Randomized Trial on Comparison of the Efficacy of Extracorporeal Shock Wave Therapy and Dry Needling in Myofascial Trigger Points

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Objective: The aim of the study was to compare the efficacy of radial extracorporeal shock wave therapy and dry needling in the treatment of myofascial trigger points in the upper trapezius muscle.

Design: A total of 65 patients with myofascial trigger points were randomly divided into extracorporeal shock wave therapy group ($n = 32$) and dry needling group ($n = 33$). Patients received 3 wks of treatment at 1-wk intervals (in both groups). Visual analog scale, pressure pain threshold, Neck Disability Index, and shear modulus were evaluated before treatment, immediately after the first therapy, 1 mo, and 3 mos after the completion of the third therapy.

Results: Significant improvements of visual analog scale, pressure pain threshold, and Neck Disability Index scores were observed at all time points after treatment ($P < 0.01$) in both treatment groups. The shear modulus of myofascial trigger points was reduced in both dry needling group ($P < 0.05$) and extracorporeal shock wave therapy group ($P < 0.01$) immediately after the first treatment. Significant reductions in shear modulus were maintained up to 3-mo posttreatment in both groups ($P < 0.01$). There were no significant differences between the radial extracorporeal shock wave therapy group and dry needling group.

Conclusions: The extracorporeal shock wave therapy is as effective as dry needling for relieving pain, improving function, and reducing shear modulus for patients with myofascial trigger points after a series of three treatments.

Key Words: Myofascial Pain Syndrome, Myofascial Trigger Points, Extracorporeal Shock Wave Therapy, Dry Needling, Shear Wave Elastography

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Myofascial pain syndrome (MPS) is one of the most common causes of chronic musculoskeletal disorders, which presents significant medical and financial burdens to modern society.[1,2] Neck and upper back pain is the typical symptom of MPS. The upper trapezius muscle is commonly involved in MPS and therefore triggers great interest among researchers. Within palpable taut bands, the irritable points characterized by referred pain and autonomic dysfunction are referred to as myofascial trigger points (MTrPs).[3] The MTrPs are usually identified as important anatomic and physiologic initial factors of MPS. An active MTrP is characterized by spontaneous pain or pain response, whereas a latent MTrP is only a tender palpable nodule dependent on compression.[4]

To date, there are no unified diagnostic standards for MPS. It requires detailed medical history and physical examination to confirm the existence of MTrPs. In clinical practice, stimulating local or referred pain via manual palpation is a relatively reliable method for detecting MTrPs. Although the pathophysiologic mechanisms of MTrPs remained unknown, multiple promising evaluation methods could be used to detect the abnormal changes of MTrPs. For example, the application of ultrasound imaging for musculoskeletal diseases has several advantages including safety, high cost-effectiveness, portability, and convenience.[5,6] The shear wave elastography (SWE) is emerging as a practical tool for assessing tissue elasticity and viscosity properties via estimating the speed of propagating shear wave. Earlier studies have shown that the SWE could be used to evaluate the MTrPs both qualitatively and quantitatively and distinguish the active MTrPs from latent MTrPs.[7] Previous research also indicated that the shear wave speed of MTrPs was significantly higher than that of normal tissue.[8] Many studies have been performed to verify the reliability and validity of SWE for detecting the MTrPs. For example, Eby et al.[9] reported satisfactory correlations between the SWE

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measurements and traditional materials testing in *porcine brachialis* whole-muscle samples. Maher et al.[7] reported that the shear modulus was reduced after the dry needling treatment and concluded that the SWE was sensitive enough to identify the elastic changes of tissue.[7] To the best of our knowledge, the immediate- and long-term effects of the extracorporeal shock wave therapy (ESWT) and dry needling (DN) based on ultrasonographic features of MTrPs have not been reported elsewhere.

Multiple methods could be used to help relieve pain for MPS patients, including physiotherapy, manipulative therapy, acupuncture, and injection (e.g., lidocaine and botulinum toxin). In the treatment of MTrPs, DN is defined as an invasive procedure where a solid filament needle was inserted into the soft tissues directly.[10] The efficacy of DN has been well demonstrated in previous studies. It was believed that the local twitch responses elicited by DN facilitated pain relief and muscle stiffness reduction. Ziaeifar et al.[11] reported that DN led to significant improvements in pain intensity, pressure pain threshold (PPT) and disability for patients with MTrPs.

The ESWT has been applied as a noninvasive, effective, and safe tool for musculoskeletal diseases. The important parameters of ESWT include the energy flux density (EFD) and total acoustic energy. The primary therapeutic effects of ESWT refer to the direct beneficial pulses at the target points, and the secondary effects refer to the biological effects, which may induce tissue repair and regeneration.[12] For example, Ji et al.[13] once observed the efficacy of focused ESWT (EFD = 0.056 mJ/mm^2) and placebo ESWT (EFD = 0.001 mJ/mm^2) for MTrPs and proved that ESWT was effective for pain relief after four times therapies in 2 wks. Similar results were obtained by comparing the focused ESWT (EFD = 0.10 mJ/mm^2) with trigger point injections combined with transcutaneous electrical nerve stimulation for MTrPs. Moreover, it was reported that the ESWT induced referred pain and twitching response when the localized probe was applied to the MTrPs.[14] Compared with focused ESWT, radial ESWT generates lower pressure over a longer period and propagates divergently within the tissue. Although there is now sufficient scientific evidence about the effectiveness of radial ESWT in epicondylitis, plantar fasciitis, and calcific tendinitis treatment,[15,16] the application of radial ESWT in upper trapezius MTrPs has not been fully explored. More in-depth studies are needed to explore the short- and long-term effects of radial ESWT based on the mechanical properties.

This randomized, controlled trial was designed to compare the efficacy of radial ESWT and DN in treating patients with upper trapezius MTrPs. We hypothesized that ESWT would be at least as effective as DN for the purpose of pain relief, function restoration, and muscle stiffness improvement.

METHODS

Participants

The participants were recruited from the Department of Rehabilitation Medicine of Sun Yat-Sen Memorial Hospital, Sun Yat-Sen University from January 2016 to December 2016. The patients were evaluated carefully based on medical and treatment histories, musculoskeletal examinations (including neurologic examination, etc.) and imaging examinations before the beginning of the study. The palpation was performed by a clinician with more than 20 yrs of experience, who determined the presence or absence of active MTrPs according to the criteria defined by Gerwin et al.[17] and Travell and Simons.[18] The active trigger point was defined as a painful nodule, which reproduced or exacerbated the patient's spontaneous pain. Patients who met the following criteria were included: (*a*) having only one active trigger point in one side of upper trapezius muscle (single MTrP instead of multiple MTrPs was chosen to avoid the influence of overlapped or spontaneous pain pattern induced by multiple MTrPs,[19] and the identification of MTrPs was determined following Simons and Travell's criteria); (*b*) a duration of symptoms for at least 6 mos; and (*c*) aged between 16 and 60 yrs. Exclusion criteria included the following: (*a*) patients with neurological deficits (including positive Spurling's sign, paralysis, weakness, paresthesia, etc.); (*b*) abnormal neuroimaging findings (cervical disc herniation and infection, etc.) in x-ray, computed tomography, and magnetic resonance imaging; (*c*) history of cervical disc hernia, radiculopathy, myelopathy, fibromyalgia, whiplash, spondylosis, and spinal stenosis; (*d*) received pain medications, physical therapies (including ESWT and DN), surgeries, or trigger point injections in the previous 6 mos; (*e*) concomitant painful disorders, psychoemotional distress, and other factors; and (*f*) ruled out other potential causes of their symptoms other than upper trapezius muscle MTrPs. This study has been registered (Registration ID: ChiCTR-INR-17014029) and the protocol was approved by the Medical Ethics Committee of Sun Yat-Sen Memorial Hospital (SYSEC-KY-KS-058). All participants gave written informed consent.

Randomization was conducted using the Web site tool (https://www.random.org/). Once subjects were enrolled, they received a numbered opaque sealed envelope from the research nurse, and the nurse was blinded to the patients' condition. The envelopes contained preassigned and randomized numbers generated by the method mentioned previously. Unfortunately, it was impossible to blind participants to the allocation, but the examiners and sonographers who performed the assessment were not aware of the treatment allocation. Finally, a total of 65 participants were eventually enrolled and randomly divided into two groups, namely, the ESWT group (n = 32) and the DN group (n = 33). Participants in both groups did not receive other forms of intervention for MPS. All participants were instructed not to take analgesic medicine or receive physiotherapy during the treatment and follow-up period. The participants were informed to report any intolerable soreness and other feelings induced by ESWT or DN during the treatment and follow-up period, and the abnormal feelings were reported via telephone and recorded in written form by the research nurse. The body position of participants and manual identification of MTrPs were similar to the methods reported in our previous study (Fig. 1).[20] This study conforms to all CONSORT guidelines and STROBE checklist and reports the required information accordingly (see CONSORT Checklist, Supplemental Digital Content 1, http://links.lww.com/PHM/A762, and STROBE Checklist, Supplemental Digital Content 2, http://links.lww.com/PHM/A763).

Extracorporeal Shock Wave Treatment

In our pilot study, the patients with trapezius muscle MTrPs received the radial ESWT with low EFD

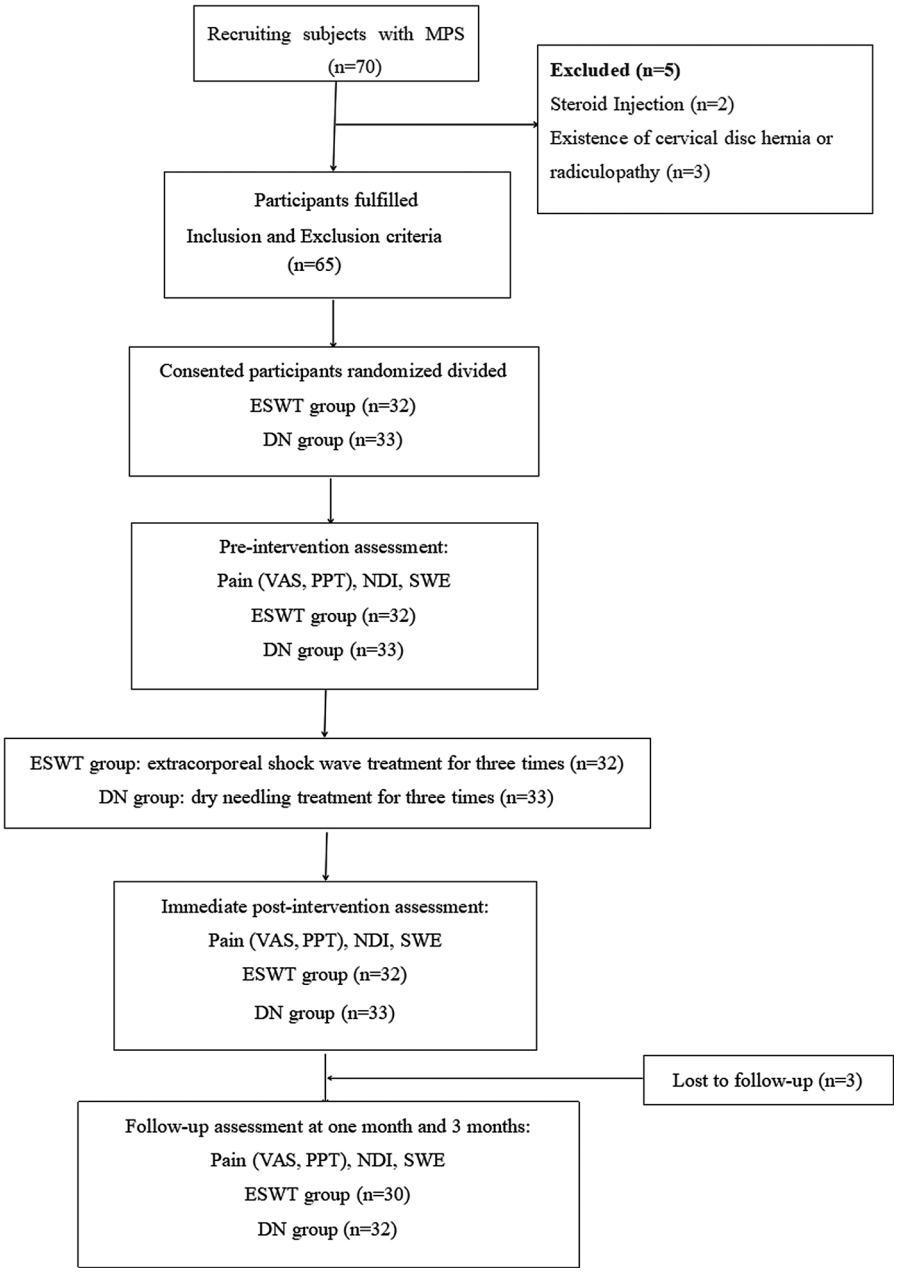

FIGURE 1. Flowchart of the study protocol.

(EFD = 0.10 mJ/mm^2) based on a previous research.[14] None of them reported unacceptable soreness after every treatment or during the follow-up. The radial extracorporeal shock wave was applied by designated physiotherapist using Swiss Dolor Clast (Electro Medical Systems, Nyon, Switzerland). Before the treatment, the MTrPs were specifically confirmed by twitching response induced by the localized probe. Participants in ESWT group were given 2000 shock waves (EFD = 0.10 mJ/mm^2), with 1500 impulses targeting the confirmed MTrPs and 500 impulses surrounding the taut band. The participants undertook the ESWT at 1-wk interval for three times (total of 6000 shock waves). Intact skin was confirmed and clean coupling gel was used during the treatment.

Dry Needling

The DN treatment was performed once per week for a total of three times. For the DN group, solid filament needles were inserted into the MTrPs of patients in the sitting position. The taut band was identified and the twitch response was elicited when the DN was applied. The needle is 0.30 mm in diameter and 50 mm in length. The DN depth was 30–35 mm at each trigger point and it was manipulated up and down using a "fast-in and fast-out" technique inside the MTrP for 10 times in accordance to the standard DN protocol, as proposed in our previous study.[20]

Outcome Measures

Visual analog scale (VAS), PPT, Neck Disability Index (NDI), and shear modulus of the upper trapezius MTrPs were

evaluated at baseline, immediately after treatment, 1-mo, and 3-mo follow-up. To evaluate the immediate effects, the patients were assessed immediately 15–30 mins after the first treatment. The examiners were blinded to the group allocation.

Visual Analog Scale

The pain intensity was assessed using the VAS. The VAS is 10 cm long, anchored with the words "no pain" and "worst pain imaginable" at the opposite ends.[21] According to a previous study, the mean reduction in VAS of 2.0 cm represents a clinically significant difference in pain severity that corresponds to effective treatments.[22] Participants were requested to mark a point along the scale that best represented the level of pain experienced before treatment, immediate after treatment, 1 mo, and 3 mos after treatment.

Pressure Pain Threshold

Pressure pain threshold is defined as the least amount of pressure needed to provoke pain. A digital pressure algometer was used to assess the PPT as recommended by Fischer.[23] The procedure was performed with an algometer (Model PTH AF2; Pain Diagnostics and Thermography, Great Neck, NY), by placing the rubber tip area (1 cm^2) perpendicular to the identified MTrPs and pressing at a rate of 1 kg/sec.[20] The MTrPs were identified by the presence of local or referred pain. The patients were asked to report "yes" as soon as they began to feel pain and then the compression stopped. Three repetitive measurements at an interval of 30 secs were performed at the same point, and the average value was calculated and used for further analysis. Data were collected at the follow-up time points as mentioned previously.

Neck Disability Index

The Neck Disability Index (NDI) is a widely used self-rating scale to evaluate the impact of pain on daily activities. The satisfactory reliability and validity of the Chinese version of the NDI have been proven.[24] According to the previous study, the minimum detectable change is 5.0 points, and the minimum clinically important difference is in the range of 3.5–5.0 points.[25]

Shear Wave Ultrasound Elastography

The mechanical properties of MTrPs were quantitatively measured by elastographic technique. Participants underwent the sonographic examinations using Aixplorer US system (SuperSonic Imaging; Aix en Provence, France) with a 4- to 15-MHz linear array transducer. The MTrPs of upper trapezius were landmarked and the transducer was oriented to transverse over the regions of interest until the MTrPs appeared. Supersonic shear imaging mode was used to obtain the shear modulus map. The 10 × 10-mm square regions of interest were set around the identified MTrPs based on the clinical evaluation as mentioned previously and the values of shear modulus across three measurements were averaged for each participant. The elastographic evaluations were made before treatment, immediately after the first therapy, 1 mo, and 3 mos after treatment. Again, the sonographers were blinded when acquiring the ultrasound data.

Data Analysis

The sample size was calculated before the study with respect to the VAS, which was the primary outcome measure of the present research. Based on the mean and SD of VAS in preliminary experiment, the power analysis was performed with $\alpha = 0.05$ (two-sided) and $\beta = 0.20$ for analysis of variance (ANOVA) with repeated measures. There were at least 24 cases in each group for statistical analysis. Considering the probability of loss during follow-up (20%–30%), a total of 70 patients were recruited for both groups.

All data were analyzed using SPSS Version 17.0 for Windows (SPSS Inc, Chicago, IL). The demographic data were examined by descriptive statistics, and measurements were presented as means ± SDs. χ^2 analysis was used for nonparametric data. Before execution of repeated measures ANOVA, sphericity test of Mauchly and compound symmetry were performed. In the case of satisfaction of the sphericity assumption ($P > 0.05$), we accepted the null hypothesis that the variances of the differences between all combinations were equal. If the sphericity assumption was not satisfied ($P < 0.05$), the P value for the within-subjects factor needed to be adjusted. Analysis of variance for repeated measure ANOVA was used to compare the VAS, PPT, NDI, and shear modulus of patients' pretreatment, immediate posttreatment, 1-mo, and 3-mo follow-up. We further performed post hoc comparisons, and P value <0.05 was considered statistically significant.

RESULTS

Demographics Data

Two patients in the ESWT group and one patient in the DN group dropped out for the follow-up period because they received other treatments, which disqualified them to continue with the study. There was no withdrawal recorded because of the adverse effects of therapies. The demographic and clinical characteristics of dropouts did not differ from the rest of the participants. After the exclusion of dropped-out patients, a total of 62 patients including 30 in ESWT group (female: 73.3%) and 32 in DN group (female: 65.6%) completed the study. No significant differences were found between the ESWT group and the DN group in demographic characteristics including age and sex distribution, etc. (Table 1).

Changes of VAS

For the VAS assessment, the sphericity assumption was satisfactory ($P = 0.96 > 0.05$). Despite of the significant time effects ($F = 113.76$, $P < 0.01$), there were no interaction effects ($F = 0.91$, $P = 0.44 > 0.05$) or differences in accordance with

TABLE 1. Demographic and clinical characteristics of patients

	ESWT Group	DN Group	*P*
Sex (female/male)	22/8	21/11	0.51
Age, yr	32.47 ± 10.58	33. 09 ± 12.78	0.10
Pain duration, mo	8.30 ± 3.10	8.91 ± 2.73	0.50
Referred pain (positive/negative)	16/14	19/13	0.63
Affected side (left/right)	17/13	15/17	0.44

groups ($F = 0.27$, $P = 0.60 > 0.05$). For both the ESWT and DN groups, pain relief was detected immediately after the first treatment, and significant decrease of VAS scores was maintained at 1- and 3-mo follow-up ($P < 0.01$). No statistical differences of VAS were observed between the two intervention groups at any time point (Table 2).

Changes of PPT

Repeated measures ANOVA indicated no significant differences between the two groups ($F = 0.15$, $P = 0.70 > 0.05$) or interaction effects ($F = 0.39$, $P = 0.72 > 0.05$). Time effect was found to be significant, resulting in significantly higher values of PPT immediately after the first treatment ($P < 0.01$) and maintained up to 1 and 3 mos compared with pretreatment baseline ($P < 0.01$). Again, no significant differences were found between the two groups at various time points (Table 2).

Changes of NDI

Neck Disability Index was evaluated at baseline, 1-, and 3-mo follow-up. Similarly, there was no significant difference between the two groups ($F = 0.02$, $P = 0.90 > 0.05$) or interaction effect ($F = 0.65$, $P = 0.52 > 0.05$). According to the repeated measures of ANOVA, the significant reductions of NDI scores after ESWT and DN treatment were noted after 1 and 3 mos, respectively ($F = 176.54$, $P < 0.01$, and $F = 146.88$, $P < 0.01$). The differences of NDI scores between the two groups at corresponding time points were not significant (Table 2).

Changes of Shear Wave Elastography

Myofascial trigger points were usually presented with focal hypoechoic areas on ultrasound imaging, whereas the normal tissue appeared isoechoic with homogeneous echotexture. Sphericity assumption of SWE was found to be unsatisfactory. There was significant interactive effect ($F = 16.61$, $P < 0.01$) and time effect ($F = 180.61$, $P < 0.01$). There was no significant difference of SWE between the two groups at the baseline. In the present study, the shear modulus decreased significantly in both the ESWT and the DN groups, whereas further decrease of shear modulus of the ESWT group compared with the DN group was detected immediately after the first treatment ($P < 0.01$). For the ESWT group, the shear modulus decreased significantly by 28.8% from 46.87 ± 6.79 kPa to 33.35 ± 5.23 kPa immediately after the first treatment (Figs. 2A, B, $P < 0.01$), and further decline was detected at 1- and 3-mo follow-up ($P < 0.01$). For the DN group, an immediate reduction by 6.9% from 44.83 ± 6.37 kPa to 41.70 ± 6.54 kPa was also observed (Figs. 2C, D, $P < 0.05$), and the DN group demonstrated further reduction in shear modulus at 1 and 3 mos ($P < 0.01$) (Table 2 and Fig. 2). No significant differences were found between the ESWT group and the DN group with regard to shear modulus at 1- and 3-mo follow-up.

Safety

There were no complications or other reported soreness after both the ESWT and the DN treatment during the 3-mo follow-up.

DISCUSSION

The present study was designed to compare the immediate and long-term effects of ESWT and DN treatment on upper trapezius MTrPs. Positive results were obtained for VAS, PPT, NDI, and sonoelastography of MTrPs for both treatment groups. Although the pathophysiologic mechanisms underlying the MTrPs development were still not clear, the current data proved that ESWT was at least as effective as DN in pain relieving and function restoration for MPS patients after the completion of the therapy (once per week for 3 wks).

TABLE 2. Outcome measurements of VAS scores, PPT (kPa), and NDI among patients at different time points

	Baseline	Immediate After First Therapy	1 mo After Treatment	3 mos After Treatment		*F*	*P*	η^2
VAS								
ESWT	3.57 ± 1.04	2.93 ± 0.94**	1.73 ± 0.91**	1.50 ± 0.82**	Group	0.27	0.60	0.01
DN	3.78 ± 1.18	2.78 ± 1.07**	1.91 ± 1.00**	1.69 ± 1.03**	Time	113.76	<0.01	0.66
					Group × time	0.91	0.44	0.02
PPT								
ESWT	206.90 ± 34.24	253.10 ± 51.26**	320.13 ± 61.15**	316.97 ± 52.37**	Group	0.15	0.70	<0.01
DN	198.63 ± 35.16	246.03 ± 46.91**	317.09 ± 49.82**	320.84 ± 46.08**	Time	169.95	<0.01	0.73
					Group × time	0.39	0.72	0.01
NDI								
ESWT	15.37 ± 2.04	——	9.57 ± 1.77**	9.07 ± 1.70**	Group	0.02	0.90	<0.01
DN	15.31 ± 2.44	——	9.38 ± 2.46**	9.47 ± 1.87**	Time	318.92	<0.01	0.84
					Group × time	0.65	0.52	0.01
SWE								
ESWT	46.87 ± 6.79	33.35 ± 5.23**	28.59 ± 3.88**	30.98 ± 5.21**	Group	1.68	0.2	0.03
DN	44.83 ± 6.37	41.70 ± 6.54*	27.16 ± 3.26**	31.01 ± 5.65**	Time	180.61	<0.01	0.75
					Group × time	16.61	<0.01	0.22

Values are mean ± SD.

*$P < 0.05$, **$P < 0.01$, immediate after treatment, 1-mo follow-up, and 3-mo follow-up compared with baseline; #$P < 0.05$, ##$P < 0.01$, comparisons between the ESWT and DN groups at corresponding time points.

kPa, kilopascal.

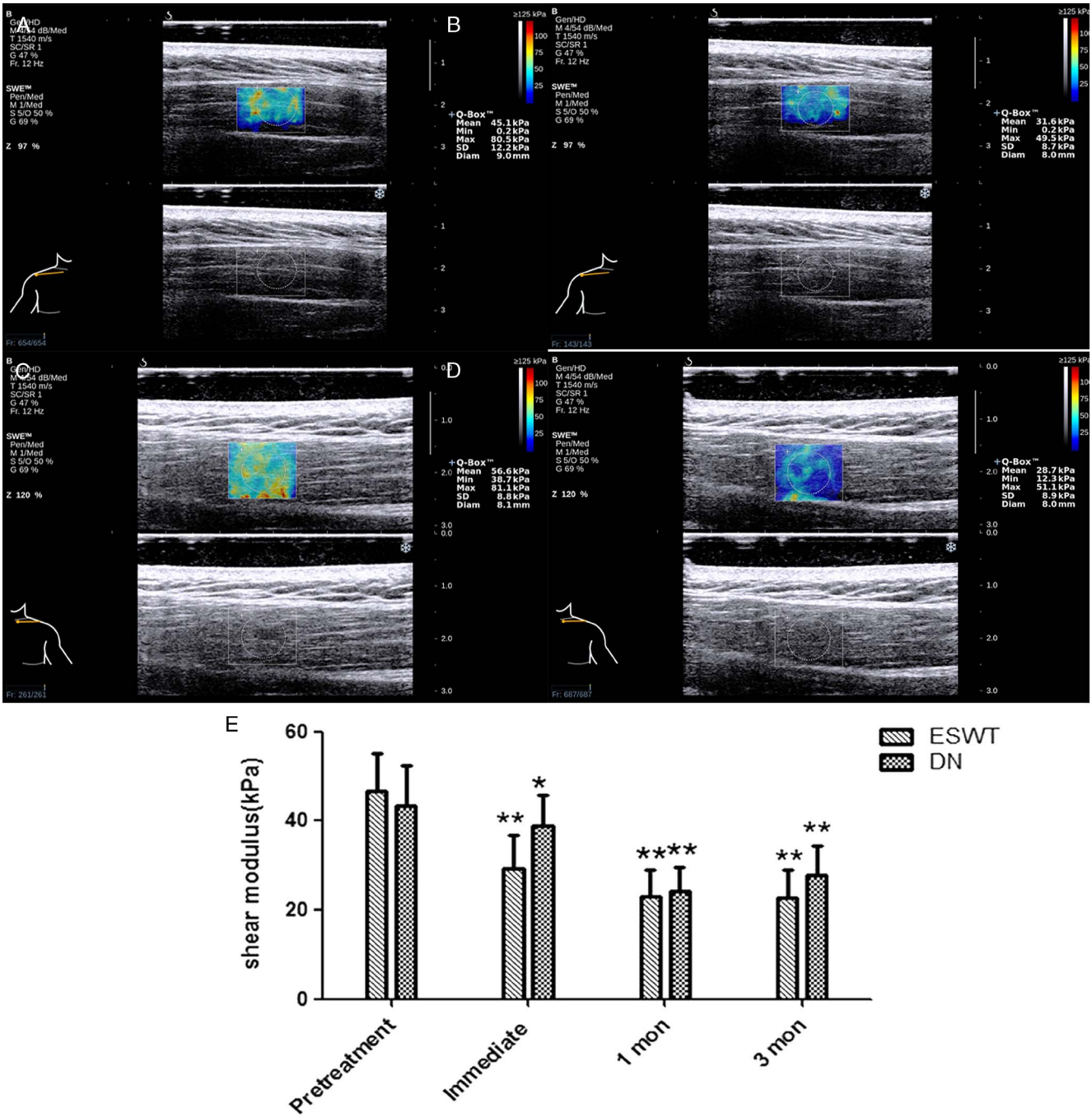

FIGURE 2. Changes of shear modulus in the upper trapezius MTrPs resulting from ESWT and DN for 3 mos. Color-coded representation of MTrPs: before ESWT (A) and immediate after first ESWT (B); before DN treatment (C) and immediate after first DN (D). E, Comparisons of shear modulus changing over time between the ESWT group and the DN group. *$P < 0.05$, **$P < 0.01$, immediate posttreatment, 1-, and 3-mo follow-up compared with the baseline; #$P < 0.05$, ##$P < 0.01$, comparisons between the ESWT and the DN group at corresponding time points.

The MPS is a complicated neuromuscular disorder involving both the peripheral and central mechanisms. When MTrPs were left untreated or inadequate treated, the continuous pain induced by hyperirritable spots would send persistent impulses via afferent nerves to the spinal cord, which further developed into the spinal segmental sensitization.[26] Thus, desensitization of MTrPs should be goal to develop a durable and effective treatment.

Both ESWT and DN contributed to confirm typical localized twitching response and referred pain when mechanical pressure or needles were applied, which might be helpful for clinical diagnosis of MTrPs. Ample evidence proved that the DN treatment had both the immediate and long-term analgesic effects for MTrPs when compared with sham group and other intervention groups.[7,27] Relatively, there were fewer studies to evaluate the effects of ESWT on MTrPs, especially on the immediate therapeutic effects. To date, there is still no standard guideline defining the optimal parameters of EFD or treatment course for ESWT. In a previous study, the ESWT (EFD = 0.10 mJ/mm^2)

was undertaken with 1500 impulses each time at 1-wk intervals totaling 4500 impulses.[14] In another study by Muller-Ehrenberg and Licht,[28] the participants were treated with ESWT (EFD = 0.04–0.26 mJ/mm^2) for 1–2 sessions per week, which resulted in significant pain relief for MTrPs. In our study, the EFD was set to 0.10 mJ/mm^2 considering the therapeutic effects and patients' tolerance according to our pilot experiment. We found the significant pain relief immediately after treatment, at 1-, and 3-mo follow-up in both the ESWT and DN groups. It was noteworthy that the minimal clinically differences of NDI were also detected in both groups after 1 and 3 mos, which indicated that both treatments contributed to long-lasting effects of function restoration.

According to previous researches and current data, we proposed that ESWT and DN were both effective in MTrPs treatment for pain relief and function recovery. We found statistically significant improvements occurred after both the ESWT and DN treatment; however, the quantitative reductions in VAS were relatively minimal. These results were similar to those reported by Ji et al.,[13] because they observed that the VAS significantly decreased from 4.91 ± 1.76 to 2.27 ± 1.27 in the intervention group after four sessions of ESWT treatment (0.056 mJ/mm^2, 1000 impulses) for MTrPs. Moreover, we have observed the positive responses to treatments, including the statistically significant decrease in pain and improvement of MTrPs status based on other assessments, which did not conflict with our primary purpose of this study. Common mechanisms might exist when comparing the two interventions. First, both the ESWT and DN treatment helped break the vicious circle of "pain spasm decreased blood flow pain" via mechanical effects including cavitational effect and direct pressure release. Ballyns et al.[29] used DN for active MTrPs in the trapezius and observed an increased blood flow to the active trigger points. Moreover, previous studies indicated that the localized twitch response produced by DN might interrupt motor end-plate noise, and the spinal cord mechanisms involving remote effects were also proved in animal model.[30] The analgesic effects of ESWT were of particular concern, because the immediate effects might be resulted from hyperstimulation and transient dysfunction of synapse transmission, and long-term pain relief was more likely because of the enhanced angiogenesis, increased blood flow to ischemic tissue, and higher tissue oxygen saturation. Previous studies also demonstrated that the highly concentrated energy of shock wave relieved pain by destroying unmyelinated sensory nerve fibers. Takahashi et al.[31] further reported repeated shock wave therapy provided cumulative effects on nerve fibers compared with the effect of just one application. Second, both the ESWT and DN treatment helped attenuate localized energy crisis. Shah and Gilliams[32] found that DN improved ischemia status of local tissue and further lowered the levels of substance P and calcitonin gene-related peptide.[32] Similarly, animal studies showed that ESWT had an influence on substance P and calcitonin gene-related peptide expression in the dorsal root ganglion, accompanied by improved microscopic circulation and local metabolism of MTrPs.

Chronic myofascial pain syndrome usually leads to muscle soreness and stiffness. Sensitive tools for tissue elasticity assessment are vital for both basic research and clinical practice, because the changes of mechanical properties of MTrPs offer important insight of the disease progression. Noninvasive, dynamic, and real-time imaging technology for in vivo musculoskeletal system is of significant clinical interest. In recent years, ultrasound elastography has been widely used to evaluate the muscle stiffness, whereas the objective quantification of MTrPs still needs further study. The ultrasound technique assists sonographers in distinguishing the MTrPs from normal tissue, whereas the highly accurate diagnosis usually depends on the sonographers' experience and scanner settings. Gerber et al.[33] observed the pain relief and palpable reduced muscle stiffness in MPS patients after 3 weekly DN treatment. Guo et al.[34] once reported that the Young's modulus of MTrPs decreased from 43.4 ± 15.6 kPa to 29.0 ± 5.9 kPa after the manipulation treatment once every other day for a total of seven times. Maher et al.[7] performed quantitative evaluations of MTrPs considering both the treatment and posture effects, and the time effects demonstrated a 29.5% reduction in shear modulus after DN, and posture effects demonstrated a 21% reduction from the sitting to prone position. We compared the shear modulus changes of MTrPs in both ESWT and DN groups, and the elasticity improvements were significant when comparing the immediate and long-term therapeutic effects to pretreatment baseline. In this study, we found reductions of 28.8% and 6.9% in shear modulus after the immediate ESWT and DN treatment and further reductions of 33.9% and 30.8% in both groups, respectively, at 3-mo follow-up. These results implied that the SWE was sensitive enough to detect the therapeutic effects. In 2012, Ballyns et al.[8] conducted a preliminary study and demonstrated that muscle tissue in symptomatic subjects was mechanically more heterogeneous and stiffer compared with normal muscle in control subjects. Our data also confirmed that the shear modulus was reduced along with symptom relief, and these gains were maintained at least 3 mos in both the ESWT and DN groups. The mechanisms of elastic recovery after the ESWT and DN treatment were still unclear. Although present researches failed to establish a definitive causal link between the muscle stiffness and pain, we believe that more researches were needed to advance the understanding of tissue reparative process. More evidences based on histological and molecular biologic researches are needed to verify this hypothesis.

Overall, the MTrPs treatment could be divided into invasive and the noninvasive therapies. The ESWT has the following advantages over the DN treatment. First, the ESWT is noninvasive, free from skin infection, and simple to operate in outpatient environment. However, DN carries potential risks of significant adverse events, such as penetrating lungs and blood vessels injuries, which might induce patients' negative emotions as phobia and anxiety. Second, the total amount of energy of ESWT is associated with EFD and impulses (total energy = EFD (mJ/mm^2) × mm^2 × number), it is possible to adjust the intensity and impulses according to patients' tolerance. Third, the ESWT could be applied to relative larger surface of interest (including the taut band and surrounding tissue) by adjusting the probe location. Moreover, from the pathophysiology perspective, the ESWT usually induces microscopic changes within cells via the mechanotransduction effects and promotes conversion of the mechanical pressure into molecular signal. Although it might require higher cost than DN because of the equipment cost and space limitation, the

ESWT could be an alternative option for MTrPs treatment considering the patients compliance.

The novelty and significance of this study are using shear wave elastography to quantitatively compare the effectiveness of ESWT and DN in treating MTrPs, including the analgesic effects and muscle stiffness improvement. Some limitations of this study should be acknowledged. First, we did not assess the outcomes after the third therapy, which included the influences of both one single treatment and long-term effects. The subjective bias should be considered, because the patients were not blinded to the treatments, and no inactive control intervention or normal control group was involved for ethical reasons. In addition, we did not divide the patients into subgroups with different intensities, intervals, and frequencies of ESWT because the dose-dependent manner of total energy might influence the therapeutic effects and cost-effectiveness. The identification of optimal regimens and cost-effective analysis should be an important tendency in the future. The patients with multiple MTrPs are usually characterized by overlapped pain patterns, and these patients should be included in future studies. More participants from multiple clinical centers with longer follow-up period are needed for future study. Moreover, the current results should be interpreted based on noninferior trial design and the false-negative possibility (discriminating capacity 80%) should be considered. These limitations should be considered in future studies to provide sufficient evidence for clinical practice.

CONCLUSIONS

In this study, we concluded that the ESWT was as effective and safe as DN for the purpose of pain relief, function restoration, and muscle stiffness reduction in treatment of upper trapezius MTrPs for a 3-mo period after a series of three treatments. The SWE could be recommended for clinical and research use for myofascial pain syndrome evaluation. Further research is necessary to explore the cost-effectiveness of the two inventions and optimal parameters of ESWT for MTrPs.

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