Thermographic Characterization of Osteoarthrosis of the Temporomandibular Joint

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This study assessed the use of electronic thermography in the thermal image characterization of 20 patients with osteoarthrosis of the temporomandibular joint as proven by radiographic detection of bone erosions. Thermal assessments included: pattern recognition, pattern symmetry, absolute temperature, ΔT measurements, and mean temperature measurements and differences within five designated anatomic zones. In patients with osteoarthrosis of the temporomandibular joint, results demonstrated some characteristically abnormal thermal patterns; low levels of thermal symmetry; and substantially elevated absolute temperature measurements, mean temperature zone measurements, and ΔT values. These observations suggest that electronic thermography may prove to be clinically useful as a diagnostic method of assessing temporomandibular joint disorders, particularly osteoarthrosis. However, more extensive studies are needed before thermographic evaluation of the temporomandibular joint will be accepted clinically.

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Osteoarthrosis (OA) (also called osteoarthritis, degenerative joint disease), when it occurs in the temporomandibular joint (TMJ), presents as a chronic degenerative process with destruction of bone and articular cartilage. This may lead to bone spur formation, bone erosion, pain, joint stiffness, limitation of motion, reduced vertical joint space, and changes in the morphology of the joint.[1,2] The current diagnostic imaging methods for the assessment of OA of the TMJ include plain film radiography, panoramic radiography, tomography, arthrotomography, arthroscopy, computerized tomography, and magnetic resonance imaging. Most of these techniques either require ionizing radiation or are invasive, and all are expensive. An alternative diagnostic imaging method, electronic thermography (ET), is inexpensive, nonionizing, and noninvasive. Vascular heat emissions from the human face (and especially the TMJ) may be imaged rapidly using noncontact infrared thermal imaging systems. Electronic thermography already has been shown to portray symmetric thermal patterns in normal subjects and asymmetric thermal patterns in patients with a variety of disorders,[3] including myofascial pain syndromes,[4] myositis,[5] TMJ disorders,[6–14] and motor and sensory radiculopathy,[15] as well as the inflammation of arthritis[16] and bursitis.[17]

The dental literature has recently reported assessments of normal TMJ patients[12,18,19] and patients with internal derangement of the TMJ.[14] However, the thermal changes seen in patients having OA have not been adequately defined. This study is designed to characterize the abnormal thermal patterns of the TMJ in patients with

OA as an early step in the assessment of ET as a diagnostic test of TMJ disorders. This is the second in a series of four reports examining the use of ET in the diagnosis of TMJ disorders.

Materials and Methods

Population

Our targeted population consisted of consenting adult volunteers who required a complete TMJ tomography examination. All patients received a careful clinical examination at the University TMJ Clinic. A detailed medical history and the findings from a thorough clinical examination were obtained and recorded and then assessed by the oral radiologist. Only patients who had radiologically interpreted OA of the TMJ were selected for this study (eliminating patients with acute muscle spasm, sinus disease, polyarthritis, etc). Radiographs were examined and a written report prepared by the oral radiologist. Twenty patients (mean age = 36 years; 16 women, 4 men) having at least 1.5 mm of bone erosion present on the superior lateral aspect of the condyle (as seen on frontal, protruded-jaw tomograms; Fig 1) participated in this study. Patients were divided into two groups: group 1 patients had radiographically proven bone erosion(s) on only one side of the jaw and were classified as unilateral OA; group 2 patients were those having proven bilateral condylar bone erosions and were classified as bilateral OA. Clinical symptoms such as clicking or limited opening were not used as eligibility criteria.

Fig 1 Frontal tomograph of the mandibular condyle with the jaw in a protruded position; note presence of a condylar bone erosion (*arrow*) of at least 1.5 mm on the superior lateral aspect of the condyle, which implies the classification of OA.

Thermography Equipment

Facial thermography was conducted using an Agema 870 thermovision unit (infrared scanner, control unit, thermal image computer TIC-8000 and Meds 1.0 software, cables, stands, supports, and color monitor [all Agema Infrared Systems, Secaucus, NJ]) coupled to a 35-mm camera using color print film. Room conditions for thermographic examinations included a draft-free environment (no windows, closed doors), temperature control (ranging from 20°C to 22°C), variable lighting, a patient-positioning chair, and a small hand-held electric fan.

Facial Imaging

All patients received a facial thermographic examination. Facial thermograms were taken using right and left lateral projections at two imaging sensitivities (0.5°C and 1.0°C). Each patient's face was cleared of hair before the examination (tied back using an elastic headband). The face and TMJ regions were wiped with a damp cloth and air dried using a small electric fan. The patient was seated and a 15-minute time period was allowed for facial temperature equilibration before thermograms were made. Images were stored on computer disk and also photographed for evaluation.

Methods of Image Characterization. Subjective thermal image assessments were made including (*1*) thermal pattern characterization of individual TMJ images and (*2*) thermal pattern symmetry assessments comparing paired TMJ images. Objective thermal assessments were made including (*1*) absolute (spot) temperature measurements, (*2*) differences in absolute (spot) temperature measurements of paired TMJ images (calculation of ΔT), (*3*) mean temperature measurements of the five anatomic zones related to the TMJ,[19] and (*4*) differences in the mean temperatures of these five anatomic zones (obtaining additional ΔT measurements).

Thermal Pattern Characterization. Color photographs (9 × 12.5 cm) of paired TMJ thermal images were evaluated independently by two examiners. Each examiner subjectively evaluated the individual examples (made up of two thermograms) for regions of increased, average (normal), or decreased temperature. The specific question asked of each examiner was "How would you best characterize the thermal pattern of the TMJ?" Image characterizations were made using lateral projections at 0.5°C and 1.0 °C imaging sensitivity (Table 1).

Assessment of Thermal Image Symmetry. The same color prints used in the subjective thermal pattern characterization were used for assessment of thermal symmetry by comparing the temperature distribution (color patterns) over the anatomic region of the TMJ with the corresponding region of the opposite side of the face. Scoring ranged from 1 to 6 using the following scale: 1 = > 80% symmetry; 2 = 65% to 80% symmetry; 3 = 50% to 65% symmetry; 4 = 35% to 49% symmetry; 5 = 20% to 34% symmetry; 6= 0% to 19% symmetry; 0 = cannot be evaluated (poor image, poor positioning, etc).

This scale was selected because its discriminant points were easy to estimate on a repeatable and routine basis. Assessments were made at both 0.5°C and 1.0°C imaging sensitivity.

Absolute (Spot) Temperature Measurements. All 40 TMJ images were measured for absolute temperature and verified using a noncontact, infrared hand-held thermometer (accuracy/measurement error of ± 0.1°C per manufacturer's specifications, Horida IT-330, Miyanohigashi, Japan). Measurements were made of the following regions (Fig 2): (*1*) the hot central TMJ spot (hot yellow inner core), (*2*) the warm ring around the hot yellow core (red ring), and (*3*) the surrounding field (pink area between the two hot yellow zones). In addition, an absolute (spot) temperature measurement was made of the hot yellow area over the external auditory meatus (EAM or ear canal).

Differences in Absolute (Spot) Temperature Measurements. The right- and left-sided absolute (spot) temperature measurements were compared for each subject. Calculation of differences produced four ΔT values for each set of paired images.

Mean Temperature Measurements Over the TMJ and Related Anatomic Zones. Five anatomic zones related to the TMJ were measured for mean temperature (Fig 3): zone 1 included the area directly over the TMJ; zone 2 included a larger area over and anterior to the TMJ; zone 3 was limited to the region over the body of the mandible; zone 4 included the whole midregion of the face, including the TMJ region; and zone 5 covered the entire half face, including the TMJ. Mean temperature measurements were made using all 40 TMJ images.

Differences in Mean Temperature Measurements Over the TMJ and Related Anatomic Zones. Differences in the mean temperatures measured for the five anatomic zones were calculated, producing ΔT values for each set of paired images.

Table 1 Subjective Thermal Pattern Classifications of 20 Subjects With Osteoarthrosis of the TMJ

Imaging sensitivity	Side	n	TMJs with most common pattern (%)	TMJs with other pattern (%)
Group 1 (unilateral OA)				
0.5°C	affected	10	2 (20%)	8 (80%)
	unaffected	10	5 (50%)	5 (50%)
1.0°C	affected	10	2 (20%)	8 (80%)
	unaffected	10	5 (50%)	5 (50%)
Group 2 (bilateral OA)				
0.5°C	right affected	10	4 (40%)	6 (60%)
	left affected	10	4 (40%)	6 (60%)
1.0°C	right affected	10	4 (40%)	6 (60%)
	left affected	10	5 (50%)	5 (50%)
Total				
0.5°C	affected	30	10 (33%)	20 (67%)
	unaffected	10	5 (50%)	5 (50%)
1.0°C	affected	30	11 (37%)	19 (63%)
	unaffected	10	5 (50%)	5 (50%)

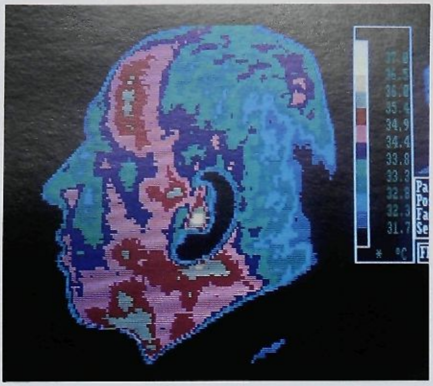


Fig 2 Lateral TMJ thermogram demonstrating the four regions (measured at 0.1°C sensitivity, imaged at 0.5°C sensitivity): region 1 = central TMJ region, region 2 = red ring around region 1, region 3 = pink field between regions 2 and 4, and region 4 = central EAM.

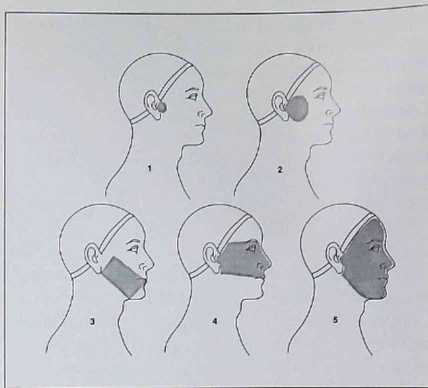


Fig 3 The five anatomic zones related to the TMJ measured in this study.

Results

Thermal Pattern Characterization

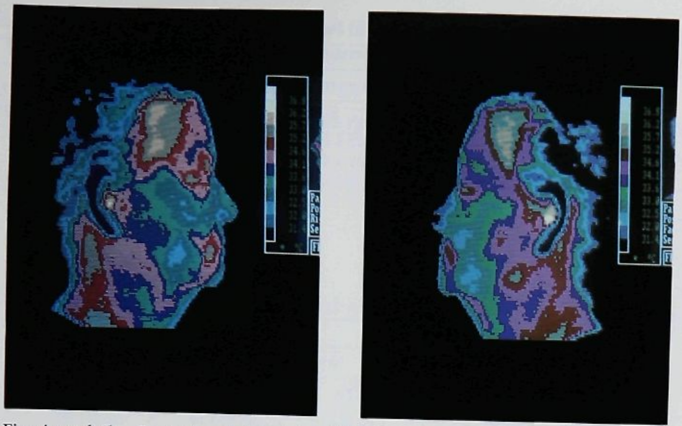
Results of the subjective characterizations of color TMJ thermal patterns are shown in Table 1. Observer reliability was high, calculated at 96%. One third of the images of patients with abnormal TMJs demonstrated a common pattern, as did half of those of patients with normal TMJs. A range of patterns was identified when viewing properly thermal-focused images of affected joints.

At 0.5°C imaging sensitivity, the most common abnormal pattern involved a large yellow (hot) region around the TMJ and a second hot area around the EAM. These two hot areas would fuse together forming a slanted figure 8–shaped hot area in approximately half of the images; on occasion, the figure 8 would enlarge into a single round or c-shaped hot (yellow) area. The entire hot region around and adjacent to the TMJ also was found to be variable in size, being at least two, and on occasion five, times larger than the expected size of the yellow (hot) zone seen on normal thermal images of the TMJ.[19] Figures 4a and 4b show examples of thermograms taken of TMJ OA patients imaged at 0.5°C sensitivity.

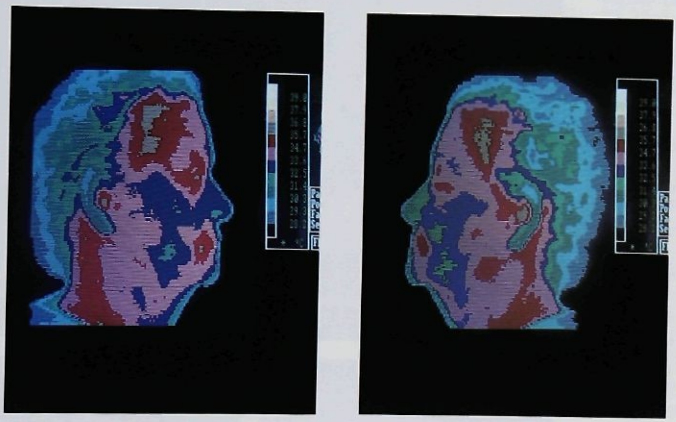
At 1.0°C imaging sensitivity, the most frequent abnormal color pattern was found in images of 11 of the 30 affected TMJs (37%). The two yellow (hot) areas over the TMJ and EAM were within a red zone having a variety of shapes and sizes. The red zone in OA cases was two to four times larger than that seen on normal images; on occasion there were vertical and/or horizontal red extensions or spurs radiating from the TMJ area. The two yellow regions over the TMJ and EAM were variable in size and shape but always larger than those seen on normal thermal images.[19] Figures 5a and 5b are examples of OA TMJ thermal patterns imaged at 1.0°C sensitivity.

Assessment of Thermal Image Symmetry

Results of the subjective thermal image symmetry assessment are shown in Table 2. Observer reliability was calculated at 90%. Images taken at 1.0°C demonstrated slightly higher thermal symmetry than did those taken at 0.5°C (30% vs 15% of images displayed thermal symmetry at the > 65% level). There were no cases with high levels of thermal symmetry (> 80% symmetry). Poor levels of thermal symmetry (< 65% symmetry) were found to occur in slightly more than three fourths of the images assessed. Very low levels of thermal symmetry (< 50% symmetry) were found to occur in one fourth of the images. Overall, patients with OA of the TMJ, both unilaterally and bilaterally, demonstrated poor thermal symmetry on TMJ



Figs 4a and 4b Examples of right (*a*) and left (*b*) TMJ thermographs of a 42-year-old female having OA of the left TMJ (imaged using 0.5°C sensitivity).



Figs 5a and 5b Examples of right (*a*) and left (*b*) TMJ thermographs of same patient as seen in Figs 4a and 4b, imaged using 1.0°C sensitivity. Note the increased temperature (red region) over the left TMJ, indicating OA.

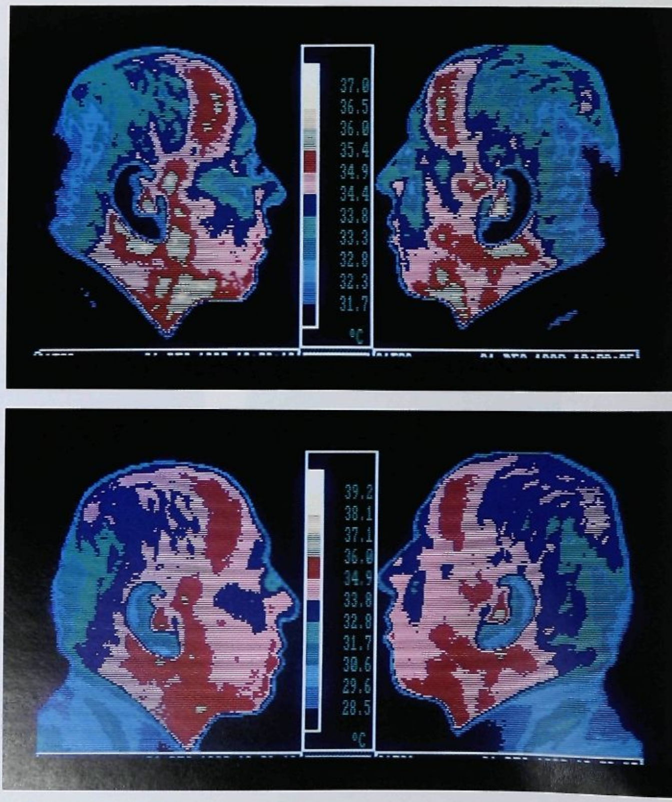
thermograms at both 0.5°C and 1.0°C imaging sensitivities (Figs 6a and 6b).

Absolute Temperature Measurements

The results of the objective measurements of absolute temperature are shown in Table 3. The region over the EAM on affected joints demonstrated the highest temperatures, ranging from 36.3°C to 36.5°C. The same region over unaffected joints measured 36.0°C. The region immediately over the TMJ measured approximately 35.8°C for all affected joints (both unilaterally and bilaterally affected). The same region measured over un-

Table 2 Subjective Assessment of Thermal Pattern Symmetry Assessing 20 TMJ Thermograms Imaged at 05°C and 1.0°C Sensitivity on Patients With OA of the TMJ

			Symmetry rating (% of thermal symmetry)				
Imaging sensitivity	n	> 80%	65%–80%	50%–64%	35%–49%	20%–34%	< 20%
Group 1 (unilateral OA)							
0.5°C	10	0	1	7	1	1	0
1.0°C	10	0	4	3	2	1	0
Group 2 (bilateral OA)							
0.5°C	10	0	2	5	2	1	0
1.0°C	10	0	2	6	1	1	0
Total							
0.5°C	20	0	3	12	3	2	0
1.0°C	20	0	6	9	3	2	0



Figs 6a and 6b Right and left (paired) TMJ thermograms imaged from 55-year-old male using 0.5°C sensitivity and demonstrating poor TMJ thermal symmetry (*a, top*). Right and left TMJ thermograms imaged on the same patient using 1.0°C sensitivity again demonstrating poor thermal symmetry over the TMJ (*b, bottom*).

Table 3 Mean Absolute Temperature Measurements (SD) of the Four Regions Around the TMJ

	Group 1 (unilateral OA, n = 10)			Group 2 (bilateral OA, n = 10)		
Region measured	Affected side*	Unaffected side*	ΔT*	Right side*	Left side*	ΔT*
TMJ center	35.8 (0.36)	35.2 (0.84)	0.5 (0.64)	35.9 (0.49)	35.7 (0.29)	0.3 (0.30)
TMJ ring	35.3 (0.39)	34.7 (0.66)	0.4 (0.52)	35.2 (0.32)	35.2 (0.28)	0.2 (0.10)
TMJ field	34.7 (0.43)	34.4 (0.62)	0.4 (0.33)	34.8 (0.35)	34.8 (0.24)	0.2 (0.18)
EAM	36.4 (0.25)	36.0 (0.32)	0.3 (0.23)	36.5 (0.39)	36.4 (0.39)	0.2 (0.21)

*°C.

Table 4 Mean Temperature Measurements (SD) and Absolute Differences in Temperature From Side-to-Side (SD) of the Five Anatomic Zones

	Group 1 (unilateral OA, n = 10)			Group 2 (bilateral OA, n = 10)		
Anatomic Zone	Affected side*	Unaffected side*	ΔT*	Right side*	Left side*	ΔT*
Small TMJ	35.2 (0.30)	34.4 (0.38)	0.4 (0.21)	35.5 (0.46)	35.2 (0.29)	0.3 (0.13)
Large TMJ	34.6 (0.37)	34.9 (0.49)	0.3 (0.24)	35.0 (0.45)	34.7 (0.29)	0.3 (0.18)
Midface	34.2 (0.52)	34.3 (0.52)	0.2 (0.15)	33.4 (0.39)	34.2 (0.28)	0.1 (0.16)
Mandible	34.2 (0.62)	34.0 (0.62)	0.3 (0.25)	34.1 (0.68)	34.0 (0.60)	0.1 (0.11)
Entire half-face	34.4 (0.48)	34.1 (0.50)	0.2 (0.18)	34.5 (0.39)	34.4 (0.29)	0.1 (0.12)

*°C.

affected joints was found to be 35.2°C. For all measurements the standard deviations were relatively large, ranging from 0.25°C to 0.84°C.

Differences in Absolute Temperature Measurements (ΔT)

The results of the differences in absolute temperature measurements (ΔT) are shown in Table 3. Both groups of patients demonstrated large ΔT values immediately over the TMJ. Group 1 patients (with unilateral OA of the TMJ) demonstrated the greatest mean ΔT value (0.5°C) and had the greatest clinically relevant difference (affected vs unaffected joint when comparing TMJs in the same patient). Group 2 patients (with bilateral OA of the TMJ) showed mean ΔT differences of 0.3°C. All ΔT values, including those in the TMJ-center region (0.3°C to 0.5°C), the TMJ ring region (0.2°C to 0.4°C), the TMJ field region (0.2°C to 0.4°C), and the EAM region (0.2°C to 0.3°C) were significantly different ($P < .05$, Student's t test) from those of normal TMJ subjects (mean ΔT values of 0.0°C to 0.1°C).[19] However, in most cases the standard deviations of the ΔT values were large, ranging from 0.10°C to 0.64°C.

Mean Temperature Measurements Over the TMJ and Related Anatomic Zones.

The results of the mean temperature measurements of the five designated anatomic zones are shown in Table 4. The small zone immediately over the TMJ was found to have the highest temperature, ranging from 35.2° to 35.4°C in all 30 affected joints. The same zone measured over the 10 unaffected joints was found to be 34.8°C. Similarly, the large anatomic zone over and around the TMJ had the next highest temperature, ranging from 34.7°C to 34.9 °C in affected joints. The same zone measured over the 10 unaffected joints was found to be 34.4°C. In both groups of patients, the region over the mandible demonstrated the lowest temperature, ranging from 34.0°C to 34.1°C. The standard deviation of the mean ΔT values ranged from 0.11°C to 0.68°C.

Differences in Mean Temperature Measurements (ΔT) Over the TMJ and Related Anatomic Zones

Results of calculating the differences in mean temperature (ΔT) by anatomic zone are shown in

Table 4. The small zone immediately over the TMJ was found to have the greatest ΔT values, ranging from 0.3°C to 0.4°C. The large area over and around the TMJ had the next greatest temperature difference from side-to-side (0.2°C). The three other zones (mandible, midface, and entire half face) had temperature differences ranging from 0.1°C to 0.3°C. In most cases the standard deviations of the mean ΔT values were substantial, ranging from 0.11°C to 0.25°C.

Discussion

These subjective assessments of ET among patients with unilateral and bilateral TMJ OA consisted of two parts: pattern recognition and right-side vs left-side thermal symmetry evaluations. A common range of thermal patterns was found, but this pattern was seen in less than one third of the 20 cases studied. At 0.5°C sensitivity, this range of patterns is best described as: Two relatively hot areas, one over the EAM and the other over the TMJ; these areas vary in shape and size and may fuse together to form a slanted figure 8–shaped or large c-shaped relatively hot region (Figs 4a and 4b).

At 1.0°C sensitivity (Figs 5a and 5b) a second range of patterns was found that are best described as: One relatively hot area (yellow region) over the EAM with possibly a second relatively hot area over the TMJ; these areas vary in shape and size but are larger than those seen on normal subjects; and the hot (yellow) areas are surrounded by a large red zone also varying in shape and size and on occasion having extensions (or spurs) present radiating from the TMJ region superiorly and/or anteriorly toward the midface. This appearance differs markedly from the pattern commonly seen on thermograms of normal TMJs.[21]

The subjective thermal symmetry of TMJ images was evaluated, showing a relatively low level of thermal symmetry in cases of TMJ OA. Approximately 25% of the images were rated as less than 50% symmetric, only 25% of the images were rated moderately symmetric (65% to 80% symmetry), and no cases of high thermal symmetry were found. These observations are in sharp contrast with our previous finding that 90% of normal TMJs demonstrate more than 65% thermal symmetry.[19] Subjective thermal symmetry assessment indeed may have clinical value in evaluating TMJ disorders.

The objective part of our study, consisting of absolute temperature measurements and ΔT calculations, also demonstrated substantial differences between abnormal and normal TMJs. Both absolute and mean temperatures were elevated over abnormal TMJs for the EAM region (36.4°C), the TMJ-center region (38.8°C), the small TMJ zone (35.3°C), and the large TMJ zone (34.8°C), as compared with the same measurements over normal TMJs (36.0°C, 38.4°C, 34.8°C, 34.4°C). We believe that these differences are important. In the future they may allow for quantitative assessment of the severity of TMJ disorders.

Of even greater significance were the ΔT calculations derived in this study. For unilateral OA cases, ΔT over the TMJ center region was 0.5°C, markedly different from the 0.1°C ΔT of normal TMJs (SD = 0.1°C). The ΔT findings in this study also are important, and, when combined with the previously described observations, they represent the first indication that ET may have clinical value as a diagnostic test for OA of the TMJ. However, the standard deviations of other measurements recorded in this study indicated relatively large differences, as great as 0.8°C, thereby limiting the significance of some of the findings. More research, involving larger samples of subjects, is needed to determine the clinical significance of observed differences between groups of patients and individual patients with TMJ disorders.

Acknowledgments

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Resumen

Characterización Termográfica de la Osteoartrosis de la Articulación Temopromandibular

Este estudio comparó los reportes de stress de pacientes Finlandeses afectados por desórdenes craneomandibulares (DCM) y de personas que no eran pacientes; por medio de la utilización del Inventario de los Síntomas de Stress como medio de examen masivo. Así mismo se realizó una comparación de los reportes de stress entre los pacientes Finlandeses y Americanos, afectados por DCM. El nivel de stress total de los pacientes que sufrían de DCM fué mayor en comparación a las personas que no se consideraban pacientes. Los pacientes presentaron puntajes elevados en las subescalas somáticas, siendo los síntomas de tensión muscular los más característicos. Estos resultados concuerdan con los resultados Americanos. Sin embargo, no se encontraron diferencias estadísticamente significativas en el caso de los síntomas emocionales.

Zusammenfassung

Thermographische Charakterisierung der Osteoarthrose des Kiefergelenkes

In dieser Studie kam die elektronische Thermographie zur Anwendung für die Charakterisierung thermischer Bilder von Patienten mit arthrotischen Kiefergelenken. Die Diagnose war vorgängig röntgenologisch bestätigt worden. Beurteilt wurden thermische Muster und Symmetrien, absolute Temperatur, Temperaturunterschiede sowie mittlere Temperatur und Temperaturunterschiede zwischen fünf definierten anatomischen Zonen. Die resultate zeigten typischerweise abnormale thermische Muster, asymmetrische Verhältnisse und allgemein erhöhte Werte für die absolute und die mittlere Temperatur und für die Temperaturunterschiede. Diese Beobachtungen lassen die elektronische Thermographie als klinisch vielversprechend erscheinen in der Beurteilung von Patienten mit Myoarthropathien des Kausystems, insbesondere Osteoarthrose. Bis die thermographische Untersuchung des Kiefergelenkes jedoch klinisch akzeptiert sein wird, sind weitere und grössere Studien nötig.