Adhesive dentistry sensory stimulus technique as a neuromechanism for the treatment of orofacial pain associated to temporomandibular disorders: Case study

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ABSTRACT

Purpose: The authors intend, by presenting a case study, emphasize the neuromodulation process of orofacial pain induced by the stimulation of the sensory and motor stimulation of the trigeminal nerve, which can play an important role on pain modulation.

Materials and methods: A 25 year-old woman presenting orofacial pain was referred to the stomatology service at the Centro Hospitalar do Porto. After collecting the patient's anamnesis, the thermographic camera FLIR i7 was used to record the thermal status of the orofacial structures, before the adhesive dentistry sensory stimulus protocol, after 45 minutes, and after one week.

Results: This study suggests the relation of adhesive dentistry sensory stimulus technique in the neuromodulation of orofacial pain and its association with the temporomandibular disorders. As the tongue senses the stimulus of the resin composite placed on the palatal surface of the 1st premolar, 2nd premolar and 1st molar of the maxilla, this can promote and induce an effect regarding a peripheral nerve neuromodulation resulting in a blockage of the nociceptive trigeminal pathway from temporomandibular disorders.

Conclusion: Orofacial pain is a common complaint among the patients that come to a dentistry appointment, which may have different diagnosis and treatments. A positive effect on the patient's symptomatology was confirmed clinically on subsequent dental appointments and monitored by infrared thermography.

1. Introduction

Neuromodulation emerges in contrast to the lack of efficiency of other therapies, such as medications, in some well-known neurological disorders, like migraines or multiple sclerosis.^{1–4} Besides surgical approaches, this non-invasive alternative treatment is one of the growing areas of medicine, however, the mechanism of action of peripheral

nerve stimulation (PNS) underlying remains largely unknown, namely the peripheral trigeminal nerve modulation.^{3,5} There are different neurostimulation methods, but so far, the electrical impulses are the most reported, followed by the magnetic, chemical and the tactile techniques.^{2–4} This technique has applications in different fields of medicine namely in the area of chronic back pain, pain from Complex Regional Pain Syndrome (CRPS) and Reflex Sympathetic Dystrophy

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(RSD). Neuromodulation encompasses the use of targeted electrical, chemical and biological technologies to the nervous system in order to improve function and quality of life being applied through different techniques and comprises four treatment modalities: spinal cord stimulation, spinal drug delivery systems, brain stimulation and PNS.

Actually, the PNS for head and facial pain, relies on the stimulation of a field containing the thin and unnamed nerve branches e.g. trigeminal branches.⁶ This is an essential fact for the application of neuromodulatory modality in the area of temporomandibular disorders (TMD). TMD is a term that characterizes a subgroup of musculoskeletal disorders that involves a variety of symptoms with pain and dysfunction of the masticatory muscles, the temporomandibular joint (TMJ) and the adjacent structures. The recognizable signs can be limitations in the range of motion, disturbances associate to the mandibular kinematic during mouth opening-closing and joint noises.^{7–9}

From a clinical point of view, it is useful to have an objective and efficient evaluation on the differential diagnosis of orofacial pain, since TMD have a multifactorial aetiology associated to its condition, where the afferent pathways of the trigeminal nerve plays an important role on the pain processing.

The trigeminal nerve, the fifth cranial nerve (CN V) is mixed having both, sensory and motor functions, it is the largest of the 12 cranial nerves and has three major divisions: the ophthalmic nerve (V1); the maxillary nerve (V2) and the mandibular nerve (V3). The first two divisions are purely sensory, whereas the mandibular nerve has sensory and motor functions. The sensory part provides, for example, tactile, proprioceptive to the face and mouth; on the other hand, motor function control some muscles such as the masseter and temporal which belong to masticatory muscles group.^{10,11} Likewise, some attempts have been made in order to understand the pathway and the neuroanatomy of the existing pain of the TMJ. The anatomical explanation in the basis of this research can be associated to the work carried out by Davidson et al.¹² where in each specimen, the auriculotemporal nerve, a branch of the mandibular portion (V3) of the trigeminal nerve, was found to innervate the lateral part of the capsule of the TMJ. In 75% of the specimens, the masseteric nerve, a branch of the mandibular portion (V3) of the trigeminal nerve, was found to innervate the anteromedial part of the capsule of the TMJ. In 33% of the specimens, there is a branch coming through the mandibular notch to innervate the anteromedial part of the capsule that is not from the masseteric nerve; this nerve is believed to have passed through the lateral pterygoid muscle after leaving (V2). These anatomical considerations are important to understand the pathophysiology of orofacial pain and the interdependence of the certain cranial nerves. The lingual nerve is a branch of the mandibular division (V3) of the trigeminal nerve, which supplies general sensory innervation (not the gustative one) to the anterior 2/3 of the tongue. It also carries fibers from the facial nerve (CN VII), which brings taste information via the chorda tympani. In fact, the somatosensory perception of the tongue is important, as referred by Sakamoto et al.¹³ as a characteristic of somatosensory processing of the tongue, neural activation was found in contralateral and ipsilateral hemispheres to the stimulation. Compared with primary somatosensory cortex-SI, secondary somatosensory cortex-SII, has been speculated to serve a higher level of cognitive function in somatosensory processing, such as attention, decision making, object recognition, and the integration of nociceptive and non-nociceptive inputs.^{14–18} The above cited studies present results indicating that there is a clear difference in somatosensory processing between stimulation of the antero-lateral and postero-lateral parts of the tongue.

Regarding TMD, the trigeminal nerve integrity is compromised because abnormalities of central nervous system (CNS) functions and processes suggest that ascending or/and descending nociceptive pathways are affected.¹⁹ The adhesive dentistry sensory stimulus technique, as a neuromechanism for the treatment of orofacial pain associated to TMD, is based on the gate control theory. In 1965, Ronald Melzack and Patrick Wall²⁰ introduced this theory in which a non-pain input closes

the gates to the painful input that prevents pain sensation from travelling to the CNS. Neuromodulatory techniques may influence the development or reshaping of neural circuits, reprogramming them.²¹

For this purpose, our research intends to understand the neuro-mechanism associated to the modulatory effect of the adhesive dentistry sensory stimulus technique, explaining this therapeutic approach in terms of pathophysiology, anatomy of the trigeminal pathway and its effect on orofacial pain resulting from TMD. Additionally, the medical infrared thermography measurements can be used as a complementary method of diagnose during the treatment to quantify the anatomophysiology changes on specific regions of interest (ROI), before and after the treatment. Furthermore, it is necessary to emphasize the importance a dentist can have as a health care provider regarding the orofacial neuromodulation, once only qualified professionals can perform this type of intraoral technique.

2. Material and methods

This case study is based on a 25-year-old woman to whom some questions were asked: (a) to describe the orofacial pain or headaches that maybe felt last month; (b) the burden of that pain in the daily activities; (c) if she has noticed any sign of bruxism, jaw joint noise or jaw locking.

Before the clinical examination, infrared thermography was performed with a specific camera, FLIR i7, Wilsonville, USA, regarding the ROI correspondent to the anatomical sites that were evaluated during the clinical examination, the TMJ, the masseter and the anterior part of the temporal muscles. These images were taken in controlled conditions, as recommended by the internationally accepted directives.^{22,23} The acquisition of thermal images followed a rigorous protocol in a controlled environment with an ambient temperature of 21 °C and a relative humidity of 48%, care was taken with lighting, airflow and reflections.

The thermograms were obtained using a FLIR i7, with a focal plane array sensor size of 140 × 140, noise equivalent temperature difference of < 150 mK at 25 °C, and measurement accuracy of ± 2% of the temperature reading. The angle camera lens was placed perpendicular in relation to the patients head at a distance of 0.80 m (Fig. 1), to obtain the best thermal images.²⁴

The thermal images were analysed and processed with FLIR ThermoCAM Researcher Pro 2.10 software package, by defining three ROI, a square ROI over the masseter muscle area, a rectangle over the anterior part of the temporal muscle area, and a circle over the TMJ area to assess its surface mean temperature and use it as an indicator. Bilateral asymmetry was calculated taking in consideration the contralateral ROI,²⁵ which was also used as a pathological index. Then, the clinical examination was performed by the dentist, consisting on the

Fig. 1. Acquisition of the right lateral thermogram with the thermal imaging infrared camera, FLIR i7.

Fig. 2. Placement of the resin composite on the palatal surface of the 1st premolar, 2nd premolar and the 1st molar of the maxilla.

evaluation of the mandibular kinematics, including the opening patterns, the protrusive and lateral movements. The last moment of this extra-oral examination was the bilateral palpation of some of the masticatory muscles (masseter, anterior part of the temporal) and the TMJ. The patient was asked to perform some excursive movements and referred which are the painful areas during the palpation.

After the acquisition of the thermal images, the protocol of the adhesive dentistry stimulus sensory technique defined sequential steps before the placement of the resin composite on the palatal surface of the 1st premolar, 2nd premolar and the 1st molar of the maxilla, which was done on both sides of the maxilla, (Fig. 2). The first step was the tooth surface preparation, which was done with 37% phosphoric acid for 15 seconds, after rinsed with water spray for 30 seconds and dried with air spray for 30 seconds. Then a Universal Scotchbond 1XT 3 M adhesive was applied also in the palatal surface of the supra-cited teeth in both, maxillary right quadrant and maxillary left quadrant, air sprayed for 5 seconds and light cured for 10 seconds using a light curing unit, a Light Emitting Diode - LED unit. This was followed by the application of two layers of a nanohybrid resin composite, being each layer light cured separately with the LED unit for 20 seconds. One of the layers of the restorative material used on the adhesive dentistry stimulus sensory technique can be blue in order to easily identify the resin composite from the tooth structure. Clinically, the surface smoothness of the restorative material used in the adhesive dentistry stimulus technique is essential and this was performed following the finishing and polishing steps of the protocol. This procedure was done using a low abrasive rubber in order to fulfill the criteria of a symmetrical proportion and integration of the resin composite to the palatal surfaces of the involved teeth, while a polishing paste was applied with a soft brush mounted in contra-angle using circular movements with low rotation. The thermograms were taken 45 minutes and one week after the placement adhesive dentistry stimulus technique.

3. Results

The patient suffered from pronounced sleeping and awakening bruxism, arthralgia of the right TMJ, bilateral pain on the region of the masseter muscles, anterior part of the temporal muscles with greater intensity and frequency on the right side. Fig. 3a and b shows respectively the right and left thermal images of the patient before the adhesive dentistry stimulus technique intervention, and Table 1, the average temperature of the ROI, as well as, the differences towards the contralateral side. The pre-treatment findings of the infrared thermograms are in accordance with the symptomatology referred by the patient in terms of pain intensity of the masseter muscles, the anterior part of the temporal muscles and specially the right TMJ, since the temperature differential of the right TMJ and the contralateral TMJ is of 0.9

Fig. 3. Right (a) and left (b) thermograms, where it is possible to observe a higher temperature on the region of interest correspondent to the right masseter muscle.

Table 1

Initial infrared imaging values of the lateral thermograms of the cranio-cervical-mandibular complex, right and left view.

ROI Assessed	Right Temp (°C)	Left Temp (°C)	Temperature Asymmetry (°C)
Temporalis	35.4	34.9	0.5
TMJ	33.8	32.9	0.9
Masseter	33.1	32.9	0.2

°C. The anterior part of the temporal muscle on the right side has a temperature value of 35.4 °C comparing with the left part of the anterior temporal muscle of 34.9 °C. These mentioned ROI present an asymmetry value of more than 0.3 °C; only the masseter muscle presents an initial asymmetry between the right side and the left side of the cranio-cervico mandibular complex (CCMC) thermograms of 0.2 °C.

After the placement of the adhesive dentistry (45 min), new thermograms of the patients were taken (Fig. 4a and b), and the respective ROI represented at Table 2. The post-treatment findings of the infrared thermograms demonstrate a decrease of the temperature asymmetry of 0.1 °C, 0.6 °C and 0.1 °C for the anterior part of the temporal muscle, the TMJ and masseter muscle ROI respectively. These results are in accordance with the post-treatment palpation of the referred structures were the patient mentioned less muscle and articular pain sensitivity, in addition to the fact that the patient mouth opening was done with “less effort”.

One week after the placement of the adhesive dentistry, new thermograms were taken that are show at Fig. 5a and b, and the respective temperature measurements presented on Table 3. The clinical findings of the patient were satisfactory since there was no longer a limitation of the mandibular movement, the muscle soreness was reduced and the symptomatology of the right TMJ was diminished. This is in accordance with thermographic data analyses after one week of treatment of the

Fig. 4. Lateral thermogram right (a) and left view (b), 45 minutes after the placement of the adhesive dentistry. The ROI showed a decrease in the overall temperature, especially on the most painful site, the region of interest associated to the right masseter muscle.

Table 2

Infrared imaging values of the lateral thermograms of the CCMC, 45 minutes after placement of the resin composite, right and left views.

ROI Assessed	Right Temp (°)	Left Temp (°)	Temperature Asymmetry (°)
Temporalis	35.3	34.9	0.4
TMJ	33.2	32.9	0.3
Masseter	32.1	32.2	0.1

Fig. 5. Lateral thermogram right view (a) and left view (b), one week after the placement of the adhesive dentistry.

Table 3

Infrared imaging temperature of the lateral thermograms of the cranio-cervical-mandibular complex, one week after placement of the resin composite, right and left views.

ROI Assessed	Right Temp (°)	Left Temp (°)	Temperature Asymmetry (°)
Temporalis	34.7	35.0	0.3
TMJ	32.5	33.0	0.5
Masseter	32.0	32.2	0.2

adhesive dentistry sensory stimulus technique, where the asymmetry values compared with the initial thermogram of the CCMC presents lower values in all ROI with exception to the masseter muscle that remains with 0.2 °C.

4. Discussion

This study suggests the relation of adhesive dentistry sensory stimulus technique in the neuromodulation of orofacial pain and its association with the TMD. In the present research, it was performed the adhesive dentistry sensory stimulus technique for the evaluation of the excitability of the trigeminal nervous system in a patient with TMD. Previously, a number of animal studies of experimentally-induced muscle pain have shown that activation of the muscle nociceptors markedly influences the proprioceptive properties of the muscle spindles through a central neural pathway,²⁶ and that produces a washing of the local algogenic substance which return to normal the tendon reflexes.

The presence of pain in the CCMC can be correlated to the sensitization of the trigeminal nociceptive system and CNS hyperexcitability. TMD may be associated with the phenomenon of central and peripheral sensitization. Constant nociceptive input stimulus from the injured sites may result in excessive depolarization of the central nociceptive neurons, which can promote excitotoxicity and loss of inhibitory mechanisms and eventually provoke prolonged pain.²⁷

Truini et al. showed that cutaneous nociceptive input induced distinct changes in trigeminal motoneuronal excitability in healthy subjects.²⁸ This phenomenon may reflect a function of cutaneous nociceptive afferents. The perioral and intra-oral nociceptive input to the trigeminal motor system almost certainly serves to ensure the rapid

inhibitory action needed for nocifensive function, thus requiring a dedicated multisynaptic reflex pathway. On the same way, Sugiyo et al.²⁹ emphasized that the trigeminal transition zone has access to multiple rostral targets involved in pain transmission and modulation and plays a unique role in integrating noxious information from the orofacial region.

On a study carried out by Nash et al.³⁰ unilateral injections of hypertonic saline into the masseter muscle or the overlying skin caused pain that began within 10 s of the start of the injection and subsided to pre-injection levels within approximately 7 minutes, where muscle pain was described as dull and aching, while cutaneous pain was described as sharp and burning. The work of Nash et al. involved functional magnetic resonance imaging, where the signal-intensity changes showed muscle and cutaneous pain evoked increases in signal intensity in a number of brain regions. These included bilateral activation of the thalamus, SI, SII, mid-cingulate cortex (MCC) and the insula. Innocuous brushing of the right lower lip resulted in bilateral activation of the SI and SII. However, innocuous lip brushing evoked only contralateral activation within the thalamus, in contrast to the bilateral activation observed with both cutaneous and muscle orofacial pain. Nash et al. revealed that acute unilateral muscle and cutaneous orofacial pain evoke bilateral thalamic, SI and SII activation in awake human subjects. In addition, the magnitude and timing of the signal increases are similar on both sides of the brain, although the sizes of activated clusters appeared larger on the ipsilateral side. This contrasts with innocuous stimulation, which evokes larger areas of contralateral activation. These findings strongly suggest that orofacial noxious information is relayed bilaterally to the cerebral cortex via bilateral ventral posterior nucleus of the thalamus relays.

The present findings of our study with the implementation of the adhesive sensory stimulus technique intend to suggest that the neuro-modulation process of orofacial pain induced by the stimulation of the sensory and motor stimulation of the mandibular nerve, has an influence on the trigeminal nerve, which can play an important role on pain modulation. Nevertheless, this is an experimental technique englobed in a treatment modality that is under investigation, where in the future there is the need of providing further investigations with a larger sample in order to produce the evidence needed for broad acceptance on the adhesive dentistry sensory stimulus technique and for its integration in the clinical routine as a neuromechanism of orofacial pain modulation. The intent of our research is to correlate our findings and results with the present conception of neuromodulation which took shape in the 1965 with the publication of gate control theory of pain Melzack et al.²⁰ It proposed the existence of a gate involved in pain perception that could be opened or closed depending on the differential activation of small and large neural fibers.

The presence of sensory fibers type II on the anterior region of the tongue are the second most highly myelinated fibers, group Aβ, they allow the transmission of somatosensory information, as well as, nociceptive information. The type II fibers, under pathological conditions, may become hyper-excitable leading to stimuli that would usually elicit sensations of tactile touch causing pain. The resin composite placed on the upper teeth, as described before, has the intention of promoting a neuromechanism where the constant stimulus of the tongue will eventually change the modulation on pain perception on the trigeminal motor neuron, inducing the blockage of a nociceptive afferent information that had the initial origin on the masseter muscle, which is innervated by the masseteric nerve, from the trigeminal nerve. This mechanism can be the basis of the adhesive sensory stimulus technique, since the un-myelinated C nerve fibers, which respond to tissue damage are present in the masseter muscle spindles. Nociceptors located in deep structures play a fundamentally different role in mediating responses to noxious stimuli. Specifically, they play no role in evoking reflexes that cause movement away from a noxious stimulus.³¹

Nociceptive pain arises from bone, muscle, skin, or internal organs, and is a result of stimulation of pain receptors. Stimulation of the

nociceptors by tissue damage results in action potentials in the peripheral nerve fibers. The action potentials pass via the neuron cell bodies in the dorsal root ganglion.^{32–35} This results in muscle contraction and movement away from the cause of the injury. In addition to initiating these simple pain reflex arcs, the axons of some pain neurons synapse with neurons whose axons enter ascending tracts in the spinal cord. These ascending axons stimulate pain centers in the thalamus within the midbrain.³⁶

Neuromodulation has demonstrated efficacy in the treatment of pain pathologies resistant to conventional medical management or surgery. In doing so, it has become an alternative as a treatment modality in order to improve the patients' quality of life. Its benefits are associated to an evidence of improved pain relief, functional status, health-related quality of life, and reduced demand for healthcare resources.^{37–39} The three commonly applied neuromodulatory techniques for chronic pain are spinal cord stimulation, PNS and deep brain stimulation.⁴⁰

For instance, it is noteworthy that syndromes in which the pain is mainly felt in a specified nerve distribution, e.g. the ophthalmic division of the trigeminal nerve, can be modified by stimulation in the corresponding dermatome. This significant observation implies that the key part of PNS may be closely related to brain function and, particularly, of brain plasticity.⁴¹ PNS has been successfully used for treatment of occipital neuralgia, trigeminal neuropathy, intercostal neuralgia, post-thoracotomy pain, inguinal and abdominal pain, post-herpetic neuralgia in the face and body, cervicogenic headaches, migraines and cluster headaches. Chronic pain in the low back and in the neck, two very common clinical conditions, have also been successfully treated with PNS.⁴¹

The area of dentistry is an emerging field for the application of techniques that can assist the modulation of orofacial pain associated to TMD. The adhesive dentistry stimulus sensory technique is an intra-oral technique that can be useful and have clinical applications. The dentist is a qualified professional capable to identify and treat TMD providing this technique as a regular procedure and solution within many others that are available like pharmacologic, intra-oral appliances, physiotherapy with the use for example of Transcutaneous Electrical Nerve Stimulation (TENS) or even acupuncture.^{42–45}

Acupuncture, for example, is a technique considered to be capable of stimulating the regulatory systems of the organism, such as the central and peripheral nervous system, the endocrine system and the immunological system.⁴⁶ Beneath the surface, acupuncture needles engage collagen fibers, the connective tissue matrix, nerve endings, and vessels. Deeper needle insertion stimulates mechanoreceptors in muscle tissue. Needle manipulation causes mechanoreceptor and nociceptor activation as well as vasodilation changes and modifications in tissue biochemistry.⁴⁷ Furthermore, acupuncture have shown promising results on the pain relief together with a decrease on the muscle activity and its relaxation.^{48,49}

It is reasonable to investigate and fulfil the scientific criteria that explains the neuromechanism associated to procedures such as the adhesive dentistry stimulus sensory technique, which is another approach that promotes a direct stimulation of peripheral nerves that may inhibit primary afferents and ultimately produce a nociceptive blockade. In this research, it was found a possible relation of effect of the lingual sensory nerve of the tongue on the adhesive dentistry, placed on the palatal surfaces of the 1st premolar, 2nd premolar and 1st molar, regarding the action of the mandibular nerve, which is a mixed nerve that supplies the muscles of mastication, namely the masseter and temporal that are included in the ROI of this study. These ROI and the TMJ, which has the sensory portion of the mandibular nerve responsible for pain information, were monitored with infrared thermography. Our findings suggest that there is a response induced by the CNS on the painful areas and ROI, such as the masseter muscle, the anterior part of the temporal muscle and the TMJ, by the sensory input of the trigeminal nerve, in this particular case, the mandibular branch.

Fig. 6. Temperature differential of the lateral thermogram right view (a) and left view (b), since the beginning of the treatment (t = 0), 45 min and one week after the placement of the adhesive dentistry stimulus technique.

The thermograms of the CCMC showed that the ROI of the anterior part of the temporal muscle, the masseter muscle and the TMJ of the right side of the patient which corresponded to the painful site, had a decrease in the temperature asymmetry, from the first appointment prior to the placement of the adhesive dentistry resin composite to the lateral thermograms of the CCMC realised 45 minutes after the treatment and on the lateral thermograms of the CCMC made 7 days later at the dental consultation (Fig. 6). During the first clinical examination of the patient, it was possible to evaluate anatomical sites like the masseter muscle and in particular the anterior part of the temporal muscle that was hypertonic being possible to correlate the extra-oral palpation of this muscle with the infrared thermal images that presented an asymmetry of more than 0.5 °C. This is indeed in accordance with some literature regarding the information obtained by the thermograms of the face where the asymmetry of 0.3 °C was associated to local inflammation, hyperactivity or a painful site.^{50–52}

The temperature differential associated to the ROI of the TMJ also decreased from the initial infrared thermogram, being the major difference measured on the second thermography 45 minutes after the adhesive dentistry stimulus sensory technique. Nevertheless one week after, the temperature of the right TMJ was of 32.5 °C comparing to the left TMJ with 33 °C, this corresponds to a thermal asymmetry of 0.5 °C, which can be associated to the compression of the articular disc during the parafunctional habit of clenching the teeth.

The assessment of TMD and the consequent treatment of the patient, should have as a first option a conservative a non-surgical management. Irreversible surgical procedures should remain as the ultimate solution for these patients. In this research, the authors do not intend to state that the technique above described is the best and exclusive treatment, but highlight the efforts that should be made to provide an optimal care, where the understanding of the PNS is very important from a pathophysiology and anatomical point of view when dealing with orofacial pain related with TMD. There should be the comprehension that the treatment of TMD respects an integrative model of various therapeutic approaches, since the aetiology of TMD is multifactorial. There is no one-way philosophy, neither a single and unique prescription, but instead there is a biopsychosocial model associated to the patient with TMD, so it is not advisable to treat everybody the same way, there are significant and substantial differences among human beings. Therefore, care should be taken with the physiological and structural adaptation of each individual.

Polonowita AD et al., in a 1-year consecutive series of 162 chronic TMD cases, found out that a simple non-invasive protocol for managing chronic TMD with self-help, exercises, and oral devices resulted in clinically and statistically meaningful improvements in pain, function and quality of life.⁵³ Also, a general consensus among TMD experts was carried out identifying jaw exercises as an effective treatment and that

they should be recommended to patients with TMD pain and disturbed jaw function.⁵⁴

Our results showed that the patient treated with the adhesive dentistry stimulus sensory technique, has a greater value for mouth opening after one week since the first appointment and presented less pain on the pressure pain thresholds after palpation of the referred structures. Thus, there was a clinical improvement between the first appointment and the follow-up consultation when evaluating the muscular condition and the TMJ. Therefore, this technique can be a valuable step and considered as an appropriate conservative treatment when dealing with a patient suffering from TMD with both myalgia and arthralgia. Resende et al. highlighted the effectiveness of conservative therapies such as occlusal splints, manual therapy and counselling in pain, quality of life and sleep in TMD patients.⁵⁵ Another study carried out by Barbosa et al. on the effects of masticatory muscles endurance exercises on patients with orofacial pain and TMD, showed that time until fatigue and muscle efficiency were higher in the intervention group comparing with the placebo group that received a simulated laser therapy.^{55,56} Lindfors et al. concluded that the information about the cause of the symptoms and the treatment will make the patient with masticatory myofascial pain involved in the treatment. These authors also noted the fact that these patients having their own tools, like the jaw exercises, to tackle the problems themselves in case of the symptoms appearing again was very appreciated.⁵⁷ This is in line with our study, since the implementation of the adhesive dentistry stimulus sensory technique not only advises the patient on what kind of oral motor functions the patient has to execute in order to provide consistency to the treatment, but implies a commitment of the patient with TMD treatment. Our findings also highlight the importance of individual and adequate information when counselling the patient of some of the parafunctional habits related with the functional disturbances of the TMJ, which accordingly to the adhesive dentistry stimulus sensory technique can provide the breakdown of a vicious cycle like tooth clenching. Aggarwal et al. reported that self-management interventions should be a priority for early intervention in primary care of chronic orofacial (principally TMD) pain in preference to invasive, irreversible and costly therapies.⁵⁸ This is also in accordance with one of the main findings of our study, where the infrared thermography analysis of the affected areas reinforces the benefits of the adhesive technique by showing a decrease in the temperature asymmetry from the beginning to the end of the treatment. The results of our study, indicate that infrared thermography seems to be an interesting and helpful diagnostic screening tool, since it allows to quantify the temperature values of certain ROI often associated to arthralgia or myalgia of the masticatory muscles, which was the case of this patient. The use of this imaging technique gives clinicians a chance of assessing TMD at an early stage of the development of this pathology, since many patients can have more than one diagnosis. For this purpose, the interpretation of the thermograms will provide a mapping of the areas corresponding to the anatomical structures of interest, namely the anterior part of the temporal muscle, the masseter muscle and the TMJ, and enable clinicians to confirm if the treatment modality is correct, or if any adjustment is needed. Based on present results, infrared thermography compared the ROI before the treatment with the adhesive dentistry technique and after the treatment. This was made at two different stages, 45 min after the placement of the resin composite and one week after the first appointment, where the information obtained from the thermograms of the CCMC are in accordance with the clinical health status of the patient related to TMD, which referred the absence of pain. In clinical practice, besides the clinical history and examination, the outcome of the infrared thermography as a diagnostic and therapeutic tool can provide a reliable and valid guidance of the patient in order to avoid the transition from acute pain to chronic pain, reducing the risk of central sensitization of pain.

The adhesive dentistry stimulus sensory technique can be useful as a cognitive-behavioral therapy for TMD patients, in particular individuals

that have bruxism and clench their teeth during the day, this is awake bruxism, and so they have the awareness of this parafunctional habit. From a clinical point of view, the guidelines and information provided by the clinician to the patient with the indication of the stimulus technique of the tongue on the resin composite will certainly interrupt this neuromuscular pattern. Consequently, there will be a diminishing of the muscle hyperactivity of the masticatory muscles, such as the masseter and temporal muscles, interrupting the cycle of pain associated to the symptomatology of these areas. However, if a patient present sleep bruxism which is the masticatory muscle activity during sleep, the resin composite possibly has lower effect, since the patient might unconsciously grind the teeth. For this purpose, it could be advisable to use an occlusal splint to diminish the harmful effects of rhythmic masticatory muscle activity.⁵⁹

The data from this case study should be considered as preliminary, since this is a pilot study carried out in a single person. This is the major limitation of our research and in the future a larger sample should be analysed. Another possible limitation is that the screening of TMD was not performed with the reference test - the Diagnostic Criteria for Temporomandibular Disorders (DC/TMD), yet it was performed by a regular clinical examination of an experienced clinician in the field of orofacial pain. Probably in the upcoming studies it should be interesting to gather information from the DC/TMD, the infrared thermography and the adhesive dentistry stimulus sensory technique. Nevertheless, the main purpose of our research was achieved, since the authors intended to highlight the anatomical considerations associated to the adhesive dentistry stimulus sensory technique, which promotes a stimulation of the peripheral nerves and inhibition of primary afferents, thus producing nociceptive blockade. However, it is necessary to gather sufficient scientific evidence in order to prove the efficacy of this methodology, since in terms of clinical applications there are sufficient indications for the implementation of this technique, taking always in consideration the importance of the differential diagnose in orofacial pain.

5. Conclusions

The modulatory effect of this adhesive dentistry sensory stimulus technique as a neuromechanism for the treatment of orofacial pain associated to TMD may be a promising solution for these group of patients.

This work, as a pilot study in this area, may lead to a better understanding of central processing in the nociceptive trigeminal pathway and the development of new approaches to treat orofacial pain with origin in the masticatory muscles.

Neuromodulation can be a valid treatment option for orofacial pain. A multidisciplinary approach can contribute to enhance the research in this field, as well as, the implementation of different modulatory techniques for the treatment of TMD.

Clinical relevance

Temporomandibular disorders can have different and multidisciplinary clinical approaches. Trigeminal nerve's neuromodulation may help to treat orofacial pain with origin in the masticatory muscles.

Declaration of competing interest

The authors do not have conflicts of interest to declare.

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Abbreviations

CCMC	Cranio-cervico mandibular complex
CNS	Central nervous system
CRPS	Complex regional pain syndrome
DC/TMD	Diagnostic criteria for temporomandibular disorders
PNS	Peripheral nerve stimulation
ROI	Regions of interest
RSD	Reflex sympathetic dystrophy
TENS	Transcutaneous electrical nerve stimulation
TMD	Temporomandibular disorders
TMJ	Temporomandibular joint

References

- Schoenen J, Coppola G. Efficacy and mode of action of external trigeminal neurostimulation in migraine. *Expert Rev Neurother*. 2018;18(7):545–555.
- Bastani A, Cofre Lizama LE, Zoghi M, et al. The combined effect of cranial-nerve non-invasive neuromodulation with high-intensity physiotherapy on gait and balance in a patient with cerebellar degeneration: a case report. *Cerebellum Ataxias*. 2018;5:6.
- Leonard G, Lapiere Y, Chen JK, Wardini R, Crane J, Ptitto A. Noninvasive tongue stimulation combined with intensive cognitive and physical rehabilitation induces neuroplastic changes in patients with multiple sclerosis: a multimodal neuroimaging study. *Mult Scler J Exp Transl Clin*. 2017;3(1) 2055217317690561.
- Riederer F, Penning S, Schoenen J. Transcutaneous supraorbital nerve stimulation (t-SNS) with the Cefaly(®) device for migraine prevention: a review of the available data. *Pain Ther*. 2015;4(2):135–147.
- Jakobs M, Schuh-Hofer S, Unterberg A, Ahmadi R. Subcutaneous trigeminal nerve field stimulation for refractory facial pain. *J Vis Exp : JoVE*. 2017(123).
- Van Buyten J-P, Linderer B. Invasive neurostimulation in facial pain and headache syndromes. *Eur J Pain Suppl*. 2011;5(2):409–421.
- Dworkin SF, LeResche L. Research diagnostic criteria for temporomandibular disorders: review, criteria, examinations and specifications, critique. *J Craniomandib Disord : Fac Oral Pain*. 1992;6(4):301–355.
- Okeson J. *Management of Temporomandibular Disorders and Occlusion*. vol. 69. St Louis: Mosby Elsevier; 2008.
- National institutes of health technology assessment conference statement: management of temporomandibular disorders, april 29–may 1 1996. Oral surgery, oral medicine, oral pathology. *Oral Radiol Endodontol*. 1997;83(1):177–183.
- Joo W, Yoshioka F, Funaki T, Mizokami K, Rhoton Jr AL. Microsurgical anatomy of the trigeminal nerve. *Clin Anat*. 2014;27(1):61–88.
- Zheng JP, Song M, Zhan XX, Li CZ, Zong XY, Zhang YZ. Endoscopic approach to the trigeminal nerve: an anatomic study. *J Cranio-Maxillo-Fac Surg: Off Publ Eur Assoc Cranio-Maxillo-Facial Surg*. 2014;42(5):674–682.
- Davidson JA, Metzinger SE, Tufaro AP, Dellon AL. Clinical implications of the innervation of the temporomandibular joint. *J Craniofac Surg*. 2003;14(2):235–239.
- Sakamoto K, Nakata H, Yumoto M, Kakigi R. Somatosensory processing of the tongue in humans. *Front Physiol*. 2010;1:136.
- Mima T, Nagamine T, Nakamura K, Shibasaki H. Attention modulates both primary and second somatosensory cortical activities in humans: a magnetoencephalographic study. *J Neurophysiol*. 1998;80(4):2215–2221.
- Torquati K, Pizzella V, Della Penna S, et al. Gating* effects of simultaneous peripheral electrical stimulations on human secondary somatosensory cortex: a whole-head MEG study. *Neuroimage*. 2003;20(3):1704–1713.
- Wasaka T, Nakata H, Akatsuka K, Kida T, Inui K, Kakigi R. Differential modulation in human primary and secondary somatosensory cortices during the preparatory period of self-initiated finger movement. *Eur J Neurosci*. 2005;22(5):1239–1247.
- Nakata H, Inui K, Wasaka T, et al. Movements modulate cortical activities evoked by noxious stimulation. *Pain*. 2004;107(1-2):91–98.
- Romo R, Hernandez A, Zainos A, Lemus L, Brody CD. Neuronal correlates of decision-making in secondary somatosensory cortex. *Nat Neurosci*. 2002;5(11):1217–1225.
- Moayeddi M, Davis KD. Theories of pain: from specificity to gate control. *J Neurophysiol*. 2013;109(1):5–12.
- Melzack R, Wall PD. Pain mechanisms: a new theory. *Science*. 1965;150(3699):971–979.
- Mercante B, Deriu F, Ranson CM. Auricular neuromodulation: the emerging concept beyond the stimulation of vagus and trigeminal nerves. *Medicine*. 2018;5(1).
- Ring EFJ, Ammer K. The technique of infrared imaging in medicine*. [Internet]. *Infrared Imaging*. IOP Publishing; 2015<https://doi.org/10.1088/978-0-7503-1143-4ch1>. [1–10]. Available from.
- Ammer K. The Glamorgan Protocol for recording and evaluation of thermal images of the human body. *Thermol Int*. 2008;18:125–129.
- Vardasca R, Rita Marques A, Diz J, Seixas A, Mendes J, Ring EFJ. The influence of angle and distance on temperature readings from the inner-canthi of the eye. *Thermol Int*. 2017;27:130–135.
- Vardasca R, Ring EFJ, Plassmann P, Jones C. Thermal symmetry of the upper and lower extremities in healthy subjects. *Thermol Int*. 2012;22:53–60.
- Ro JY, Capra NF. Modulation of jaw muscle spindle afferent activity following intramuscular injections with hypertonic saline. *Pain*. 2001;92(1-2):117–127.
- Eide PK. Wind-up and the NMDA receptor complex from a clinical perspective. *Eur J Pain*. 2000;4(1):5–15.
- Truini A, Romaniello A, Svensson P, et al. Experimental skin pain and muscle pain induce distinct changes in human trigeminal motoneuronal excitability. *Exp Brain Res*. 2006;174(4):622–629.
- Sugiyo S, Takemura M, Dubner R, Ren K. Trigeminal transition zone/rostral ventromedial medulla connections and facilitation of orofacial hyperalgesia after masseter inflammation in rats. *J Comp Neurol*. 2005;493(4):510–523.
- Nash PG, Macefield VG, Klineberg LJ, Gustin SM, Murray GM, Henderson LA. Bilateral activation of the trigeminothalamic tract by acute orofacial cutaneous and muscle pain in humans. *Pain*. 2010;151(2):384–393.
- Grett G, Ottestad E, Callister R, Angst MS. *Nociceptor*. ScienceDirect; 2012.
- Yam MF, Loh YC, Tan CS, Khadijah Adam S, Abdul Manan N, Basir R. General pathways of pain sensation and the major neurotransmitters involved in pain regulation. *Int J Mol Sci*. 2018;19(8).
- Dubin AE, Patapoutian A. Nociceptors: the sensors of the pain pathway. *J Clin Invest*. 2010;120(11):3760–3772.
- Skjarevski V, Ramadan NM. The nociceptive flexion reflex in humans – review article. *Pain*. 2002;96(1-2):3–8.
- Standring S. *Gray's Anatomy: The Anatomical Basis of Clinical Practice*. 41st ed. Elsevier; 2016.
- Milner R, Doherty C. Chapter 1 - pathophysiology of pain in the peripheral nervous system. In: Tubbs RS, Rizk E, Shojha MM, Loukas M, Barbaro N, Spinner RJ, eds. *Nerves and Nerve Injuries*. San Diego: Academic Press; 2015:3–22.
- Kumar K, Taylor RS, Jacques L, et al. Spinal cord stimulation versus conventional medical management for neuropathic pain: a multicentre randomised controlled trial in patients with failed back surgery syndrome. *Pain*. 2007;132(1-2):179–188.
- Kumar K, Taylor RS, Jacques L, et al. The effects of spinal cord stimulation in neuropathic pain are sustained: a 24-month follow-up of the prospective randomized controlled multicenter trial of the effectiveness of spinal cord stimulation. *Neurosurgery*. 2008;63(4):762–770 discussion 70.
- Kemler M, De Vet H, Barendse G AM, van den Wildenberg F AJM, van Kleef M. Effect of spinal cord stimulation for chronic complex regional pain syndrome Type I: five-year final follow-up of patients in a randomized controlled trial. *J Neurosurg*. 2008;108:292–298.
- Kumar K, Rizvi S. Historical and present state of neuromodulation in chronic pain. *Curr Pain Headache Rep*. 2014;18(1):387.
- Stanton-Hicks M, Panourias IG, Sakas DE, Slavin KV. The future of peripheral nerve stimulation. *Prog Neurol Surg*. 2011;24:210–217.
- Shimada A, Ishigaki S, Matsuka Y, et al. Effects of exercise therapy on painful temporomandibular disorders. *J Oral Rehabil*. 2019;46(5):475–481.
- Durham J, Al-Baghdadi M, Baad-Hansen L, et al. Self-management programmes in temporomandibular disorders: results from an international Delphi process. *J Oral Rehabil*. 2016;43(12):929–936.
- Ferreira A, Costa D, Oliveira A, et al. Short-term transcutaneous electrical nerve stimulation reduces pain and improves the masticatory muscle activity in temporomandibular disorder patients: a randomized controlled trial. *J Appl Oral Sci*. 2017;25(2):112–120.
- Greene C, Menchel H. The use of oral appliances in the management of temporomandibular disorders. *Oral Maxillofac Surg Clin N Am*. 2018;30(3):265–277.
- Politti F, Vitti M, Amorim CF, Tosello Dde O, Palomari ET. Correspondence of the auricular acupoint with the upper trapezius muscle: a electromyographic study. *Complement Ther Clin Pract*. 2010;16(1):26–30.
- Leung A, Khadivi B, Duann JR, Cho ZH, Yaksh T. The effect of Ting point (tendinomuscular meridians) electroacupuncture on thermal pain: a model for studying the neuronal mechanism of acupuncture analgesia. *J Altern Complement Med*. 2005;11(4):653–661.
- Chou LW, Hsieh YL, Kao MJ, Hong CZ. Remote influences of acupuncture on the pain intensity and the amplitude changes of endplate noise in the myofascial trigger point of the upper trapezius muscle. *Arch Phys Med Rehabil*. 2009;90(6):905–912.
- Gomes AVBT, Silva MCF, Souza Júnior PFD, et al. Tratamento do estresse psicológico pela acupuntura, avaliado pela eletromiografia do músculo trapézio. *Revista Dor*. 2012;13:220–224.
- Lerkvalekul B, Jaovisidha S, Sungkarat W, et al. The comparisons between thermography and ultrasonography with physical examination for wrist joint assessment in juvenile idiopathic arthritis. *Physiol Meas*. 2017;38(5):691–700.
- Wóźniak K, Szyzka-Sommerfeld L, Trybek G, Piątkowska D. Assessment of the sensitivity, specificity, and accuracy of thermography in identifying patients with TMD. *Med Sci Monit*. 2015;21:1485–1493.
- de Melo DP, Bento PM, Peixoto LR, Martins SKLD, Martins CC. Is infrared thermography effective in the diagnosis of temporomandibular disorders? A systematic review. *Oral Surg Oral Med Oral Pathol Oral Radiol*. 2019;127(2):185–192.
- Polonowita A, Thomson W, Thorburn D. Clinical efficacy of a simplified approach to managing chronic temporomandibular disorders: evidence from a 1-year case series. *Oral Surg Oral Med Oral Pathol Oral Radiol*. 2019;128(3).
- Lindfors E, Arima T, Baad-Hansen L, et al. Jaw exercises in the treatment of temporomandibular disorders-an international modified delphi study. *J Oral Facial Pain Headache*. 2019;33(4).
- Short-term effectiveness of conservative therapies in pain, quality of life, and sleep in patients with temporomandibular disorders: a randomized clinical trial. In: Resende Cd, Medeiros FdO, Rêgo CdF, Bispo A, Barbosa G, Almeidaads. *Cranio*. 2019(15):1–9.
- Barbosa M, Tahara A, Ferreira I, Intelangelo L, Barbosa A. Effects of 8 weeks of masticatory muscles focused endurance exercises on women with oro-facial pain and temporomandibular disorders: a placebo randomised controlled trial. *J Oral Rehabil*. 2019;46(10):885–894.
- Lindfors E, Magnusson T, Ernberg M. Patients' experiences of therapeutic jaw exercises in the treatment of masticatory myofascial pain-A postal questionnaire study. *J Oral Rehabil*. 2019;46(9):800–806.
- Aggarwal VR, Fu Y, Main CJ, Wu J. The effectiveness of self-management interventions in adults with chronic orofacial pain: a systematic review, meta-analysis and meta-regression. *Eur J Pain*. 2019;23(5):849–865.
- Giannakopoulos N, Katsikogianni E, Hellmann D, et al. Comparison of three different options for immediate treatment of painful temporomandibular disorders: a randomized, controlled pilot trial. *Acta Odontol Scand*. 2016;74(6):480–486.