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Research Article

Infrared Thermography: A Cutting-Edge Diagnostic Tool with a Focus on Temporomandibular Disorder

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Abstract

Objective: To identify and describe the main applications of thermography in the field of medicine, with an emphasis on its use in temporomandibular dysfunction (TMD).

Methodology: A narrative literature review was conducted, based on the collection and analysis of scientific studies related to the use of thermography in clinical diagnosis, with a particular focus on temporomandibular disorders (TMD). Relevant articles were selected from recognized scientific databases, prioritizing recent studies with high methodological quality Studies published in indexed journals over the past 15 years that provided data on potential adverse effects associated with the use of thermography in medicine were included. Excluded from the review were studies consisting solely of abstracts, conference communications, letters to the editor, non-peer-reviewed monographs from social media, and articles published in languages other than English or Spanish. The search was conducted in the PUBMED, Scielo, and Google Scholar databases. The search terms used included: "Infrared thermography" and "Medical applications", "Thermal imaging" and "Medicine", "Infrared thermography" and "Healthcare", "Medical applications of infrared thermography", "Temporomandibular disorder" and "Infrared Thermography", "Thermography" and "Temporomandibular dysfunction". Fourteen articles that met the study objective and inclusion/exclusion criteria were selected.

Clinical Relevance: The studies analyzed demonstrated that infrared thermography (IRT) has shown great potential in various medical fields. In oncology, it has been used to differentiate melanoma metastases from benign lesions with high specificity. In breast cancer, IRT assisted by CAD and machine learning can detect precancerous areas. In pulmonary surgery, it helps identify intersegmental planes. It is also used to detect thyroid cancer and to study thermoregulation under extreme conditions. In dermatology, it is useful in wound management, infections, and skin diseases. In rheumatology, it allows the assessment of degenerative and inflammatory joint diseases. However, while infrared thermography has demonstrated usefulness in evaluating certain medical conditions, its effectiveness in diagnosing temporomandibular dysfunction (TMD) is limited. Although thermal differences in affected areas have been observed, these are not consistent enough to distinguish TMD patients. The low area under the curve (AUC) in diagnostic tests suggests limited accuracy for TMD diagnosis. Nevertheless, a correlation between muscle pain and temperature changes has been noted, and combining IRT with complementary tests improves its efficacy, indicating that more research and integrated methods are needed to enhance its clinical applicability.

Keywords: Thermography, Clinical Applications, Cancer, Dermatology, Rheumatology, Temporomandibular Dysfunction.

Introduction

Temporomandibular Joint

The stomatognathic system comprises a complex network of anatomical structures responsible for functions such as mouth opening, swallowing, breathing, sucking, and facial expression. This system encompasses the temporomandibular joint (TMJ), the maxilla and mandible, associated muscles and tendons, dental arches, salivary glands, the hyoid bone, and the muscles linking it to the scapula, sternum, and cervical region [1].

The temporomandibular joint (TMJ) is classified as a ginglymoarthrodial joint, formed by the articulation of the mandibular condyle within the glenoid fossa of the temporal bone. Structurally, it functions as a dual-compartment synovial joint separated by an articular disc. This disc is positioned between the condyle and the fossa, contributing to smooth articulation and load distribution. The joint is stabilized laterally by a surrounding ligamentous structure and encased in a capsule filled with synovial fluid, which serves to lubricate the joint and deliver nutrients. In the absence of sufficient synovial fluid, increased friction and shear stress can result in degeneration of the disc. Unlike most joints that feature hyaline cartilage, the TMJ's articular disc is composed of fibrocartilage, providing enhanced resistance to stress. This disc, housed within the capsule which is thicker at its periphery and thinner centrally, plays a crucial role in shock absorption, load management, and allowing complex mandibular movements [2]. The articular disc is anchored to the mandibular condyle anteriorly and posteriorly by ligamentous structures, allowing controlled movement during mandibular dynamics.

Vascular supply to the temporomandibular joint and associated musculature is provided by branches of the maxillary artery and the external carotid artery. The central zone of the disc remains avascular, which has implications for its healing capacity. The disc maintains a flexible attachment to the condyle, functioning in a hinge-like manner during joint activity; however, this mobility may predispose it to positional instability. Anatomically, the disc separates the joint into superior and inferior synovial compartments, each contributing to distinct biomechanical functions. The inferior compartment, composed of the mandibular condyle, supporting ligaments, and the inferior surface of the disc, primarily facilitates rotational mandibular movements [3]. Mandibular opening initiates with rotational movement occurring within the lower compartment of the temporomandibular joint. As the mouth continues to open, translational movement becomes predominant in the upper compartment. During this phase, the articular disc glides along the temporal bone, while the mandibular condyle advances over the articular eminence. The coordinated motion of both the disc and condyle facilitates complete mandibular depression, allowing full mouth opening [3]. Throughout the developmental period, the mandibular growth center resides beneath the fibrocartilaginous layer, rendering it particularly susceptible to injury from pathological influences. Both the articular disc and the mandibular condyle possess the capacity for adaptive remodeling in response to the functional demands of the masticatory system. However, when these demands surpass the individual's physiological tolerance, altered joint biomechanics and excessive mechanical load may contribute to the onset of osteoarthritis or other degenerative joint disorders [4]. The temporomandibular joint (TMJ) is one of the most active joints in the human body, enabling essential functions such as mastication, swallowing, and verbal expression through its extensive range of motion [1,5]. Near 2,000 to 2,500 mandibular movements occur daily, thus any modification of the TMJ may impact its performance capacity and essential functions.

Temporomandibular Disorders

Temporomandibular disorders (TMD) can present in individuals of all ages and genders. Globally, the prevalence ranges from 5% to 12%, although in certain regions it may reach between 21.5% and 50.5% [6], and it is the second most frequent musculoskeletal pathology, after chronic lower back pain [7]. Temporomandibular disorders (TMD) affect between 20% and 60% of children and adolescents, with females showing a higher incidence [8].

Although the etiology of temporomandibular disorders (TMD) remains not fully understood, it is widely accepted to be multifactorial, involving anatomical, pathophysiological, and psychosocial components. Effective management requires careful identification of both predisposing and contributing factors. When clinically feasible, it is essential to distinguish between myogenous TMD, which stems from muscular overload, fatigue, or spasm of the masticatory muscles, and intra-articular TMD, which is associated with mechanical or inflammatory disturbances within the temporomandibular joint itself [9,10].

The predominant cause of temporomandibular disorders (TMD) is dysfunction within the musculoskeletal system. Habitual behaviors like bruxism, teeth grinding, jaw clenching, improper posture, as well as psychological factors such as stress and anxiety, often play a significant role in triggering muscle pain and spasms in the masticatory region [11,12].

Also, cognitive and psychiatric conditions, including depression and anxiety, along with autoimmune diseases, fibromyalgia, and other persistent pain syndromes, are often linked to TMD, suggesting that TMD may be a component of a broader, and complex pain disorder [10].

Causes of TMD within the joint itself involve issues like internal joint displacement, osteoarthritis, inflammation of the joint capsule, excessive joint movement, and injuries due to trauma. Additionally, inflammatory diseases such as rheumatoid arthritis and ankylosing spondylitis may contribute to joint internal derangement [4,13].

Temporomandibular disorders (TMD) do not result from just one cause but emerge from a complex combination of factors, which may involve biochemical alterations, anatomical irregularities, muscle impairments, injuries, genetic variations, hormonal fluctuations, systemic illnesses, and more [14]. Additionally, whiplash injuries have been also linked to TMD onset [14]. Being the incidence of TMD among whiplash patients between 14,1% and 37.6% [15]. Temporomandibular disorders (TMD) do not result from just one cause but emerge from a complex combination of factors, which may involve biochemical alterations, anatomical irregularities, muscle impairments, injuries, genetic variations, hormonal fluctuations, systemic illnesses, and more [14]. Additionally, whiplash injuries have been also linked to TMD onset [14]. Being the incidence of TMD among whiplash patients between 14,1% and 37.6% [15].

High blood pressure and insulin resistance are known to be key health issues that are becoming more common and can affect the development of TMD. Studies show that having high blood pressure can disrupt the body's natural way of controlling pain and might play a role in causing painful TMD. People with TMD often have a stronger reaction to uncomfortable sensations, which suggests that their pain may partly come from problems in how the brain manages pain signals. This process could be affected by their usual blood pressure levels [16]. Evidence shows that hypertension, higher BMI, and reduced average SpO2 levels independently increase the risk of more frequent bruxism episodes [17]. Additionally, it has been suggested that autoimmune and inflammatory disorders can trigger the development of TMD. A small portion of participants (15%) tested positive for ANA/RF in one study [18].

Similarly, a statistical link between TMD and Hashimoto's thyroiditis (HT) has been reported, with muscle pain and stiffness observed in 86.5% of HT patients and disc displacement found in 63.4% [19]. Additionally, Ehlers-Danlos syndrome, particularly the hypermobile type, has been connected to TMD, showing a strong relationship with its symptoms and joint bone changes [20]. Furthermore, genetic factors and congenital blood clotting disorders have also been associated with TMD. Alternatively, Patients with inherited bleeding disorders, particularly hemophilia, are more prone to developing temporomandibular disorders (TMD) than those without such conditions. Common symptoms of TMD include pain and discomfort in the face and jaw area, restricted movement of the TMJ, trouble speaking and chewing, stiffness, ringing in the ears, and clicking or popping noises during mouth movements [21]. Accurate and objective diagnosis of TMD is crucial for effective treatment. When symptoms continue and worsen over time, they can negatively impact a person's quality of life and mental health, potentially aggravating pre-existing conditions like depression, ongoing stress, and anxiety [10,14].

Given the complex and multifactorial nature of temporomandibular disorders (TMD), their origin and progression are best understood through the biopsychosocial model. This framework emphasizes that TMD does not arise from a single cause but rather from the ongoing interplay of various biological, psychological, and social influences. Over time, factors such as genetic predisposition, muscular and joint dysfunction, emotional stress, behavioral habits (like bruxism), and social or environmental stressors can interact and contribute to the onset and persistence of TMD symptoms. This comprehensive model highlights the importance of a holistic approach to both diagnosis and treatment, addressing not only the physical aspects but also the mental and social dimensions of the disorders [22].

Criteria for the Diagnosis of TMD (Temporomandibular Disorders)

Taking into account the bio-social approach, the International Network for Orofacial Pain and Related Disorders Methodology (INFORM) established the diagnostic criteria for TMD in 2014. These criteria are based on a comprehensive approach that uses standardized and validated tools [23].

They are primarily established in the DC/TMD (Diagnostic Criteria for Temporomandibular Disorders), a system that includes both clinical evaluation and the patient's perspective [23]. They can be summarized in the following points:

a) Standardized Medical History: The collection of medical history should be thorough, covering information about symptoms, duration, characteristics of pain, functionality, and relevant medical background [23].

b) Validated Clinical Assessment: A clinical evaluation is conducted that includes specific physical tests to assess the function of the masticatory system, the mobility of the temporomandibular joint, and the presence of pain or dysfunction [23]. Among the available assessment tools, a combination of the 5 classic TMD symptoms (5Ts) from the DC/TMD, the Physical Symptom Scale-8 (PSS-8), and the Patient Health Questionnaire-4 (PHQ-4) provides an efficient way to simultaneously identify TMD, somatic, and psychological symptoms [24].

c) Patient Perspective: The diagnosis should be largely guided by the symptoms reported by the patient, including pain intensity, functional limitation, and impact on quality of life [23].

d) Imaging: It is used only in selected situations where it may influence diagnosis or treatment, such as in cases of trauma or severe joint dysfunction. Magnetic resonance imaging (MRI) is the tool of choice for soft tissues, while cone beam computed tomography (CBCT) is used to assess bony structures [23]. The Diagnostic Criteria for Temporomandibular Disorders (DC/TMD) categorize TMD into two primary groups: (a) conditions associated with pain, such as muscle pain (myalgia), joint pain (arthralgia), and headaches linked to TMD; and (b) joint-related disorders, which involve different forms of disc displacement, degenerative changes in the joint, and joint dislocation or subluxation [25].

TMD is often linked to other long-lasting pain conditions besides headaches, such as fibromyalgia, myofascial pain, and nerve pain in the face that may occur after whiplash injuries [26]. These conditions should be considered when diagnosing TMD, as they can sometimes have similar symptoms. While acute TMD pain usually improves on its own and has a good outcome, chronic TMD pain can lead to ongoing difficulties with daily activities and may be connected to mental health issues. To help evaluate and classify painful TMD, the Graded Chronic Pain Scale (GCPS) is used as a tool that considers both physical and psychological factors [10].

The current standard for treating patients with temporomandibular disorders (TMD) involves a biopsychosocial approach, meaning that care should address physical, neurological, and psychological aspects of the condition [27]. Cognitive-behavioral therapy (CBT) and guided self-management techniques are essential parts of treatment and should always be included, alongside physical rehabilitation. Thus, health professionals are encouraged to combine orthopedic treatments (like physical therapy), neurological strategies, and psychological support. If symptoms persist, second-line treatments may involve medications that help regulate the nervous system. These medications can work by reducing the activity of pain-signaling chemicals or by modifying how nerve cells respond to pain.

In some cases, a temporary oral appliance (like a night guard) may be recommended, typically for short-term use, such as during sleep. Surgery is rarely needed and is reserved only for specific, severe cases where all other treatments have failed [27].

Thermography as a Diagnostic Method

Monitoring body temperature has long been an important part of diagnosing and treating health conditions, dating back to ancient times. In fact, Hippocrates reportedly used wet clay to observe how quickly it dried over swollen areas, helping him identify abnormal heat linked to disease. In a healthy person, skin temperature remains stable under normal environmental conditions and is mainly influenced by blood flow beneath the skin. However, when surface temperature changes, it may signal underlying problems such as inflammation, infection, or tumors. Infrared medical thermography (IRT) is a modern technique that captures images of the skin's temperature patterns. It's a safe, non-invasive, painless, and radiation-free method, making it suitable for repeated use without risk. Thermography helps identify subtle temperature differences that could point to issues in the nervous system, blood vessels, or metabolism. This is done using advanced thermal cameras that are highly sensitive to heat. They detect the infrared radiation naturally emitted by the skin, something the human eye can't see, and convert it into electronic signals. These signals are then transformed into thermograms, which are visual representations of temperature using colors or shades of gray, allowing healthcare professionals to analyze and track changes in body temperature accurately [28].

Infrared thermography can be used in different ways depending on the method of application: active thermography involves measuring temperature changes after applying a heat or cold stimulus; dynamic thermography captures how temperature evolves over a period of time; and passive thermography monitors temperature without any external stimulation [29].

This tool has been used in multiple branches of medicine, including the evaluation of inflammations, diagnosis of vascular diseases, monitoring of oncological treatments, and the surveillance of muscular and bone health. By allowing detailed visualization of thermal differences in the body, thermography offers an efficient way to detect abnormalities related to various medical conditions. It is non-invasive tool, meaning it does not require physical contact with the patient, which is essential to avoid discomfort or risks. Additionally, thermography is a fast technique that provides real-time results, which can be crucial in urgent diagnostic situations or in the continuous monitoring of patients.

Another major advantage is that, being contactless, it avoids exposure to ionizing radiation, as occurs with other imaging diagnostic methods such as X-rays. This makes thermography an attractive option for patients who require constant monitoring or frequent diagnostic methods without additional risks. Therefore, in this work, a narrative review was conducted to identify and describe the main applications of thermography in the field of medicine, with an emphasis on the use of thermography in temporomandibular dysfunction. Throughout the review, the goal is to provide an overview of how this technology has been used in various medical areas and demonstrate its viability in diagnosing TMD. In this regard, the following research questions were raised:

What are the most common medical conditions in which thermography is used?

Is there evidence of the efficacy of this technique in diagnosing temporomandibular dysfunction?

Review Methodology

This work consists of a narrative review of the literature, in which scientific publications addressing the clinical applications of thermography, especially in the context of temporomandibular disorders (TMD), were examined. The selection process prioritized high-quality, methodologically sound studies published in recent years and sourced from reputable academic databases. Studies published in indexed journals that provided data on possible adverse effects related to the use of thermography in medicine over the last 15 years were included. Excluded from the review were works consisting solely of abstracts, conference communications, letters to the editor, non-peer-reviewed monographs on social networks, and articles published in languages other than English or Spanish. The literature review was carried out using the PUBMED, Scielo, and Google Scholar databases. The search formulas were:

1. Infrared Thermography and Medical Applications.
2. Thermal Imaging and Medicine.
3. Infrared Thermography and Healthcare.
4. Medical Applications of Infrared Thermography.
5. Temporomandibular Disorder and Infrared Thermography.
6. Thermography and Temporomandibular Dysfunction.

Fourteen studies that met the objectives and inclusion/exclusion criteria of the work were selected. Their description and discussion were organized by topic according to the aim of the study, as shown below.

Results and Discussion

Applications of thermography in the Field of Medicine Cancer:

Melanomas

In a 2013 study led by Amber L. Shada, MD, researchers investigated the effectiveness of infrared thermography (IR) in distinguishing between cutaneous melanoma metastases and benign skin lesions. The technique relies on detecting variations in skin surface temperature, under the assumption that malignant tumors often have increased blood flow and metabolic activity, making them warmer than non-cancerous tissues. The findings revealed that melanoma metastases consistently showed higher temperatures compared to similar-sized benign lesions. The accuracy of infrared thermography varied depending on the size of the lesion. For small lesions (0–5 mm), the method demonstrated a sensitivity of 39%, meaning it correctly identified a smaller portion of true positives, but it showed a specificity of 100%, meaning it correctly identified all true negatives, no benign lesions were misclassified as malignant. As lesion size increased, both sensitivity and specificity improved notably. For medium- sized lesions (15–30 mm), sensitivity reached 95%, and specificity remained at 100%, making it highly reliable for detecting larger metastases.

The positive predictive value (PPV), the likelihood that a positive thermography result truly indicates melanoma, ranged from 88% to 100%, depending on lesion size. The negative predictive value (NPV), the likelihood that a negative result truly indicates a benign lesion was 95% for medium lesions and 80% for lesions larger than 30 mm. Overall, the study suggests that while IR thermography may have limited sensitivity for very small lesions, it becomes a much more effective diagnostic tool for larger skin abnormalities, offering a non-invasive, radiation-free method to help differentiate between malignant and benign growths [30]. These results were confirmed in a subsequent study by Lese et al. in 2022 [31].

Breast Cancer

A comprehensive review conducted in 2018 analyzed multiple studies focused on digital infrared imaging for medical diagnostics, particularly in breast cancer detection. The researchers highlighted the importance of structured models in processing thermographic data and emphasized that developing reliable computer-aided diagnostic (CAD) systems for interpreting infrared images would not be feasible without incorporating foundational frameworks, such as the widely used hemispherical model, which simulates heat transfer in biological tissues. As part of their investigation, the team performed a comparative evaluation of different breast cancer detection techniques, integrating modern computer vision approaches and deep learning algorithms. Their findings suggested that adopting a computational perspective, specifically through the lens of computer science and artificial intelligence, can significantly enhance the interpretation of thermographic images. This interdisciplinary contribution, combining engineering and medical insights, was seen as a valuable advancement in improving the accuracy and efficiency of infrared-based breast cancer diagnostics [32]. In addition, research work published in 2020 showed that thermography can help detect inflammation and areas that might indicate cancer. Precancerous tissues and the areas around breast cancer tend to be warmer than healthy breast tissue. One big advantage of using thermography is that it can identify these changes even before clear symptoms appear. This approach uses machine learning, which is a type of technology that lets computer programs learn and improve by analyzing data, without needing step-by-step instructions from programmers [33]. Thus, machine learning can help interpret these thermal scans and highlight possible regions that require further investigation by a physician.

Primary Diagnosis of Lung Lesions

Infrared thermography can help during lung surgery, specifically when removing certain parts of the lung, called pulmonary segmentectomy [34]. This surgery requires the surgeon to carefully identify the boundary between the lung segments that need to be removed and the healthy parts that should stay. Because blood flow affects temperature, the team used thermal imaging to spot differences between areas with normal blood flow and those where blood vessels had been tied off (ligated). When the arteries supplying a lung segment are closed, that part of the lung no longer gets blood, causing its temperature to drop compared to the healthy, well-perfused areas. Earlier studies with animal lungs showed that parts without blood flow can be 1.5 to 2°C cooler than parts with normal circulation. In the human study, the researchers found that about three minutes after the blood vessels were tied off, the temperature in those ligated lung areas dropped by over 2.1°C [34]. This temperature difference became even clearer when surgeons inflated the lung before checking the thermal images and waited around five minutes, making it easier to see the exact boundary between the sections. This technique can provide surgeons with a quick, clear way to identify lung segments during surgery, improving accuracy and safety [34].

Primary Diagnosis of Thyroid Lesions

In 2017, a group of Brazilian researchers developed specific protocols to standardize how thermal images of the thyroid gland are captured and processed. These protocols included methods for autonomous registration, which means automatically aligning and organizing the thermal images to ensure consistency and accuracy in analysis [35]. The main goal behind this work was to enhance early detection of thyroid cancer, which is crucial for improving patient outcomes and prognosis. To achieve this, the team focused on analyzing the thermal images through several advanced techniques. This involved extracting important features from the images, such as temperature patterns and variation, using specialized image processing tools. These features help highlight differences between healthy and potentially diseased thyroid tissue. Furthermore, they explored ways to classify patients based on these thermal patterns, distinguishing those with normal thyroids from those who might have abnormalities or cancer. This combination of careful image capture, processing, and classification represents a promising approach to non-invasive screening and diagnosis, potentially allowing earlier and more accurate identification of thyroid problems [35].

Thermoregulation

Also, it has been explored how the human body controls its temperature across various climate conditions by using a model centered on the body's exergy balance, a concept related to energy efficiency in thermoregulation. This approach helped to better understand how the body maintains temperature stability in different environmental settings [36]. This model considers the mutual influence of environmental factors (such as external temperature and humidity) and personal factors (such as individual physiology and physical activity), which affect the body's exergy balance (hBExB). Exergy is a measure of the energy available to do work, and in this context, it refers to the energy the body needs to maintain a stable body temperature and perform its functions. The balance between environmental and personal factors is crucial to determining the conditions in which the body feels healthy, comfortable, and stimulated, which is key for making recommendations about the best conditions for health and well-being. The body's temperature regulation systems are essential for preserving physiological balance both at rest and during physical activity. At rest, the body keeps its internal temperature stable, but physical exercise challenges this balance because it generates heat due to metabolic production (the heat generated as a byproduct of chemical processes occurring in the body during physical activity). This heat overload must be controlled to prevent the body from overheating. Measuring tympanic temperature (that is, the temperature in the ear) using an infrared temperature scanner is one of the techniques used to monitor body temperature. These devices are non-invasive and allow temperature measurement without causing discomfort to the patient. Over the last decade, this measurement method has become increasingly accepted because it allows continuous monitoring of core temperature in outdoor or field environments, which is especially useful in research and situations such as monitoring athletes or patients in extreme temperature conditions [36].

Finally, IR thermography has also become a key tool in the study of thermoregulation, as it allows monitoring of surface body temperatures. Studies have been conducted using thermograms (thermal images) to examine how temperatures are distributed between central areas (such as the torso) and peripheral areas (such as the limbs). A notable example is the analysis of temperature distributions between central and peripheral body parts in extremely low birth weight newborns, who may have difficulty regulating their body temperature efficiently [36].

Dermatological Applications

According to a recent comprehensive review [37], many studies have looked into how infrared thermography (IRT) can be used to help with different skin problems. It has proven very useful for managing wounds, detecting skin infections like cellulitis, identifying blood vessel issues, and spotting deep skin inflammation such as hidradenitis suppurativa. This is because changes in the skin's surface temperature can show important signs of what's happening beneath the skin, helping doctors understand how the disease is progressing. For other skin-related tests and conditions like allergy tests, excessive or reduced sweating, redness and pain in the hands or feet, reactions to cold, and even detecting cancer spread to lymph nodes, using IRT is more complicated. These cases often need extra steps, including special calculations, tests that provoke a reaction, or methods to cool the skin, to get accurate results. This is because these conditions may not present a clear or immediate thermal response that can be detected simply with standard infrared thermography, making it necessary to resort to additional methods for accurate and reliable results [37]. Although the technique is promising, professionals must familiarize themselves with factors that can contribute to false positive and false negative results. These factors include the influence of environmental conditions, the technique used, and individual patient characteristics. Differences in IRT sensitivity and specificity across various conditions can cause confusion if these factors are not properly managed. Despite these challenges, there is sufficient scientific evidence supporting the use of IRT as a complementary tool in clinical evaluation for diagnosis, severity determination, and monitoring of various skin diseases. Infrared thermography offers a non-invasive and efficient tool to monitor thermal changes occurring in the skin, which can be crucial for detecting pathologies at early stages, evaluating treatment response, and performing accurate follow-up during disease progression [37].

Diagnosis of Rheumatic Diseases

A recent review looked at how infrared thermography (IRT) can help evaluate joint diseases caused by inflammation or degeneration. The findings show that IRT is a useful tool for assessing patients with rheumatic conditions, providing important information that can assist in diagnosis and treatment [38]. Another study compared people with different levels of disease activity (high and moderate) to healthy individuals. They measured the temperature of their fingers using infrared thermography under three conditions: at rest, after cooling, and after warming back up. Several temperature-related factors were analyzed, such as the average finger temperature during these phases, how much the temperature changed after cooling and warming, and detailed maps showing how heat was distributed [39].

The study found that patients with high disease activity had distinct thermal patterns. For example, they had a reduced ability to warm their fingers back up after cooling, shown by a smaller area under the warming curve and less difference between warming and cooling phases. They also experienced smaller overall temperature changes compared to those with moderate disease activity [39]. These results suggest that infrared thermography can provide valuable information, especially for patients whose symptoms are unclear or difficult to diagnose just by physical examination. By observing how the body responds to temperature changes, thermography offers additional clues about disease activity that might not be obvious otherwise.

Facial Surface Evaluation

Infrared thermography has been used to map and identify specific temperature zones on the face, helping to understand normal thermal patterns. In a study involving a diverse group of 161 adults aged 26 to 84, detailed thermal images of the face were captured to examine how skin surface temperature varies across different facial regions [40].

The study found consistent thermal patterns in over 95% of the participants, indicating that certain facial areas show distinct temperature differences known as thermal gradients. Notably, temperature variations were influenced by factors such as gender, ethnicity, and medical conditions like toothaches, use of dental prosthetics, and migraine history. However, age and side of the face (right vs. left) did not significantly affect the absolute temperatures in individuals with normal thermal patterns, showing only a minimal difference between the two sides [40]. Specific regions of the face showed higher temperature levels, including the inner corner of the eyes (medial palpebral commissure), corners of the mouth (labial commissure), the temple area, the area above the nose between the eyes (supratrochlear region), and the ear canal. In contrast, areas like the lower corner of the mouth, the outer corner of the eyes, and the folds beside the nose (nasolabial area) showed cooler temperatures [40]. This study is highly relevant in the evaluation of the facial surface, as it establishes a pattern of facial thermal gradients that can be used to identify both normal physiological conditions and possible alterations related to various pathologies. By identifying facial areas with specific thermal gradients, the study facilitates the detection of potential abnormalities in skin temperature, which could be related to medical conditions such as odontalgia (tooth pain), migraines, or the use of dental prostheses. The ability to detect thermal variations on the face can be useful for early and non-invasive identification of health issues. It is important to note that the study establishes a normality pattern in terms of facial temperature, which is crucial for distinguishing between what is considered normal and what could indicate pathology. This pattern can be a valuable resource for various research and clinical applications, proposing a non-invasive tool for continuous monitoring of facial well-being. The ability to identify thermal changes in specific areas of the face could be valuable both for early disease diagnosis and for clinical and aesthetic applications [40].

Use of Thermography in Temporomandibular Dysfunction

The first attempts to use thermographic cameras for diagnosing temporomandibular dysfunction (TMD) were made in the mid-1990s. In these early studies, efforts were made to correlate the temperature of the temporomandibular joint (TMJ) area with the clinical symptoms of patients. This included the thermographic characterization of internal TMJ disorders, diagnosis of TMJ arthralgia, evaluation of asymptomatic TMJ, and degenerative joint diseases [41]. However, due to the limitations of thermal cameras and the procedures available at that time, these studies were more exploratory, aiming to identify the potential of thermography for this type of diagnosis. Current thermography can offer a useful tool to assess inflammation, temperature, and other factors associated with TMD, providing a non-invasive way to monitor and differentiate between different types of dysfunctions in the TMJ. This can improve the accuracy of early diagnosis of this condition and allow better follow-up and treatment of patients affected by TMD [42].

A study highlighting the importance of thermography as a diagnostic tool for identifying patients with temporomandibular dysfunction (TMD) was conducted by Wozniak et al [43]. This study looked at how well thermography works to detect temporomandibular dysfunction (TMD) by measuring its sensitivity, specificity, and overall accuracy. The research involved two groups of young adults: 50 people showing symptoms of TMD and another 50 without any symptoms. Participants' ages ranged roughly from 19 to 25 years old. Each person was interviewed using a standard questionnaire to assess their TMD symptoms, and thermal images of their faces were taken using a specialized camera.

Additionally, the participants performed a 10-minute chewing exercise to see how this affected the temperature measurements. The key finding was that the difference in skin temperature between the right and left sides of the face (called ΔT) was the most useful measurement for diagnosing TMD.

This difference became even more pronounced and helpful after the chewing test. Specifically, temperature differences below 0.26°C before chewing and below 0.52°C after chewing identified 95.5% of people without TMD, showing a high specificity (meaning it was good at ruling out those without the disorder). However, the sensitivity (ability to correctly identify those with TMD) and overall accuracy were moderate [43]. These results suggest that thermography combined with a simple chewing test can improve the ability to detect TMD, especially by confirming who does not have the disorder. Although thermography alone is not completely reliable for diagnosis, it shows promise as a supportive tool to enhance clinical evaluations and guide treatment decisions, underlying its potential as a complementary tool in the diagnosis of TMD, which could facilitate a faster and less invasive evaluation of the condition.

In another blinded cross-sectional study [44], this study clinically explored how the severity of temporomandibular disorder (TMD) relates to skin temperature changes over key facial areas the temporomandibular joints (TMJs), masseter muscles, and anterior temporal muscles. The research included 60 women aged 18 to 40, divided into four groups based on their Fonseca Anamnestic Index (FAI) scores, which categorize TMD severity as none, mild, moderate, or severe (15 participants per group) [44]. Using infrared thermography, skin temperatures were measured at the TMJs and over the muscles involved in jaw movement. Statistical tests showed that skin temperature over both the right and left TMJs was significantly higher in those with more severe TMD symptoms. The correlation between the FAI scores and TMJ skin temperature was weak but statistically meaningful, indicating a consistent link between symptom severity and local temperature increases [44]. Clinically, this means that infrared thermography can serve as a valuable tool in assessing TMD by providing objective temperature data that reflects underlying inflammation or muscle activity around the TMJ. Higher skin temperatures in patients with severe TMD likely represent increased inflammatory processes or muscle tension in the joint area. In practical terms, thermography can complement standard clinical evaluations, which often rely on patient-reported symptoms, by adding measurable physiological information. This can improve diagnostic accuracy and help monitor disease progression or response to treatment, making it a useful addition for clinicians managing TMD patients.

However, another study reported results that differ from the previous ones regarding the effectiveness of thermography in evaluating temporomandibular dysfunction (TMD) [45]. This study aimed to assess patients with and without temporomandibular disorders (TMD) by using infrared thermography to measure differences in thermal radiation. The researchers applied quantitative tests of sensitivity and specificity, examined thermal asymmetry, and explored the relationship between thermal intensity and pain felt during palpation. To achieve this, both clinical and thermographic evaluations were quantitatively analyzed. Participants were divided into two groups based on the Research Diagnostic Criteria for Temporomandibular Disorders (RDC/TMD): a TMD group (45 patients) and a control group (41 individuals without TMD according to the Fonseca Anamnestic Index). Thermal images focused on specific areas the masseter muscle, anterior temporal muscle, and TMJ, and average values from these regions were compared between groups using a receiver operating characteristic (ROC) curve analysis. Additionally, correlations between pain intensity and average temperature were tested, along with associations between temperature asymmetry and pain asymmetry [45]. The results showed no significant differences in mean temperatures, both absolute and relative, between patients with TMD and those without ($p > 0.05$). Interestingly, a negative correlation emerged between pain on palpation and temperature in the masseter muscle, meaning that as pain increased, local temperature tended to decrease [45]. This work highlights an important limitation of this approach: while thermography can provide some physiological information, its sensitivity and specificity are insufficient for confidently diagnosing TMD without complementary clinical assessments.

Conclusions

From the analyzed studies overall, it’s clear that infrared thermography (IRT) offers promising potential as a non-invasive tool to detect physiological changes associated with temporomandibular disorders (TMD) and related conditions. It can highlight temperature differences linked to inflammation or muscular activity, which are relevant for assessing disease severity and monitoring treatment progress. Combining IRT with functional tests, like chewing, appears to improve diagnostic accuracy by revealing dynamic thermal changes.

However, the evidence also consistently shows important limitations. Thermography alone often lacks sufficient sensitivity and specificity to reliably differentiate between TMD patients and healthy individuals. The thermal patterns can be influenced by many factors, such as individual variability, environmental conditions, or the complex nature of pain, hat reduce its diagnostic precision.

Additionally, correlations between pain and temperature are sometimes weak or inconsistent, suggesting that thermal imaging should not replace traditional clinical examinations but rather serve as a complementary tool.

Therefore, although infrared thermography shows some potential for diagnosing TMD, studies suggest that further research is needed to better understand the relationship between thermal differences and the severity of dysfunction. Additionally, better ways to combine thermography with other clinical and diagnostic tests should be explored to improve its applicability in the treatment and management of patients with TMD.

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