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COMPARATIVE STUDY OF DIGITAL THERMOMETRY AND INFRARED THERMOGRAPHY FOR TEMPERATURE MEASUREMENT IN A PRIVATE DENTAL SERVICE – PILOT STUDY

ACURÁCIA DA TERMOMETRIA DIGITAL E TERMOGRAFIA INFRAVERMELHA PARA A AFERIÇÃO DA TEMPERATURA EM UM SERVIÇO DE ODONTOLOGIA PRIVADO - ESTUDO PILOTO

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Uniterms:

Thermography; thermometers; body temperature; skin temperature; covid-19.

ABSTRACT

Purpose: The purpose of this study was to analyze the temperatures measured through conventional digital thermometry and infrared thermography comparatively, in a group of patients from a private dental health service. **Materials and methods:** A convenience retrospective sample of 25 female patients, were submitted to temperature recordings using thermograms of the brain thermal tunnel (BTT) and frontal region, and digital thermometry in the frontal region. The data obtained from the two anatomical sites evaluated were statistically analyzed to create a temperature dispersion graph. **Results:** It was observed that the mean temperature measured with the digital thermometry was 36.3ºC with a standard deviation of ±0.60, and was the one that presented the highest value in relation to Infrared Thermography, as well as less variation of average individual temperatures($p<0.05$). **Final considerations:** Digital thermometry showed low specificity, while Infrared Thermography proved to be a tool with greater sensitivity for measuring body temperature, especially in the BTT region.

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Unitermos:

Termografia; termometrôs; temperatura corporal; covid-19.

RESUMO

Objetivo: O objetivo deste estudo foi analisar comparativamente as temperaturas medidas por termometria digital convencional e termografia infravermelha, em um grupo de pacientes de um serviço odontológico privado. **Materiais e Métodos:** Uma amostra retrospectiva de conveniência de 25 pacientes do sexo feminino, foram submetidas a registros de temperatura usando termogramas do túnel térmico cerebral (TBT) e região frontal, e termometria digital da região frontal. Os dados obtidos nos dois sítios anatômicos avaliados foram analisados estatisticamente para criar um gráfico de dispersão de temperatura. **Resultados:** Observou-se que a temperatura média aferida com a termometria digital foi de 36,3ºC com desvio padrão de ±0,60, sendo a que apresentou maior valor em relação à Termografia Infravermelha, bem como menor variação das temperaturas médias individuais (p<0,05). **Considerações finais:** A termometria digital apresentou baixa especificidade, enquanto a termografia infravermelha mostrou-se uma ferramenta com maior sensibilidade para mensuração da temperatura corporal, principalmente na região do BTT.

INTRODUCTION

The emergence of the COVID-19 pandemic became an emerging threat to health and the global economy[1]. Among the many initial signs that may compose the clinical overview of SARS-Cov-2 infection, it is possible to mention fever, dry cough, nasal congestion and diarrhea, in addition to symptoms such as sore throat, headache and fatigue[2,3]. Particularly, fever is a common symptom to COVID-19 and many other infections that compromise the airways, such as severe acute respiratory syndrome (SARS), Influenza (H1N1), Ebola Hemorrhagic Fever, among others[4]. Since the global scenario facing such biological challenges, containment measures were adopted for the progression of such diseases, especially COVID-19. More accurate body temperature measurement methods have been widely used in educational centers, malls, offices, supermarkets, hospitals, and other workplaces in order to identify increased body temperature in likely infected individuals [5-6].

For measuring temperature during COVID-19, the main methods widely been used were digital non-contact infrared thermometers (NCITS) and infrared thermography (IRT) cameras[7]. NCITS are portable devices which measure just one heat point (one pixel) of the evaluated surface (in this case is the human skin) exhibiting its value on the display. Generally, they have the Color Glow system, which emits colors on the display to alert whether or not there is a feverish state. Also, they measure the temperature on the surface of the skin, and as a rule, such light lock is applied in the frontal region or anatomical site close to the temporal artery[8, 9]. However, when compared to other methods that use temperature to identify potentially infected individuals, they presented a new potential error due to the emissivity of skin surface depending on environmental factors such as direct sunlight, ambient temperature, and the correct equipment utilization[10].

IRT is a method able to assess the temperature of an object or body over to absolute zero by capturing the emitted infrared radiation, and thus also provides information about skin's surface temperature. This technique has been widely used due to its ability to monitor mass population temperature and to be contactless and non-invasive[11]. Besides, it allows the identification of the probable anatomical site of dysfunctions such as neuropathies, microangiopathies, osteo-articular dysfunctions and many other organic disorders[12-16].

The identification of the real brain temperature may be obtained through the study of Brain-eyelid Thermal Tunnel (BTT), which represents a link between skin and the cavernous sinus around the hypothalamic thermoregulatory center that transfers brain thermal energy to the skin surface via a thermophysical pathway[17]. Since it reflects the intracranial temperature, this channel is not directly influenced by exogenous factors. Thus, it has been shown to be a more accurate noninvasive method for measuring human brain temperature, since this is unimpeded by the body´s thermal barrier through transorbital thermophysical configurations.

This pilot study aimed to analyze the temperatures measured using conventional digital thermometry and infrared thermography comparatively in patients from a private health service.

MATERIAL AND METHODS

This was a retrospective and cross-sectional study, approved by the Ethics and Research Committee on Human Beings of the Bahiana School of Medicine and Public Health, under protocol number (4,333,341). All volunteers signed the Free and Informed Consent Term prior to taking part in the study.

To calculate the sample size, the *GPower* (Universitat Kiel, Germany) was used, with α=5%, power of 80 % and effect size of 0.25, increased by 20% in case of eventual participants withdrawal. The sample comprised 25 female patients from a private dental clinic, through free demand who previously participated in a facial thermographic analysis study. These thermographic records were obtained before the dental procedures and recorded in their clinical archives (18).

Firstly, patients underwent a detailed anamnesis to confirm and assure that they all met the study inclusion criteria. Patients considered eligible were those whose age was between 45 and 55 years old, without comorbidities and who were willing to participate in the research by signing the informed consent form. Breast-feeding patients, pregnant women, carriers of autoimmune and infectious-contagious diseases were not included, as well as smokers and those with a thermal asymmetry greater than or equal to 0.3º (Δt≥0.3º) in the Regions of Interest (ROIs) corresponding to the front region and to the BTT.

Initially, digital thermometry was performed using the device Smart sensor (HF120 NO:03086488, São Paulo, Brazil). The registered temperature was described in the medical record, which had the center of the frontal region as the standard anatomical reference point.

It was also done two thermograms corresponding to the basal temperature of the BTT and the other related to the center of the frontal region, both represented by Figure 1. The basal temperature of the participants was measured with an infrared camera from the brand FLIR ONE Pro (Victoria, Australia) by using 160×120 pixels resolution, accuracy of +/- 3% and 8.7 Hz frame rate that captures images in real time. The equipment ranges from -20°C to 400°C temperature and has a thermal sensitivity (MRDT) of 150mK. Also, it acts in the spectral range of electromagnetic waves between 8 and 14 μ m, corresponding to a far infrared range.

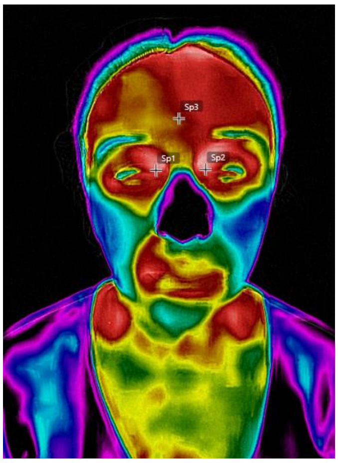


Figure 1 – *Regions of Interest (ROIs) identified in termogram where Sp1 and S2 represent brain thermal tunnel (rigtht and left sides, respectively) and Sp3 indicates the center of frontal region near to supratrochlear e supraorbital artheries.*

Initial temperature measurements were taken in the morning in order to standardize the influence of circadian cycle on body temperature throughout the day.

For capturing the thermal images, the following protocol was adopted: patients positioned in the dental chair, with the Frankfurt horizontal plane. The camera was placed on a tripod, with height and distance from the volunteer's face of 1 m. Frontal facial thermal image captures were taken with a thermal range of 28º to 37°C. Regarding environment’s temperature, it was controlled by a thermohygrometer around 22°C ± 1°C whereas humidity was settled with a maximum of 60%. To avert thermal changes, any sources of air convection that would directly reach the participants were avoided.

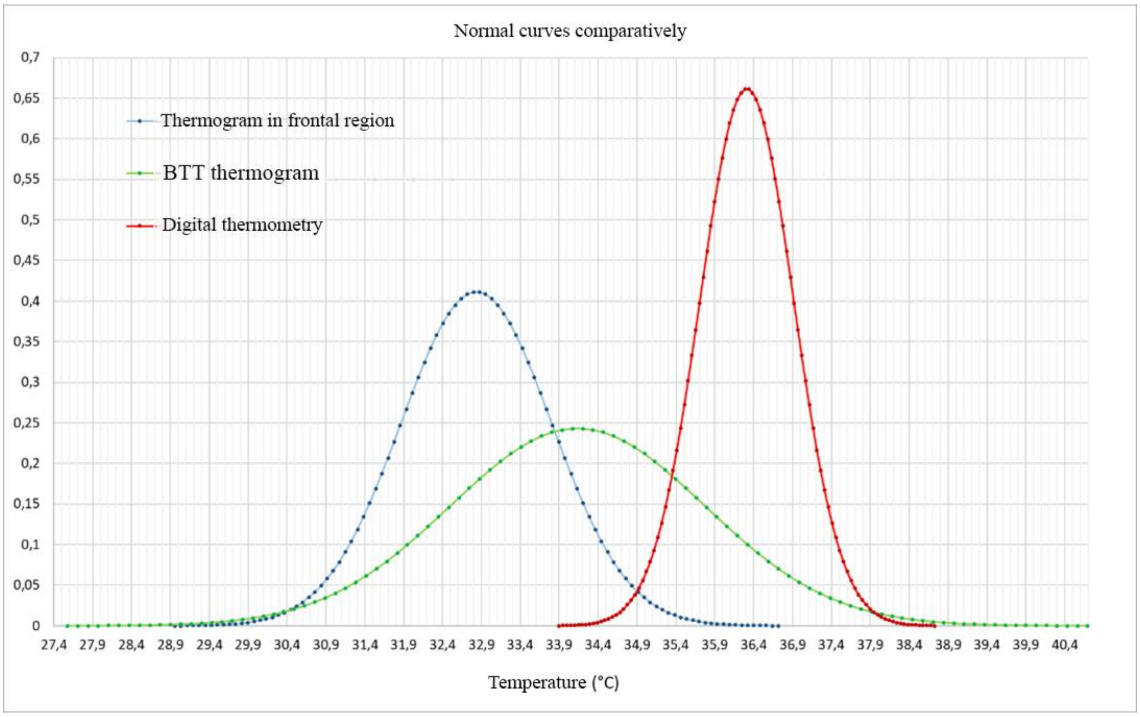
All temperature records were reported in an EXCEL spreadsheet (Windows-10 version 21H2). Data obtained from the two anatomical sites evaluated were statistically analyzed.

For statistical analysis, the ANOVA test was applied to verify the normality of data distribution and the means and medians were obtained with the respective standard deviations and quartiles of the temperature variable. The significance level was 5%.

RESULTS

Graphic 1 represents the Gaussian curves with the temperature values obtained through the frontal region and BTT thermograms, as well as those temperature values of frontal region taken from the digital thermometer. It was noticed that the curve regarding to BTT showed a higher level of flattening in comparison to the others. The curve corresponding to the temperatures measured with the digital thermometer in the frontal region showed a lower dispersion level as well as that calculated from the thermographic records in the same anatomical region.

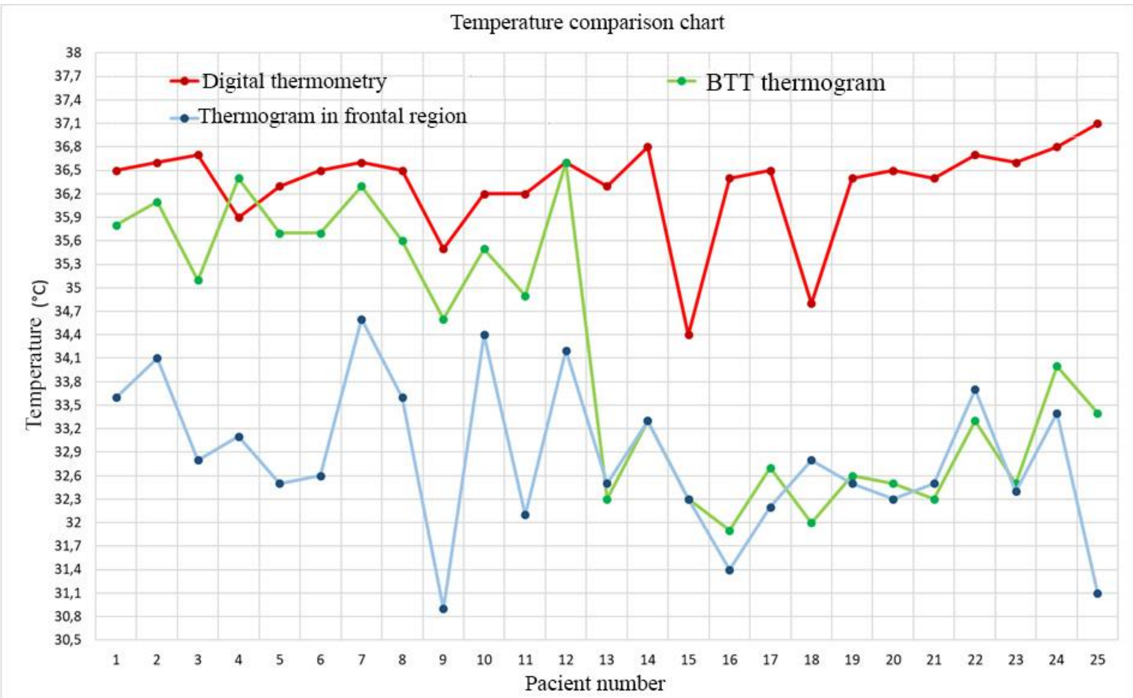
Graphic *1–Gaussian curve with data obtained through the two temperature measurement methods.*



Source: Own authorship.

Additionally, graph 2 illustrates the distribution of individual temperatures of each study participant.

Graphic *2: Average temperature individually obtained from each patient 2.*



Source: Own authorship.

The mean temperature obtained through the digital thermometer in the frontal region was higher than that observed in thermograms and corresponded to 36.31^{0}C (± 0.60). The thermograms corresponding to the BTT and the frontal region reported an average temperature of 34.14ºC (± 1.6) and 32.84ºC (± 0.96), respectively. In addition, descriptive analyzes (median and quartiles) were also performed aiming of identifying the general and specific characteristics of the studied sample. The median temperature obtained through the digital thermometer in the frontal region was larger than that observed in thermograms and corresponded to 36.5^{O}C (36.3- 36.6). The thermograms corresponding to the BTT and the frontal region respectively showed median of 34ºC (32.5-35.7) and 32.6ºC (32.3-33.6). Such differences were statistically significant ($p > 0.05$); (Table 1).

Table 1: *Record of averages and median temperature from the measurement methods, with their respective standard deviations and interquartile intervals*.

Measurement method	Mean	SD	Median	Quartiles
Digital thermometer of frontal region	36.31*	±0.60	36.5*	36.3-36.6
Thermographic image of the BTT	34.13*	±1.60	34.0*	32.5- 35.7
Thermographic image of frontal region	32.83*	±0,96	32.6 *	32.6 -33.6

*ANOVA ($p<0.05$)

DISCUSSION

Severe acute respiratory syndrome (SARS) resulting from SARS-Cov-2 (COVID19) infection brought up an urgency in global health and economy (19), then, several safety protocols have been developed aiming to reducing and/or controlling spread of the virus. Such protocols mainly monitored the common symptoms of the disease such as sore throat, nasal congestion, headache and fatigue, in addition to signs such as dry cough, diarrhea and especially fever[20-21]. Infrared Thermography (IRT) and digital thermometers were the most common methods used for measuring body temperature during COVID-19[22]. Thus, the present study aimed to comparatively evaluate the assessment of temperatures in different ROIs using such methods.

In the present pilot study, it was revisited clinical records containing temperature records obtained through thermograms and digital thermometry of a sample of 25 patients who participated in a previous survey of facial temperatures using IRT. Sample was considered as convenience since the patients were selected based on the availability criterion, without statistical criteria. Thus, the number of participants may be considered small to describe the accuracy of thermography and thermometry methods when compared to other studies, but it can be used to compare the results obtained from these two methods[23]. As a matter of fact, the authors suggest to expand this sample in further studies to compare results in larger populations and perform accuracy tests between both methods of measuring temperature.

Furthermore, as a way of reducing variability in the results, all participants were selected because they were female and were close in age, which ranged from 45 to 55 years. According to Geneva et al., 2019, it is known that women have a comparably larger percentage of body fat distribution subcutaneously, which in turn correlates with lower average skin temperatures[24]. Age also represents a variable to be considered once elderly individuals tend to have a reduction in body temperature when compared to young adults, due to factors such as a reduction in the basal metabolic rate and a decline in ability to regulate body temperature[25]. In addition, there are other factors which modify the thermographic images such as wrinkles caused by the migration of adipose tissue and facial atrophy resulting from aging process. It generates hyperradiant areas in the thermographic measurement and other variables such as follicle, beard and hair, which show hyporradiant areas in the image obtained by the thermographic camera, generating thermal instability[26]. These variables were considered for determining the inclusion criteria of participants in this study. NCITS is still considered an affordable, non-invasive, fast, portable and convenient method for measuring body temperature when used in the frontal region or in the surroundings of the temporal artery. Due to these advantages, digital thermometry is a great option to reduce risk of dissemination during pandemics besides being effective for monitoring the temperature of large groups[27]. Digital thermometer assesses the infrared radiation energy on the surface of the skin from a pixel of the evaluated surface, however a limitation of this method is that surface of the skin may have a difference of some ºC for the real body temperature[28]. More, it is a sensitive method to environmental variables such as cold or windy environments, incidence of direct light on the evaluated surface and the correct use of the equipment using the inclination, positioning indicated by the manufacturers and the distance from the device to the body or object evaluated. In the use of NCITS, it is difficult to obtain an equipment that confirms its proper functioning, as well as references to confirm whether the indicated temperatures actually correspond to reality [29,30,31].

From the data obtained in this research through the measurement of the temperature in the frontal region using the infrared non-contact digital thermometer, it was possible to notice that there was a smaller level of dispersion of the mean temperatures in comparison to the temperatures indicated by the IRT. Also, the average of the temperatures measured by digital thermometry in the frontal region was significantly higher in relation to the averages obtained through the thermograms of the BTT and the frontal region. So, it may be suggested that the flatter temperature curve for BTT seems to indicate greater individual variability as well as greater sensitivity of the IRT in capturing a temperature in an anatomical site that reflects the actual brain temperature. The greater sensitivity of IRT can be explained due to the specifications described by the manufacturer of the infrared camera, which overcome those described in digital thermometry in terms of quality and quantity.

Infrared cameras emerged in the 1960s as a military equipment developed by the US Army for monitoring heat patterns and nighttime monitoring.[32] However, this technology was quickly expanded for use in different areas such as engineering, medicine, veterinary medicine and ecology. It has advantages similar to digital thermometers as portability, friendly usability, and since it is a non-invasive method, does not require contact with the skin what makes it an alternative for temperature monitoring in epidemic outbreaks. Among some advantages such the possibility of calibrating the camera, which is not present in digital thermometers[33,34]. The camera reflects a heat map in real time of both evaluated object and the environment for comparison. Also, it provides the evaluation of structures such as the Brain Thermal Tunnel (BTT), which most faithfully represents the intracranial temperature once it is not influenced by exogenous factors. However, the greatest limitation to its use in everyday clinical practice is the high cost of the initial investment for acquiring the equipment, as well as the need of technical qualification from the evaluator.

Based on the evaluation of other studies that have also compared digital thermometers with the IRT, as in Abreu et al., (2020)[35]. The mean temperature assessed in the frontal region with NCITS was lower 1.07±0.49°C (mean±SD) than in BTT (p=0.008, two-tailed paired t-test). In our study, it was observed the opposite. According to these authors, their results could be explained by the low thermal conductivity of the adipose tissue layer and possible variations in the thickness between patients' dermis. Although this region is also irrigated by the superficial temporal artery and other smaller vessels that run parallelly and superficially to the skin in the frontal region. Also, thermal variation can be related to patient's emotional state and environmental change. When the frontal temperature was measured using the IRT, there was an average difference of 2ºC compared to tympanic thermometer used to assess the core temperature. In the present study, the frontal temperature measured by digital thermometers was higher when compared to other methods including IRT of the frontal region. This fact may indicate the low specificity of digital thermometers for assessing temperature, while measurements in the BTT region with thermographic cameras reflects core temperature more precisely[36].

CONCLUSION

Finally, NCITS are non-invasive, contactless and low-cost technologies able to quickly measure skin surface temperature, but have low specificity when assessing in frontal or radial regions. By the other side, IRT which is also non-invasive, proved to be a more sensitive and accurate method for measuring core temperature, especially that one indicated by BTT. Thus, both methods can be used as complementary exams for screening patients with suspected diseases that have fever as one of the main symptoms of COVID-19.

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