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Short-term effectiveness of auricular vagus nerve stimulation in patients with myofascial pain syndrome

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ABSTRACT

Objectives: To evaluate the effect of auricular vagus nerve stimulation (VNS) applied in addition to ischemic compression and stretching exercises on pain, trigger point (TP) sensitivity, grip strength, quality of life and autonomic functions in patients with myofascial pain syndrome (MPS).

Methods: Sixty patients, who had neck pain, met the diagnostic MPS criteria of Travell and Simons were included in the study. The subjects were randomly divided into VNS group (n = 30) or control group (n = 30). Each group performed 10 sessions of TP ischemic compression and stretching exercises (5 days/week). Ten sessions of 30-minute long auricular VNS were added to the treatment in VNS group. Pain severity [Visual Analogue Scale (VAS)], TP sensitivity (algometer), grip strength (Jamar dynamometer), quality of life [Short Form-36 (SF-36)] and autonomic function [Composite Autonomic Symptom Scale-31 (Compass-31)] were evaluated before and after 10 sessions of treatment.

Results: The VAS, algometer and Jamar measurements showed significant improvement in both groups. A statistically significant improvement was found in orthostatic intolerance, secretomotor and pupillomotor subscales of Compass-31 scale in the VNS group following the treatment ($p < 0.05$) while no significant difference was observed in the control group ($p > 0.05$). The control group showed significant improvement in all parameters of SF-36 scale, while the VNS group showed significant improvement in physical function, social functionality and pain parameters ($p < 0.05$). The changes in the VAS, algometer, Jamar scores and secretomotor subscale of the Compass-31 scale were statistically higher in the VNS group than in the control group ($p < 0.001$, $p < 0.001$, $p = 0.001$ and $p = 0.011$, respectively).

Conclusions: It can be argued that auricular VNS increases the effectiveness of ischemic compression and stretching exercises in patients with MPS. Further and detailed studies are needed in which the effect of VNS alone or in combination with other treatments in patients with MPS is examined and the physiological mechanisms are investigated.

Keywords: Myofascial pain syndrome, auricular vagus nerve stimulation, ischemic compression, autonomic nervous system, quality of life

Myofascial pain syndrome (MPS) is a painful syndrome caused by taut bands and trigger points (TP) in the muscles, tendons, ligaments, and fascia [1]. Having a prevalence of 12% in the community, MPS has been reported to be mostly seen in individuals between the ages of 30-50 and to be 2 times

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more common in women than in men. All or a combination of muscle spasm, muscle tenderness, limitation of movement, stiffness, fatigue, and autonomic dysfunction may accompany this painful syndrome [2].

The aim of MPS treatment is to inactivate the trigger points that cause pain, to reduce the tension in the muscles and to restore tissue elasticity, to use these muscles with the correct posture and to enable the person to perform daily life activities without any problems. Various medical and conservative treatments are used in the treatment of MPS. Hot and cold pack application, spray and stretching, ischemic compression, ultrasound, therapeutic massage, transcutaneous electrical nerve stimulation, trigger point injection with local anesthetic, dry needling, botulinum toxin injection, stretching exercises, biofeedback are the most commonly used ones. However, in addition to these methods, reducing stress and investigating psychological factors are of significance in the regression of these symptoms [3].

Stimulation of the tenth cranial nerve, the vagus, may affect the autonomic nervous system, reducing the perception of pain and increasing recovery in patients with MPS. It has been shown in the studies conducted on animals that beyond the inhibitory effect the vagus nerve creates through its central connections, it may also have a peripheral effect on nociceptors [4]. In light of these data, it can be thought that auricular vagus nerve stimulation (VNS) will contribute to the MPS treatment. VNS can modulate dystonic symptoms as well as afferent inputs that affect brain regions involved in the formation of sympathovagal balance [5]. The mechanisms (central or peripheral) that provide the analgesic effect with the stimulation of the vagus nerve are still unclear. Very few studies have been conducted on this issue [4]. Offering the most appropriate and effective treatment method to patients suffering from this syndrome, which causes a decrease in the quality of life and loss of workforce, will both reduce the treatment costs and save time for the patient. This study was conducted to evaluate the additional benefits of auricular VNS in patients with MPS.

METHODS

The study was planned in accordance with the Principles of the Declaration of Helsinki. Approval was obtained from the Clinical Research Ethics Committee of Bahçeşehir University on 04.04.2018 with the decision numbered 2018-07/01. The study was carried out between June 2018 and April 2019. All volunteers presented their informed consent before their enrollment in the study.

Sixty patients aged 20-60 who checked into to the Physical Therapy and Rehabilitation Unit of Istanbul Memorial Hospital with the complaint of neck pain, who met the diagnosis and MPS criteria of Travell and Simons, and who had at least one active TP palpable on the trapezius muscle and a taut band were included in this study [6]. Exclusion criteria were as follows: having cervical disc herniation, radiculopathy or myelopathy, having acute inflammatory disease, use of antispasmothic and analgesic medications, and pregnancy.

Randomization of the study was done using the closed-envelope method through odd and even numbers. The subjects were randomly divided into two groups as VNS and control group. Thirty individuals were assigned to each group. Trigger point ischemic compression and stretching exercises were performed for 10 sessions 5 days a week in the control group. In addition to the treatment used in the control group, a total of 10 sessions of auricular VNS were performed for 30 minutes in the VNS group.

All participants were evaluated before the first session, and the same parameters were re-evaluated after 10 sessions of treatment. The participants were evaluated for pain, pressure pain threshold, grip strength, quality of life, and autonomic functions.

Application of Ischemic Compression

The most sensitive TP of the cases with active TPs in the upper fibers of the M. trapezius was determined through palpation. Progressive ischemic compression was applied to this determined TP was 10 times for at least 20 seconds in each session. During the application, a constant pressure was applied with the thumb on the palpable trigger point on the M. trapezius for a certain period of time. As the pain began to subside, the pressure was gradually increased to maintain the same level of pain [7].

Stretching Exercises

The subjects participating in the study were first shown how to do stretches, then they performed them

as self-stretches. In order to provide relaxation by reducing the pain on the trigger points and to increase the range of motion of both active and passive joints by bringing the muscles to their normal length [8], M. Trapezius muscle stretching exercises were performed with 10 repetitions in each session, and the hold time at the last point was determined as 20 seconds.

Vagus Nerve Stimulation

In our study, auricular VNS was applied to both ears simultaneously from the tragus and concha parts by using a specially manufactured earpiece, the size of which can be adjusted according to the ear size, and the Vagustim® device, which is connected to the earpiece. In order for the earpiece connected to the device to conduct the electric current well, conductive gel was applied to the metal part of the earpiece that would contact the patient and placed in a way that coincided with the inner outer surface of the tragus and the concha. The frequency of the Vagustim device connected to the earpiece was set to 10 Hz and its pulse duration to less than 500 microseconds, in modulated TENS mode and biphasic asymmetric waveform. The intensity of the current was adjusted by questioning the sensory threshold of the participants.

Pain Assessment

Visual analog scale (VAS) was used in evaluating the severity of pain. Participants were asked to mark their mean pain during last 48 hours on the line on a 10 cm Likert scale, with "no pain" at the left end (0 cm) and "worst pain" (10 cm) at the right end. Measurements from the starting point of the scale (left end) to the patient's marks were measured in centimeters and recorded as pain intensity [9].

Evaluation of Pressure Pain Threshold

Pain threshold measurements of the participants were performed using the digital algometer branded Algometer Commander Jtech Medical 801-478 USA. The taut bands in the upper fibers of the M. trapezius were found by palpation, and painful trigger points here were marked. The algometer was placed at these points with an angle of 90° and measurements were made. Pain threshold measurements were repeated 3 times and the arithmetic average was taken. The subjects were asked to report the first time they felt pain, and the pain threshold was recorded by reading the value displayed on the device. In all three measurements, a 30-second rest period was given in between [10].

Grip Strength Evaluation

The grip strength measurement of the participants was made using the Jamar hydraulic dynamometer. The measurement was performed with the patient in a sitting position, with the elbow with strong grip at 90° flexion, the forearm neutral and the arm adjacent to the trunk [11]. The patient was asked to grasp the dynamometer and squeeze it with all his/her strength, the measurements were repeated 3 times and the arithmetic averages were taken. These force measurement results were recorded in kilograms.

Questioning of Autonomic Functions

The autonomic functions of the participants were evaluated with COMPASS-31. The Autonomic Symptom Profile (ASP) is a questionnaire designed to comprehensively assess the severity, distribution, and autonomic functional capacity of symptoms in patients with autonomic disorders. The Composite Autonomic Symptom Score (COMPASS) is derived from the ASP and questions autonomic functions with 84 selected questions. Complexity in the scoring algorithm of COMPASS resulted in ambiguous and inconsistent scores. Because the scoring algorithm of this test is complex and requires computer analysis, COMPASS-31 was developed. Selected from ASP and COMPASS to evaluate autonomic function, 31 questions were grouped under 6 areas. A maximum raw score was determined for all areas individually, and a weighting factor was assigned to each area based on the existing perception of the importance of the areas to reflect autonomic failure. The maximum weighted score ranges from 0 to 100. A high score indicates autonomic failure [12].

Questioning of Quality of Life

The Short Form-36 (SF-36) questionnaire was used to question the quality of life. The SF-36 is one of the most widely used and validated forms of questioning quality of life. It was developed and brought into use as a questionnaire by Rand Corporation in 1992 [13].

Statistical Analysis

IBM SPSS Statistics 21.0 (IBM Corp. Released 2012. IBM SPSS Statistics for Windows, Version 21.0. Armonk, NY: IBM Corp.) and MS-Excel 2007 programs were used for statistical analysis and calculations. Statistical significance level was set at $p < 0.05$. The Shapiro-Wilk test was used to evaluate whether the variables in the study were in accordance with the normal distribution. The median (Interquartile Range - IQR) values were used to display the descriptive statistics of the variables that were found not to show normal distribution, and the mean ± SD (Standard Deviation) values were used for the variables with normal distribution. In the comparison of the measurement values before and after the application, the t-test results were used for the normally distributed variables, and the Wilcoxon-Signed Rank test results for those not normally distributed. In the comparison of VNS and control groups before and after the treatment, the t-test results were used for normally distributed variables, and Mann-Whitney U-test results for non-normally distributed variables.

RESULTS

In the VNS group, 27 patients (mean age: 38.14 ± 9.94 years) and 26 patients in the control group (mean age: 35.42 ± 10.74 years) completed the study. The CONSORT flow diagram of the study was given in Fig. 1. There was no significant difference in demographic data between the VNS and control groups ($p > 0.05$) (Table 1).

When the baseline values of the groups were compared, a statistically significant difference was observed only in the gastrointestinal subscale of the Compass-31 scale ($p = 0.027$) and the energy/vitality and mental health subscales of the SF-36 scale ($p = 0.025$ and $p = 0.004$, respectively) (Table 1).

In the VNS group, the pre- and post-treatment VAS scores, algometer and grip strength values showed significant differences ($p < 0.001$, $p < 0.001$ and $p < 0.001$, respectively) (Table 2).

When the Compass-31 scale was analyzed for the VNS group, a statistically significant difference was

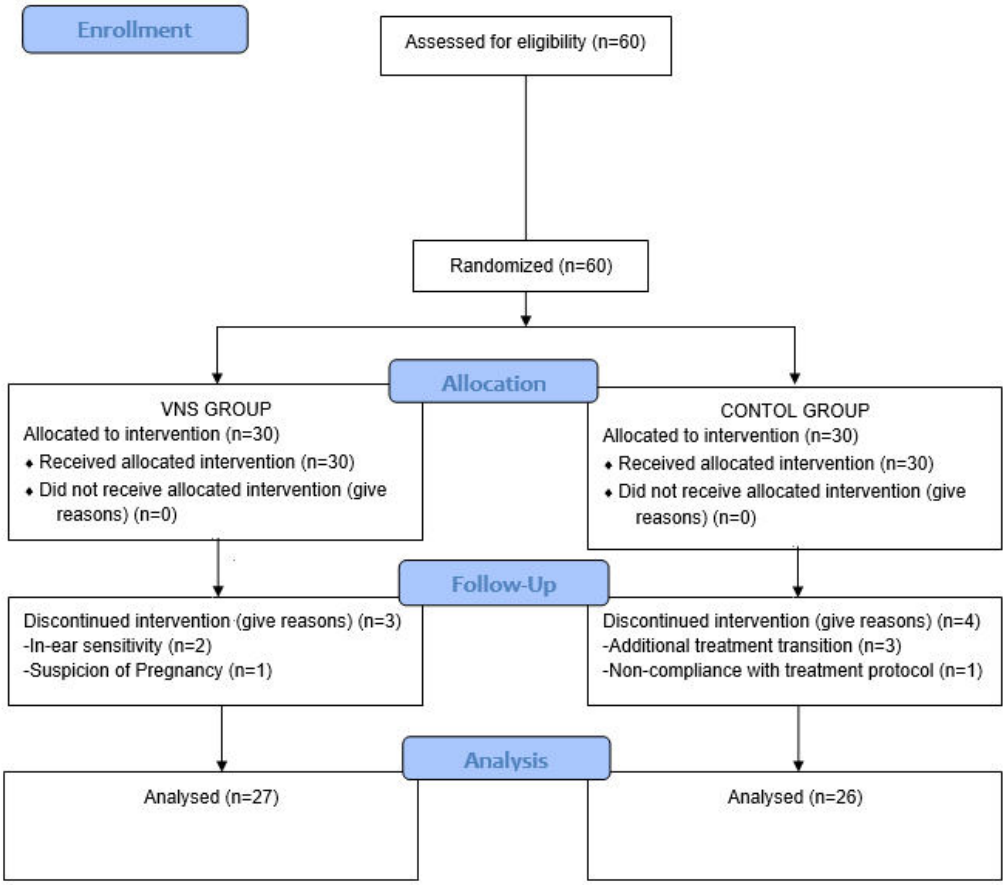

Fig. 1. Consort flow diagram.

Table 1. Comparison of demographic parameters and baseline characteristics of the groups

		VNS Group (n = 27) Mean ± SD / Median (Min-Max)	Control Group (n = 26) Mean ± SD / Median (Min-Max)	Z / t	*p* value
Age (year)		38.14 ± 9.94	35.42 ± 10.74	0.959	0.342[i]
BMI (kg/m$^{2)}$		24.82 ± 4.37)	24.19 ± 4.68	0.511	0.584[i]
Symptom Duration (month)		6.00 (0.25-36)	5.50 (0.50-60)	-0.411	0.681[m]
VAS		6.00 (4-9)	6.00 (5-8)	0.779	0.436[m]
Algometer (kg/cm²)		6.81 ± 2.57	7.48 ± 2.63	-0.926	0.359[i]
Grip strength (kg)		23.32 ± 5.56	24.00 ± 9.67	0.274	0.785[i]
Compass-31	**Orthostatic intolerance (0-10)**	4.00 (2-7)	4.00 (2-8)	1.634	0.102[m]
	Vasomotor (0-6)	2.50 (2-4)	3.00 (2-4)	1.010	0.313[m]
	Secretomotor(0-7)	2.00 (0-5)	0.00 (0-3)	0.684	0.494[m]
	Gastrointestinal(0-28)	9.00 (6-16)	10.00 (9-11)	2.207	**0.027[m]**
	Bladder (0-9)	1.00 (0-4)	0.00 (0-5)	1.116	0.264[m]
	Pupilomotor(0-15)	5.59 ± 2.69	5.04 ± 2.57	0.766	0.447[i]
SF-36	**Physical function**	80.00 (45-100)	90.00 (40-100)	1.875	0.061[m]
	Role physical	25.00 (0-100)	25.00 (0-100)	0.604	0.546[m]
	Emotional function	100 (0-100)	66.66 (0-100)	0.650	0.515[m]
	Energy/vitality	42.22 ± 17.12	53.65 ± 18.84	2.313	0.025[i]
	Mental health	56.29 ± 13.76	68.46 ± 15.15	3.062	0.004[i]
	Social function	75.00 (25-100)	62.50 (25-100)	0.207	0.836
	General health	49.81 ± 17.62	51.15 ± 23.38	0.236	0.814[i]
	Pain	47.50 (12.50-70)	47.50 (22.50-80)	0.207	0.836[m]

BMI = Body Mass Index, VAS = Visual Analog Scale, Min = Minimum, Max = Maximum, SD = Standard deviation.
[i]Independent sample t test / [m]Mann Whitney U test

observed only between the pre- and post-treatment orthostatic intolerance, secretomotor and pupillomotor subscales ($p = 0.004$, $p = 0.002$ and $p = 0.007$, respectively) (Table 2).

When the SF-36 scale was analyzed for the VNS group, a statistically significant difference was observed only between the pre- and post-treatment physical function, social functionality and pain subscales ($p = 0.009$, $p = 0.011$ and $p = 0.002$, respectively) (Table 2).

In control group, there were statistically significant differences between the pre- and post-treatment VAS scores, algometer and grip strength values ($p < 0.001$, $p < 0.001$ and $p = 0.003$, respectively) (Table 3).

When the SF-36 scale was analyzed for the control group, a statistically significant difference was observed between the pre- and post-treatment values of all subscales ($p < 0.05$ for all) (see Table 2).

When the changes observed in the VNS and control groups following the treatment were compared, the changes in the VAS, algometer and Jamar scores in the VNS group were found to be statistically significantly different compared to the control group ($p < 0.001$, $p < 0.001$, and $p = 0.001$, respectively). Similarly, a significant change was found in favor of the VNS group in the secretomotor subscale of the Compass-31 scale ($p = 0.011$). When the changes observed

Table 2. Comparison of pre-treatment and post-treatment values of VAS, Algometer, Grip strength, Compass-31 and SF-36 scores within VNS group

		Pre-treatment Mean ± SD/ Median (Min-Max)	Post-treatment Mean ± SD/ Median (Min-Max)	Z/t	*p* value
VAS		6.00 (4-9)	4.00 (2-6)	-4.615	**< 0.001[w]**
Algometer (kg/cm²)		6.82 ± 2.57	10.04 ± 2.95	9.278	**< 0.001[p]**
Grip strength (kg)		23.32 ± 8.56	25.39 ± 8.27	5.540	**< 0.001[p]**
Compass-31	**Orthostatic intolerance (0-10)**	4.00 (2-7)	3.00 (2-6)	-2.897	**0.004w**
	Vasomotor (0-6)	2.50 (2-4)	3.00 (2-3)	0.0000	1.000[w]
	Secretomotor (0-7)	2.00 (0-5)	1.50 (0-3)	-3.035	**0.002[w]**
	Gastrointestinal (0-28)	9.00 (6-16)	8.50 (9-11)	-1.633	0.102[w]
	Bladder (0-9)	1.00 (0-4)	0.00 (0-5)	-1.642	0.101[w]
	Pupillomotor (0-15)	8.00 (6-10)	6.50 (5-9)	-2.699	**0.007[w]**
SF-36	**Physical function**	80.00 (45-100)	85.00 (60-100)	-2.600	**0.009[w]**
	Role physical	25.00 (0-100)	50.00 (0-100)	-1.930	0.054[w]
	Emotional function	100 (0-100)	100 (0-100)	-1.813	0.070[w]
	Energy/vitality	42.22 ± 17.12	48.33 ± 19.75	-1.849	0.076[p]
	Mental health	56.29 ± 13.76	59.70 ± 15.73	-1.524	0.140[p]
	Social function	75.00 (25-100)	87.50 (50-100)	-2.530[W]	**0.011**
	General health	49.81 ± 17.62	50.93 ± 16.23	-0.560[p]	0.580
	Pain	47.50 (12.50-70)	67.50 (22.50-90)	-3.109[W]	**0.002**

VAS = Visual Analog Scale, Min = Minimum, Max = Maximum, SD = standard deviation.
[w]Wilcoxon-Signed Rank test / [p]Paired t test

following the treatment in the other subscales of the Compass-31 scale and the SF-36 scale were compared, no significant difference was found between the two groups ($p > 0.05$) (Table 4).

DISCUSSION

To the best of our knowledge, this study is the first to examine the effect of VNS on MPS. VNS was applied from both ears noninvasively so the possible asymmetric effects (central and peripheral) of unilateral stimulation were avoided. In addition, tragus and concha regions were stimulated concomitantly to increase the affected auricular vagus nerve fibers. Besides these strengths of the study; the limited number of participants in the groups, the absence of a group in which VNS was applied alone, the non-similarity of the effect mechanisms of the treatments applied in the VNS group, and the absence of sham treatments can be considered among the limitations.

MPS is a complex syndrome characterized by TPs and taut bands. Individuals with clinical MPS have a high recurrence rate. Patients may have muscle stiffness, muscle pain, headache, dizziness, nausea, vomiting and sleep problems that affect their daily activities [14]. Variable sympathetic hyperactivity, along with sweating, vasoconstriction, vasodilation, and piloerection, has also been reported in the myofascial TP regions [15].

Studies in rabbits and humans have shown that the increase in sympathetic activation contributes to the

Table 3. Comparison of pre-treatment and post-treatment values of VAS, Algometer, Grip strength, Compass-31 and SF-36 scores within Control group

		Pre-treatment Mean ± SD/ Median (Min-Max)	Post-treatment Mean ± SD/ Median (Min-Max)	Z/t	*p* value
VAS		6.00 (5-8)	4.00 (3-7)	-4.572	**< 0.001**[w]
Algometer (kg/cm²)		7.48 ± 2.63	9.09 ± 2.65	7.888	**< 0.001**[p]
Grip strength (kg)		24.00 ± 9.67	24.53 ± 9.47	3.341	**0.003**[p]
Compass-31	**Orthostatic intolerance (0-10)**	4.00 (2-8)	3.00 (2-6)	-1.518	0.085[w]
	Vasomotor (0-6)	3.00 (2-4)	3.00 (2-4)	-1.000	0.317[w]
	Secretomotor (0-7)	0.00 (0-3)	0.50 (0-3)	-0.758	0.448[w]
	Gastrointestinal (0-28)	10.00 (9-11)	9.00 (7-11)	-1.000	0.317[w]
	Bladder (0-9)	0.00 (0-5)	0.00 (0-4)	0.000	1.000[w]
	Pupillomotor (0-15)	7.00 (5-9)	6.00 (4-10)	-1.207	0.227[w]
SF-36	**Physical function**	90.00 (40-100)	92.50 (50-100)	-2.124	**0.034**[w]
	Role physical	25.00 (0-100)	62.50 (0-100)	-2.701	**0.007**[w]
	Emotional function	66.66 (0-100	100 (0-100)	-2.373	**0.018**[w]
	Energy/vitality	53.65 ± 18.84	58.26 ± 17.20	-2.150	**0.041**[p]
	Mental health	68.46 ± 15.15	74.15 ± 13.58	-3.335	**0.003**[p]
	Social function	62.50 (25-100)	81.25 (37.50)	-3.508[W]	**< 0.001**
	General health	51.15 ± 23.37	54.81 ± 23.68	-2.774[p]	**0.010**
	Pain	47.50 (22.50-80)	68.75 (35-90)	-4.536[w]	**< 0.001**

VAS = Visual Analog Scale, Min = Minimum, Max = Maximum, SD = standard deviation.
[w]Wilcoxon-Signed Rank test / [p]Paired t test

modulation of motor activity in TPs. However, there is little evidence of sympathetic-sensory interaction in myofascial TP to explain local and referred pain. Autonomic nervous system dysfunctions are thought to be effective in maintaining chronic musculoskeletal pain. It is believed that increased sympathetic activity exacerbates the spontaneous pain seen in TN in patients with chronic neck and shoulder pain [16]. Thus, autonomic nervous system abnormalities are thought to play a role in myofascial TP-related chronic pain [17].

The vagus nerve has a wide distribution throughout the body and, with its central connections, the vagus plays an important role in the control of homeostasis. Functional disorders in the autonomic nervous system are associated with the disruption of this balance. Stimulation of the vagus nerve via the cervical or auricular pathway can contribute to homeostasis and modulate pain and inflammation [5, 18]. Thanks to the neurophysiological data obtained in recent years, the effects of VNS on pain have become more comprehensible [19].

In our study, we aimed to examine the effect of auricular VNS applied in addition to ischemic compression and stretching exercises on pain, TP sensitivity, and grip strength in patients diagnosed with MPS. In addition, the SF-36 and COMPASS-31 scales were used to evaluate quality of life and autonomic functions. When we reviewed the literature, we observed that although there were many studies on the treatment

Table 4. Comparison of the post-treatment and pre-treatment differences of the groups

		VNS Group mean ± SD	Control Group mean ± SD	*p* value
VAS		-2.77 ± 0.80	-1.96 ± 0.66	**< 0.0010[m]**
Algometer (kg/cm²)		3.22±1.80	1.61 ± 1.04)	**< 0.0010[i]**
Grip strength (kg)		2.07±1.94	0.52 ± 0.79	**0.001[i]**
Compass-31	**Orthostatic intolerance (0-10)**	-1.095 ± 1.48	-0.625 ± 1.06	0.496[m]
	Vasomotor (0-6)	0.000 ± 0.632	-0.285 ± 0.755	0.429[m]
	Secretomotor (0-7)	-0.875 ± 1.295	-0.115 ± 0.816	**0.011[m]**
	Gastrointestinal (0-28)	-2.333 ± 0.577	-1.000 ± 1.414	0.197[m]
	Bladder (0-9)	-0.407 ± 1.185	0.000 ± 0.282	0.211[m]
	Pupillomotor (0-15)	-1.900 ± 1.370	-0.625 ± 1.597	0.102[m]
SF-36	**Physical function**	3.70 ± 7.01	1.92 ± 4.70	0.456[m]
	Role physical	13.88 ± 40.03	15.38 ± 24.57	0.924[m]
	Emotional function	16.04 ± 42.73	14.10 ± 26.95	0.992[m]
	Energy/vitality	6.11 ± 17.17	4.61 ± 10.94	0.708[i]
	Mental health	3.40 ± 11.61	5.69 ± 8.70	0.423[i]
	Social function	12.03 ± 21.78	11.05 ± 12.41	0.926[m]
	General health	1.11 ± 10.31	3.65 ± 6.71	0.295[i]
	Pain	16.85 ± 20.50	21.34 ± 10.95	0.522[m]

VAS = Visual Analog Scale, Min = Minimum, Max = Maximum, SD = standard deviation.
[i]Independent sample t test / [m]Mann Whitney U test

of MPS, there was no study on the use of VNS. There have been opinions arguing that sympathetic activity in intramuscular TPs in MPS increases and there is an increase in pain that develops because of this increase [16, 20]. Therefore, we investigated the change in pain in patients with MPS through auricular VNS application.

Hanten *et al*. [21] reported that a home program consisting of ischemic compression and stretching exercise was effective in reducing TP tenderness and pain intensity in individuals with neck and upper back pain. In another randomized controlled study, it was found that the application of ischemic compression in 41 patients with chronic myofascial shoulder pain can reduce symptoms in the treatment of myofascial pain [22]. In our study, the ischemic compression and stretching application applied in the control group yielded results similar to the literature. There was a decrease in the patients' pain after the treatment. In addition to the reduced pain, an increase in grip strength was also observed.

In a randomized controlled study examining cervicogenic headache caused by myofascial TPs, it was reported that the application of ischemic compression was effective [23]. Hodgson and Fryer [24] used an algometer to measure the effect of ischemic compression on pressure sensitivity on latent TPs in the upper trapezius muscle in 37 subjects with myofascial TP. As a result, they found that application of ischemic compression can be an effective treatment for TPs [24]. Similarly, there was a decrease in the TP sensitivity and an increase in the pain pressure threshold in the control group in our study. When the patients were compared before and after the treatment, statistically significant changes were found in VAS, algometer and Jamar grip strength measurements. It is believed that the decrease in pain and sensitivity in TPs causes an increase in grip strength.

When the responses given by the control group on the Compass-31 scale were examined, no significant change was observed. Although there was a decrease in pain, there was no change in the scores of the Compass-31 scale, which reflects the autonomic nervous system activity, suggesting that the application of trigger point ischemic compression and stretching exercises have a local effect. When the SF-36 scores in the

control group were examined, statistically significant improvements were observed in all subscales. This could have occurred as a result of a reduction in pain.

There is a case report in the literature in which percutaneous VNS was applied to a patient with treatment-resistant cervical dystonia. The patient had a subjective improvement in mobility, sleep and mood, in addition to dystonia. A decrease in muscle tonus was observed [59. In a study by Busch *et al*. [19], a decrease in mechanical and pressure pain sensitivity and an increase in mechanical pain threshold were found in healthy individuals through noninvasive VNS. Clancy *et al*. [25] revealed that transcutaneous VNS reduces sympathetic activity in healthy individuals. Similarly, a decrease in pain, an increase in pain pressure threshold and grip strength, and an improvement in autonomic nervous system functions were observed in the VNS group in our study. In addition, when the changes observed as a result of the treatment between the two groups were compared, clinically more improvement was achieved in the VAS, algometer and grip strength measurements in the VSS group. It can be stated that VNS increases the effectiveness of application of trigger point ischemic compression and stretching exercises in the treatment of MAS. Although the control group showed more improvement in the SF-36 scale, there was no difference between the two groups when compared in terms of the amount of change. We think that this may be due to the differences that existed between the groups at the beginning. When the changes in the Compass-31 scale were compared, there was no statistically significant difference between the groups, except for the secretomotor subscale. Myofascial TP treatment may cause physiological changes in the autonomic nervous system [26]. Although ischemic compression therapy applied to the control group is a peripheral and local treatment method, it had a central effect on the body and may have affected Compass-31 scores accordingly.

It was observed in our study that the application of VNS in patients with MPS increased the effectiveness of ischemic compression and stretching therapy in terms of pain, algometry and grip strength. This may have occurred as a result of combining a central treatment (VNS) and a local treatment. VNS plays an important role in the modulation of pain and nociception thanks to its central effects [27, 28]. However, there are also studies in the literature indicating that VNS application reduces ischemia [29, 30]. Further studies are needed to more clearly reveal the physiological mechanisms by which VNS increases the effectiveness of ischemic compression and stretching exercises.

Limitations

The limited number of participants in the groups, the absence of a group in which VNS was applied alone, the non-similarity of the effect mechanism that the treatments applied in the VNS group created on the body, and the absence of sham treatments can be considered among the limitations of the study. No side effects related to the treatments were detected in the participants.

CONCLUSION

The application of ischemic compression and stretching stands out as an effective method in the treatment of MPS. This result is consistent with previous studies in the literature. However, no studies examining the effectiveness of VNS in MPS have been found in the literature. Our study is the first of its kind in this regard. It can be stated that VNS increases the effectiveness of the application of trigger point ischemic compression and stretching exercises in the treatment of MPS. More detailed studies are needed to examine the effect of VNS alone or in combination with other treatments in patients with MPS, and to investigate the physiological processes.

Authors' Contribution

Study Conception: SÜ, DKÇ, AVÖ; Study Design: SÜ, DKÇ, AVÖ; Supervision: SÜ, DKÇ, AVÖ; Funding: SÜ, DKÇ, AVÖ; Materials: SÜ; Data Collection and/or Processing: SÜ, DKÇ, AVÖ; Statistical Analysis and/or Data Interpretation: DKÇ, AVÖ, SHA; Literature Review: SÜ, DKÇ, AVÖ, SHA; Manuscript Preparation: SÜ, DKÇ, AVÖ, SHA and Critical Review: SÜ, DKÇ, AVÖ, SHA.

Conflict of interest

The authors disclosed no conflict of interest during the preparation or publication of this manuscript.

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