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THERMOGRAPHY – A REVIEW

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ABSTRACT Thermography is a technique of measurement of skin temperature distribution on the body over a given period of time. It is a noncontact, noninvasive method that utilizes the heat from an object to detect, display, and record thermal patterns and temperature across the surface of the object. Over the years, various devices have been used to measure the amount of heat dissipated by the body and most recently thermography has been emerged to detect the oral and maxillofacial pathologies. It is used to detect malignancies of the maxillofacial region such as vitality of teeth, TMJ disorders, chronic orofacial pain, assessing inferior alveolar nerve deficit, and detection of herpes labialis. The present article highlights the history, basic principles, types and applications of thermography and its beneficial role in detecting the maxillofacial pathologies in dentistry.

KEYWORDS : Facial telethermography, Infrared thermography, Liquid crystal thermography, Telethermography.

INTRODUCTION:

Heat has a profound cognitive impact on humans.[1] A strong relationship exists between life and body temperature where moderate body temperature associates with normal health and severe body temperature associates with disease process.[2] Human skin is very sensitive and is remarkably good absorber and emitter of infrared radiation having an emissivity of 0.97 in the infrared spectrum.[3] As the quantity of blood circulation at various parts of the skin differs, the temperature changes accordingly. Therefore, diseases affect the flow of blood may result in the irregularities in distribution of temperature.[4] These changes can be evaluated by a method known as Thermography.

Thermography is an imaging technique that allows to record the distribution of thermal radiation emitted by the surface of the body and transforming it through the laws of physics into temperature values.[5] Earlier to thermography, an array of devices have been employed such as thermometers, thermistors, thermocouples and liquid crystal imaging systems for determining the body temperature.[6] Compared to other imaging modalities thermography is characterized as not being invasive and not having side effects such as exposure to nuclear radiation for the accuracy of diagnosis through immediate results by recording a simple image that resembles a photograph.[5]

HISTORY:

The diagnostic application of infrared thermography began in Germany, in 1952 followed by the medical association of thermography in 1954 which was operating as German Society for Thermography and Regulation Medicine.[6] (Table:1)

Table 1: Reported Research On Thermography.

S.No	Year	Scientist	Research
1.	400 BC	Hippocrates	Human body temperature was used as a medical diagnostic sign.
2.	130-210 AD	Galen	Body heat is produced by the bio-combustion of food. Galen theory: Feedback between sensory and motor nerves, today it is known as a primary mechanism of thermoregulators.
3.	1592	Galileo	Invented the semi-quantitative air thermometer called Galileo's thermoscope, which exhibits temperature changes.
4.	1611	Sanctorius	Modified the thermoscope and invented a thermometer, which demonstrated the variation in core temperature of humans in both health and diseases.
5.	1872	Wunderlich	He introduced fever measurements as a routine clinical diagnostic procedure.
6.	1928	Czerny	He documented the first infrared image of a human subject in Frankfurt.
7.	1931	Hardy	Initiated the modern era of telethermometry. He described the physiological role of infrared emission of human skin and its potential diagnostic importance.
8.	1951	Schwamm and Reeh	A single-detector infrared bolometer for sequential thermal measurement of defined regions of the human body surface for diagnostic purposes.[4,6,7]

PRINCIPLE:

The thermography principle is the variation in amount of blood circulation at different layers of skin, the temperature changes accordingly. Consequently, disorders that affect the blood flow too result in abnormalities in temperature

distribution and when evaluated these will provide valid diagnostic information.[1]

CHARACTERISTICS OF THERMAL IMAGES:

Thermal images are characterized by:

1) Spatial resolution: The minimum temperature difference that can be measured at two distinct spots on an image.

2) Temporal resolution: The time delay between a change in temperature at a certain spot on the monitored area and the corresponding change on the thermal image.[8]

TYPES OF THERMOGRAPHY:

There are two commonly used methods of obtaining thermal images.

A. Semi-quantitative contact method:
- Liquid crystal thermography (LCT)

B. Quantitative infrared-detecting noncontact methods:
a. Infrared telethermography (ITT)
b. Dynamic area telethermography (DAT)
c. Facial telethermography (FTT)

C. Microwave thermography[2,9]

A) Semi-quantitative contact method:

a) Liquid crystal thermography(LCT):

It uses a thermometer comprising of pliable rubber sheets with cholesteric crystals inserted within them. Numerous sheets of crystals are attached on a structure with a clear side, which are inflatable within the frame for better adaptability of body's shape. Once adapted, the crystals changes color like dark brown color for cool areas and red colors for warmer areas from their neutral color, indicating the temperature distribution over the skin. Subsequently color display is then snapped by Polaroid photography representing the thermogram, used for diagnostic evaluation.[1,2,4,9]

Advantages: Less expensive and are portable when compared to electronic tele-thermography units.

Disadvantages: LCT is technique sensitive and requires timely skin contact to record a reproducible temperature distribution. The temperatures recorded are not accurate due to the contact of the crystal sheet with the body surface which can cause compensatory warming/cooling of the contact area.[9]

B) Quantitative infrared-detecting noncontact methods:

a) Infrared Telethermography(ITT):

ITT is a non-contact method of determination of temperature, where the detector is placed at a single spot. It comprises of an amplifier-digitizer, an infrared detector, a microcomputer along with a video clip. The infrared detectors include linear array infrared detectors, single element infrared detector and two-dimensional array detectors. The single detector infrared radiation thermography functions in a manner such that as the infrared radiation emitted by the face entered the germanium lens, passed via the mirrors. The electric signals are converted to digital values by an amplifier. These signals are reconstructed into a digitized thermal image.[10]

Infrared detectors:

Because of the low intensity of infrared detectors precise measurement of the infrared emission from small areas of skin within a reasonable short time period (30 msec) requires photon detectors, to produce electrical pulse each time they absorb the infrared photon. These pulses can be amplified and counted individually, or can be integrated into a instantaneously measurable electric current.[11,12]

Advantages: ITT has higher speed, reliability, and maintenance-free performance since they require no moving parts.

Disadvantages: limited spatial resolution.[1,9]

b) Dynamic Area Telethermography (DAT):

It is the advancement in infrared imaging in which quantitative assessment of temperature changes over a non-uniform temperature area is measured. To record the temporal thermal behavior, a series of thermal images are taken from each subarea. The values of each subarea unit constitute a time series of temperatures, using Fast Fourier transform (FFT). The characteristic feature of DAT is that the FFT spectra can project the underlying temporal thermal behavior in terms of thermoregulatory frequencies. Another additional quality of DAT is the possibility to determine the microspatial homogeneity of skin temperature which is the representation of temporal behavior of cutaneous perfusion.[13]

c) Facial Telethermography (FTT):

Heat emission is directly related to cutaeneous vascular activity, yielding enhanced heat output on vasodilatation and reduced heat output on vasoconstriction. The pattern of radiative heat dissipation is normally symmetrical. The significant difference between the absolute facial temperature of men were found to be higher over 25 anatomic zones than women. The rationale behind this is that men have more basal metabolic than women and his skin dissipates more heat per unit area of body surface. Similarly age and ethnicity variations in facial temperature can also occur.[14]

C) Microwave Thermography:

The thermal radiation emitted from the tissues is captured by the device which has an antenna that is capable of detecting microwaves of a cylinder of tissue with a diameter of 1.5cm and depth of 2cm in the 3-3.5GHz range. Microwaves have a depth of penetration of 4cm and a wavelength of -10cm. Here, the microwaves travel unaffected to the skin surface suggestive of true core temperature.[15]

APPLICATIONS OF THERMOGRAPHY IN DENTISTRY:

Thermography can be performed in the clinical set up which can be done on a given spot or over an extended area of interest.

1) Chronic orofacial pain:

Using telethermographs for patients with chronic pain, in 1996 Gratt and his colleagues classified them as normal when selected anatomic area (T) values range from 0.26 - 0.35^{0}C, hot when it is >0.35^{0}C, and cold when it is <0.35^{0}C.

Hot thermographs had the clinical diagnosis of:
(1) Sympathetically maintained pain,
(2) Peripheral nerve mediated pain,
(3) TMJ arthropathy,
(4) Maxillary sinusitis.

Cold thermographs:
(1) Peripheral nerve-mediated pain,
(2) Sympathetically independent pain.

Normal thermographs:
(1) Cracked tooth syndrome,
(2) Trigeminal neuralgia,
(3) Pretrigeminal neuralgia,
(4) Psychogenic facial pain.

This new system of thermal classification resulted in 92% agreement in classifying pain patients making it as an important diagnostic parameter.[16,17]

2) Temporomandibular joint disorders:

TMJ pain patients with internal derangement and osteoarthritis were found to have asymmetrical thermal patterns with increased temperatures over the affected TMJ region of their

face and mean area ΔT values shows + 0.4°C. Beth and Gratt in 1996 conducted a double-blinded clinical study to compare the ΔT values among active orthodontic patients, TMD patients and asymptomatic controls. The results showed that the average TMJ area ΔT values as +0.2°C, +0.4°C, and +0.1°C in these groups by suggesting that tele-thermography can distinguish between patients undergoing active orthodontic treatment and patients with TMD.[18]

3) Detection of inferior alveolar nerve deficit:

The thermal imaging of the chin has been shown to be an effective method to assess inferior alveolar nerve deficit (IAND). Subjects with no IAND show a symmetrical thermal pattern, with an area ΔT of + 0.1°C, while patients with IAND had an area ΔT of + 0.5°C on the affected side. The observed vasodilatation seems to be due to blockage of the vascular neuronal vasoconstrictive messages, since the same effect on the thermological pattern could be invoked in normal subjects by temporary blockage of the IAN, using a 2% lidocaine nerve block injection.[19]

4) Quantification of thermal insult to pulp

Dental pulpal tissue is exposed to a variety of thermal insult during various dental treatment modalities. For debonding of orthodontic brackets Eelectro Thermal Ddebonding (ETD) method is widely used. Cummings and his colleagues in 1999 performed an in-vitro study on extracted human premolar teeth applying ETD. Thermal imaging analysis was done using mercury cadmium terullide detector showed that the pulpal temperature increased from 16.8°C- 45.6°C, which can pose serious threat to pulpal vitality by stating that intermittent cooling of teeth with simultaneous thermal imaging prevents the pulpal damage.[20]

Similarly the use of ultra high speed air-driven instrumentation during cavity preparation can result in serious thermal insult to the pulp. To overcome this, it is believed that various coolants can be used to reduce the intrapulpal temperature and prevent subsequent damage to the pulp.[21]

5) Qualitative evaluation of N_2O concentration:

N_2O is a highly insoluble gas which is rapidly absorbed is eliminated swiftly by the lungs, thus it is used widely either alone or in combination with other anesthetic agents. Studies on acute and chronic occupational exposures have shown that N_2O air concentration levels as low as 50 parts per million can result in bone marrow depression, paresthesias, altered concentration, impaired visual effects, alterations in vitamin B_{12} and plasma homocysteine concentrations.[22]

6) Detection of Herpes Labialis in Prodromal Phase:

During the prodromal phase, all patients showed an increase in temperature with the mean localized change in temperature being 1.1°C ± 0.3°C over a mean thermographically positive area of 126 mm^2 ± 34 mm^2 even when the patient was asymptomatic. After 72 hours of treatment with acyclovir cream, majority of the patients returned to normal with no clinical or thermographical evidence of infection.[23]

OTHER APPLICATIONS: A thermogram can offer precise images for

1. Diagnosis of bone and nerve disorders
2. Muscular pain
3. Tissues reactions to new dental materials
4. Diagnosis of maxillofacial inflammation
5. Chronic and acute periodontitis
6. Sinus disease
7. Cancers in maxillofacial region
8. Myofascial pain dysfunction syndrome
9. Neuralgia.

ADVANTAGES OF THERMOGRAPHY:

1. Noninvasive technique.
2. Easy seating examination.
3. Minimal examination time.
4. Nonexpensive technique.
5. Obvious differences in color changes.
6. Very fast scanning of stationary targets and capturing of fast changing thermal patterns.

DISADVANTAGES OF THERMOGRAPHY:

1. Quality cameras often expensive.
2. Images are difficult to interpret accurately.
3. Unable to detect the inner temperature if the medium is separated by glass/polythene material.
4. Sensitivity and resolution reduce with distance and angle of view
5. Time-consuming procedure.

CONTRAINDICATIONS OF THERMOGRAPHY:

1. Accurate thermal image analysis in patients with fever and sunburn are difficult.
2. Facial scars can appear as pathological hypothermic lesions.[24]

CONCLUSION:

Thermography aids in the assessment and staging of various dysfunctions of the head and neck region. The unique significance of thermography is both qualitative and quantitative assessment which helps in estimation and progression of the disease in a systematic manner and hence being an important aspect in dentistry because of accurate measurement of regional temperature. Thermography may be useful in elaborating of a right diagnosis on an inflammatory reaction from maxillofacial territory. With the innovation of novel equipments and the state of the art facility, thermography in the near future will certainly re-emerge as a unique research tool in dentistry.

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