Thermography Evaluation on Facial Temperature Recovery after Elastic Gum

A. Dionísio, L. Roseiro, J. Fonseca, P. Nicolau

Abstract**—**Thermography is a non-radiating and contact-free technology which can be used to monitor skin temperature. The efficiency and safety of thermography technology make it a useful tool for detecting and locating thermal changes in skin surface, characterized by increases or decreases in temperature. This work intends to be a contribution for the use of thermography as a methodology for evaluation of skin temperature in the context of orofacial biomechanics. The study aims to identify the oscillations of skin temperature in the left and right hemiface regions of the masseter muscle, during and after thermal stimulus, and estimate the time required to restore the initial temperature after the application of the stimulus. Using a FLIR T430sc camera, a data acquisition protocol was followed with a group of eight volunteers, aged between 22 and 27 years. The tests were performed in a controlled environment with the volunteers in a comfortably static position. The thermal stimulus involves the use of an ice volume with controlled size and contact surface. The skin surface temperature was recorded in two distinct situations, namely without further stimulus and with the additions of a stimulus obtained by a chewing gum. The data obtained were treated using FLIR Research IR Max software. The time required to recover the initial temperature ranged from 20 to 52 minutes when no stimulus was added and varied between 8 and 26 minutes with the chewing gum stimulus. These results show that recovery is faster with the addition of the stimulus and may guide clinicians regarding the pre and post-operative times with ice therapy, in the presence or absence of mechanical stimulus that increases muscle functions (e.g. phonetics or mastication).

Keywords**—**Thermography, orofacial biomechanics, skin temperature, ice therapy.

I. Introduction

THE use of thermography techniques has assumed a great importance and is currently a fundamental tool in several monitoring and evaluation procedures. Thermography is a technology without direct contact and the acquisition of real time images allows to identify a spectrum with the distribution of temperature in the zone of measurement. The use of thermography started in military applications and gets significant improvements over the last years in the quality of the image and the accessibility of this equipment to other applications. For example, in civil engineering, the use of thermography to detect air leakage through the roller shutter handle and the window frame of a room has been regularly used [1].

Being a non-invasive technology, the interest of its application in the field of health has been growing, with its application in several research works in biomechanics. For example, a research work involving the evaluation of the temperature that was generated in drilling bone procedures was successfully done with good results [2]. A set of studies involving the use of thermography as a tool to evaluate musculoskeletal disorders of wind instrument players can be found in literature [3]. In fact, regarding the human body, and in particular the skin, the temperature can be considered as a function of the blood flow, controlled by the autonomous nervous system with effects on both sides of the body simultaneously. Since the thermography allows to quantify the temperature in a certain region of interest in relation to the quantification of underlying physiological phenomena, some studies have been carried out to verify the usefulness of thermography in orofacial pain and temporomandibular disorders (TMD). A recent study used thermography to evaluate the evolution of myofascial pain [4]. The authors suggest that there is a correlation between painful or inflammatory areas and thermography. Thermography allows for the objectification and monitoring of the dynamics of muscular pathologies and other pathologies that occur with pathophysiological changes in tissue temperature and with functional alterations (eg variation of cutaneous blood flow). Thermography was also used to correlate the degree of TMD severity and skin temperatures over the temporomandibular joint and masseter and anterior temporalis muscles [3].

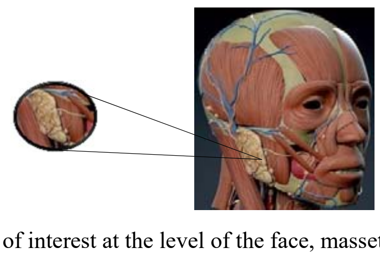

Fig. 1 Region of interest at the level of the face, masseter muscle [6]

Orofacial pain is associated with different structures of the head and neck, and in particularly to some of the principal muscles, where the temporal and masseter muscles can be highlighted. The masseter muscle, presented in Fig. 1, has its insertion at the level of the lateral surface of the mandible branch from the mandibular bevel to the mandibular angle. It can be divided into two parts, one superficial and the other

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deep [5].

Responsible for raising the jaw to close the mouth, the masseter muscle helps in the process of chewing and joining the teeth.

Despite wide acceptance of cold therapy in orthopedics and physiotherapy [7], the controlled studies of its benefits in the other biomechanics domains are few. The present study intends to be a contribution for the use of thermography as an evaluation methodology in the context of orofacial biomechanics. The objective of the presented study is to identify the oscillations of skin temperature in the left and right hemiface of the masseter muscle when different stimulus was applied, as well as to estimate the time needed to restore the initial temperature after the stimulus application, by collecting and analyzing a thermographic film.

II. Experimental Methodology

The research was carried out in the Laboratory of Applied Biomechanics, from the Polytechnic Institute of Coimbra. The study considers a group of eight volunteers, three females, and five males, with a mean age of 24.5 years. Prior to data collection, each volunteer was familiarized with the objectives of the study as well as with all the procedures to be followed, having completed a free, informed, written and oral consent, as well as a written supplementary questionnaire. The procedure includes an exclusion criteria based on non-application of cosmetics and the ingestion of energy drinks, such as coffee, on the day of data acquisition. All the female volunteers have their hair stuck and the male volunteers the beard removed.

A. Experimental Setup

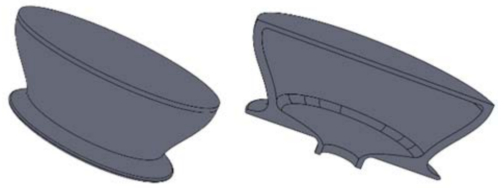
Fig. 2 shows the experimental configuration used for data acquisition. As can be seen in Fig. 2, one FLIR® thermographic camera, model T430 SC (Fig. 3) was fixed by a tripod and placed at a distance of 2 meters perpendicular to the volunteer. In order to avoid reflections, a thick black material was placed behind the volunteer and, in order to guarantee the stability and constant posture of the volunteer, a helmet secured by a tripod was used as support.

Fig. 2 Experimental setup

During the acquisition of the thermographic film, autofocus tools were defined, allowing to optimize the range of temperatures as well as the highest contrast in the image.

Fig. 3 FLIR® thermographic camera model T430 SC

The application of the ice stimulus was performed with a developed mechanical component, prototyped with PLA material, with a volume of 40 cm^3 and a contact surface of 34 cm^2. Fig. 4 shows the 3D model of this component.



(a) (b)

Fig. 4 (a) 3D model of ice container (b) Section of ice container

B. Experimental Protocol

The thermographic film was obtained following a defined experimental protocol. Factors such as the location and preparation of the examination room, the preparation of the equipment as well as the preparation of the volunteers, can affect the credibility of the obtained results being necessary to establish pre-requisites. Firstly, the volunteer was instructed to remain for 15 minutes in the room where the data were collected, at an ambient temperature of 20 ºC, relative humidity less than 50%, absence of direct light incident on the volunteers as well as of heat generators, in order to promote the acclimatization at room conditions. After, the volunteer was placed in the seat with the helmet, trying to find a static comfortably position.

For each volunteer, the data were collected in two steps, first for the right hemiface, and after for the left hemiface, following the described protocol:

a. Before the addition of ice stimulus, the thermal film from the hemiface is recorded during one minute, with particular focus in the masseter region;
b. For five minutes, the volunteer maintains the contact of the ice container into the area of the masseter muscle, as shown in Fig. 5.
c. After application of the ice, the thermal film is recorded over the hemiface until the initial temperature in the masseter muscle is achieved;
d. The volunteer stays in the room during 30 minutes in order to promote the stabilization;
e. The same procedure is then used for the left hemiface,

namely the 1 minute of film record before ice stimulus and the 5 minutes of ice container contact into the area of the masseter muscle;

f. After the ice application, thermal film is recorded over the hemiface until the initial temperature in the masseter muscle is achieved, but this time a chewing gum is provided to volunteer to be chewed in own way.

Fig. 5 Application of ice on the right hemiface

III. Results

The analysis of the collected films was performed using the FLIR ResearchIR Max software. The considered emissivity was set to 0.98, the normal value for the skin [8]. Fig. 6 shows the typical layout obtained from the software.

Figs. 7 and 8 illustrate the typical thermal images obtained in three moments for one aleatory volunteer, with a defined region of interest (ROI) corresponding to the masseter muscle. It should be noted that this region of interest at thermography level can be quantified through a color scale. In this case, it has a red and white color, with the white color representing a higher temperature and the remaining colors a lower temperature. The thermographic images 7A and 8A correspond to the moment of the recording of the initial temperature in the region of interest of the right hemiface. The images 7B and 8B corresponds to the moment after the application of the ice. Finally, the image 7C and 8C correspond to the time when the volunteer reached its initial temperature.

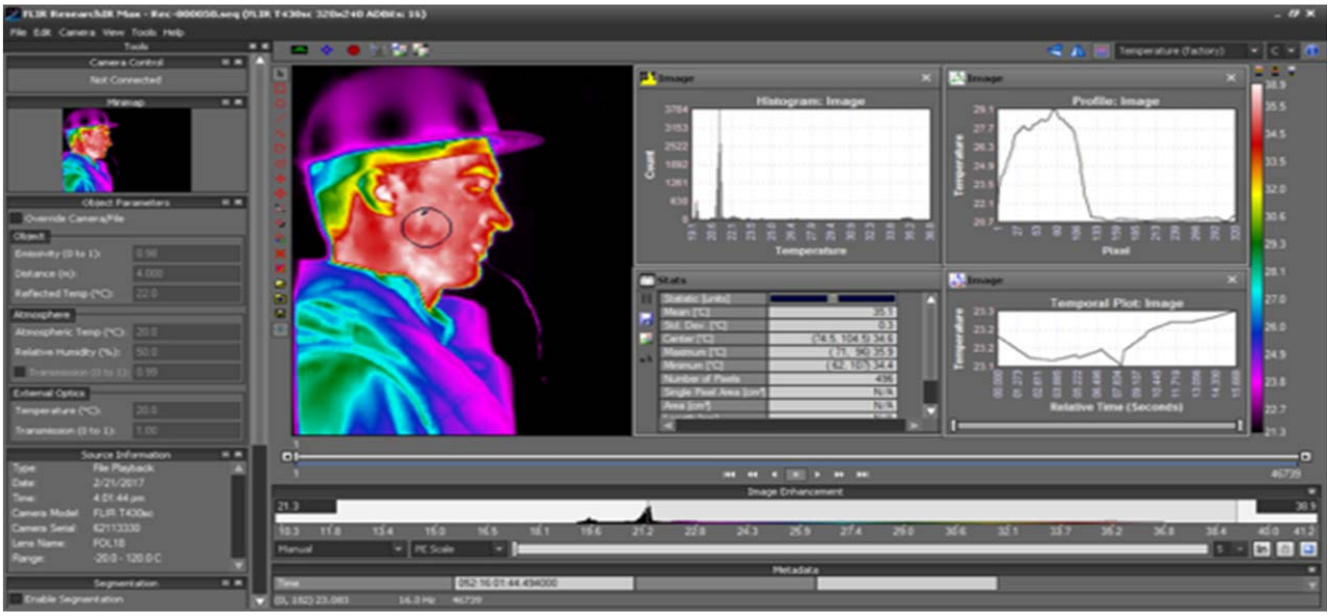
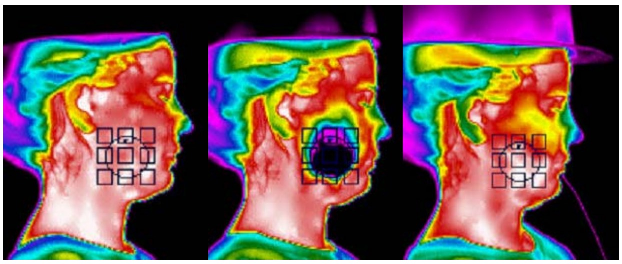
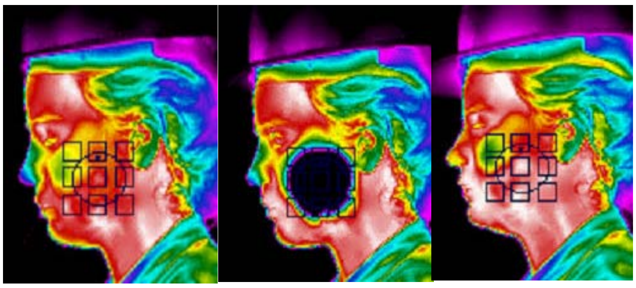


Fig. 6 FLIR ResearchIR Max software layout



(a) (b) (c)

Fig. 7 Thermographic image of the right hemiface (without chewing gum): (a) before ice stimulus (b) after application of ice (c) after reaching the initial temperature



(a) (b) (c)

Fig. 8 Thermographic image of the left hemiface (without chewing gum): (a) before ice stimulus (b) after application of ice (c) after reaching the initial temperature

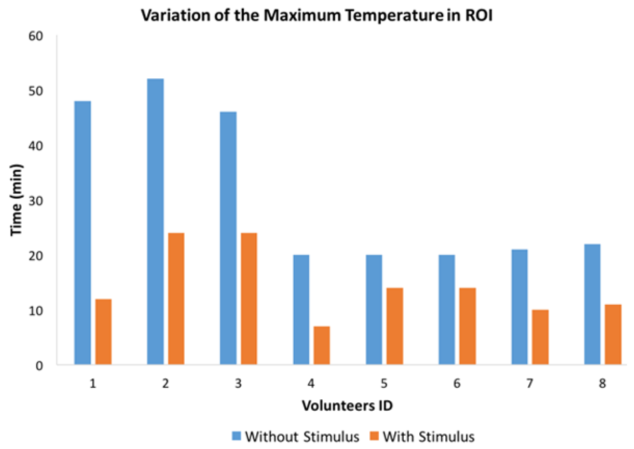


Fig. 9 Maximum temperature variation with and without chewing gum stimulus application

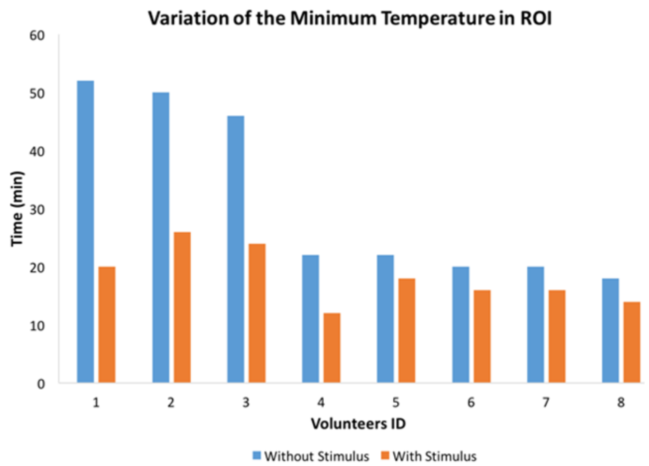


Fig. 10 Minimum temperature variation with and without chewing gum stimulus application

One important question to point out was to compare the necessary time to recovery the temperature in the region of interest. This evaluation can be identified in Fig. 9, based on the recovery of maximum temperature in the region of interest and in Fig. 10, based on minimum temperature in the same region. It is noteworthy that when a stimulus is applied, a significant decrease of recovery time occurs in all volunteers, as expected. In the figures, the volunteers 1-3 are female, and 4-8 are male. A typical sexual variation can be identified.

TABLE I
VARIATION OF THE MAXIMUM AND MINIMUM TEMPERATURE IN THE REGION OF INTEREST

Volunteer	Genre	Temperature Variation (%)	
		Maximum	Minimum
1	F	75	62
2	F	54	48
3	F	48	48
4	M	65	45
5	M	30	18
6	M	30	20
7	M	52	20
8	M	50	22

The percentage of variation of the maximum and minimum temperature for each volunteer is quantified in Table I, with a mean global reduction of 51% for maximum temperature and 35% for minimum temperature. The mean global reduction was 59% in maximum temperature and 52% minimum temperature for female volunteers. In the case of male volunteers, the mean global reduction was 45% for maximum temperature and 25% for minimum temperature.

IV. CONCLUSION

This work, despite the reduced sample, intends to demonstrate the utility of thermography in orofacial biomechanics which can be easily implemented in the treatment of orofacial pain. In fact, the applied methodology clearly shows a decrease in the time needed to reestablish the initial temperature when implementing a chewing gum stimulus. This can be due to the increase in metabolic recruitment of the muscle by the chewing process, by the increase of blood circulation on muscle metabolism, and by the neutralizing effect of the vascularization itself increased by the function.

The reasons for the sexual variation found in this study are still unknown. In light of the results obtained, the recovery times of a maximum and minimum normal region of interest temperature ranged from 20 to 52 minutes and from 18 to 52 minutes. Given that most dentists recommend post-surgical ice application times of 15 to 20 minutes with lower rests (10 to 15 minutes) for 24 to 48 hours, they are most likely to be maintaining skin temperature in lower values for longer times. Thus, the anti-inflammatory effect of the cold will be maintained; however, questions can be raised regarding the iatrogenic of this protocol by maintaining a temperature much lower than normal values and tissue hypothermia. Such is a known fact for clinicians, namely the "burn" of the skin post-ice protocol. In addition, considering the potential intersexual differences (to study in a larger sample), the times for post-surgical ice should defer between men and women.

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