RESEARCH ARTICLE

A new evaluation of heat distribution on facial skin surface by infrared thermography

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Objective: The aim of this study was to identify the facial areas defined by thermal gradient, in individuals compatible with the pattern of normality, and to quantify and describe them anatomically.

Methods: The sample consisted of 161 volunteers, of both genders, aged between 26 and 84 years (63 ± 15 years).

Results: The results demonstrated that the thermal gradient areas suggested for the study were present in at least 95% of the thermograms evaluated and that there is significant difference in temperature between the genders, racial group and variables “odontalgia”, “dental prosthesis” and “history of migraine” ($p < 0.05$). Moreover, there was no statistically significant difference in the absolute temperatures between ages, and right and left sides of the face, in individuals compatible with the pattern of normality ($\Delta T = 0.11^\circ\text{C}$).

Conclusions: The authors concluded that according to the suggested areas of thermal gradients, these were present in at least 95% of all the thermograms evaluated, and the areas of high intensity found in the face were medial palpebral commissure, labial commissure, temporal, supratrochlear and external acoustic meatus, whereas the points of low intensity were inferior labial, lateral palpebral commissure and nasolabial.

Dentomaxillofacial Radiology (2016) **45**, 20150264. doi: [10.1259/dmfr.20150264](https://doi.org/10.1259/dmfr.20150264)

Cite this article as: Haddad DS, Brioschi ML, Baladi MG, Arita ES. A new evaluation of heat distribution on facial skin surface by infrared thermography. *Dentomaxillofac Radiol* 2016; **45**: 20150264.

Keywords: thermography; anatomy; face; dentistry

Introduction and literature review

Anatomic and functional studies of the structures of interest are the bases of interpretation in imaging examinations, because from the “normal” reference values, it is possible to distinguish them from possible structural anatomic variations or regional changes. Many diagnoses of diseases that affect the facial region are made by imaging methods; however, conventional technique shows a lack of information as regards functional aspects, such as regional microcirculation and the autonomous nervous system.^{1–16}

Thermography is a non-invasive diagnostic imaging method used in medicine, capable of detecting, recording and producing infrared images that reflect the microcirculatory dynamics of the skin surface of individuals in real time, comprising the vascular, nervous and musculoskeletal systems, in addition to inflammatory processes, as well as endocrine and oncological conditions.¹ In order to maintain normal thermoregulation, the neurovegetative central nervous system, by means of the hypothalamus, controls the skin blood flow in a uniform and symmetrical manner, resulting in a right/left thermal pattern that is also symmetrical.² However, the qualitative and quantitative changes in thermal distribution are indicative of abnormality.

The fact that this imaging method is a fast and safely performed functional examination, because no ionizing radiation is used, makes thermography a most valuable dental imaging technology, providing professionals with more objective information for the diagnosis of possible orofacial changes. Furthermore, the examination allows greater precision in thermal quantification and monitoring of the region of interest (ROI).^{15,16}

Various articles^{2–16} have evaluated thermographic quantitative changes in facial skin vasomotor neurovegetative activity, that is, they calculated the absolute temperature of the ROI and conjugated gradients. However, few researches have demonstrated a standardization in the protocol of descriptive evaluation of normal facial thermal distribution of human beings.

For these reasons, the need to propose a new protocol for the interpretation of microcirculatory dynamics of the facial skin surface was verified, by identifying the thermal points of reference. The aim of this protocol is

to help professionals in the health area with the evaluation of thermograms and, consequently, make it easier for them to direct their diagnostic hypotheses.

The aim of this study was to identify the facial thermal gradient areas, with regard to the distribution of neurovegetative vasomotor activity of the facial skin surface, in individuals compatible with the pattern of normality, and to quantify and describe them anatomically.

Methods and materials

This study was approved by the Ethics Committee on Research of the University of São Paulo Dental School (FOUSP), Brazil, Protocol No. 224.079, CAAE: 11974713.9.0000.0075. The standards for the reporting of diagnostic accuracy studies (STARD) guidelines were

Figure 1 Sequence of thermograms (a–d) with change in the thermal window, for the identification of thermoanatomic reference points by means of thermal gradients (front view). IL, inferior labial (AR013, AR014); LC, labial commissure (AR011, AR012); LPC, lateral palpebral commissure (AR07, AR08); MPC, medial palpebral commissure (AR05, AR06); NL, nasolabial (AR09, AR010); ST, supratrochlear (AR01, AR02); TEMP, temporal (AR03, AR04).

Figure 2 Sequence of thermograms (a, b) with change in the thermal window, for the identification of thermoanatomic reference points by means of thermal gradients (side view). EAM, external acoustic meatus (AR05); LC, labial commissure (AR07); LPC, lateral palpebral commissure (AR03); MPC, medial palpebral commissure (AR02); NL, nasolabial (AR06); TEMP, temporal (AR01); TMJ, temporomandibular joint (AR04).

followed. All the volunteers signed the free and informed term of consent.

161 volunteers of both sexes, aged between 26 and 84 years (63 ± 15 years), were recruited and provided with guidance as regards the protocol of undergoing the thermographic examination. All the volunteers filled out a pre-evaluation chart requesting information about present and previous medical history, and the only criterion for exclusion from this study was an individual's positive state of feverishness on the day of the examination.

Protocol for the infrared thermographic examination

Standardized conditions of the room are extremely important for performing the thermographic examination. Therefore, the practical guide to neuromuculoskeletal thermography of the American Academy of Thermology was used as a guide.¹⁷

In the examination room, a thermometer was available during all the examinations, and it was positioned in a place away from heat sources in the room, in order to monitor it. The temperature established was 22°C , and thermal losses due to forced convection of air directly on the volunteer were prevented. The temperature variation in the room did not exceed 1°C in the period of 20 min. The speed of incident air measured by the anemometer was uniform and constant, not exceeding 0.2 m s^{-1} , and the relative humidity of air did not exceed 60%. The air conditioner had sufficient thermal capacity for the size of the room and its windows were fitted with outside screens to prevent sunlight entering the room. Cold lights (fluorescent bulbs) were used instead of tungsten bulbs.

The size of the room covered a space of 12 m^2 , where the distance between the volunteer and the camera was to fit in the studied region in relation to the image, corresponding to 0.71 m in all the facial takes performed: frontal and right and left side views.

Sequence of examinations

All the volunteers were instructed about the correct filling out of the clinical record chart. At the time of the interview, the professor explained some of the questions that could generate doubts, among them, the visual analogy scale¹⁸ and the pain diagram reported by the volunteers themselves. Afterwards, they were sent to undergo the infrared thermography. For better exposure of the face and to facilitate image acquisition, the volunteer's hair was fastened with hair band and covered with a disposable cap. The volunteers remained in the examination room for 15 min before the examination was performed, in order to promote thermal equilibrium between the skin and room temperatures.

For standardizing the correct position of the head, a portable cephalostat was fabricated and used. The following points of reference were considered: the vertical and horizontal shields in the posterior region of the head, with the median sagittal plane being perpendicular to the horizontal plane, and the Frankfurt plane parallel to the horizontal plane that corresponds to the imaginary line that passes through the superior border of the tragus and the most inferior point of the infraorbital rim.

To perform the thermographic examination, the volunteer was asked to sit on a stool and his/her head

Table 1 Identification of frontal thermoanatomic reference points in the thermograms (front view)

Frontal ROIs	Names of regions
AR01 and AR02	Supratrochlear
AR03 and AR04	Temporal
AR05 and AR06	Medial palpebral commissure
AR07 and AR08	Lateral palpebral commissure
AR09 and AR10	Nasolabial
AR11 and AR12	Labial commissure
AR13 and AR14	Inferior labial

ROI, region of interest.

Table 2 Identification of the right side (R) and left side (L) thermoanatomic reference points in the thermograms (side view)

<i>R and L lateral ROIs</i>	<i>Names of regions</i>
AR01	Temporal (TEMP)
AR02	Medial palpebral commissure (MPC)
AR03	Lateral palpebral commissure (LPC)
AR04	Temporomandibular joint (TMJ)
AR05	External acoustic meatus (EAM)
AR06	Nasolabial (NL)
AR07	Labial commissure (LC)

ROI, region of interest.

was positioned in the portable cephalostat. After the head was fixed in position, the thermographic examination was performed, consisting of three acquisitions (frontal, right and left sides) with the same thermal window (24–37°C).

At the time of the examination, the relative humidity of air and room temperature were noted, and the right and left tympanic temperatures of the volunteers were measured and recorded on their respective clinical record charts. During this time, the volunteers were instructed not to palpate, press, rub or scratch the skin at any time; relax the mastication muscles, keep the teeth apart and lips slightly open, until the examination was concluded.

The thermographic camera (ThermaCAM® T400; FLIR® Systems, Inc., Wilsonville, OR) was fixed on the tripod in a vertical position, and its lens was positioned parallel to the face in all image acquisitions. The examination was performed calmly, without movement of the head, that is, the operator moved the machine to

capture the images, thus avoiding any stress that could cause accentuated peripheral vasoconstriction of the skin and/or vasodilation in the facial region, resulting from voluntary movements of the volunteer’s head and neck.

Interpretation of thermograms and data evaluation

After obtaining all the thermographic images, these were saved in JPEG (Joint Photographic Experts Group) format and separated into individual files for each volunteer. For the evaluation of all thermographic images, the ThermaCAM Researcher Professional 2.10® (FLIR Systems® Inc.) was used, whose parameters used for automatic calculation of absolute temperature were: distance between the thermography appliance and the volunteer for the acquisition of the thermographic image, relative humidity of the air and ambient temperature at the time of examination. This standardization was necessary to allow for greater accuracy in the temperature values calculated by the equipment.

Owing to the absence of standardization for evaluating facial thermographs, it was necessary to propose an innovative methodology. For this purpose, a pilot study was conducted to detect the exact sites that presented a thermal gradient (Figures 1 and 2 and Tables 1 and 2). ROIs that were present in at least 95% of the thermograms evaluated, in both front and side views, were selected. To facilitate the identification of the facial thermal gradients, the suggestion is to alter the thermal window to its extremes, as exemplified in Figures 1 and 2.

Figure 3 Frontal (a) and lateral views (b, c) with the respective thermoanatomic points of reference of right (R) and left (L) sides. (a) IL, inferior labial; LC, labial commissure; LPC, lateral palpebral commissure; MPC, medial palpebral commissure; NL, nasolabial; ST, supratrochlear; TEMP, temporal. (b) EAM L, left external acoustic meatus; LC L, left labial commissure; LPC L, left lateral palpebral commissure; MPC L, left medial palpebral commissure; NL L, left nasolabial; TEMP L, left temporal; TMJ L, left temporomandibular joint. (c) EAM R, right external acoustic meatus; LC R, right labial commissure; LPC R, right lateral palpebral commissure; MPC R, right medial palpebral commissure; NL R, right nasolabial; TEMP R, right temporal; TMJ R, right temporomandibular joint.

Figure 4 Receiver operating characteristic curve of the minimum, mean and maximum temperature (T) measurements, standard deviation and difference between the minimum and maximum temperatures of all the thermoanatomic reference points.

The thermal gradient is a physical quantity that describes the gradual and continuous change of temperature as a function of the position from a source of heat, in a qualitative and quantitative way.

The thermal gradients or thermoanatomic reference points chosen for anatomic evaluation and description in this study correspond to the areas with a lower quantity of fat and regions in which the arteries are more superficial, favouring identification and

quantification of these areas. Therefore, the following are the areas with their respective anatomic descriptions (Figure 3):

- Supratrochlear: local vascularization of the supratrochlear artery and vein. The supratrochlear artery is one of the terminal branches of the ophthalmic artery (internal carotid artery). The supratrochlear vein is one of the terminal branches of the ophthalmic

Figure 5 Dispersion diagram representing high Pearson correlation between the two maximum and mean temperatures.

Table 3 Comparison of mean temperatures at frontal thermoanatomic reference points, by gender and calculation of differences in mean temperature (ΔT)

Gender (front view)	Male (n = 27)		Female (n = 134)		p-value	ΔT
	Mean	SD	Mean	SD		
T_{mean} ST L	34.51	0.59	34.14	0.78	0.021	0.37
T_{mean} ST R	34.5	0.58	34.17	0.78	0.035	0.33
T_{mean} TEMP L	34.56	0.57	34.49	0.72	0.611	0.07
T_{mean} TEMP R	34.77	0.57	34.65	0.61	0.38	0.12
T_{mean} MPC L	35.31	0.52	35.17	0.66	0.287	0.14
T_{mean} MPC R	35.31	0.55	35.13	0.66	0.181	0.18
T_{mean} LPC L	34.29	0.54	34.05	0.75	0.107	0.24
T_{mean} LPC R	34.32	0.51	34.15	0.72	0.261	0.17
T_{mean} NL L	34.28	0.88	33.76	1.09	0.022	0.52
T_{mean} NL R	34.33	0.82	33.89	1.07	0.046	0.44
T_{mean} LC L	34.8	0.65	34.57	0.75	0.132	0.23
T_{mean} LC R	34.9	0.67	34.72	0.77	0.261	0.18
T_{mean} IL L	34.22	1.08	33.88	0.91	0.093	0.34
T_{mean} IL R	34.33	1.02	33.95	0.92	0.051	0.38

IL, inferior labial (AR013, AR014); LC, labial commissure (AR011, AR012); LPC, lateral palpebral commissure (AR07, AR08); MPC, medial palpebral commissure (AR05, AR06); NL, nasolabial (AR09, AR10); SD, standard deviation; ST, supratrochlear (AR01, AR02); TEMP, temporal (AR03, AR04); T_{mean} , mean temperature.

Bold values indicate $p < 0.05$.

vein. The supratrochlear nerve is responsible for providing innervation in this area.

- Temporal: local vascularization of the superficial temporal arteries and veins (branches of the external carotid artery and retromandibular vein). The temporal nerve, branches of the facial nerve, is responsible for providing innervation in this area.
- Medial palpebral commissure: local vascularization of the angular nasal artery and vein, and dorsal nasal artery and vein (branches of the facial artery and vein). The infratrochlear nerve is responsible for providing innervation in this area.
- Lateral palpebral commissure: local vascularization of the zygomaticofacial artery and vein (branches of the superficial temporal artery and vein). The

zygomatic nerve, branch of the facial nerve, is responsible for providing innervation in this area.

- Temporomandibular joint (TMJ): local vascularization of the superficial temporal arteries and veins (branches of the external carotid artery and retromandibular vein). The temporal auricular nerve is responsible for providing innervation in this area.
- External acoustic meatus: the area of greatest concavity in the facial region, irrigated by the posterior auricular artery and vein (branch of the external carotid artery and external jugular vein).
- Nasolabial: local vascularization of the lateral nasal artery and vein (branches of the facial artery and vein). The infraorbital nerve is responsible for providing innervation in this area.

Table 4 Comparison of mean temperatures at lateral thermoanatomic reference points, by gender and calculation of differences in mean temperature (ΔT)

Gender (side view)	Male (n = 27)		Female (n = 134)		p-value	ΔT
	Mean	SD	Mean	SD		
T_{mean} TEMP L	35.3	0.44	35.14	0.66	0.24	0.16
T_{mean} TEMP R	35.27	0.74	35.26	0.56	0.942	0.01
T_{mean} MPC L	33.69	0.77	33.37	0.83	0.067	0.32
T_{mean} MPC R	33.55	0.99	33.14	1.1	0.076	0.41
T_{mean} LPC L	34.63	0.58	34.35	0.68	0.043	0.28
T_{mean} LPC R	34.51	0.53	34.34	0.73	0.26	0.17
T_{mean} TMJ L	35.02	0.51	34.69	0.63	0.011	0.33
T_{mean} TMJ R	35.06	0.54	34.9	0.69	0.254	0.16
T_{mean} EAM L	35.75	0.56	35.73	0.64	0.89	0.02
T_{mean} EAM R	35.63	0.6	35.85	0.68	0.128	0.22
T_{mean} NL L	33.89	1.15	32.72	1.36	<0.001	1.17
T_{mean} NL R	33.89	1.07	32.81	1.32	<0.001	1.08
T_{mean} LC L	34.61	0.9	34.41	0.78	0.217	0.2
T_{mean} LC R	34.63	0.83	34.52	0.83	0.523	0.11

EAM, external acoustic meatus (AR05); LC, labial commissure (AR07); LPC, lateral palpebral commissure (AR03); MPC, medial palpebral commissure (AR02); NL, nasolabial (AR06); SD, standard deviation; TEMP, temporal (AR01); T_{mean} , mean temperature; TMJ, temporomandibular joint (AR04).

Bold values indicate $p < 0.05$.

Table 5 Comparison of all temperatures without variables (“odontalgia”, “dental prosthesis” and “history of migraine”) at frontal thermoanatomic reference points, calculation of differences in mean temperature (ΔT_{mean}) and mean temperature (T_{mean}) by sides

ROIs (front view)	n	T_{minimum} ($^{\circ}\text{C}$)	T_{maximum} ($^{\circ}\text{C}$)	T_{mean} ($^{\circ}\text{C}$)	Mean temperature of T_{mean} ($^{\circ}\text{C}$)	SD	ΔT_{mean}
ST L	50	32.90	35.50	34.47	34.5	0.56	0.03
ST R	50	33	35.40	34.44	34.44	0.58	
TEMP L	50	33.40	35.60	34.71	34.8	0.50	0.16
TEMP R	50	33.60	35.70	34.88		0.48	
MPC L	50	34.60	36.30	35.42	35.38	0.42	0.09
MPC R	50	34.70	36.10	35.33		0.40	
LPC L	50	32.60	35.30	34.29	34.27	0.58	0.04
LPC R	50	33.20	35.50	34.33		0.52	
NL L	50	32	35.90	34.06	34.1	0.92	0.09
NL R	50	32.30	35.90	34.15		0.92	
LC L	50	33.50	35.90	34.77	34.84	0.60	0.12
LC R	50	33.30	35.90	34.90		0.63	
IL L	50	32.60	35.90	34.25	34.3	0.79	0.10
IL R	50	32.60	36.50	34.35		0.80	

IL, inferior labial (AR013, AR014); L, left; LC, labial commissure (AR011, AR012); LPC, lateral palpebral commissure (AR07, AR08); MPC, medial palpebral commissure (AR05, AR06); NL, nasolabial (AR09, AR010); R, right; ROI, region of interest; SD, standard deviation; ST, supratrochlear (AR01, AR02); TEMP, temporal (AR03, AR04); T_{maximum} , maximum temperature; T_{minimum} , minimum temperature.

- Labial commissure: local vascularization of the facial artery and vein (branches of the external carotid artery and internal jugular vein). The mental nerve is responsible for providing innervation in this area.
- Inferior labial: local vascularization of the inferior labial artery and vein. The inferior labial artery is a branch of the facial artery (external carotid artery). The inferior labial vein, in turn, is a branch of the facial vein. The mental nerve is responsible for providing innervation in this area.

The circular area chosen was based on the smallest size of the “circle” tool that would allow it to be displaced to adjust to each ROI in each thermogram. Therefore, the radius (r) was equal to 6 mm. To calculate the area of a circle, the mathematical formula $A = \pi r^2$ was used. When $r = 6$, we have $A = 1.13 \text{ cm}^2$.

The rainbow type pallet was chosen, with the purpose of facilitating identification, evaluation and description

of the facial thermoanatomy, and consequently, obtain the values of the minimum (T_{min}), mean (T_{med}), maximum (T_{max}) temperatures and calculation of the difference in temperature (ΔT) by the thermal difference between the right (R) and left (L) sides of the face. These data were added to the database tabulated in Microsoft Excel[®] (Microsoft Corporation[®], Redmond, WA), together with the data obtained from the pre-evaluation clinical record charts of the volunteers and were sent for statistical analysis.

The statistical program used was R 3.1.0[®] (R Core Team, 2014), for descriptive statistics, Pearson correlation coefficient and Student's t -test, considered significant when the descriptive level of the test (p) was <0.05 . Absolute values of r suggested weak correlation when $|r| < 0.4$, moderate, when $0.4 \leq |r| < 0.7$ and strong correlation when $|r| \geq 0.7$.

The variation in sensitivity and specificity for different cut-off values was evaluated by the receiver operating characteristic curve.

Table 6 Comparison of all temperatures without variables (“odontalgia”, “dental prosthesis” and “history of migraine”) at lateral thermoanatomic reference points, calculation of differences in mean temperature (ΔT_{mean}) and mean temperature (T_{mean}) by sides

ROIs (side views)	n	T_{minimum} ($^{\circ}\text{C}$)	T_{maximum} ($^{\circ}\text{C}$)	T_{mean} ($^{\circ}\text{C}$)	Mean temperature of T_{mean} ($^{\circ}\text{C}$)	SD	ΔT_{mean}
TEMP L	50	32.30	36.20	35.29	35.36	0.60	0.15
TEMP R	50	34.10	36.20	35.43		0.46	
MPC L	50	32.10	34.90	33.64	33.39	0.67	0.49 ^a
MPC R	50	29.60	35.10	33.15		1.17	
LPC L	50	33.50	35.40	34.58	34.54	0.52	0.07
LPC R	50	32.80	35.80	34.51		0.65	
TMJ L	50	33.20	35.90	34.86	34.99	0.48	0.27
TMJ R	50	33.00	35.90	35.13		0.57	
EAM L	50	34.70	36.80	35.86	35.91	0.48	0.11
EAM R	50	34.20	36.90	35.97		0.50	
NL L	50	30.10	35.30	33.04	33.07	1.38	0.07
NL R	50	30.30	35.20	33.11		1.31	
LC L	50	32.50	35.80	34.56	34.60	0.70	0.09
LC R	50	32.70	35.80	34.65		0.73	

EAM, external acoustic meatus (AR05); L, left; LC, labial commissure (AR07); LPC, lateral palpebral commissure (AR03); MPC, medial palpebral commissure (AR02); NL, nasolabial (AR06); R, right; ROI, region of interest; SD, standard deviation; TEMP, temporal (AR01); T_{maximum} , maximum temperature; T_{minimum} , minimum temperature; TMJ, temporomandibular joint (AR04).

^aUnstable region for thermal evaluation in side views.

Results

Previously, a pilot study was conducted to determine the most frequent thermal gradients in the face, in which the choices of ROIs respected the presence of at least 95% of all the thermograms evaluated.

The minimum, mean and maximum temperatures obtained of all the ROIs were evaluated by the receiver operating characteristic curve (Figure 4), in which the best temperatures for the detection of the studied areas were the maximum and mean values.

In Figure 5, significant correlation between the maximum ($T_{\max}$) and mean (T_{mean}) temperature measurements was observed, presenting a high correlation between the two temperatures ($r = 0.9435326$). Therefore, it is suggested that it makes no difference whether the maximum or mean temperature is used for the evaluation of the ROIs proposed in this study.

When comparing the maximum and mean temperatures of the right and left sides of all the volunteers, no statistically significant difference was noted between them ($p > 0.05$). However, statistically significant difference between the mean temperatures of both genders (Tables 3 and 4) was found, suggesting the facial skin temperature in males is higher than in females ($p < 0.05$). The mean of the mean difference in temperature between the genders in the front view corresponded to 0.27°C , and in the side view, 0.34°C .

By means of quantitative analysis of the results we obtained with volunteers compatible with the pattern of normality, the following decreasing order of absolute temperature, according to region, was found:

- front view: medial palpebral commissure ($T = 35.38^{\circ}\text{C}$), labial commissure ($T = 34.84^{\circ}\text{C}$), temporal ($T = 34.8^{\circ}\text{C}$), supratrochlear ($T = 34.5^{\circ}\text{C}$), inferior labial ($T = 34.3^{\circ}\text{C}$), lateral palpebral commissure ($T = 34.27^{\circ}\text{C}$) and nasolabial ($T = 34.1^{\circ}\text{C}$)
- side views: external acoustic meatus ($T = 35.91^{\circ}\text{C}$), temporal ($T = 35.36^{\circ}\text{C}$), TMJ ($T = 34.99^{\circ}\text{C}$), labial commissure ($T = 34.60^{\circ}\text{C}$), lateral palpebral commissure ($T = 34.54^{\circ}\text{C}$), medial palpebral commissure ($T = 33.39^{\circ}\text{C}$) and nasolabial ($T = 33.07^{\circ}\text{C}$).

The cut-off temperature of the frontal view was 34.59°C and 34.75°C for the lateral views. The calculations were based on the average of the temperatures in each view. Therefore, the following points of higher magnitude were found in the front view: medial palpebral commissure, labial commissure, temporal and supratrochlear, whereas the points of higher magnitude in the side views were external acoustic meatus, temporal and TMJ. When the maximum temperature reached to detect a facial thermal gradient was $>34.5^{\circ}\text{C}$, the thermoanatomical point was meant to be correctly delineated.

Initially, 161 volunteers entering the study, from which the authors excluded 111 individuals that have had any

variables (“odontalgia”, “dental prosthesis” and “history of migraine”) detected during the anamnesis. So, 50 volunteers were evaluated in the second step of the statistical analysis. The mean difference in mean temperature (ΔT) from the frontal view was 0.09°C , and from the side views, it was 0.13°C (Tables 5 and 6).

Discussion

Thermographic examination is a non-invasive diagnostic imaging modality, quickly performed and without involving ionizing radiation, capable of demonstrating neurovegetative vasomotor activity of the skin. Its principle of image formation is based on the capture and transformation of infrared radiation emitted by the human skin, into images that reflect the microcirculatory dynamics of the skin surface.^{1,4,5,7,8,10,11,15,16,19–26}

In spite of various articles having approached the thermographic examination as a promising method in dentistry,^{8,10–12,15,16,21,27} in the world literature, up to now, there is no standardization as regards the evaluation of thermograms of the face.

Skin temperature is a function of blood flow controlled by the neurovegetative system. This temperature affects the two sides of the body uniformly and simultaneously, resulting in thermal symmetry.^{4,5,7,8,10,15,16,20–22,25,27}

The parameters for thermography exams are internationally defined, in order to obtain images in the nearest state of thermal equilibrium between the body skin surface and the room temperature, without shivering or sweating while the images are captured. The parameters suggested for the interpretations and evaluation of the thermograms influenced at the same way because all the volunteers were at the same environmental conditions during the images capture.

In this study, the temperature measurements presented no significant differences between the right and left sides of the face ($p > 0.05$), in which there was a mean difference in absolute temperature (ΔT) of 0.09°C from the front view and 0.13°C from the side views. These results corroborate values found in the literature consulted, because the ΔT patterns considered normal for the face are $<0.3^{\circ}\text{C}$.^{2,6,8,10–12,15,16,20,22}

The thermal study of small regions is more faithful than that of larger regions, because the greater the image resolution (*e.g.*: 76,000 pixels) of the thermographic machine sensor the better will be the capacity of identifying the changes in temperature in small regions.¹⁵ In view of this, in this study, we chose the measurement of each ROI equal to 1.13 cm^2 .

Males presented higher skin temperature than females, as they dissipate more heat.^{12,14,28} In this study, when the mean absolute temperature of the skin surface was compared in the two genders, statistically significant differences were found ($p < 0.05$), leading to the conclusion that the mean facial skin temperature in males is higher than in females ($p < 0.05$), with $\Delta T_{\text{frontal}} = 0.27$

and $\Delta T_{\text{lateral}} = 0.34$. In the study of Christensen *et al*,¹⁴ the authors found a higher difference in temperature, corresponding to 0.7°C. However, Weinstein *et al*,¹⁰ when comparing the ΔT between genders, found not statistically significant differences.

In the literature consulted, Uematsu² affirmed that the age of the normal individual did not influence the difference in temperature of the facial regions studied. Our study was in agreement with the findings of the above-mentioned author.

Skin surface temperature can be influenced by various internal and external factors. The circadian rhythm, calorie consumption, physical activity, emotional state, relative humidity of the air and atmospheric temperature may exert a remarkable effect on skin temperature. In particular, on the extremities, even when small vascular changes occur, these will produce large changes in skin surface temperature.²⁹

The regions of thermal instability must be excluded, such as damp and/or very hairy regions, and those of the beard and scalp hair.² Our study proved that in individuals with beard, the regional temperature is statistically significant when compared with those without beard. Moreover, it is a region of lower infrared intensity, because hair is a heat insulator.

There was a difference of temperature ($\Delta T = 0.49$) already expected when analyzing the MPC area because this region is considered unstable for thermal evaluation in side view.

When analyzing the hot and cold areas of the face, the literature is unanimous about dividing them in the following manner:

- hot areas: frontal,^{2,3,7-10,12,30-32} orbital,^{3,10,12,30,31} labial,^{3,30,31} nasolabial,³¹ auricular appendages,³ temporal.^{3,7,8,10,12}
- cold areas: cheeks,^{3,6,9,30-32} hair and hairy areas,^{3,6,9,30-32} auricular pavilion or auricle,^{3,9,30-32} mento/chin.^{8,10,12}

In this research, the highest temperatures recorded were in the regions of the medial palpebral commissure and external acoustic meatus. As there is no standardization for the evaluation of the face, many findings were found in the literature consulted, in which it was very difficult to make comparison without our findings, since ours is an unprecedented study.

Conclusions

From analysis of the statistical results, we are able to affirm that:

- according to the suggested areas of thermal gradients, these were present in at least 95% of all the thermograms evaluated
- the following points of high intensity were found in the face: medial palpebral commissure, labial commissure, temporal, supratrochlear and external acoustic meatus, whereas the points of low intensity were inferior labial, lateral palpebral commissure and nasolabial
- there was no statistically significant difference between the absolute temperatures on the right and left sides of the face, in individuals compatible with the pattern of normality, in both the front ($\Delta T = 0.09^\circ\text{C}$) and side ($\Delta T = 0.13^\circ\text{C}$) views.

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