

RESEARCH

Thermographic and clinical correlation of myofascial trigger points in the masticatory muscles

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Objectives: The aim of the study was to identify and correlate myofascial trigger points (MTPs) in the masticatory muscles, using thermography and algometry.

Methods: 26 female volunteers were recruited. The surface facial area over the masseter and anterior temporalis muscles was divided into 15 subareas on each side ($n = 780$). This investigation consisted of three steps. The first step involved thermographic facial examination, using lateral views. The second step involved the pressure pain threshold (PPT), marking the MTP pattern areas for referred pain ($n = 131$) and local pain ($n = 282$) with a coloured pencil, and a photograph of the lateral face with the head in the same position as the infrared imaging. The last step was the fusion of these two images, using dedicated software (Reporter[®] 8.5—SP3 Professional Edition and QuickReport[®] 1.2, FLIR Systems, Wilsonville, OR); and the calculation of the temperature of each point.

Results: PPT levels measured at the points of referred pain in MTPs (1.28 ± 0.45 kgf) were significantly lower than the points of local pain in MTPs (1.73 ± 0.59 kgf; $p < 0.05$). Infrared imaging indicated differences between referred and local pain in MTPs of 0.5°C ($p < 0.05$). Analysis of the correlation between the PPT and infrared imaging was done using the Spearman non-parametric method, in which the correlations were positive and moderate ($0.4 \leq r < 0.7$). The sensitivity and specificity in MTPs were 62.5% and 71.3%, respectively, for referred pain, and 43.6% and 60.6%, respectively, for local pain.

Conclusion: Infrared imaging measurements can provide a useful, non-invasive and non-ionizing examination for diagnosis of MTPs in masticatory muscles.

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Introduction

Myofascial pain syndrome (MPS) is characterized by diffuse muscle pain and the presence of myofascial trigger points (MTPs).¹ MPS is much more common than is generally recognized,² affecting the quality of life of patients with this condition. Simons³ found that 85% of patients admitted to a chronic pain centre were suffering primarily from MPS. Early identification of the disease, using precise diagnostic methods, improves the effectiveness of treatment and, consequently, leads to a reduction in the cost of public health.

Clinically, an MTP can be defined as a hyperirritable nodule of spot tenderness in a palpable taut band of

skeletal muscle. The spot is a site of exquisite tenderness to palpation, from which a local twitch response can be elicited when appropriately stimulated, which refers pain to a distance. That response can cause distant motor and autonomic effects.^{4,5} Algometry, or the measurement of the pressure threshold meter (PTM), is a diagnostic method used to document the sensitivity of MTPs quantitatively. The pressure pain threshold (PPT) for the examination of MTPs is the minimal force that induces pain.^{6–9}

Infrared thermography is a non-ionizing and non-invasive imaging technique that detects the distribution of body surface heat. It detects, records and transforms into images the infrared radiation emitted by the human skin, reflecting in real-time the microcirculatory dynamic of the cutaneous surface of the patients.¹⁰ Skin temperature is a function of blood flow, which is

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controlled by the autonomic nervous system. Central control of skin temperature affects both sides of the body uniformly and simultaneously. The literature clearly documents that, in normal situations, blood flow through the skin of most parts of the body producing a symmetric thermal pattern. Qualitative and quantitative changes in symmetric thermal patterns have been reported as indicators of changes in metabolism, haemodynamics or neuronal thermoregulatory processes in the region of interest (ROI).^{11–14}

This study was designed as a diagnostic test to correlate clinical examinations using algometry and infrared thermography, corresponding to the difference between referred and local pain in MTPs.

Materials and methods

Only adult females were investigated in this study because masticatory pain disorders are more prevalent in females than in males.¹ 26 female volunteers with a mean age of 41 years were included. All subjects underwent clinical and dental examinations. The selection criteria for this research included a negative history for systemic problems (*e.g.* hypothyroidism, diabetes, hypertension, fibromyalgia), headaches, dental pain, scars or wheals on the face and articular temporomandibular disorders (TMDs). In order to detect the presence of TMDs, Research Diagnostic Criteria for Temporomandibular Disorders (RDC/TMD) were applied.¹⁵

The subject was instructed in the use of a visual analogue scale (VAS). The VAS consisted of a 100 mm line, with end points defined as “no pain” (left) and “worst pain imaginable” (right). The subjects were asked to mark pain intensity with a pencil on this line. Pain intensity was expressed as the distance in millimetres from the left end point to the pencil mark.

Measurement procedure

Thermography: Thermographic images were recorded following a standard protocol, recommended by the Academy of Neuro-Muscular Thermography.¹⁶ The subjects were instructed not to apply any lotion, make-up or powder to the skin; not to use a dryer or flat iron on the hair; and not to smoke for 2 h before the recording. Also, they were instructed to avoid skeletal manipulation, acupuncture, physical therapy, the use of transcutaneous neural stimulation units or electrodiagnostic testing for 12 h prior to the test and for at least 24 h after the test; not to drink coffee or alcoholic drinks; and not to use nasal decongestants, analgesics, anti-inflammatory drugs or any substance that alters sympathetic function.

Patients were acclimatized in a room with a mean temperature of 21 °C and a relative humidity of 80% for 15 min. They were instructed not to palpate, press, rub or scratch the skin at any time up to the completion of the entire thermographic examination. Air flow was maintained at less than 0.2 m s⁻¹, to avoid loss of heat through convection. Ambient temperature was measured using a reliable digital thermohygrometer that was visible and easy to read. Thermographic images were taken by an experienced physician who also evaluated them.

To facilitate image acquisition, the hair was held in place with a head band and a disposable head covering. The examiner had the patient sit on the examination chair. A cephalostat, constructed specifically for this study, was used in order to standardize the positioning of the patients during the thermal and photographic acquisitions (Figure 1). The subject was asked to relax the muscles with the teeth apart. In a randomized order, two series of colour thermograms were taken, from the right and left perpendicular projections.

Skin temperature of all muscles (masseter and anterior temporalis muscles) was registered using a computer-assisted infrared thermograph (ThermaCAM® T400,

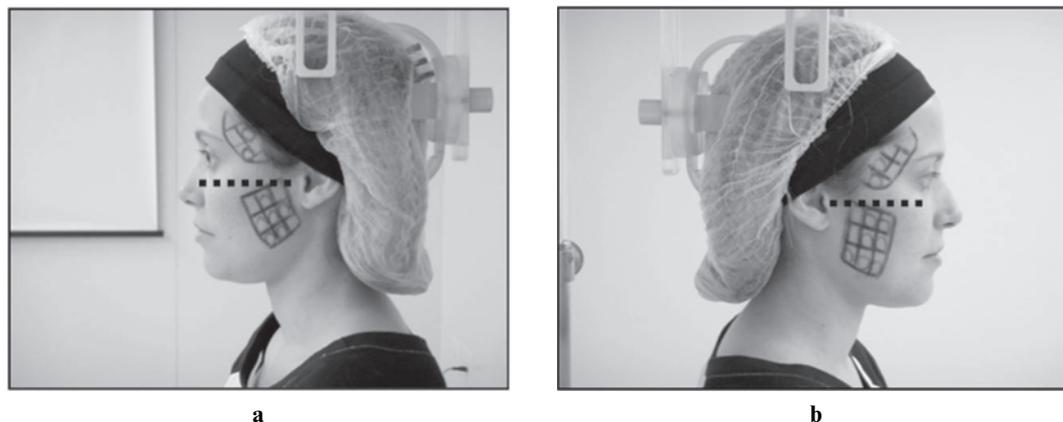


Figure 1 Figure illustrating the correct positioning of the patient with the Frankfurt plane (dotted line) parallel to the horizontal plane: (a) left side; (b) right side

FLIR Systems, Inc., Wilsonville, OR). Thermal sensitivity was 0.05 °C at 30 °C; the spectral range was 7.5 µm–13 µm; and the built-in digital video was 320 × 240 pixels. Data were obtained using high-speed (30 Hz) analysis and recording systems coupled to a desktop computer. This equipment allows images with spatial resolution (IFOV) of 1.4 mrad to be obtained for the visualization of hot spots, from a 1.4 mm to a 1 m distance, using a standard lens with no additional lenses. The infrared camera produces a matrix of temperature values. Each temperature value represents a pixel in the picture measured.

The thermograph allows quantitative and qualitative mapping of superficial temperature, which can be related to different pathological conditions and blood flow. It was possible to show the images in greyscale or in colour scales available within the software. All images were analysed and showed at least one palette of 85–100 colours, with a 0.15 °C thermal window for each colour. Thermal sensitivity of 0.51 °C per colour tone was used, based on a rainbow-type colorimetric scale (colour palette), in which the colours were, from hottest to coldest: white, pink, red, orange, yellow, light green, dark green, light blue, dark blue, purple and black (FLIR QuickReport® v. 1.2 and FLIR Reporter® v. 8.5, FLIR Systems, Inc.). The colours indirectly indicated the degree of distribution of local cutaneous blood perfusion. All images were displayed with the palette beside the image, for reference.

The distance between the camera and the lateral face being measured was adjusted to 0.75 m, at an angle of 90°, with the lens of the camera parallel to the region being assessed. The emissability value of the skin considered for this study was 0.987.

Clinical examination and algometry: A trained specialist in TMD management area divided the surface facial area over the masseter and anterior temporalis muscles into 15 ROIs (Figure 2) on each side ($n = 780$), with an area of approximately 1 cm². This marking was based on Pogrel *et al*'s¹⁷ study. The reference for defining regions of the masseter muscle were the zygomatic arch (proximal insertion) and the lateral surface of the mandibular angle (distal insertion). The temporalis muscle was evaluated only in its anterior part without hair. Examination of MTPs was performed according to the Fischer protocol,^{6,7,9} which uses the PPT to evaluate the minimal force that induces pain, expressed in number of kilograms of pressure. PTM is a hand force gauge calibrated to 10 × 0.01 kgf. Before the test, the subject was instructed to relax the muscles with the teeth apart. First, the presence and location of the MTP was confirmed via palpation and was marked using a coloured pencil. Next, the pressure threshold was measured. The PTM was applied directly onto the location of tenderness, with the axis of the shaft maintained at 90° to the examining surface. The area of the algometer tip was 1 cm². The subject was instructed to inform verbally when pain or discomfort was initially felt. At this moment, the compression

lasted for 5 s in the same location, with the same pressure maintained. The patient was asked if the pain was felt only in this location, or if it extended to another region. Finally, digital photographs (Nikon Coolpix S51® 8.1 megapixels; Nikon, Sendai, Japan) of the lateral face with the head in the same position as the infrared thermography examination were taken (Figure 3).

In order to correlate the PPT values with the values obtained from the thermographs of the ROI, the thermographs were superimposed on the digital photographs using dedicated software (Reporter 8.5—SP3 Professional Edition and QuickReport 1.2). The standardized reference points of the superimposition were midpoint of the median sagittal plane between the chin and the hyoid bone (1); lowest portion of the earlobe (2); and the apex of the nasal pyramid (3) (Figure 4).

The averages of the temperature of the ROI of the muscles were calculated individually (T), and thermal asymmetry between the corresponding opposite sides, also called the conjugated gradient of the absolute temperature (ΔT).

The definition of an adimensional variable (θ), which combines the measured local temperature with the body and the ambient temperatures, was used.¹⁰

Interpretation of the infrared camera readings was done, therefore, using an adimensional temperature (θ) which combines the measured local temperature with the body (T_b) and ambient temperatures (T_∞), according to the following equation:

$$\theta = \frac{T - T_\infty}{T_b - T_\infty} \quad (1)$$

The gradient of the normalized temperature was also used to calculate the thermal asymmetry with the corresponding opposite ROIs:

$$\Delta\theta = |\theta_{\text{right}} - \theta_{\text{left}}| \quad (2)$$

After obtaining all the data (PPT, T , θ) and calculating the gradients of temperature and normalized

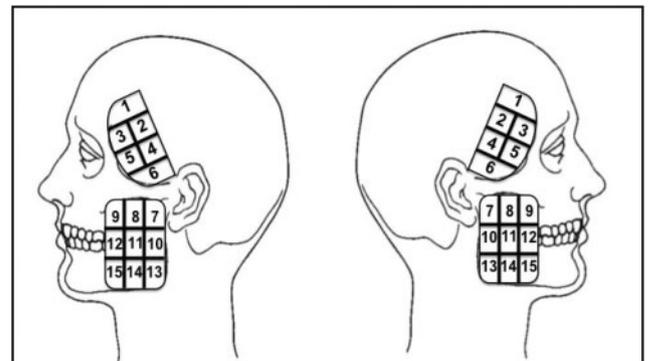


Figure 2 Schematic design of the region of interest, restricted to the masseter and anterior part of the temporal muscles, on both sides



Figure 3 Examination sequence. (a) Identification of muscle tension by extra-oral palpation of the masticatory muscles being studied; (b) marking the regions of muscle tensions with a dermatographic pencil; (c) performing digital pressure algometry on points previously identified

temperature (ΔT and $\Delta\theta$), the assessed points were divided into three groups: no MTP, MTP with local pain and MTP with referred pain.

Statistical analyses

The data were tabulated using Microsoft Excel (Microsoft Corporation, Redmond, WA). The analyses were performed using SPSS® 19 (IBM Corporation, Armonk, NY). Pearson's χ^2 test and the non-parametric Kruskal–Wallis test with Bonferroni correction were used when necessary. The sensitivity and specificity of the ratings were calculated using receiver operating characteristic (ROC) curve analysis. A level of $p < 0.05$ was considered to be statistically significant. The correlation coefficient for the entire sample was calculated using Spearman's non-parametric method.

Informed consent/ethical approval

This diagnostic test was approved by the Research Ethics Committee of the College of Dentistry of the University of São Paulo, number 210/2010, CAAE 0036.0.017.000-10. All participants gave informed consent.

Results

The sample consisted of 26 female volunteers (mean age 41 ± 15 years, range 22–82 years). Of the 780 ROIs assessed over the masseter and anterior temporalis muscles (15 ROI on each side), MTPs were found in 395 ROIs (50.6%). All volunteers were asymptomatic on the day of the examination (VAS = 0).

Of the entire sample of 395 MTPs, physical examination findings characterized 264 as points of local pain, consisting of 74 (18.7%) anterior temporalis and 190 (48.1%) masseter muscles, and 131 were points of referred pain, consisting of 35 (8.9%) anterior temporalis and 96 (24.3%) masseter muscles.

When the right ($T = 33.71^\circ\text{C} \pm 1.21$; $\theta = 0.805 \pm 0.087$) and left ($T = 33.76^\circ\text{C} \pm 1.13$; $\theta = 0.803 \pm 0.082$) hemifacials were compared, no thermal predominance was found for either side, either for T or for θ ($p > 0.05$).

The temporal muscle showed higher temperature ($T = 34.63^\circ\text{C} \pm 0.73$; $\theta = 0.861 \pm 0.768$) than the masseter muscle ($T = 33.18^\circ\text{C} \pm 1.05$; $\theta = 0.768 \pm 0.078$), for all subjects ($p < 0.05$).

The masseter muscle ($1.54 \text{ kgf} \pm 0.58$) showed greater sensitivity to pain sensations of the PPT than the temporal muscle ($1.67 \text{ kgf} \pm 0.62$) ($p < 0.05$).

The correlations between the PPT (kgf) and temperature (T) were positive and moderate ($0.4 \leq r < 0.7$), with the higher the PPT value (kgf) applied to the ROI, the higher the local temperature (Figure 5).

The values for temperature (T), normalized temperature (θ) and the PPT were greater for the points of local pain than for the points of referred pain ($p < 0.05$) (Table 1), *i.e.* the greater the pain sensitivity of the point, the lower the value of temperature and normalized temperature. The cut-off points found for T , θ , ΔT and $\Delta\theta$ are shown in Table 2; the gradient temperature in all muscles, with and without MTP, was greater than 0.3°C .

The area under the ROC curve is interpreted as the probability that the individual with MTPs has a diagnostic test result of greater magnitude than the individual without MTPs. A test that can distinguish them has an area under the ROC curve above 0.5 and is described in Table 3.

For both T and θ , the sensitivity of the method to identify MTPs with referred pain was average (50%), although the specificity was low (17%) (Table 4).

By evaluation of the cut-off points, the value of the conjugated gradient (ΔT) was higher than 0.3°C and the normalized temperature value ($\Delta\theta$) was greater than 0.036. Regarding the presence of MTPs, sensitivity and specificity for both ΔT and $\Delta\theta$ were 62.5% and 71.31%, respectively (Table 5).

Discussion

MTPs are one of the diagnostic criteria of MPS. However, they are commonly overlooked as sources of pain because the sensory experience may be local or widespread, owing to pain referral mechanisms being

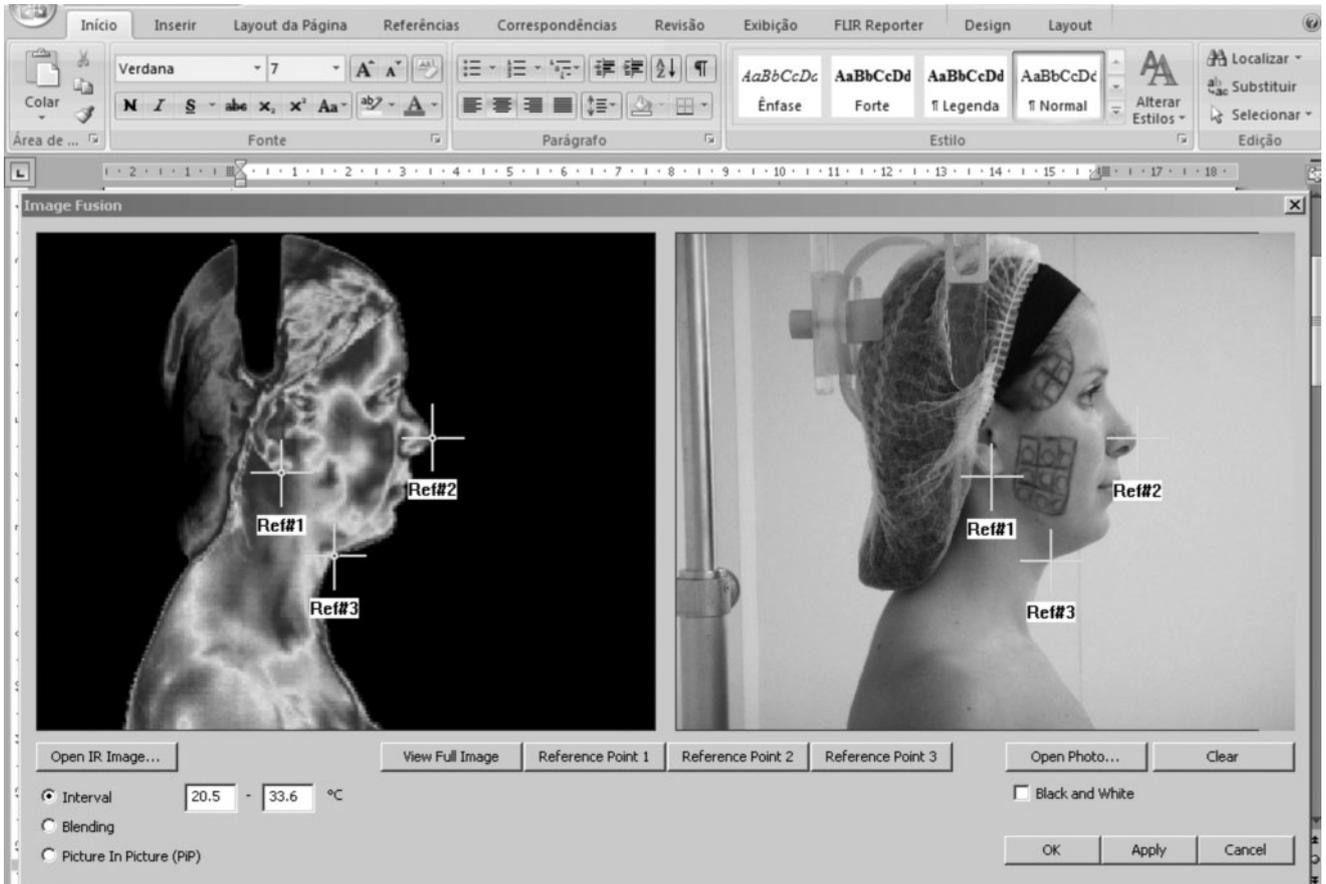


Figure 4 The software FLIR Reporter® (FLIR Systems, Wilsonville, OR) was used to calculate the value of the location of interest, which was restricted to a 1 cm² circle. In the circle drawn on the face, the absolute average temperature of the region was automatically calculated by the software

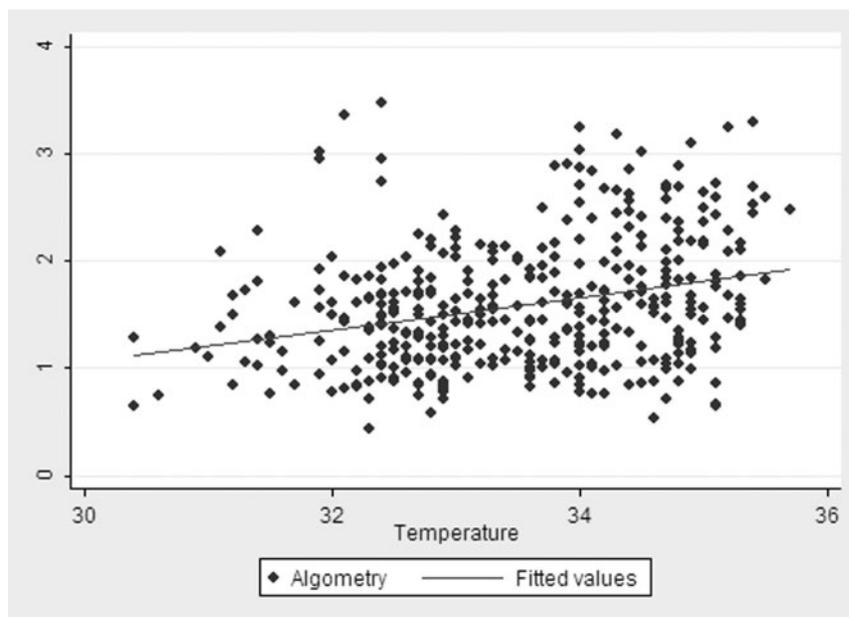


Figure 5 Correlations between the pressure pain threshold (kgf) and temperature (°C)

Table 1 Mean values, standard deviations (SDs) and post-hoc comparisons of the means of the temperature (T), normalized temperature (θ) and algometry for both groups of myofascial trigger points (MTPs)

MTP (n)	T ($^{\circ}\text{C} \pm \text{SD}$)	θ ($\pm \text{SD}$)	Algometry (kgf $\pm \text{SD}$)	p-value
Local pain (264)	33.60 \pm 1.13	0.796 \pm 0.08	1.73 \pm 0.59	<0.05
Referred pain (131)	33.36 \pm 1.10	0.761 \pm 0.07	1.28 \pm 0.45	

not yet fully understood. MTPs are thought to be initiated by a muscle or connective tissue change that sets up positive feedback with the central nervous system, resulting in sensory, motor and autonomic changes.¹⁸

Infrared thermography is a non-invasive diagnostic imaging method capable of demonstrating cutaneous, vasomotor, neurovegetative activity as the principle for image formation. It is based on the capture and transformation of long infrared radiation emitted by human skin in images that reflect the microcirculatory dynamic of the skin.^{10–13,17–27}

Despite numerous articles addressing thermographic examination as a promising method in the diagnosis of TMD,^{11–14,24} so far no study has specifically compared the thermographic study of MTPs in the masticatory muscles with the PPT using superimposition of the ROI images, as was done in this research. Because masticatory pain disorders are more prevalent in females than in males,¹ only adult females were investigated in this study; the age bracket of this sample (22–82 years) would not have influenced the results because we were evaluating a physical phenomenon, the temperature, which depends on the material being analysed (human body).

Algometry provides us with a means to gauge the pain sensitivity of trigger points quantitatively. The results of many studies confirm that MTPs are more sensitive than contralateral, MTP-free muscle areas.^{3,7,18} This study confirms those findings, and the pressure threshold for MTPs was lower in points of referred pain (1.28 kg cm⁻²) than in points of local pain (1.73 kg cm⁻²), *i.e.* the greater the pain sensitivity of the point, the lower the value of PPT.

When right–left sensitivity to pain was compared with the PPT no statistically significant difference was found between the temporal muscles, only between the masseter muscles ($p < 0.05$). Visscher *et al*²⁸ demonstrated that the PPT test result was greater on the right side of the face than on the left. According to them, a

possible explanation for this fact is that the side with the greater value is related to the dominant side of the body. However, in this study, a statistical difference ($p < 0.05$) was found when the sensitivity to pain between the temporal and masseter muscles on the same side was compared. The masseter muscle was more sensitive than the temporal muscle. These results are also in agreement with those found by Visscher *et al*.²⁸

The sensitivity and specificity to the PPT in the assessment of referred muscle pain were 0.66 and 0.73, respectively. Farella *et al*²⁹ found the sensitivity of the temporal and masseter muscles to be 0.85 and 0.67, respectively, and the specificity to be 0.87 and 0.77, respectively. Similar results for sensitivity and specificity were observed by Visscher *et al*,²⁸ respectively, for groups both without temporomandibular disorders (0.64 and 0.68), and with temporomandibular disorders (0.7 and 0.72).

Skin temperature is a function of blood flow, controlled by the autonomic nervous system. This affects both sides of the body uniformly and simultaneously, resulting in a symmetry of thermal patterns.^{3,7,10,11,13,14,17,19–21,23–25} The literature describes the infrared, hyper-radiation presence in the regions of muscle tension when compared with the unaffected opposing muscle.^{7,13,19,20,30,31} However, all authors evaluated large ROIs. Owing to its size and functionality, a single masticatory muscle can have more than one MTP. When calculating the average temperature of the entire muscle, without individualizing the MTP, a false thermal symmetry of the face might be observed because the values obtained may be dissipated by calculating the average temperature. However, when evaluating smaller areas corresponding to the size of an MTP, as was done in this study, this tends not to occur. This makes the results of thermal studies of smaller ROIs much more reliable, in relation to the study of a single ROI corresponding to an entire muscle. In addition, the higher the image resolution of the infrared sensor (in this case, 76 000 pixels), the more precise will

Table 2 Cut-off points found for temperature (T), normalized temperature (θ), gradient temperature (ΔT) and gradient of the normalized temperature ($\Delta\theta$)

Muscular patient condition	T ($^{\circ}\text{C}$)	θ	ΔT ($^{\circ}\text{C}$) ^a	$\Delta\theta$
Without MTP	>34	>0.810	<0.3	<0.036
Local pain	34–33.3	0.810–0.756	0.4	0.037
Referred pain	<33.3	<0.756	0.5	0.048

MTP, myofascial trigger point.

^aValues considered only when the contralateral side showed no MTP. In the situation in which local pain exists on one side and referred pain on the other side, the observed values were $\Delta T = 0.5^{\circ}\text{C}$ and $\Delta\theta = 0.045$.

Table 3 Areas under the receiver operating characteristic curve (AUC) of the myofascial trigger points (MTPs)

MTP – local pain \times referred pain	AUC	95% CI	
T	0.564	0.504	0.623
$\Delta\theta$	0.578	0.041	0.743
ΔT	0.609	0.451	0.766
θ	0.617	0.559	0.674
PPT	0.737	0.685	0.789

θ , normalized temperature; $\Delta\theta$, gradient of the normalized temperature; ΔT , gradient temperature; CI, confidence interval; PPT, pressure pain threshold; T, temperature.

Table 4 Sensitivity, positive predictive value (PPV), specificity and negative predictive value (NPV) for local pain and referred pain, for the obtained cut-off points

Myofascial trigger point	Measures	Sensitivity (%)	PPV (%)	Specificity (%)	NPV (%)
Local pain	<i>T</i>	17	43.5	56.1	62.6
	θ	22.7	51.2	61.7	66.4
Referred pain	<i>T</i>	50	36.8	17	74.6
	θ	51.6	39.3	22.7	70.8
	PPT (kgf)	65.6	53.4	73.4	82.1

θ , normalized temperature; PPT, pressure pain threshold; *T*, temperature.

be the thermal assessment of smaller ROIs. In this study, much smaller areas were studied, dividing the temporal muscle into six ROIs and the masseter into nine. Using this methodology based on Pogrel *et al*'s⁶ study, it was possible to observe the thermal behaviour of the cutaneous region exactly at the location of the point of muscular tension (MTP).

In this study, the temporal muscle was significantly more hyperthermic than the masseter ($T = 34.63^\circ\text{C} \pm 0.73$, $\theta = 0.861 \pm 0.061$ vs $T = 33.18^\circ\text{C} \pm 1.05$; $\theta = 0.768 \pm 0.078$, $p < 0.05$). Similar results were found in the literature.^{13,17,19,24} This difference in temperature between these muscles is explained on the basis of anatomy: the temporal muscle, in addition to being thinner than the masseter, is influenced by the superficial path of the temporal artery, which makes the region more hyper-radiant. In the thermal comparison (ΔT ; $\Delta\theta$) between the opposing sides, the temporal and masseter muscles showed no significant difference.

Although the PPT and thermographic examinations serve totally different purposes, in which the first assesses tenderness to compression and the second evaluates the local vasomotor response, moderately significant correlations were observed between the PPT values (kgf) and the temperature (*T* and θ), suggesting that the greater the force applied, the greater the local temperature recorded. Also, the temperatures (*T*, θ) at the points of local pain were higher than those at areas of referred pain ($p < 0.05$). Therefore, the temperature decreases according to the severity of myofascial dysfunction.

The most heated areas of the face were correlated with regions without MTP, seen in the ROC curve as cut-off points with *T* above 34°C and θ above 0.810, between the corresponding ROIs. At the same time, PPT values below 1.35 kgf, *T* below 33°C , and θ under 0.756 were related to MTPs with referred pain. In a middle range, values of *T* between 34°C and 33.3°C

and θ between 0.810 and 0.756 were present in cases of MTPs with local pain. These results are apparently different from those found in the literature, which state that an MTP is always hotter than the unaffected side.^{2-4,7,18,30,32} A single study also found no relationship between hyper-radiant points and active MTPs when studying the upper trapezius muscle.³³ In the present study, an inverse behaviour of the vasomotor response was observed in the ROIs, corresponding to the MTP of the masseter and temporal muscles. That is, they were cooler than the corresponding contralateral region with no MTP. The explanation formulated for this result is given on the basis of studies conducted by Simons⁵ on autonomic disorders in myofascial dysfunction. Cutaneous temperature is a function of blood flow, controlled by the autonomic nervous system. In the presence of an MTP, *i.e.* a sarcomeric contraction of the muscle fibre, there can be a response of reduced blood flow, thus reducing local muscle oxygenation (hypoxia).^{4,5,20,34,35} This hypoxia can trigger a regional sympathetic hyperactivity in the cutaneous projection area of the muscle, also decreasing the local temperature through vasoconstrictive activity.

The parameter most used in the evaluation of infrared thermography is thermal asymmetry, also known as the conjugated gradient (ΔT) between the corresponding opposite sides. According to the literature, right-left thermal differences greater than 0.3°C can define a myofascial dysfunction.^{10,12-14,24-26,36} By the evaluation of the cut-off points, the value of the conjugated gradient (ΔT) was higher than 0.3°C and the normalized temperature value ($\Delta\theta$) was greater than 0.036. When the MTPs were separated into local and referred pain, the values of $\Delta T > 0.4^\circ\text{C}$ and $\Delta\theta > 0.037$ were found to detect the point of local pain, and $\Delta T > 0.5^\circ\text{C}$ and $\Delta\theta > 0.048$ to detect ROIs with referred pain. In cases in which there was local pain

Table 5 Cut-off point, sensitivity and specificity for the absence of myofascial trigger points (MTPs), local pain and referred pain in the conjugated gradient (ΔT) and normalized conjugated gradient ($\Delta\theta$)

MTP	Measures	Cut-off point	Sensitivity (%)	Specificity (%)
With and without MTP	ΔT	0.3	61.82	50
	$\Delta\theta$	0.036	41.82	62.30
Without MTP \times local pain	ΔT	0.4	43.62	60.66
	$\Delta\theta$	0.037	43.62	58.20
Without MTP \times referred pain	ΔT	0.5	62.5	71.31
	$\Delta\theta$	0.048	50	72.95
Local pain \times referred pain	ΔT	0.5	62.5	63.83
	$\Delta\theta$	0.045	50	69.15

$\Delta\theta$, gradient of the normalized temperature; ΔT , gradient temperature.

on one side and referred pain on the other, the values recorded were $\Delta T > 0.5^\circ\text{C}$ and $\Delta\theta > 0.045$. Except for Fischer and Chang,⁷ who described MTPs with ΔT much higher, ranging from 0.5°C to 1°C , all other authors agree with the variations between 0.3°C and 0.5°C . However, they all agree in saying that the thermal image formed in the projection region of the MTP is a local vasomotor response.

In this study, the presence of an MTP in the ROI showed progressive positive predictive values of T , θ and the PPT as 36.8%, 39.3% and 53.4%, respectively. For both T and θ , the sensitivity of the method to identify an MTP with referred pain was average (50%), although the specificity was low (17%). Regarding the presence of an MTP, sensitivity and specificity for both ΔT and $\Delta\theta$ were 62.5% and 71.31%, respectively. These results suggest greater diagnostic accuracy when different temperatures (ΔT ; $\Delta\theta$), rather than absolute temperature (T), are used, even when corrected for each individual (θ) for the identification of MTPs. These results suggest that thermal values, if used in conjunction with physical assessment, can serve as a means of screening and improved diagnostic accuracy in clinical practice.

Further investigation is needed of MTPs in masticatory muscles, but these findings suggest that thermography may prove helpful in the objective evaluation of MTPs, especially if it is used in conjunction with

physical assessment, as a means of screening and of improved diagnostic accuracy in clinical practice.

In conclusion, there is a statistically significant and directly proportional correlation between algometry and thermography in the assessment of MTPs, in which the greater the force applied, the greater the local temperature recorded. When assessing sensitivity to pain and local vasomotor response, the statistical difference shows that temperature decreases as the severity of myofascial dysfunction increases. Thus, the thermographic image of the trigger point is hyporadiant when compared with the corresponding region with no MTP. In the thermographic assessment of MTPs in the masseter and temporalis muscles, the results suggest that the parameters of thermal asymmetry (ΔT and $\Delta\theta$) show greater sensitivity and specificity than local absolute temperature values (T), even when corrected for the patient's core temperature and the temperature of the room during the examination (θ). Thermography makes it possible to quantify and identify the points of MTPs, separating them into local pain and referred pain.

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