Pain Threshold Responses to Two Different Modes of Sensory Stimulation in Patients With Orofacial Muscular Pain: Psychologic Considerations

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This study focuses on the influence of trait anxiety and mood variables on changes in tooth pain threshold following two similar methods of somatic afferent stimulation, one familiar (manual acupuncture) and one unfamiliar (low-frequency transcutaneous electrical nerve stimulation [low-TENS]). Twenty-one acupuncture responders, treated for long-lasting orofacial muscular pain but naive to low-TENS, were selected for the study. In an experimental session, acupuncture and low-TENS were randomly given during two periods separated by a rest interval. Tooth pain thresholds (PT) were measured before and after stimulation with a computerized electrical pulp tester. Trait anxiety and depression were assessed with psychometric forms before the experimental session in all patients, whereas momentary mood was assessed in 10 randomly selected patients with visual analogue scales during and after the two types of stimulation. Following acupuncture, the group average PT increased significantly, whereas no significant change was observed following low-TENS. Higher scores on trait anxiety correlated significantly with a low PT increase following low-TENS, and higher ratings of stress correlated significantly with a low PT increase following acupuncture. This indicates that the magnitude of analgesia induced by these methods may be modified by psychologic factors like anxiety and stress.
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In the treatment of chronic pain, methods for stimulating somatic afferents, such as acupuncture and transcutaneous electrical nerve stimulation (TENS), have gained considerable interest. Both acupuncture and TENS have proven to be effective in treating nociceptive pain conditions; the percentage of patients successfully treated with these modalities varies between 40% and 80%.[1,2] It is apparent that certain types of pain respond better to these treatments than to others. It is therefore important to classify and define the type of pain condition being treated.[3]

Patients with temporomandibular disorders (TMD) suffering from muscle pain or myalgia of the masticatory muscles have been shown to respond favorably, with substantial reduction of pain, to both acupuncture and TENS.[4–8] Numerous studies have also shown that high-intensity somatic afferent stimulation can elevate

the pain threshold in humans and induce antinociceptive effects in animals.[9–17]

Pain relief following both acupuncture and TENS may be explained by similar central and peripheral mechanisms. The central mechanisms include the opioid systems, which are mediated by descending pathways from cortical and subcortical structures to the superficial layers of the spinal dorsal horn.[18,19] Furthermore, supraspinal and spinal mechanisms, resulting in an inhibition of the sympathetic tone, are likely to be involved.[20] In the periphery, antidromic stimulation of afferent nerve fibers results in the release of vasoactive substances such as calcitonine gene related peptide (CGRP) and vasoactive intestinal polypeptide (VIP).[21]

It is generally accepted that clinical pain relief involves complex psychologic interactions,[22–27] whereas experimental analgesia is generally discussed as related mainly to neurophysiologic and neuropharmacologic processes, with little consideration given to psychologic factors.[18,19,28–31] However, it has been suggested that anxiety, stress, and fear may play an important role in affecting pain sensitivity in experimental human subjects.[32,33]

Cornwall and Donderi[33] investigated the extent to which two different anxiety-evoking instructions (one creating anticipation of pain, the other creating anticipation of a stressful interview) influenced intensity ratings of experimental pain in healthy volunteers. They found that both types of stimuli produced higher pain- and stress-intensity ratings compared to a control situation.

An earlier study by Widerström et al[16] investigated relationships between clinical outcome, psychometrics, and experimental pain threshold changes after treatment with low-TENS in chronic pain patients suffering from musculoskeletal pain in the neck and shoulder region. In an experimental session in which low-TENS was given, clinical responders showed an elevated pain threshold (PT), whereas clinical nonresponders showed either no change or a decrease in PT after stimulation. It was suggested that the effects observed in nonresponders were the result of psychologic interaction with endogenous pain modulation. Nonresponders exhibited significantly higher levels of trait anxiety, which might have negatively influenced the clinical outcome as well as the experimental PT change.

The purposes of the present study were *(1)* to study pain threshold changes following two similar types of somatic afferent stimulation techniques in two different psychologic situations, one familiar (manual acupuncture) and one unfamiliar (low-TENS); and *(2)* to investigate whether the induced pain threshold changes were influenced by trait anxiety and mood variables.

Materials and Methods

Subjects

Subjects were recruited from patients in the Department of Stomatognathic Physiology, Faculty of Odontology, Göteborg, Sweden, who were diagnosed as suffering from TMD with chronic orofacial muscular pain according to the following criteria: *(1)* a history including complaints of orofacial pain; *(2)* a clinical examination demonstrating tenderness to palpation of the masticatory muscles; *(3)* exclusion of individuals with a history of trauma, surgery, or systemic joint, muscle, or skin diseases influencing signs and symptoms of the orofacial muscular pain; *(4)* no pathologic conditions in the temporomandibular joints (TMJs), facial skeleton, or teeth, as evaluated by panoramic radiographic examination; and *(5)* a complete or nearly complete set of natural teeth.

Thirty-three patients fulfilling these criteria were treated with acupuncture once a week for 6 weeks (see Acupuncture Stimulation below). Three months after completion of treatment, these patients filled out a form rating the pain-relieving effect of the treatment. The outcome was assessed as worse (n = 0), no improvement (n = 4), slight improvement (n = 12), substantial improvement (n = 12), and symptom-free (n = 5). Only those patients who indicated improvement, ranging from slight (n = 10) to substantial (n = 7), and those who indicated they were symptom-free (n = 4) were selected to participate in the study. Eight of the improved subjects did not participate in the study for the following reasons: acute illness (n = 1), personal (n = 4), no reproducible tooth pain threshold (n = 3).

To evaluate the influence of trait anxiety and mood variables following treatment with two stimulation modalities in two different psychologic situations (familiar versus unfamiliar), only acupuncture responders were selected for participation in the study. All subjects had improved following acupuncture; that is, they had positive effects from this type of treatment. In contrast, TENS was a novel modality in which these subjects had no previous experience. Demographic and related data are presented in Table 1. All subjects gave informed consent to procedures approved by the Ethical Committee of the Faculty of Medicine at Göteborg University.

Table 1 Sample Characteristics of Study Participants

Total number of patients	21
Men	8
Women	13
Age distribution (y)	23–71
Median	47.5
Pain duration (y)	0.5–33
Median	8.5

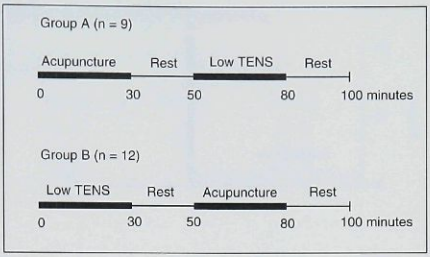

Fig 1 Experiment design for Group A and Group B.

Research Procedures

During the first session, each subject was carefully informed about the study and introduced to the methods to be used. Pain thresholds for each subject were recorded three times on the same maxillary incisor (1:1 or 2:1) during a period of 20 minutes with 10-minute intervals to familiarize subjects with the test procedure and to train them to discriminate threshold stimuli. At the end of the first session, they filled out psychometric forms (see Psychometric Measures below).

For the second session, subjects were randomly assigned to one of two groups (group A or group B). Somatic afferent stimulation was accomplished with manual acupuncture or low-TENS in two separate 30-minute periods, each followed by a 20-minute rest (Fig 1). The order of the two interventions was varied for group A and group B to avoid possible order effects. PTs were measured immediately before and after the stimulation periods and again after the rest periods. Before and during the two stimulation periods, subjects were asked to rate their momentary mood on a visual analogue scale (VAS).

Pain Threshold Measurements

A healthy maxillary middle incisor was selected for the testing based on reproducible threshold values in response to electrical stimulation. The electrical stimuli were distributed via a carbon rubber electrode (cathode) placed in a dental splint against the buccal surface of the tooth. The other electrode (anode) served as a current switch and was held by the subject. A computerized constant-current stimulator, including a security device that prevented the current from exceeding 100 μA, was used to deliver unipolar square wave pulses of 2-millisecond duration at a frequency of 20 Hz. The subject was instructed to break the current as soon as a pain sensation was perceived in the tooth.[14,16,34,35] The mean of three successive measurements was defined as the pain threshold. The procedure was randomized by means of varying the time required in each trial for the current to reach threshold level so as to prevent the time factor from biasing the patient's response. This method has been described in detail previously.[16]

Transcutaneous Electrical Nerve Stimulation

A constant-current TENS stimulator was used to deliver a train of 8 stimuli with an interpulse interval of 14 milliseconds at a frequency of 1.7 Hz. Each stimulus had a duration of 0.2 milliseconds. Three pairs of electrodes (each 50 × 30 mm) were used. One pair was applied over the infraorbital foramina and two pairs were placed on the upper limbs; one electrode was placed on the hand just distal to the junction of the metacarpal bones, between the thumb and the index finger, and the other on the arm between the lateral epicondyle and the crease of the elbow. The limb placements were chosen because intense stimulation of the hand has been shown to elicit dental analgesia.[10,16,36,37] The intensity was gradually increased during the session and varied from 15 to 40 mA. The stimulation lasted for 30 minutes, causing strong but not painful muscle contractions of the face and the arms. The only information given to the patients concerning the two modes of stimulation was that TENS is a method for treating chronic pain that offers an equivalent alternative to acupuncture. Information about TENS was made as neutral as possible to avoid setting up specific expectations, which otherwise might have influenced the effects induced by the stimulation.[38]

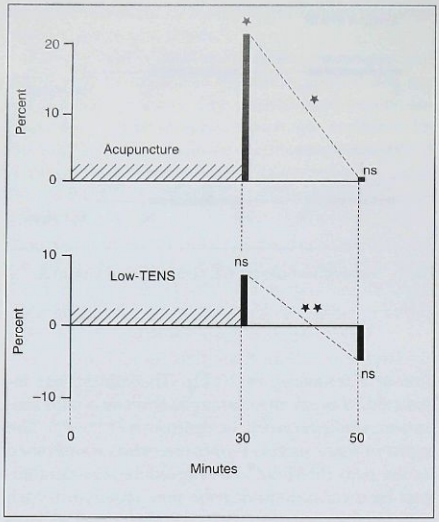

Fig 2 Average percent change in pain threshold (PT) following 30 minutes of either acupuncture or low TENS, compared to baseline. PT increased significantly directly following acupuncture ($P < .05$), but not following low TENS. The decline of the PT was significant for both acupuncture ($P < .05$) and low TENS ($P < .01$).

Acupuncture Stimulation

Sterile stainless-steel needles were inserted at the same locations (abbreviations below refer to the nomenclature recommended by the World Health Organization) used during clinical treatment. Additionally, all subjects had needles inserted in their hands, between the thumb and the index finger (LI 4). The following facial stimulation sites were most commonly used:

- The deep portion of the masseter muscle just below the zygomatic arch and anterior to the temporomandibular joint (ST 7)
- The middle of the superficial portion of the masseter muscle near the mandibular angle (ST 6)
- The anterior border of the masseter muscle below the zygomatic arch (SI 18)
- The anterior border of the temporal muscle (ST 8)
- The middle of the frontal muscle in line with the pupil when looking straight ahead (GB 14)

The total number of needles varied between 8 and 12 and the depth of insertion for each needle was 5 to 10 mm, depending on the underlying structures. The needles were left in place for 30 minutes and twirled every 10 minutes to ensure the "needle-sensation," often described as tension, numbness, tingling, tenderness, and sometimes radiating parasthesia from the point of insertion.

Psychometric Measures

Psychometric measures were used to assess subjects' psychologic characteristics and psychologic changes during the experimental procedures. Trait Anxiety Inventory (STAI-Y2) consists of 20 statements (raw score ranging from 20 to 80) and evaluates how anxious the subject is "in general."[39] Zung Self-Rating Depression Scale consists of 20 items (raw score ranging from 20 to 80) measuring both somatic and affective components of depression.[40]

Self-reported momentary mood was assessed in 10 randomly selected subjects with visual analogue scales administered before the periods of stimulation and after 15 minutes of acupuncture and low-TENS, respectively. The scales consisted of four 100-mm lines oriented vertically to measure pleasantness, alertness, relaxation, and stress. The range of mood was as follows: pleasantness = sad to happy; alertness = idle to active; relaxation = tense to relaxed; stress = not at all to very stressed.

Statistical Analysis

The main response variable, PT change, was calculated as a percentage value for the PT at termination of stimulation as compared to baseline. The PT immediately before onset of either low-TENS or acupuncture stimulation determined the baseline. Statistical analyses were based on the individual mean changes in PT. Wilcoxon's signed rank test was used for paired samples, and the Mann-Whitney *U* test was used to measure median difference between independent groups. Multiple regression analysis (forward elimination technique) was used to find the explanation variables for relative change in PT after acupuncture and TENS, respectively.[41] All tests were two-tailed. Statistical significance was considered when $P < .05$.

Results

Pain Threshold Changes

The PT changes following the two different stimulation modalities were analyzed separately since no significant order effects were observed between group A and group B (Fig 2). After 30 minutes of

Table 2 Depression and Trait Anxiety Scores for Acupuncture Responders, TENS Responders, and Healthy Normals

	Depression†		Trait anxiety‡	
	Median	Range	Median	Range
Acupuncture responders (n = 21)	34	25–63	36	23–64
TENS responders (n = 13)[16]	33	21–45	38	21–54
Healthy normals (n = 19)*	35	25–50	34	25–61

*Unpublished results.
†Zung Self-Rating Depression Scale.
‡Spielberger's State Trait Anxiety Inventory.

acupuncture, the group average PT was significantly increased by 21% (range –19 to +134) ($P < .05$) and then declined to baseline (+1%; range –31 to +74) after 20 minutes. After 30 minutes of low-TENS, the PT group average increased by 6% (range –47 to +48) (ns) and then decreased below baseline (–5%; range –50 to +22) within 20 minutes. The PT decline between t = 30 and t = 50 was significant after both acupuncture ($P < .05$) and low-TENS ($P < .01$). Although the PT increased by 21% following acupuncture and by only 6% following low-TENS, the difference did not reach significance.

Table 3 Multiple Regression Analysis Predicting the Pain Threshold Change Following Acupuncture (n = 9)

	Pain threshold change	
Predictor variable	b Coefficient	*P*
Relaxation	0.528	.060
Stress	–0.776	.031

$R^2 = 0.687$.
$P = .031$.

Psychometric Measures

Table 2 shows trait anxiety and depression scores. To compare the acupuncture responders of the present study with clinical TENS responders in a previous paper[16] and with a group of healthy subjects (unpublished results), scores are also given for these two groups. No significant differences between median anxiety and depression level, respectively, were observed between the three groups.

In an attempt to evaluate whether the four different mood variables (pleasantness, alertness, stress, relaxation) were affected by the given stimulations, 10 patients marked their momentary mood on a VAS before and during the stimulation periods. One patient was excluded as a result of language problems. The score for relaxation increased and the score for stress decreased similarly during both types of stimulation, although not significantly.

The four different mood variables and trait anxiety were included in two separate multiple regression analyses (forward elimination procedure) as independent variables to predict the percentage PT change (dependent variable) following acupuncture and low-TENS.

The multiple regression analysis in Table 3 shows that the PT change following acupuncture could be significantly ($P = .031$) predicted to 69% by two factors: the degree of relaxation and the degree of stress. Accordingly, a subject who felt relaxed and unstressed during acupuncture was more likely to develop a PT increase following the stimulation.

Table 4 Multiple Regression Analysis Predicting the Pain Threshold Change Following Low-TENS (n = 9)

	Pain threshold change	
Predictor variable	b Coefficient	*P*
Pleasantness	0.742	.064
Trait anxiety	–1.123	.014

$R^2 = 0.663$.
$P = .038$.

In comparison, the multiple regression analysis in Table 4 shows the factors influencing the PT change following low-TENS. The PT change following low-TENS could be significantly ($P = .038$) predicted to 66% by two other factors: the degree of pleasantness and the degree of trait anxiety. A subject who responded with a decrease in PT following TENS was more anxious and felt less pleasant.

Discussion

There is great variability in the pain-relieving effects of methods such as acupuncture and TENS even when similar pain conditions are treated. Moreover, in experimental studies where pain thresholds are investigated following acupuncture or TENS, the results vary between individuals despite similar experimental designs.[16] It is important to recognize that physiologic and psychologic factors constantly interact and that the response to an intervention is the product of this interaction. To provide optimal pain management and better interpretation of results from experimental studies, it is essential to identify factors that may positively or negatively affect the outcome of a treatment modality.

Even though the mechanisms of action of low-TENS and acupuncture may be regarded as similar, a subject who responds to one type of stimulation may not necessarily respond to the other.[20,42] This may be partly the result of psychologic influences. In the present study, acupuncture induced a significant PT elevation, whereas a nonsignificant PT change was seen following low-TENS. Furthermore, an increase in PT following treatment with either modality was inversely correlated with "negative" psychologic factors, such as anxiety (low-TENS) and stress (acupuncture). This is consistent with clinical studies showing a negative correlation between anxiety and pain relief.[27,43]

In this study, a familiar (acupuncture) and an unfamiliar (low-TENS) form of stimulation were used to induce PT changes in subjects who had previously received a series of acupuncture treatments for myogenic TMD pain. All of the subjects were acupuncture "responders," ie, they had all experienced pain reduction following this treatment. It may be assumed that a patient exposed to a familiar treatment modality, by which a successful result has been accomplished, would have the most favorable psychologic response, ie, positive expectations, both in the experimental and clinical situations when this type of stimulation is used.[37,44] The significant PT increase and the relationship between a high PT change following acupuncture and lower levels of stress observed in this study supports this assumption. In contrast, a treatment that is entirely novel may induce some degree of anxiety, stress, or fear. Following low-TENS, no significant average change in PT was observed, and the significant relationship between a low PT change and high levels of trait anxiety indicates that anxiety may counteract analgesia. Since no measurement of expectation was made, it is difficult to estimate to what extent expectations have influenced PT, but it should be emphasized that the risk for bias was decreased by the computerized tooth pain threshold measurement device used.

The results from the present study support the study of Widerström et al[16] and suggest that momentary mood changes and anxiety influence the magnitude of pain threshold increase. As shown by the psychometric measures in Table 2, acupuncture responders in the present study and TENS responders in the study of Widerström et al[16] scored similarly on the trait anxiety and depression scales. The mood measurements failed to reveal significant differences between the two types of stimulation, although "alertness" approached statistical significance ($P = .06$), indicating increased mental activation during low-TENS compared to that during acupuncture.

It has been observed that low-frequency electrical stimulation via acupuncture needles or surface electrodes usually induce an increase in PT of larger amplitude than what is achieved by manual needle stimulation.[10,45] Considering this, one would have expected to find a higher PT elevation following low-TENS than after acupuncture. A possible explanation may be an interaction between the signals from skin and muscle afferents, resulting in a reduced PT elevation when transcutaneous electrodes are used as compared to deep needling (manual acupuncture), where mainly muscle afferents are stimulated. Although acupuncture induced a significant PT elevation and low-TENS failed to induce a significant change, there was no significant difference in PT response between the two modalities. The lack of significant differences calls for caution in the comparison between the two modalities, but does not detract from the finding that factors such as anxiety and stress negatively affect experimental analgesia. Furthermore, this result is consistent with unpublished data from a systematic investigation of the role of changes in mood. In the latter study, responders to acupuncture, as evidenced by a significant increase of the PT, changed to nonresponders when mental stress was induced during electroacupuncture. In that study, a high PT following acupuncture was also correlated to low levels of stress.

Although a number of factors contribute to the complicated concept of pain relief and experimental analgesia, this study suggests that psychologic factors such as anxiety and mood may influence the pain-relieving effects of stimulation modalities like acupuncture and TENS. This suggestion is supported by clinical observations that better pain relief following acupuncture can be obtained if a patient is psychologically prepared instead of anxious or under stress.[46,47]

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Resumen

Respuestas al umbral del dolor de dos tipos diferentes de estimulación sensitiva en pacientes con dolor muscular orofacial: Consideraciones psicológicas.

Este estudio se concentra en la influencia de ciertos factores psicológicos sobre los cambios en el umbral del dolor dental luego de dos métodos similares de estimulación aferente somática, uno conocido (acupuntura manual) y otro desconocido (estimulación nerviosa eléctrica transcutánea de baja frecuencia [ENET-baja]). Para este estudio se seleccionaron 21 personas que habían respondido al tratamiento con acupuntura, y habían tenido tratamiento para el dolor muscular orofacial de larga duración, pero sin haber sido expuestos a la ENET-baja. Se aplicaron los tratamientos de acupuntura y ENET-baja al azar, durante dos períodos, en una sesión experimental separada por un intervalo de descanso. Los umbrales de dolor dental (UD) fueron medidos antes y después de la estimulación con un vitalómetro pulpar eléctrico computarizado. La ansiedad y la depresión fueron evaluadas con formularios psicométricos antes de la sesión experimental en todos los pacientes, mientras que la disposición del ánimo transitorio fue evaluada en nueve pacientes seleccionados al azar con escalas análogas visuales durante y después de los dos tipos de estímulo. Luego de la acupuntura, el promedio de los UD del grupo aumentó significativamente, mientras que no se observó un cambio significativo luego de la ENET-baja. Las puntuaciones más altas de la ansiedad se correlacionaron significativamente con un aumento leve de los UD, luego de la ENET-baja; y las mayores puntuaciones del estrés se correlacionaron significativamente con un aumento leve de los UD, luego de la acupuntura. Esto indica que la magnitud de la analgesia inducida por estos métodos puede ser modificada por los factores psicológicos, tales como la ansiedad y el estrés.

Zusammenfassung

Antworten der Schmerzschwelle auf zwei verschiedene Arten der sensorischen Stimulation bei Patienten mit orofazialem Muskelschmerz: psychologische Betrachtungen

Diese Studie konzentriert sich auf den Einfluss gewisser psychlogischer Faktoren auf Veränderungen der Zahnschmerzschwelle nach zwei ähnlichen Methoden der somatischen afferenten Stimulation, eine bekannte (manuelle Akupunktur) und eine unbekannte (niedrig-frequente transkutane elektrische Nervenstimulation [low-TENS]). Einundzwanzig Akupunktur-Responder, behandelt wegen langandauernden orofazialen Muskelschmerzen, aber unbefangen zu low-TENS, wurden für die Studie ausgewählt. In einer Versuchsssitzung wurden Akupunktur und low- TENS zufällig während zwei Perioden angewendet, getrennt durch ein Ruheintervall. Die Zahnschmerzschwellen (PT) wurden vor und nach der Stimulation mit einem computerisierten elektrischen Pulptester gemessen. Aengstliche Persönlichkeit und Depression wurden mittels psychometrischen Formularen vor der Versuchssitzung bei allen Patienten beurteilt, währenddem die momentane Stimmung bei neun zufällig ausgewählten Patienten mit visueller Analogskala während und nach den zwei Typen der Stimulation beurteilt wurde. Nach der Akupunktur stieg der durchschnittliche PT der Gruppe signifikant an, dagegen war keine signifikante Veränderung im Anschluss an low-TENS beobachtet worden. Höhere Werte bei der ängstlichen Persönlichkeit korrelierten signifikant mit mit einem niedrigen PT-Anstieg nach low-TENS, und höhere Stressquoten korrelierten signifikant mit einem niedrigen PT-Anstieg nach Akupunktur. Dies deutet darauf hin, dass das Ausmass der Analgesie, induziert durch diese Methoden, modifiziert werden kann durch psychologische Faktoren wie Angst oder Stress.