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The use of thermovision in the detection of asymptomatic facial inflammation – Pilot study

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Abstract

Introduction: Asymptomatic inflammatory foci resulting from chronic dental infections or the presence of foreign bodies, e.g., in the sinuses, leading to serious local and systemic complications. These conditions, despite the absence of symptoms, are a source of bacterial, toxic, allergic, and neurogenic effects. Despite the developed radiological diagnostics in the form of pantomographic images and cone beam computed tomography (CBCT), thermal imaging is increasingly mentioned as an auxiliary tool in detecting and treating inflammatory foci of the craniofacial region. It is due that thermal imaging can bring indirectly metabolic information about studied tissues and thus allow the detection of early inflammatory lesions yet not invisible on X-ray diagnostics. The purpose of the study was to apply and validate a protocol for identifying asymptomatic inflammatory foci in the maxillofacial area using thermal imaging.

Material and methods: Patients referred to the institute were examined for the presence of inflammatory foci. Analysis of radiographs revealed asymptomatic foci in the maxillary sinus, which were associated with the presence of a displaced foreign body. Thermographic examinations were performed using a FLIR T540 thermal imaging camera.

Results: The obtained results showed a significant temperature difference between the suspected and opposite sinus. It was also confirmed that after the foreign body was removed from the sinus the temperature showed a dynamic decrease in time.

Conclusions: According to the study, thermography has the potential to become an essential diagnostic tool for inflammation of odontogenic origin. It offers non-invasiveness, safety, real-time imaging, painless and completely safe.

Keywords: thermography; dentistry; maxillary sinus.

Introduction

The thermovision is a non-invasive, non-contact method of measuring the temperature distribution on a body surface. Nowadays, thermography is used in a wide range of scientific fields. In medicine, thermography is used in oncology, sports medicine, as well as in dentistry.[1-8] The use of the thermovision camera in dentistry is extensive, as evidenced by numerous international publications. Of particular note is the use of thermographic imaging in the diagnosis of inflammation of the maxillary sinus.[2]

The development of the paranasal sinuses begins in the 3rd to 4th month of fetal life.[10] Anatomically, the maxillary sinus is the largest of the sinuses located in the middle part of the skull, lateral to the nose. It has a natural outlet that connects to the middle nasal meatus. It is formed by 5 walls - anterior, posterior, superior, floor and medial.[11] There is no lateral wall.

The absence of pathological conditions within the maxillary sinus is very important for the normal functioning of the human body. The air passing through this structure is heated and saturated with water vapour. The lining consists of a mucous membrane covered by a migrating epithelium, so that the air is also purified. The maxillary sinus, a natural space, is a resonator for the voice, giving it sound and colour.[10-11] It is physiological to have the roots of molars, premolars and even canines in the lumen of the maxillary sinus.[12] Periapical lesions in these teeth require endodontic treatment. One of the complications of such treatment is the extrusion of root canal filling material. This most commonly involves gutta-percha and sealant. Consequently, this leads to dentoalveolar sinusitis.[13]

Surgical treatment (tooth extraction), periodontal and pulp inflammatory lesions can also be mentioned in the aetiology of this condition.[14]

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Authors' contribution:
A – Research concept and design, B – Collection and/or assembly of data, C – Data analysis and interpretation, D – Writing the article, E – Critical revision of the article, F – Final approval of the article.

Diagnosis of foreign bodies in the sinuses is based on case history, clinical examination and interpretation of radiographic studies (OPG/CBCT). Despite the developed radiological diagnostics in the form of pantomographic images and cone beam computed tomography (CBCT), thermal imaging is increasingly mentioned as an auxiliary tool in detecting and treating inflammatory foci of the craniofacial region. It is due that thermal imaging can bring indirectly metabolic information about studied tissues and thus allow the detection of early inflammatory lesions yet not invisible on X-ray diagnostics. Such images may give some additional information for maxillofacial surgeon to prepare the procedure plan.

The most common treatment is the Caldwell-Luc procedure, which involves making an osteotomy in the front wall of the maxillary sinus. This allows the surgeon to access the sinus and remove the inflamed mucosa and foreign body. This procedure is highly invasive, and an alternative modern treatment is functional endoscopic sinus surgery (FESS). Using endoscopy, we can perform the surgery intranasally, which is less traumatic for the patient.

Materials and Methods

The measurements occurred at the Outpatient Clinic of Maxillofacial Surgery of the SUM in Katowice. The study was approved by the Ethical Committee of the Silesian Medical University (approval number PCN/CBN/0052/KB1/67/I/22). The research group consisted of 6 patients with foreign bodies detected in the sinus. The control group consisted of 6 healthy (i.e., without concomitant disease) volunteers who underwent thermal imaging of the maxillary sinus. Each patient had two follow-up examinations, after removal of the foreign body. The whole patient group included in the trial were diagnosed with dental pathology based on clinical and radiographic examination.

All qualified subjects are adults, of both sexes, with a diagnosed good general condition. The patients were examined, after 30 seconds, from the opening of the mouth according to a procedure that was developed in the paper "Is Thermal Imaging a Helpful Tool in Diagnosis of Asymptomatic Odontogenic Infection Foci-A Pilot Study".[2] Qualified patients underwent a radiological examination, through which we visualized the nasal sinuses. The measurements were conducted using a FLIR Systems T540 thermal imaging camera. The room temperature where the measurements were taken was a stable 23 ± 1 [°C], and the humidity was 50%. The skin emissivity was set at 0.98. The distance from the thermal imaging camera to the patient was 0.4±0.05 m, according to the guidelines for thermal imaging diagnostics in medicine. Patients waited about 20 minutes to acclimatize to the ambient temperature before performing the test.[15] During this time, physical activity should be reduced to a minimum. Several hours, before the measurements were taken, patients were advised not to consume hot drinks and meals. Patients were asked to take a sitting position, then the head was immobilized and the mouth was opened. Patients were asked to rinse their mouths for about 1 minute. The measurements taken include the maxillary sinus area. The thermal image included the sinus with the foreign body and the sinus on the opposite side, which was used for temperature comparison. Thermal images were analyzed in ThermaCAM Researcher Pro 2.10, in which areas of interest were selected. The ROI (Region of Interest) was determined by a maxillofacial surgeon based on X-ray images and their experience.

The ROI connected with the maxillary sinus was placed from the periapical area above the tooth till the connection of the internal chick skin to the gum.

These areas included the area of the maxillary sinus with foreign bodies ($T_{surgical}$) and the area of the sinus on the opposite side ($T_{healthy}$). From the areas, lesions were read to the average temperature, which was always calculated as the average of all pixels in the selected area.

The temperature difference (DT) was calculated as the average temperature difference between the ROI where the foreign object has been removed ($T_{surgical}$) and the opposite healthy site without any procedure($T_{healthy}$), $DT = T_{surgical} - T_{healthy}$

Statistical calculations were performed in MS Office Excel 2022 and Statistica 10.

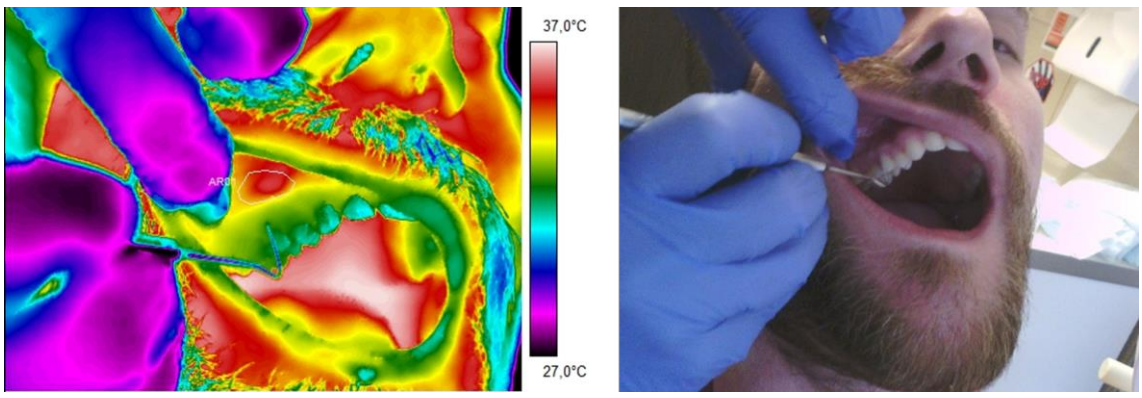


Figure 1. Thermal image and digital picture illustrating the scheme of maxillary sinus area marking.

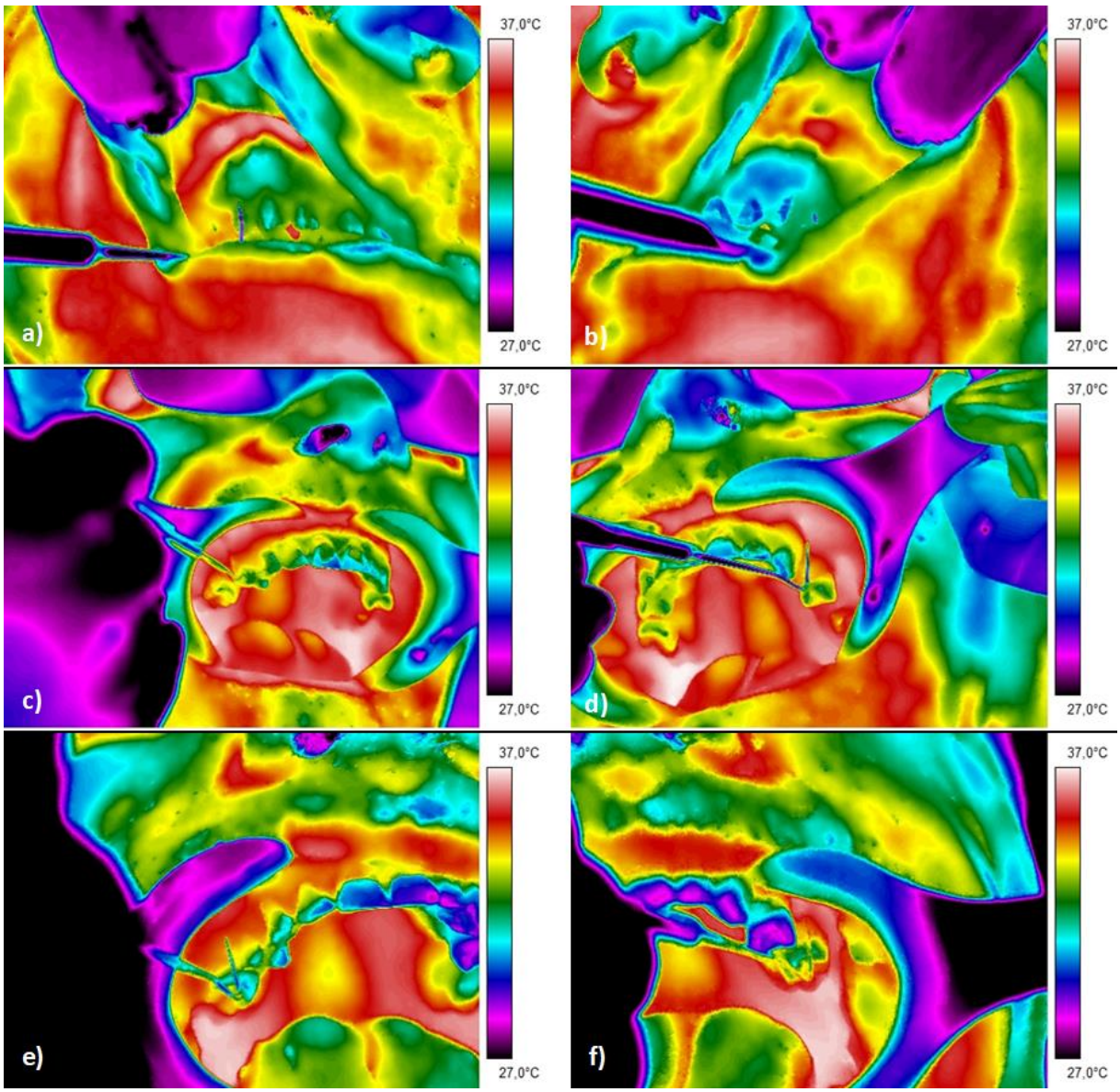


Figure 2. The representative thermal images of patient who had two follow-up examinations performed, where: a) Thermal image before the first examination. Left sinus with a foreign body. b) Control thermal image of the right maxillary sinus. c) Thermal image after 1 month after procedure. Left sinus from which the foreign body has been removed. d) Control thermal image of the right maxillary sinus taken one month after the procedure in the left sinus. e) Thermal image at the third examination – 2 months after the procedure. Left sinus from which the foreign body has been removed. f) Control thermal image of the right maxillary sinus taken two months after the procedure in the left sinus.

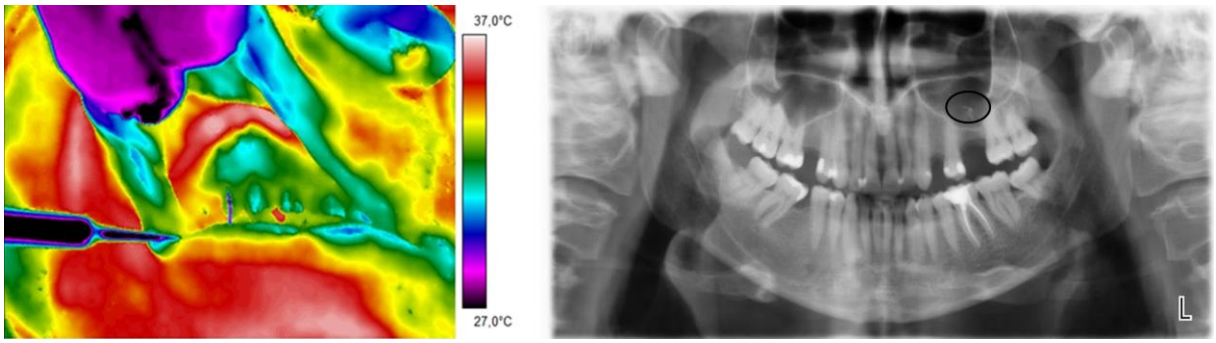


Figure 3. Comparison of a thermal image and a pantomogram showing a foreign body in the maxillary sinus.

Results

Figure 2 shows thermal images obtained for the patient for whom the greatest difference was observed 30 seconds after opening the mouth. Thermograms of healthy opposing maxillary sinuses were obtained in the same manner. The greatest temperature differences over time are shown in **Figure 4**. The thermal images were taken before treatment (surgical removing the foreign object) and 1 and 2 months after the procedure.

The first and second temperature parameters indicated an elevated temperature opposite to the last measurement which indicated the absence of inflammation. It was taken two months after the removal of the foreign body from the left sinus.

The Mann - Whitney U test showed significant differences between the absolute values of the mean temperatures of the maxillary sinus regions with foreign bodies and their opposite (**Figure 5**).

The median of absolute values of the mean temperatures of the maxillary sinus regions with foreign bodies was significantly higher than the contralateral with $p < 0.05$. The corresponding absolute values were 0.2 and 0 for the patients and control groups, respectively.

Discussion

Scientific studies indicate a growing interest in modern diagnostic and therapeutic methods, of which thermal imaging is certainly one.[2,5-7] This method is becoming increasingly popular, including the dental specialty. Conventional radiological diagnostics for dentoalveolar sinusitis, i.e. orthopantomography and cone beam computed tomography, seem to have certain disadvantages due to ionizing radiation compared to the thermal imaging camera. It should be noted that X-ray imaging cannot be replaced by thermal imaging but can bring additional data and thus improve the patient's diagnosis so the further treatment process, due to functional information about the metabolic activity of examined tissues. Thermal imaging is a completely safe method and does not use any ionizing radiation so does not require a heavy lead apron and can therefore be performed on elderly patients and young children. In addition, thermal imaging is completely safe for pregnant women at any stage of pregnancy. The small size and portability of the thermal imaging camera mean that it can be used anywhere - for example, on patients who are lying down. Another argument in favor of thermal imaging is accessibility, finance and maintenance. However, the correct use of such a camera requires professional staff and training as well as quality assurance what can do medical physicist. Appropriate measurement conditions (room temperature or patient acclimatization) should always be maintained. Today's thermal imaging cameras are very sensitive to temperature change, so they can detect a temperature change of 0.02 °C. As a result, we can expect the most accurate images we care about when examining a patient. Thermal imaging, as we can read in many literatures, provides valuable insights into metabolism and its dynamic changes over time, which have been associated with various pathologies.[5-6,16]

The study aimed to develop a non-invasive diagnostic test for patients with foreign bodies in the maxillary sinuses. We were assisted by a protocol from the paper "Is Thermal Imaging a Helpful Tool in Diagnosis of Asymptomatic Odontogenic Infection Foci-A Pilot Study" in which it was shown that the greatest temperature difference between the periapical area of suspected and contralateral healthy teeth occurs 30 seconds after opening the mouth.[2]

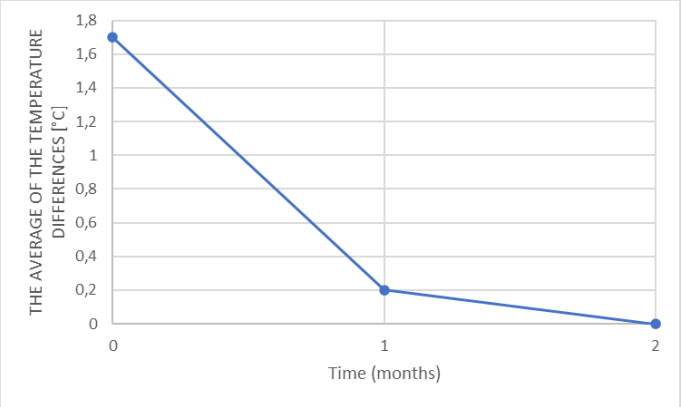


Figure 4. Mean temperature differences in the maxillary sinus and contralateral sinus regions measured before (0) treatment (surgical removing the foreign object) and 1 and 2 months after the procedure.

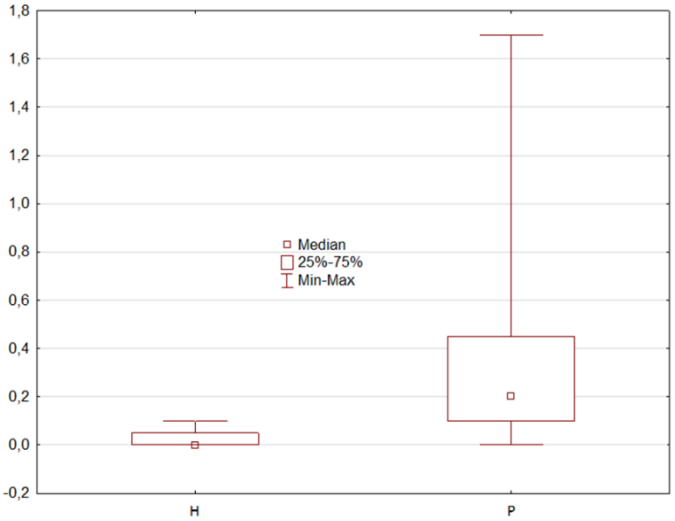


Figure 5. Box and whisker plot - absolute values of mean temperature differences of maxillary sinus area with foreign bodies and their opposite site, where DT was calculated as the average temperature difference between the ROI where the foreign object has been removed and opposite healthy site without any procedure; P – patients and H control group (healthy).

Modern dentistry is increasingly using equally tomography, and X-ray however, both techniques determine mainly structural changes. However, it is still a structural evaluation and does not provide a parametric assessment of metabolic changes, which is only available with the complementary use of thermal imaging - thermal imaging. The use of both diagnostic techniques makes it possible to compare the images obtained (**Figure 3**), so that the doctor is in possession of accurate information about the situation of bone structures and foreign bodies, as well as the location of soft tissues and their level of metabolism as well as inflammation, so that he can be sure that the planned procedure will be successful. In addition, the use, as in the present study, of thermography in the evaluation of the effects of such surgical treatment gives parametric information about the metabolic state of the tissues that we cannot obtain when using only X-ray.

This study aimed to develop a research method that could serve oral health professionals who use infrared thermal imaging cameras for intraoral diagnosis. It should be noted that the presented and discussed results were just a pilot study and that there will be an expansion of the study in the near future. With a larger study group, it will be able to identify body temperature trends and their meaning in the prediction of therapy effects. Thermography, being a non-invasive diagnostic method, is suited as a tool to support the field of dentistry. The handiness, mobility, lack of ionizing radiation and affordability of a thermal imaging camera make it an ideal tool for the dentist. Its ease of operation and technique for developing thermograms means that this method may become fully automated in dentistry and all medicine in the future, especially when the standard protocols of use and artificial intelligence are introduced. It is possible due to many different indirect metabolism information given on the thermal images connected with blood flow, inflammatory state changes, and proper extracellular matrix rebuilding can be read.

Conclusions

The findings from this study present promising evidence supporting the potential utility of thermography in diagnosing foreign bodies within the maxillary sinus. Furthermore, it was observed that following the successful removal of the foreign body, study tissue temperature normalization has occurred in time.

The statistical significance of the measurements strengthens the validity of using thermography as a non-invasive and painless complement to conventional diagnostic approaches. Therefore, with its safety and ease of implementation, thermography emerges as a valuable adjunctive method in the diagnostic armamentarium for maxillary sinus foreign body detection and monitoring.

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