite sides of the body may suggest nerve impairment.[11,15,17] Although the precise mechanisms of these thermal changes are not understood completely,[18] thermography appears to be useful in identifying clinically significant abnormalities.

The results of this pilot investigation suggest the potential of using thermography in the assessment of IAN deficit. This has important implications in clinical management because an initial loss of sensation is not an indication for IAN surgery unless it is known that the IAN is severed (neurotmesis). Complete nerve dysfunction after 4 to 6 weeks justifies the need for exploratory surgery to determine the extent of injury and, if indicated, surgical repair.

Table 2 Temperature Measurements and Thermal Differences (ΔT) of Six Patients With Known IAN Deficit

Patient	Cause of IAN deficit	Gender, Age (y)	Duration of IAN deficit (d)	Affected side (°C)	Unaffected side (°C)	ΔT* (°C)
1	Trauma	F, 35	28	34.5	34.1	+0.4
2	Third molar extraction	F, 35	12	34.1	33.1	+1.0
3	Root canal	F, 66	35	34.4	34.0	+0.4
4	Third molar extraction	F, 52	14	34.2	33.8	+0.4
5	Trauma	M, 21	21	35.1	34.8	+0.3
6	Implant	M, 38	186	36.1	35.7	+0.4
Mean (SD)		41.3 (15.8)	49.3 (67.5)	34.7 (0.8)	34.3 (0.9)	+0.5 (0.2)

*Affected side versus unaffected side
†Statistical significance using Student's t test: t statistic = 4.65, $P < .000$.

Current clinical protocols involve a 4-to-6-week delay prior to surgical exploration, based on the estimated time it takes for regenerating axon tips to advance from the third molar area to the lip. If recovery does not proceed satisfactorily, surgical exploration is required, since lesions of complete transection (neurotmesis) benefit by early microsurgical resection and repair.[19] After 6 months of altered neurosensory sensation, the nerve dysfunction may be considered permanent. Currently, there is no sound scientific basis on which to determine the need for, or timing of, surgical exploration of these complex neurologic lesions, and also the type of surgical repair to perform. A useful step in approaching these problems would be the development of an easy-to-conduct, noninvasive, objective test of IAN deficit. Because of the increasing litigation involving iatrogenic IAN injuries,[1] mapping and recording of the area of nerve dysfunction following IAN injury could also prove useful in resolving medicolegal conflicts following oral and maxillofacial surgical procedures. Electronic thermography is inexpensive, nonionizing, and noninvasive, and it provides objective anatomic and physiologic information about the affected region. This study demonstrated significant temperature differences; however, absolute temperature measurements of the normal chin (right side, mean temperature = 35.2°C; left side, mean temperature = 35.0°C) were considerably higher than the mean temperature of the unaffected side in the IAN deficit patients (34.3°C). We believe that this is probably due to the small size of our study coupled with a substantial degree of variation in absolute temperature from patient to patient (high = 36.3°C, low = 33.1°C, SD 0.9°C). It also is possible that some temperature robbing (redirected blood flow) to the affected side occurs in IAN deficit patients. More research is needed to clarify these preliminary findings.

Thermal asymmetry was identified in six patients with nerve deficits in this pilot study, but a question arises as to what one would expect from a long-standing nerve deficit. Do the thermal changes remain hot, do they become cold, or do they revert to normal? Because the pathophysiologic mechanisms of the thermal changes were unclear, the thermal manifestations of chronic nerve deficits was conjectural. However, we speculate that cases of reversible nerve damage eventually manifest as normal thermograms, whereas cases of irreversible nerve damage continue to show a certain degree of thermal asymmetry. Although thermography has conceptual appeal as a noninvasive diagnostic tool for monitoring nerve damage and recovery, its potential needs to be validated by future studies.

We found ET to be both fast and convenient to use in the clinical setting. Study patients and control subjects alike found the procedure to be comfortable, and all displayed interest in observing their own thermal images. Since ET is inexpensive, nonionizing, and noninvasive, it promises to aid in the diagnosis and management of IAN injuries if clinical efficacy can be demonstrated. Larger controlled studies on the use of ET in the assessment of IAN deficit are being planned. More extensive research is needed before thermographic evaluation of IAN deficits can be accepted as a clinically useful tool.

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Resumen

Estudio piloto sobre la termografía para la evaluación clínica de la deficiencia del nervio alveolar inferior

La deficiencia neurosensorial es una complicación importante en la cirugía maxilofacial. Este experimento evaluó la habilidad de la termografía electrónica para identificar deficiencias del nervio alveolar inferior en un estudio piloto clínico. La población de este estudio consistió de seis pacientes afectados por la deficiencia del nervio alveolar inferior, y por 12 personas normales. Se tomaron termogramas faciales proyectados frontalmente, a 18 sujetos, y luego medidos por medio de una unidad Agema 870 y una computadora TIC-8000. El análisis matemático de las medidas térmicas incluyó la temperatura y los cálculos de los cambios de temperatura (ΔT) de la zona anatómica sobre la región mentoniana de la cara. Los resultados indicaron: *(1)* niveles altos de simetría térmica del mentón en sujetos normales (ΔT = 0,1°C, DS = 0,1°C); *(2)* niveles bajos de simetría térmica en pacientes con deficiencias del nervio alveolar inferior (ΔT = +0,5 °C, DS = 0,2 °C); *(3)* diferencias estadísticamente significativas en los valores de los ΔT (t = 4,82, P > ,001) en pacientes con deficiencia del nervio alveolar inferior; y *(4)* variaciones en las temperatura absoluta de la región mentioniana en ambos grupos. Este estudio piloto demostró la asimetría térmica en pacientes con deficiencia del nervio alveolar inferior e indicó que la termografía es prometedora; en cuanto a que es un examen simple, objetivo, no invasor para la evaluación de las deficiencias nerviosas. Sin embargo, se necesitan estudios mas extensos antes de que los procedimientos termográficos sean aceptados clínicamente.

Zusammenfassung

Thermographie für die klinische Beurteilung von Ausfällen des N. alveolaris inverior

Neurosensorische Verluste stellen eine Hauptkomplikation der Kiefergesichtschirugie dar. Diese Studie beurteilte die Fähigkeit der elektronischen Thermographie zur Identifikation von Sensibilitätsausfällen des N. alveolaris inferior in einer klinischen Pilotstudie. Die untersuchte Gruppe bestand aus sechs Patienten mit Ausfällen des N. alveolaris inferior und aus 12 normalen Personen. Frontal projizierte Gesichtsthermogramme wurden an 18 Personen angefertigt und ausgemessen mit einer Agema 870-Unit und eines TIC-8000 Computer. Die mathematische Analyse der thermischen Messungen beinhaltete die Temperatur und DT-Berechnung der anatomischen Zone über der Kinnregion des Gesichts. Die Resultate ergaben *(1)* einen hohen Grad von thermischer Symmetrie des Kinns bei normalen Personen (DT = 0.1°C, SD = 0.1°C); *(2)* einen geringen Grad von thermischer Symmetrie bei Patienten mit einem Ausfall des N. alveolaris inferior (DT = +0.5°C, SD = 0.2°C); *(3)* statistisch signifikante Unterschiede der DT-Werte (t = 4.82, P > .001) bei Patienten mit Ausfällen des N. alveolaris inferior; und *(4)* absolute Temperaturunterschiede der Kinnregion in beiden Gruppen. Diese Pilotstudie zeigte eine thermische Asymmetrie bei Patienten mit Ausfällen des N. alveolaris inferior und legt nahe, dass die elektronische Thermographie eine vielversprechende, einfache, objecktive, nichtinvasive Methode für die Beurteilung von Nervenausfällen darstellt. Auf jeden Fall sind weitere ausführliche Studien notwendig, bevor thermographische Verfahren klinisch anerkannt werden.