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Infrared Thermal Camera in the Diagnosis of Periodontal Disease: A Mini-Review

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Abstract

Infrared thermal cameras have emerged as a groundbreaking tool in various medical fields, including dentistry. These cameras utilize infrared technology to detect and visualize temperature variations on the surface of the skin and oral structures, which can reveal underlying pathological processes. In dentistry, this method is beneficial for identifying temperature changes that may indicate inflammation or infection. One such condition is periodontitis, an inflammatory disease affecting the periodontal tissues, including the gingiva, ligaments, and bone. Periodontitis can lead to temperature changes in the affected areas, making thermography a promising tool for evaluating the health of the periodontium. By capturing subtle temperature variations, infrared thermal cameras provide a non-invasive and efficient way to assess periodontal conditions without the need for radiation or invasive procedures. This review highlights the principles of thermography and its current applications in diagnosing various oral and dental conditions. It also explores the future potential of thermography in the early detection and monitoring of periodontal diseases. As a diagnostic tool, infrared thermography could enhance the accuracy of diagnoses and improve the management of periodontal diseases, offering a more patient-friendly approach than traditional methods. With further research and technological advancements, thermography holds great promise in revolutionizing the way periodontal conditions are diagnosed and treated.

Keywords: Bleeding, Gingivitis, Gingival Index, Periodontitis, Probing, Thermography.

Mini review article **Corresponding Author*, e-mail: *shrouk.nabil.h@gmail.com* https://doi.org/10.62877/28-IJCBS-24-26-20-28

1. Introduction

Periodontal diseases are most common chronic inflammatory bacterial disease that dramatically affects tooth loss and has adverse effects on patient's esthetics, self-confidence, and masticatory function. Thus, the ability to early diagnose and treat these diseases may decrease the risk of tooth loss [1]. Furthermore, development of periodontal disease is not consistent amongst all teeth and sites. So, understanding and evaluations of clinical signs of individual sites are crucial [2]**.** Periodontitis, in particular, is ranked as sixth most common human disease, impacting over 10% of global population, making it a major area of concern for specialists and researchers [3] . Furthermore, in 2014, the WHO reported that 80% of the population in Egypt was affected by periodontitis. Despite this significant prevalence, there have no effective preventive measures or screening programs implemented to tackle this issue or establish a consistent periodontal health protocol [4] . In 2019, a study assessed prevalence and severity of periodontitis among adult Egyptians and examined its association with various risk factors. The study found that 89.8% of participants had periodontitis, with 70.8% in stage I and 15.2% in stage II. Only 4.4% and 2.05% were in stage III and stage IV, respectively [5].

2. Etiopathogenesis of periodontal disease

Oral microbiome, comprising around 700 bacterial species, exists within the oral cavity [6]. This microbial community forms a distinctive and varied ecosystem, engaging in both metabolic and physical interactions. These interactions lead to formation of complex biofilm communities, where physico-chemical gradients create specific ecological niches that cater to diverse metabolic needs of microorganisms [7]. Complexity of inflammation and immune responses in periodontal diseases arises from overlap of immunological events across different disease phases. It's important to note that categorizing immune response into systems like innate and adaptive immunity is somewhat arbitrary, as proposed by immunologists. While it may be easier to describe inflammation in distinct categories, the mechanisms of inflammation, resolution, and healing involve all components of immune system working together to protect periodontium. As lesion progresses, it's crucial to remember that earlier pathways continue to function [8]. The four cardinal signs of inflammation are redness, hotness, odema, and pain, which are result of dilation of small blood vessels, accumulation of fluid outside blood vessels, increased blood flow, and chemical mediators such as prostaglandins, bradykinin, and serotonin in area of injury [1]. The inflammatory process is associated with synthesis and release of interleukin-1 (IL-1) from monocytes and macrophages. IL-1 is considered a neutrophil pyrogen, affects thermoregulatory center in brain. Furthermore, existence of IL-1 locally contributes to increased cellular infiltration at inflammatory sites, leading to an increase in fluid permeation, & elevated levels of neutrophils; consequence of these activities is a rise in local temperature [9].

3. Assessment of periodontal disease and the challenges in diagnosis

During the chairside diagnosis of periodontal patients, we regularly screen three cardinal signs of gingival inflammation swelling, redness, and pain but the fourth important cardinal sign of gingival inflammation which is the sub gingival temperature is usually underestimated [10]. In periodontics, the traditional methods of diagnosis of periodontitis are so far based on clinical and radiographic findings, that is pocket depth (PD), clinical attachment loss (CAL) or radiographic bone loss, and gingival indices such as Gingival Index (GI), Bleeding on Probing (POB) and Plaque Index (PI) [11]. The clinical diagnosis of periodontal disease is obtained by probing and measuring attachment loss. Several problems have been pointed out such as infectious aggression by dental instrument, time-consuming for both dental professionals and patients, and patient discomfort due to bleeding, pain, and itching during probing. Also, calibration of probing b/w examiners is required for standardization of the assessment of periodontal disease [12].

Other methods are complementary to clinical findings, like panoramic radiography which is commonly used to determine and visualize the loss of alveolar bone in periodontal diagnosis and disease monitoring. Additionally, Cone beam computed tomography (CBCT) provides three-dimensional views of the defects within the tooth-supporting bone, this allows improved treatment planning. However, X-ray-based techniques cannot visualize soft tissue processes such as inflammatory changes associated with water retention within the bone in addition to the high radiation dose to the patient and high cost of these radiographs [13]. Furthermore, (MRI) is a technique using non-ionizing radiation that generates high tissue contrast and provides very detailed images of soft tissues including the dental pulp, nerves, and gingiva. There are disadvantages of MRI diagnostics such as its high costs and its limited availability. Another drawback to MRI diagnostic is artifacts that caused by restorative material [14].

4. Development of temperature-based diagnostic techniques

Thermal probes were sensitive diagnostic devices for measuring inflammatory changes in periodontal tissue. It has used in many clinical studies for sub gingival temperature measurement with benefits of using this probe such as a rapid response time (<1sec), high accuracy (±0.1 °C), and high reproducibility. In addition, its physical shape and dimensions are like conventional periodontal probes. So, it allows measurement of CAL, PD, and BOP [15]. A temperature-sensitive probe has been developed and is available in the market to measure periodontal pocket temperature, which is known as Periotemp. Furthermore, it has a computerized thermometer that displays actual sub gingival temperature and a risk level with two-color light indicators. It has been reported that this probe can aid in the early diagnosis of periodontal disease and also it can detect disease activity by measuring the subgingival temperature related to inflammatory changes [16]. In addition, the performance of the PerioTemp was reported to be comparable to that of an infrared thermometer (Thermoscan IRT 3520, Braun, Kronberg, Germany) with only about 0.18 °C in the mean difference for the measured gingival temperature [17]. A new generation of infrared cameras was able to detect changes of 0.02 ◦C that may reflect pathophysiological pathways underlying specific inflammatory conditions [18]. Many devices enable measuring body temperature, such as thermistors, liquid crystal imaging systems, thermocouples, and thermometers have also advancement of thermography which is mapping ability for temperature distribution [19].

5. Principles of Thermography

Thermography is a modern imaging method in which the infrared radiation emitted by an object allows the mapping and analysis of the exact temperature distribution on the surface of the object. It involves non-contact temperature measurement using thermal imaging cameras and subsequent image analysis. Thermal images detect changes in body temperature which may correlate with the changes that occur in local blood supply and tissue metabolism [20] .The American Academy of Medical Infrared Imaging recognized the medical infrared thermography and suggested that infrared imaging is a painless method that does not rely on ionizing radiation therefore it is helpful as an advanced supplementary diagnostic tool [21]. Infrared detectors, also known as thermographic cameras, are capable of sensing emitted thermal radiation and converting it with high precision into a visible digital image called a thermogram. The initial conversion of heat signals into electrical signals, which are easy to record, is performed by a conversion device. These thermal images can be observed in real-time and subsequently processed on a computer [22]. Thermography is currently only method that can identify earliest and smallest metabolic disruptions through thermal signals, allowing for predictions of clinical manifestations of inflammation. Consequently, insights gained from thermography surpass mere anatomical details, as method is straightforward, painless, and noninvasive [18] figure 1.

Thermograms depict the thermal profile of skin or mucous membranes by using a color-coded system that quantitatively represents the temperature [23]. To standardize thermogram analysis, the International Organization for Standardization (ISO) has established the norm ISO/TR for medical equipment like thermographic cameras. This standard recommends a rainbow temperature scale for diagnosing fever, where high temperatures are represented in red and low temperatures in blue. Thermal differences in corresponding tissues can also be visualized using this high-contrast rainbow scale. However, grayscale is preferred for vascular system analysis, and some software allows for custom color scales based on clinical needs [24-25]. Advancements in technology have made thermography a reliable temperature measurement method. However, certain basic criteria must be met for its use in diagnostics. The quality of thermal images relies on both the technical equipment and the examiner's expertise. Various factors can adversely affect thermographic results, impacting the actual thermal values. These factors range from patient-related issues (before and during the examination) to the testing environment, camera calibration, and image analysis and interpretation. While there is no universal consensus on procedural protocols, thermographic companies provide specific technical specifications and recommendations for conducting examinations across different medical fields [26].

6. Applications of thermography in dental and oral medicine

There is a total of 119 published research that was carried out in different fields of dentistry using infrared thermography [69 longitudinal studies, 46 cross-sectional studies, and 4 reviews]. Interestingly, only 3 published research in the field of periodontics, two of them are longitudinal studies and only one is a cross-sectional study**.** Accordingly, there is a gap in knowledge about diagnostic accuracy of using infrared thermal cameras in diagnosis of periodontal diseases [19] .

6.1. Endodontics

One of the pioneering thermographic studies in endodontics was conducted by McCullagh et al. in 1997. This study examined the thermal changes on the root surfaces of extracted premolars during the thermomechanical filling of root canals using warm condensation of gutta-percha.[27]. The findings indicated higher speeds of reduction increased the root temperature, necessitating greater local blood supply for heat dissipation. At that time, the detrimental effects of thermal condensation on root and periodontal space, such as disruption of blood flow and potential bone necrosis from temperatures exceeding 60°C, were not fully understood [28]. Another study investigated morphological and temperature changes in tooth roots irradiated with an 810 nm laser diode aimed at sterilization. This research highlighted the need to adhere to specific thermal thresholds (in increments of 10°C) and radiation times, especially in areas where the root walls are thinner, like inter radicular zones and near the apex [29]. Thermographic assessments have also utilized to evaluate the extent of periodontal damage when filling root canals with systems like Thermafil Plus, for preparing endodontic pins, testing dental pulp vitality, and monitoring hydraulic flow during canal irrigation with various endodontic needles [30] Another study revealed that acute periapical abscess exhibited the highest temperatures in thermal images in comparison to acute pulpitis with apical periodontitis and chronic periapical abscess. Thermography in these cases may be capable of detecting inflammatory reactions in preclinical stage, allowing for earlier diagnosis [31].

6.2. Odontology

Thermographic diagnosis of caries began in 1998, as noted by Matsuyama and subsequently by Kaneko. This approach was primarily used to quantify lesion activity rather than merely detect the presence of caries. The thermal radiation emitted from dental tissues can change due to dehydration, particularly as water evaporates from hard dental tissues, which exhibit different moisture content in enamel and dentin, especially in carious lesions [32]. In 2005, Al Qudai et al. reported temperature differences during the light-curing of various dental restorative materials. Their thermographic analysis revealed that flow able composites reached the highest thermal values (43.1°C), while packable composites registered lowest temperatures (22.4°C). These significant temperature differences raise concerns about potential impacts on pulp vitality [33]. Infrared thermography is also utilized in teeth whitening procedures to assess thermal effects of energy sources on decomposition of hydrogen peroxide, which can affect nerve health. Kabbach et al. found that LED sources generated less heat compared to halogen lamps, making them less harmful to dental tissues [34].

6.3. TMJ Pathology

Temporomandibular dysfunctions (TMD) exhibit complex and multifactorial causes, presenting various painful symptoms. Conditions affecting the masticatory muscles, the temporomandibular joint (TMJ), and the articular disc can complicate diagnosis despite previous diagnostic efforts. Infrared thermography can aid in diagnosing certain TMD, such as osteoarthritis, showing correlations between TMJ pain and thermal changes in surrounding areas. Recent studies have confirmed relationships between the severity of TMJ disorders and skin temperature in facial regions and thermal changes in muscles like the masseter [35-36].

6.4. Oral and Maxillofacial Surgery

Thermographic research has revealed distinct thermal patterns in the oral and maxillofacial regions, particularly when comparing malignant conditions to other pathologies like inflammation and benign tumors. Elevated temperatures in the skin and mucous membranes above carcinomas were noted, surpassing those observed in acute inflammation. This increased thermal activity correlates with enhanced blood flow due to the accelerated metabolism of neoplastic cells. While thermography cannot replace traditional imaging methods, it can complement radiological and histopathological assessments in diagnosing malignant tumors. Historical studies have demonstrated its efficacy in identifying neoplastic infiltration in cases of basal cell carcinoma [37]. Infrared thermography is valuable for monitoring chemotherapy toxicity in oral and maxillofacial neoplasms, as well as assessing radio-mucositis severity and inflammation after surgical procedures, including tooth extractions and bone fractures. Additionally, it effectively diagnoses inferior alveolar nerve damage, particularly during certain surgical interventions [38]. Minor labial salivary gland functionality, usually evaluated through other imaging and analysis methods, has also successfully assessed with thermography. Areas of labial mucosa that are moistened by saliva appear more opaque in thermograms compared to hyposialic areas, owing to saliva's infrared opacity [39].

6.5. Periodontology and Implantology

In 1986, Barnett et al. successfully tested thermography to assess inflamed gingiva by observing thermal rebalancing after cooling. The resulting thermograms indicated varying degrees of tissue inflammation severity. Recent thermographic studies on young patients with aggressive periodontitis revealed diagnostic thermodynamic behaviors related to periodontal vascularization.

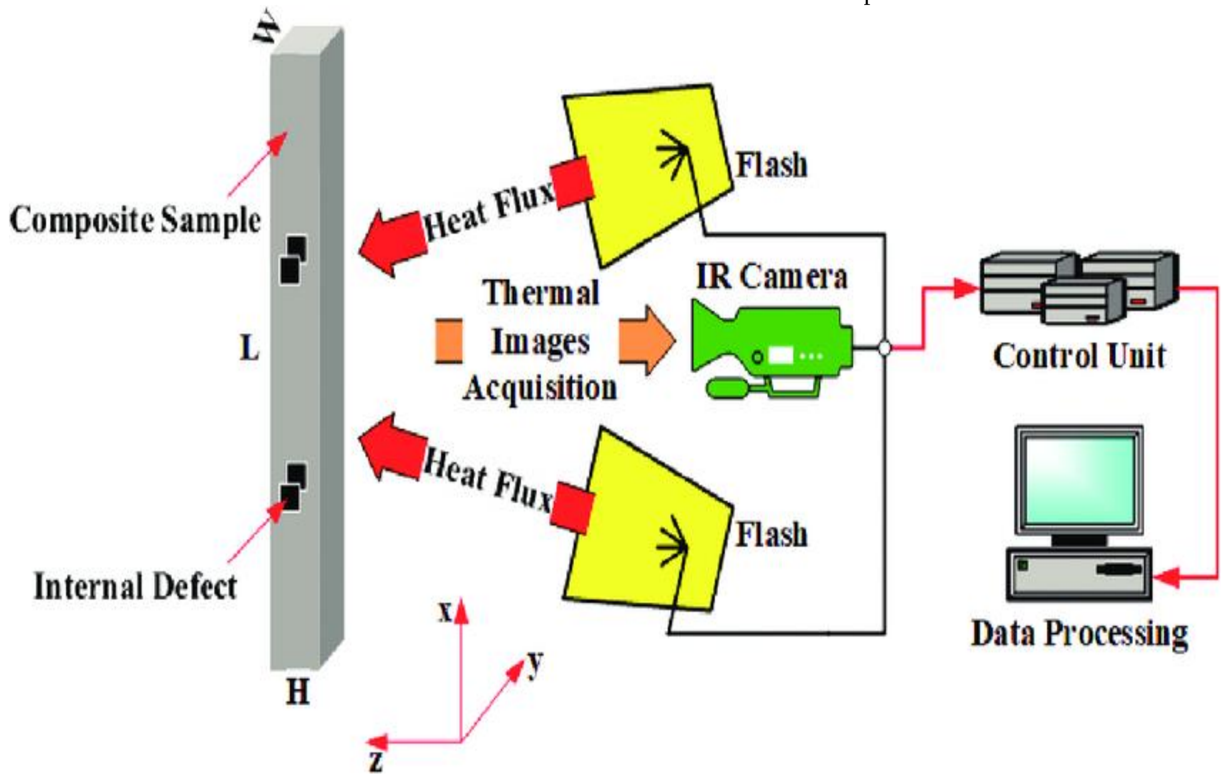

Figure 1: Schematic diagram for the principle of thermography showing the image acquisition by the camera then the analysis of the image through the software [46].

Infrared thermography is also significant in detecting tumor infiltrates in conditions such as leukemia and monitoring laser treatments in periodontal therapy to minimize thermal damage [40-41]. The healing process of peri-implant bone is complex and heavily reliant on effective primary healing. During implant preparation, temperatures can reach around 56°C, which may impair alkaline phosphatase function and hinder bone healing, possibly leading to osteonecrosis. Therefore, using external cooling systems during the procedure is crucial. Infrared thermography has identified how different drill designs influence thermal generation in surrounding tissues, with cylindrical drills producing higher temperatures than conical ones. This technology has also been applied in the intraoral welding of titanium clips, ensuring safe temperature levels in surrounding tissues during the process [42].

6.6. Prosthodontics

Thermographic studies in dental prosthetics are relatively scarce. However, in fixed prosthodontics, thermography has helped evaluate heat generation when preparing abutments for fixed restorations, such as whole ceramic crowns, by comparing different grinding and cutting techniques. In implantology, thermographic assessments have tracked thermal changes in cortical bone during low-speed drilling and evaluated irrigation systems, helping identify factors that contribute to thermal peaks during bone preparation [43]. In removable dentures, early studies in 2010 and 2011 utilized thermography to visualize mucosal changes under prostheses and assess the low thermal resistance of materials used for dentures. Thermograms showed how denture materials retained and reflected the temperature of the supporting mucosa, providing insights into conditions like denture stomatitis and potentially allowing for a non-invasive diagnostic approach for other structural changes in the oral cavity [44-45].

7. Conclusions

Advancements in infrared detector technology have significantly improved the accuracy of thermal imaging as a diagnostic tool in dentistry. Enhanced thermal sensitivity, spatial resolution, and the non-invasive nature of thermography have led to its integration into various dental specialties, including endodontics, odontology, TMJ pathology, periodontics, oral and maxillofacial surgery, prosthodontics, and implantology. Thermal images can be digitally stored and analyzed with specialized software, allowing for more efficient interpretation, particularly when utilizing color-coded thermograms. Compared to traditional diagnostic techniques, infrared thermography offers numerous benefits, such as speed, patient comfort, and the absence of contraindications or side effects. Its capacity for systematic evaluation of disease progression suggests a promising future for thermography as a valuable research and diagnostic tool in periodontal diseases.

Declaration of Conflicting Interest

The authors declare that there is no conflict of interest.

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