The Advantage and Basic Approach of Infrared Thermography in Dentistry

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Abstract

This review aimed to review the application of infrared thermography in dentistry and describe how inflammation makes treatment more effective. One of the methods whose working principle is by determining the thermal pattern characteristics is Infrared Thermography. Infrared thermography has a connected role within the assessment of inflammation. Inflammation signs are known as symptom of many infectious diseases, injury or related tissues, neurodegenerative diseases, and cancer. Literature were searched in all databases such as PubMed, Medline, and Google Search for articles published between 1979 and 2019. By means of a systematic online database search and based on the PRISMA guidelines related to word infrared thermography, dentistry, inflammation articles were identified using the search engines PubMed, Medline, and Google Scholar. After screening the abstracts and applying the eligibility criteria on those which were fully accessible, 62 articles were included in the review. 692 studies were excluded due to the defined inclusion and exclusion criteria and 62 studies have finally been included in the evaluation process. This was followed by an analysis and discussion of the methodology.

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Introduction

Currently, body temperature is one of the most commonly used indicators of health status in humans. The thermal pattern of muscle may be explained based on anatomy: the temporalis muscle is thinner than the masseter muscle, and it is influenced by the superficial path of the temporalis artery. This research also confirms that the temperature of cutaneous facial areas over the masseter and anterior temporalis muscles decreases in the presence of myogenous TMD body especially skin can determine the changes in the human body and the consequences that exist and changes in normal temperature distribution as a sign of a pathological process.[1]

One of the methods in which working principle is determining the thermal pattern characteristics is infrared thermography. Moreover, infrared thermography method is can to examine all diseases that were hard to diagnose in dentistry. This technique is entirely safe and quite simple in its implementation.[2]

Since it is painless and straightforward to perform and it is well accepted by patients, thermography has become an integral component of complex diagnostic procedures, especially in the diagnosis of different diseases in the area of psychophysiology, social interaction, emotion feeling, including dentistry. Infrared thermography is known as an important additional role in the assessment of dental-oral related illnesses, diseases, and in their clinical diagnosis.[3]

Infrared thermography has a connected role within the assessment of inflammation.[4] Inflammation has been well known by having five cardinal signs such as symptom of many infectious diseases, linked with a broad range of injury of related tissues, neurodegenerative diseases, and cancer.[5,6] The relation of inflammatory processes with thermal product makes infrared thermography examinations an advancement in dentistry.

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Therefore, the aim of this article was to review the application of infrared thermography in dentistry and describe how inflammation makes treatment more effective.

The Advantage of Infrared Thermography in Dentistry

Many research methods in dentistry use radiography, computed tomography, magnetic resonance imaging, ultrasound.[7,8] According to radiography, researchers confirmed the damaging effects of ionizing radiation on the human body. The widespread use of radiation diagnostic methods requires careful monitoring of radiation doses since the biological effect of low doses of ionizing radiation associated with research does not imply a direct radiation reaction, at the same time it may cause long-term effects in the form of induced malignant diseases, genetic consequences, and shortened life.[9] Moreover, some researchers have identified many disadvantages of the devices mentioned above: lag of the dynamics of radiological signs from clinical manifestations;[7] subjectivity of interpretation of research data; inexpediency of application to control the effectiveness of treatment; computed tomography method and magnetic resonance imaging are expensive, require special equipment, time-consuming and experienced staff.[8]

The characteristics of the infrared thermography working principle are by determining the thermal pattern.[10] Infrared thermography is a non-invasive and non-ionizing bidimensional imaging technique that maps the distribution of body surface thermal radiation into images. It is based on the capture and transformation of infrared radiation emitted by the human skin to form images that reflect the local vasomotor response.[9]

The accuracy of this new methodology has found 92% cases. Both, data and reliability of infrared thermography imaging to identify some diseases were close to 100%, and generally for primary examinations were close to 80%.[10] Besides, this method does not cause patients distress.[11-14] The infrared thermography is totally safe and quite easy to operate,[15-17] including for pregnant women and kids.[18-19]

Application in Dentistry

The infrared Thermography method can be used to examine the temporomandibular joints (TMJ) which could help to make treatment more effective and prevent crippling deformation of the joints. Thermography has found the sites of discomfort varied; in some cases, the symptoms were experienced over and around the masseter muscle.[2] It has been reported that asymptomatic TMJ subjects have symmetrical thermal patterns with mean delta T values of 0.1°C. Whereas subjects suffering from TMJ pain were found to have asymmetrical thermal patterns with increased temperature over the affected TMJ region with mean delta T values of 0.4°C. [20]

In temporomandibular joint disorder (TMD) study, infrared imaging indicates that the temporalis was significantly more hyper-radiant than the masseter muscle. This finding adds to the understanding of mild to moderate temporomandibular joint disorder (TMD) subjects correlated with the level of pain in the subjects.[21] Furthermore, difference temperature within the region of connected muscle could also be explained supported anatomy: the striated muscle is dilutant than the masseter muscle, and it's influenced by the superficial path of the temporalis muscle artery. This analysis conjointly confirms that the temperature of body covering facial areas over the facial muscle and anterior temporalis muscle muscles decreases within the presence of myogenous TMD.[2]

Infrared thermography is known as an accurate method for neurodegenerative and musculoskeletal diseases.[21,22] Infrared thermography is considered to be an effective method to diagnose the inferior alveolar nerve (IAN) deficit since 1995. Deficit of IAN can be attributed to blockage of vascular neuronal vasoconstriction.[23] This device also found the increase in skin temperature connected to neck and shoulder stiffness.[24] The researcher also found that an increase in skin temperature over the masticatory muscles after splint therapy of TMD.[25] Other applications of infrared thermography in dental sciences include the evaluation of craniomandibular disorders,[26] detection of carotid occlusal disease,[27,] and quantification of the effects of post-surgical inflammation.[28,29]

The application of infrared thermography has also been carried out in *vitro* studies, carried out on the extraction of human premolar teeth that can detect severe damage to pulp tissue.[30] Another *in vitro* study used infrared

thermography that has succeeded in the pattern of heat distribution during preparation a high speed cavity,[31] application of dental bone drilling,[32] monitoring changes in bone temperature during the drilling process for preparation of implant location,[33] and studying the thermal effects of laser Nd: YAG on tooth roots during the sterilization process.[34]

Nowadays, infrared thermography can determine the presence or absence of pulp tissue blood flow in the capacity of pulp vitality tests, using at least 40 maxillary teeth that sectioned the root at its middle third and widened the canal to allow the injection of water at 37°C. This research concluded that the low-temperature thermal stimulation produces an immediate temperature drop in teeth both with and without simulated irrigation.[35]

Standard Guideline for Performing the Examination

Working with Infrared Thermography requires accounting for many factors that can influence either the evaluation or the interpretation of the thermal images. Attempting to control for such a large number of factors may seem impossible, but simply being acquainted with these factors is an essential step in many contexts.[36] Various research recommends to use the practical Guidelines for Dental-Oral and Systemic Health Infrared Thermography-American Academy of Thermology-AAT and the standard protocol by the Academy of Neuromuscular Thermography to manage research perform.[2,3] Many researchers have used to support the guideline to increase effectiveness of this method. Application to conduct a non-invasive measurement of the cutaneous temperature of masticatory muscle with and without the myogenous temporomandibular disorder (TMD) uses the standards for the reporting of diagnostic accuracy studies (STARD) guidelines.[2]

During the examination time, participants are told not to touch, press, scrape the skin at any time, relax the muscles of the mastication, hold the teeth apart and the mouth partially open until the test was complete.[37] The examination was accomplished in a respectful manner, without any kind of head movement while the inspector moved the machine to capture the images. Except to avoid any stress that could cause magnified peripheral vasoconstriction of the skin and/or vasodilatation in the facial area resulting from voluntary movement of the head and neck of the volunteer.[38] Vibrations or camera motion cause not only a shifting of the monitored object in the image but also cause blurring of the image.[39]

For the thermographic examination, standardized room conditions are extremely important. During the examination, the relative humidity of air and room temperature were noted. Examination of TMJ and/ or TMD, The volunteers' temperatures are measured and documented in their respective medical records in three different regions of interest (front, right and left).[40] In general, to ensure thermographic examination properly, thermography was performed at room temperature between 18°C and 25°C with humidity around 60% .[41] Selection of sample also important in order to get perfect result. Some of the factors influencing the measurement of skin temperature with the use of Infrared Thermography are sunbathing, use of skin cream, dehydration, and smoking.

Another factor to consider is the selection of camera to record the images.[40] The most common cameras are used to acquire infrared images of the masseter and anterior temporalis regions recorded using a computer-assisted infrared camera with thermal sensitivity of the object is 0.05 at 30°C.[2,42] However, the proposed monitoring procedure can be applied using any camera.[39] The Infrared Thermography camera set in a vertical position on the tripod, and in all image acquisitions, the lens was placed parallel to the face.[36] The appropriate position of the camera is important to receive the finest image recording. The lens has to be positioned in parallel to the plane of interest, oriented perpendicularly to the plane, and at the lowest angle of inclination possible. The error could be minimized by using a tripod.[41] The distance between the camera and the lateral face being measured was adjusted to 0.80 m, at an angle of 90°, with the lens of the camera parallel to the region being assessed.[10] Ensuring to get of highest resolution of infrared thermography is possible,[36] because each pixel in the image will produce one thermal information, and this might play a characteristic aspect in determining regions of interest. The Infrared Thermography camera must be turned on at least 10 min before perform to allow the synchronization of the camera's electronic components in relation to the

environment. Finally, a recommended checklist must be prepared to ensure that the correct protocol in applying Infrared Thermography in human subject.[40]

Inflammation and Infrared Thermography

Inflammation characterized by five cardinal signs, namely rubor, tumor, calor, dolor, and function leases as symptom of many infectious diseases. Inflammation is also linked with a broad range of changes that occurs in a living tissue and organ system and considered the cornerstone of pathology. The observed indicative of injury of the living microcirculation and related tissues.[5,6].

As well as infrared thermography approach, the infrared thermography detects serious conditions such as infection, injury, neurodegenerative diseases, and cancer, ranging from the acute inflammation to chronic inflammatory connected with heat associated with changes in microvascular form and function. This crucial character of inflammatory processes related to thermal produce makes the infrared thermography possible to detect serious conditions such as injury, infection, cancer and neurodegenerative diseases.[5,6] The sensation of heat in inflammation is caused by the increased movement of blood through dilated vessels into the environmentally cooled extremities, result in increased redness [44] Consequently, the temperature of the inflamed area will be higher than the temperature of the surrounding tissue.

The principle of infrared thermography is to inspect and measure variations within the heat transmitted by the body within the variety of infrared radiation and convert them into electrical signals.[45] The variety of infrared radiation as a mean temperature for the normal condition by using thermography was found the ≅31°C, and abnormal condition was ≅34°C.[10] As impulses, electrical signals were fed into the computer that analyses the temperature and vascular changes, thereby manufacturing high-resolution pictures.[42] The data result was recorded both quantitatively and qualitatively. Quantitatively, research by Gratt et.al[46] had confirmed thermograms were classified when zone delta T was 0 to +/-0.25°C as normal when zone delta T was high more significant than 0.35°C as hot and when zone delta T was lesser than 0.35°C as cold condition. While qualitatively, the pictures of warmer areas within the body appeared red, and the colder areas blue in color.

Changes in the variation of temperature can be measured using thermography. At the start of an acute inflammation, the phase of neurogenic contraction of local blood vessels occurs; consequently, all inflammatory lesions demonstrate the presence of specific leukocytes in any lesion.[6] Inflammation mediators cause vascular responses in the form of increased vessel endothelial permeability and shift of water from plasma to perivascular space.[47] The inflammatory reaction will change the blood supply of inflammatory sites as well as change of its metabolism will cause local increase of temperature independent of febrile state. Increasing blood flow as well as increased tissue catabolism causes a significant rise in local temperature.[48,49]

The blood vessels responsible for flow and pressure are arterioles. Arterioles manage flow and pressure through a mechanism called myogenic vasoconstriction.[44] This vasoconstriction refers to a change in transmural pressure due to the acute reactions of the blood vessel. This response is crucial to the production of resting vascular tone on which vasodilator and vasoconstrictor effects are exerted by other control mechanisms.[48] In addition to myogenic constriction in arterioles, endothelial cells (ECs) in arteries and arterioles can sense changes inflow and release local autacoids, such as NO, lipid metabolites, and other mediators to increase or decrease vessel diameter. During acute inflammatory responses, leukocyte-derived mediators such histamine and bradykinin will cause arteriolar dilation thereby increasing blood flow leading to rubor.[44]

A crucial connected role of Infrared thermography to a potential inflammation is easy to discover signs of an abnormal condition in a pre-clinical stage. As known, inflammation is initiated as a protective response to challenges with pathogens and foreign bodies, or injury, experienced by host tissues. This mechanism is characterized by vascular dilation, increased capillary permeability, increased blood flow, and recruitment of leukocytes. Polymorphonuclear neutrophils are among the first leukocyte responders to accumulate in the inflamed site. These cells are crucial as the first line of defences of the innate immune system because of their phagocytotic and microbicidal functions.[49]

The other blood precursor that recruited from hematogenous precursor cells, called monocytes. Once newly recruited monocytes migrate through the vessel wall in order to fragment extracellular matrix (ECM) proteins, this condition creates space for monocytes to migrate into the wound.[50] In addition, inflammation is also known to be closely related significantly to the decrease in the volume of dental plaque and gingival bleeding.[51] As known, the involvement of macrophages and monocytes is closely related to the healing process. The healing process consists of four integrated and overlapping phases: hemostasis, inflammation, proliferation, and tissue remodeling.[50] These stages and their biophysiological functions must occur in the proper succession, at a typical time, and continue for a specific duration at an optimal intensity. Based on this, the approach using Infrared thermography has good potential in evaluating the wound-healing process, such as tooth extraction and flap surgery (wound excision) or to evaluate dental plaque and gingival bleeding.

Although the inflammatory response is protective, failure to remove noxious materials produced by neutrophils via phagocytosis, failure to clear apoptotic inflammatory cells, and a delay of apoptosis characterizes the chronic and pathological lesion.[47,52] Accordingly, loss of resolution and failure to return tissue to homeostasis results in neutrophil-mediated destruction and chronic inflammation, are significant causes of human inflammatory pathologies, including cancers and periodontal diseases.

Disorders involving progressive and irreversible damage to the central nervous system are another important group of diseases involving chronic inflammation.[19] Theria et al.[53] states a heat shock response in chronic inflammation represents the major homeostatic response in addition to the inflammatory response to extracellular insult required as a defence against protein function. Furthermore, one acute inflammatory condition which involves the nervous system in dentistry is acute pulp inflammation. As is known, Pulpal inflammation is a pulp disease characterized by pain in the trigeminal nociceptor. The interaction of superoxide dismutase (SOD1) with macrophage cells in response to reactive oxygen species (ROS) is known to provide a different physiological response in the acute pulp inflammation.[54]

Moreover, inflammation mediators cause vascular responses in the form of increased vessel endothelial permeability and shift of water from plasma to perivascular space. It causes problems in capillary blood's inflammatory outflow, which is reflected in edema and reddening.[55] Edema is the result of increased passage of fluid from dilated and permeable blood vessels into the surrounding tissues, infiltration of cells into the damaged area, and in prolonged inflammatory responses deposition of connective tissue. Edema can cause initial damage and stretch of the sensory nerve. This is the initial basis that inflammation can detect the initial damage to the nerves. This statement is also reinforced by the fact that loss of nerve functions will refer to loss of simple mobility in the joints due to edema and pain.[44] Moreover, as known IL-1α IL-1β, and MMP-9 have relation to standard clinical periodontal parameters and biohumoral markers of periodontal inflammation in reducing pain, edema and inflammation.[56]

Parshikova SA et al. confirmed chronic inflammation is implicated at every level of tumorigenesis includes initiation, promotion, malignant conversion, invasion, and final metastasis.[19] Chronic inflammation causes cancer by damaging and scarring the tissue, and reshaping the structure of the tissue and leading to changes in gene expression that support tumorigenesis.[57] Link inflammatory cells on cancers are initiated by infections.[58-60] Persistent infections within the host induce chronic inflammation. As known, all inflammatory lesions demonstrate the presence of specific leukocytes in any lesion.[6] Leukocytes and other phagocytic cells induce DNA damage in proliferating cells, through their generation of reactive oxygen and nitrogen species produced normally by these cells to fight infection. These species react to form mutagenic agent.[61] Hence, repeated tissue damage and regeneration of tissue, highly reactive nitrogen and oxygen released from inflammatory cells, interacts with DNA in proliferating epithelium resulting in permanent genomic alterations such as point mutations, deletions, or rearrangements.[62]

Conclusions

The relation of inflammatory processes both acute and chronic inflammation to thermal

produce in infrared thermography working principle makes this method important early detection of many cases in dentistry including cancer.

Declaration of Interest

The authors report no conflict of interest.

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