Comparison of Radial Extracorporeal Shock Wave Therapy and Local Corticosteroid Injection Effectiveness in Patients With Carpal Tunnel Syndrome

A Randomized Controlled Study

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Objective: The aim of the study was to compare the effectiveness of radial extracorporeal shock wave therapy and local corticosteroid injection on pain, function, and nerve conduction studies in the treatment of idiopathic carpal tunnel syndrome.

Design: A total of 72 patients who were diagnosed as having carpal tunnel syndrome were included in the study. The radial extracorporeal shock wave therapy group received radial extracorporeal shock wave therapy, the local corticosteroid injection group received local corticosteroid injection, and the control group only used a resting hand splint. The patients were evaluated using a Visual Analog Scale–pain, a Visual Analog Scale–numbness, the Boston Symptom Severity Scale, the Boston Functional Status Scale, and handgrip strength tests before treatment 1 and 12 wks after the treatment.

Results: Both clinical and nerve conduction study parameters improved with all three groups, and this effect continued at the 12th-week follow-up of the patients. The Visual Analog Scale–pain, Visual Analog Scale–numbness, Boston Symptom Severity Scale, and Boston Functional Status Scale scores in the first week after the treatment, as well as Visual Analog Scale–pain and Boston Functional Status Scale scores in the 12th week after the treatment, were significantly lower in the local corticosteroid injection group compared with the other two groups.

Conclusions: Our study revealed the success of radial extracorporeal shock wave therapy, splint, and local corticosteroid injection, but symptom relief was greater in the first week and 12th week with local corticosteroid injection.

Key Words: Carpal Tunnel Syndrome, Local Corticosteroid Injection, ESWT, Electroneuromyography

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What Is Known

- The efficacy of local corticosteroid injection (LCI) in the treatment of carpal tunnel syndrome (CTS) is well known.

What Is New

- Extracorporeal shock wave therapy (ESWT) seems to be an emerging approach in the treatment of CTS. Studies in literature have revealed the effectiveness of ESWT in the treatment of CTS. Our study is important because it is the first to compare LCI and radial ESWT (rESWT) with a control group. In addition, the total number of patients was higher than in other studies. We concluded that both treatment methods were effective in CTS. However, in our study, unlike other studies in the literature, we concluded that the LCI was significantly superior to ESWT. In addition, according to our study, ESWT provides no additional benefit to using a splint.

Carpal tunnel syndrome (CTS) is caused by compression of the median nerve while it passes through the carpal tunnel and is the most common nerve entrapment neuropathy of the upper extremity.[1] A great number of conservative and surgical methods are used in its treatment. Surgery quickly relieves the pressure on the median nerve, but postoperative complications cause a delay in returning to normal function. For this reason, different approaches are being developed in the treatment of CTS. Local corticosteroid injections (LCIs) under the transverse carpal ligament are widely used in the treatment of mild and moderate CTS.[2] Local corticosteroid injections are administered to reduce the inflammation and swelling of the soft tissue around the median nerve and thereby reduce the pressure on the median nerve. However, LCIs can lead to several complications, including infection, and tendon and median nerve injury.[3] Corticosteroids also limit tenocyte function by reducing proteoglycan and collagen synthesis, which reduces the mechanical strength of the tendon, leading to degeneration.[4] As an alternative to LCI, nonsteroidal anti-inflammatory drugs, diuretics, vitamin B, resting splints, and physical therapy agents are used. However, the effectiveness of some of these methods has not been fully proven, and the effectiveness of some is short term.[2] Therefore, alternative treatment methods have been needed in CTS and extracorporeal shock wave therapy (ESWT) has begun to be investigated and used.[5–7]

Shock waves were first used in urology in the 1970s to break up ureteral stones. Today, shock waves are used extensively in the treatment of plantar fasciitis, lateral humeral epicondylitis, fracture nonunion and delayed union, and calcified tendinitis

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of the shoulder.[8] Extracorporeal shock wave therapy is also used in the treatment of different diseases, such as peripheral neuropathies, interdigital neuroma, and symmetric polyneuropathy.[9,10] Extracorporeal shock wave therapy has been investigated and used as a new method in the treatment of CTS.[5–7] Extracorporeal shock wave therapy stimulates nitric oxide (NO) production by stimulating neurogenesis, angiogenesis, and neuronal NO synthase using vascular endothelial growth factor.[11–13] It is stated that the increase in NO slows down the transmission of pain, reduces pain with an opiate-like effect, increases perfusion by vasodilation, and causes nerve healing. In animal studies, ESWT has been shown to be effective on pain with an increase in substance P and neurovascular regeneration.[14] It is thought to affect pain by decreasing the production of calcitonin gene-related peptide from the dorsal root.[15] Although the effect of ESWT on the pathophysiology of CTS are fully established, experimental studies revealed that ESWT reduced the inflammatory effect by increasing the production of NO, removed the damaged axons, and increased axonal regeneration.[11,16] When all the pathogenetic processes are considered, symptoms, such as pain and numbness in CTS, are expected to decline after ESWT.

Our study aimed to clinically and electrophysiologically determine whether rESWT combined with splint use, LCI combined with splint use, and splint use only had superiority over each other in patients with mild and moderate idiopathic CTS.

METHODS

This study was conducted between January 2019 and May 2019 in the Ahi Evran University Training and Research Hospital, in the department of physical medicine and rehabilitation. Patients aged between 18 and 65 yrs who were admitted to the Ahi Evran University Physical Medicine and Rehabilitation Outpatient Clinic and diagnosed as having mild and moderate CTS through clinical parameters and nerve conduction studies (NCSs), who were cooperative, who were able to understand the information stated in the patient information form correctly, and who accepted to participate in the study were included.

The exclusion criteria were as follows: Having any systemic diseases such as renal failure, peptic ulcer, diabetes mellitus, hypothyroidism, coagulopathy, inflammatory rheumatic disease, or having a cardiac pacemaker, cervical radiculopathy, polyneuropathy or brachial plexopathy, systemic corticosteroid use, fracture or trauma history in the forearm and wrist which received treatment, pregnancy and lactation, having received a CTS surgery, thoracic outlet syndrome or severe CTS. A written informed consent form was signed by the participants before they were included in the study.

The American Association of Neuromuscular and Electrodiagnostic Medicine's CTS classification was used. The American Association of Neuromuscular and Electrodiagnostic Medicine classified CTS according to electrophysiologic findings as follows: mild CTS: prolonged sensory or mixed distal latency ± reduced amplitude; moderate CTS: prolonged sensory or mixed distal latency ± reduced amplitude, and prolonged median motor distal latency (mMDL); and severe CTS: sensory response loss or low amplitude motor response, routine sensory responses and palms are defined as very severe CTS in the absence of motor responses.[17] Median sensory distal latency <3.6 ms, mMDL <4.2 ms, and median sensory nerve conduction velocity (mSNCV) >50 m/sec were considered to be normal.[18]

Radial ESWT

Patients in the rESWT group received one session of rESWT once per week, a total of three sessions. A Modus ESWT Touch Shock Waves device (Turkey) was used for rESWT with a frequency of 5 Hz, pressure of 4 bar, and 2000 shock pulses. The wrist of the patients with CTS was placed on the table with the volar side facing up. The wrist was supported from the dorsal side so that the wrist was extended at 15–20 degrees. Ultrasound gel was applied over the carpal tunnel at the proximal carpal tunnel (scaphoid pisiform level) line on the volar side. Each ESWT session lasted 6 mins 41 secs. In addition, an off-the-shelf static wrist splint was used.

Local Corticosteroid Injection

A local methylprednisolone (Depo-Medrol) injection of 1 ml (40 mg, without lidocaine) was administered to the patients in the injection group 1 cm proximal to the distal wrist crease from between the flexor carpi radialis and palmaris longus tendons using a 22-gauge needle tilted at an angle of 45 degrees. In addition, an off-the-shelf static wrist splint was used.

Splint Use

Patients were instructed to use their off-the-shelf static wrist splints that kept the wrist in a neutral position for 2 mos while sleeping at night and resting during the day (splints were used for all groups in the same way).

Outcomes

In the repeated analysis of variance, which was suitable for our research method and the nature of the variables in the research, in the G*Power program, 0.4 effect size, 0.01 significance level, and sample size required to provide 0.8 power were calculated. The total number of participants was 63 people. We aimed to collect 10% more (approximately 70 people).

Primary Outcome

Boston Carpal Tunnel Questionnaire

The Boston Carpal Tunnel Questionnaire, which consists of a symptom severity subscale (Boston-SSS) and functional status subscale (Boston-FSS), is widely used for clinical studies to obtain information about the symptom severity and functional status of CTS.[19,20]

Secondary Outcomes

Pain and Numbness Assessment

A 10-cm Visual Analog Scale (VAS)[21] was used to evaluate the severity of pain and numbness. A horizontal 10-cm-long ruler was used (0 = no pain or no numbness and 10 = most severe pain or most severe numbness).

Electrophysiologic Examinations

Electrophysiologic examinations were performed before treatment and in the posttreatment 12th week. A Nihon Kohden Neuropack S1 MEB-9400 electroneuromyography device was

used for all patients by the same researcher. The temperature of the patients' hands was kept at >32°C during the study. In the electrophysiologic examinations, median sensory and motor distal latencies and amplitudes were evaluated. Sensorimotor response measurements were performed according to the standard protocol.[18] The recorded parameters included the median sensory nerve action potential (mSNAP) amplitude, the median compound muscle action potential (mCMAP) amplitude, the median sensory distal latency, the mMDL, and the mSNCV. Participants who showed abnormal electrodiagnostic findings other than CTS were removed from the study.

Hand Grip Strength

A Jamar dynamometer was used to measure handgrip strength. The Jamar dynamometer measures static grip strength in pounds and kilograms. Measurements were made as recommended by the American Hand Therapists Association, with the patient in a sitting position, arm adduction, elbow at 90-degree flexion, and the forearm in a neutral position. The patients were asked to tighten the dynamometer for at least 3 secs with maximum contraction. Three measurements were made by taking a 1-min break between measurements. The average of three measurements was recorded in kilograms. Measurements were made at the beginning of the study and in the first and 12th posttreatment week follow-ups.

The study was approved by Ahi Evran University Faculty of Medicine Clinical Research Ethics Committee (Decision no: 2018-01/11) and the Turkish Medicines and Medical Devices Agency. Written informed consent forms were obtained from each patient who participated in the study. The trial was registered on the ClinicalTrials.gov with identification number "NCT03792945." This study conforms to all Consolidated Standards of Reporting Trials guidelines and reports the required information accordingly (see Checklist, Supplemental Digital Content 1, http://links.lww.com/PHM/B398).

Statistical Analysis

The Statistical Package for the Social Sciences (SPSS) version 20 was used for statistical analyses. Mean and standard deviation were used for descriptive analyses. Normally distributed numerical variables were compared using one-way analysis of variance between the groups. Nonnormally distributed numerical variables were compared using the Kruskal-Wallis test between the groups. Pairwise comparisons between the groups were performed using the Mann-Whitney *U* test and assessed with Bonferroni correction. Qualitative variables were compared between the groups using the χ^2 test. Normally distributed numerical variables of changes before treatment and the first and 12th week after the treatment between the groups were analyzed using the dependent sample *t* test, and nonnormally distributed numerical variables were analyzed using the Friedman test. The comparisons with the pretreatment between the groups were analyzed using the Wilcoxon test or the dependent sample *t* test. Statistical significance was accepted as $P < 0.05$.

RESULTS

A total of 92 patients who met the inclusion criteria of the study were randomized into three groups using the sealed envelope method. Groups were determined as rESWT, LCI, and splint. The researcher performed the randomization and enrolled the participants. A total of 120 closed envelopes were prepared by writing rESWT in 40 of them, LCI therapy in 40, and splint therapy in 40. The envelopes were mixed and placed in a box. Each patient who agreed to participate in the study was asked to draw an envelope from the box. Thirty-three patients received an envelope with rESWT, 28 patients received an envelope with LCI therapy, and 31 patients received an envelope with splint therapy. Some of the patients had bilateral CTS. Both hands of these patients were treated using the same method. However, the symptomatic hand was included in the study. In patients with the same symptom severity in both hands, the dominant hand was included in the study. Seven patients in the ESWT group were lost to follow-up (two patients could not be reached, three patients stated that they could not attend treatment and follow-up because of personal and family reasons, and two patients did not come for follow-up in posttreatment week 12). Five patients in the LCI group were lost to follow-up (three patients could not be reached and two patients stated that they could not attend treatment and follow-up because of personal and family reasons). Eight patients in the splint group were lost to follow-up (three patients could not be reached, two patients stated that they could not attend treatment and follow-up because of personal and family reasons, and three patients did not attend follow-up in posttreatment week 12; although the patients who were called by phone to come for the follow-up stated that they would attend, they did come to the appointment on the specified date). A total of 72 patients were analyzed. No blinding method was used. During the first visit, the patients were first informed about their illnesses and the treatment process.

The participant diagram and information about the treatments are summarized in a Consolidated Standards of Reporting Trials flow diagram (Fig. 1). Demographic data of the participants (Table 1) were not different from those of the nonparticipants.

Pretreatment VAS-P, VAS-N, Boston-SSS, Boston-FSS, and handgrip strength showed no significant difference between the groups (Fig. 2). The mSNAP amplitude and mSNCV, one of the pretreatment NCS parameters, were significantly higher in the control group compared with the other two groups. The mCMAP amplitude, mMDL, and median motor conduction velocity were not significantly different between groups.

The comparison of intragroup and intergroup primary and secondary outcomes is given in Table 2. In the intragroup comparison, VAS-P, VAS-N, and Boston-SSS showed significant improvement in the first week after the treatment compared with pretreatment values in all three groups. The Boston-FSS and handgrip strength improved significantly in the LCI group, but not in the ESWT and control groups. The VAS-P, VAS-N, Boston-SSS, and Boston-FSS showed significant improvement in all three groups in the 12th week after the treatment. Handgrip strength improved significantly only in the LCI group. The mSNCV improved significantly in all three groups. The mSNAP amplitude did not differ significantly. The mMDL showed significant improvement in the LCI and control groups but showed no statistically significant difference in the rESWT group.

In the intergroup comparison, VAS-P, VAS-N, and Boston-SSS showed a significant difference between groups in the first week after the treatment. There was a significant improvement

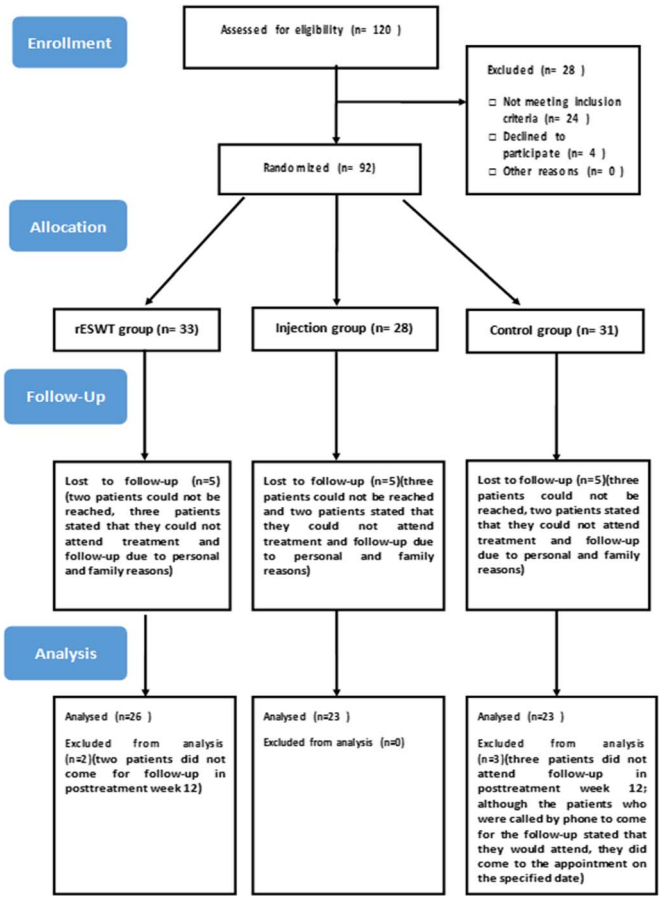

FIGURE 1. Consolidated Standards of Reporting Trials flow diagram.

in these values in the LCI group compared with the ESWT and control groups. Boston-FSS differed significantly between the groups in the first week after the treatment. This difference was between the ESWT-LCI groups and was in favor of the LCI. Handgrip strength did not differ significantly between the groups in the first week after the treatment. The VAS-P and Boston-FSS differed significantly between groups in the 12th week after the treatment. The difference in VAS-P was between the ESWT and LCI groups and was in favor of the LCI group. The difference in Boston-FSS was in favor of the LCI and control groups. The VAS-N, Boston-SSS, and handgrip strength did not differ significantly between the groups in the 12th week after the treatment. The mSNAP amplitude and mMDL showed a significant difference between the groups in the 12th week after the treatment. There was a significant improvement in the control group compared with the ESWT and LCI groups. The mSNCV, median motor conduction velocity, and mCMAP amplitude did not differ significantly between groups in the 12th week after the treatment.

DISCUSSION

In recent years, ESWT has been used as a new treatment method for CTS.[5–7] In 2013, Seok et al.[5] conducted the first study in the literature evaluating ESWT in CTS and compared it with LCI. Seok et al.[5] compared the effectiveness of single-session fESWT (focus ESWT) and LCI in 31 patients with mild and moderate CTS in the first and third months. They found a significant improvement in the VAS and Boston-SSS at both time points in both groups. The fact that Seok et al.[5] obtained results with ESWT as satisfactory as the well-known LCI led to new research on this subject. We aimed to compare the effectiveness of ESWT and LCI in mild and moderate CTS by including a larger number of patients and a control group. Similarly, VAS-P, VAS-N, and Boston-SSS showed significant improvement in the 12th week after the treatment in all three groups in our study. Unlike the study by Seok et al.,[5] all clinical parameters decreased statistically significantly in the LCI group compared with the rESWT and control group in the first week after the treatment in our study. In addition, VAS-P and Boston-FSS showed a statistically significant decrease in the LCI group compared with the rESWT and control groups in the 12th week after the treatment. According to our study, it can be concluded that LCI is more effective in the treatment of CTS. When we compared the rESWT and control groups, we observed no significant superiority in the rESWT group in any of the clinical parameters in the first week after the treatment and in the 12th week after the treatment. In the study by Seok et al.,[5] it was reported in NCS that there was a significant improvement in mSNCV, mSNAP amplitude, median sensory distal latency, and mMDL only in the LCI group. In the study of Seok et al.,[5] although there was an improvement in nerve conduction values after ESWT, this improvement did not reach a statistically significant level. Unlike the study by Seok et al.,[5]

TABLE 1. Demographic data of all patients included in the study ($N = 92$)

		rESWT ($n = 33$)	LCI ($n = 28$)	Control ($n = 31$)	P
Sex	Female	23 (69.7%)	20 (71.4%)	27 (87.1%)	0.208[a]
	Male	10 (30.3%)	8 (28.6%)	4 (12.9%)	
Age, yr		51.1 ± 7.1	54.1 ± 9.6	50.4 ± 9.8	0.214[b]
Height, cm		164.5 ± 7.8	163.9 ± 8.7	163.4 ± 8.5	0.767[b]
Weight, kg		83.5 ± 15.8	84.8 ± 11.6	79.7 ± 11	0.257[b]
BMI, kg/m^2		30.7 ± 4.7	31.7 ± 5	30 ± 4.8	0.659[b]
Duration of the complaint, mo		19.2 ± 24.1	17.4 ± 20.3	18.1 ± 24	0.987[b]
Hand receiving treatment	Right	23 (69.7%)	20 (71.4%)	24 (77.4%)	0.771[a]
	Left	10 (30.3%)	8 (28.6%)	7 (22.6%)	
Dominant Hand	Right	30 (90.9%)	26 (92.9%)	27 (87.1%)	0.748[a]
	Left	3 (9.1%)	2 (7.1%)	4 (12.9%)	
Bilateral CTS	Yes	27 (81.8%)	21 (75%)	21 (67.7%)	0.430[a]
	No	6 (18.2%)	7 (25%)	10 (32.3%)	
No. comorbid diseases		0.6 ± 0.6	0.6 ± 0.6	0.5 ± 0.6	0.779[b]
No. drugs used		0.7 ± 0.9	0.5 ± 0.7	0.5 ± 0.8	0.642[b]
Pretreatment VAS-pain		6.5 ± 2.4	6.5 ± 2.1	5.9 ± 2.8	0.726[b]
Pretreatment VAS-numbness		7.2 ± 2.1	7.3 ± 2.2	6.1 ± 2.9	0.230[b]
Pretreatment Boston-SSS		31.7 ± 8.7	31 ± 7.8	27.9 ± 8.1	0.232[b]
Pretreatment Boston-FSS		21.1 ± 7.1	19.5 ± 7.4	20.3 ± 8.9	0.682[b]
Pretreatment hand grip strength, kg		21.1 ± 10.6	22.7 ± 9.2	22 ± 7.6	0.510[b]
Pretreatment mSNAP amplitude, mV		17.9 ± 6.7	16.5 ± 5.2	21.3 ± 5.6	0.005[bc]
Pretreatment mCMAP amplitude, mV		8.9 ± 1.9	8.2 ± 2.3	8.4 ± 2	0.375[b]
Pretreatment mMDL, ms		4.4 ± 0.6	4.5 ± 0.5	4.2 ± 0.5	0.051[b]
Pretreatment mSNCV, m/sec		37.4 ± 4.8	37.8 ± 9	40.7 ± 4.7	0.027[bd]
Pretreatment mMCV, m/sec		55.3 ± 3.1	55.4 ± 2.9	56 ± 3.2	0.691[b]

[a] χ^2 test.

[b] Kruskal-Wallis test.

[c] $P = 0.017$ among rESWT control group; $P = 0.002$ between LCI control group (Mann-Whitney U test).

[d] $P = 0.005$ between rESWT control group (Mann-Whitney U test).

BMI, body mass index; mMCV, median motor conduction velocity.

mSNCV significantly improved in our study in the rESWT group. However, a splint was given to all three treatment groups in our study, and mSNCV showed no significant difference between the groups. Thus, it can be thought that the significant improvement in mSNCV was because all patients used splints. The similar results of the two studies in terms of clinical objective evaluations suggest that the healing effect of ESWT on nerve regeneration is insufficient. Electrophysiologic recovery can be shown as evidence that splint therapy relieves the compression that causes neuropraxia and thus conduction slowdown. Studies are showing that this improvement in the control group is valid during the use of the splint. In the study of Vahdatpour et al.,[7] the results of pain, symptom severity, and nerve conduction parameters were better in the control group when a splint was given for 3 mos, but the symptoms worsened again at the end of the next 3 mos after the splint was discontinued. Although the splint reduces the pressure on the median nerve and reduces the symptoms, when the splint is released, the symptoms worsen as a result of the increase in median nerve pressure. Therefore, it can be said that the effect of the splint is short term and temporary. If we had planned a sixth-month follow-up, we might have observed that the significant improvement in the control group had disappeared after the splint was discontinued.

In the study of Atthakomol et al.,[22] LCI and rESWT were compared in patients with CTS. There was a significant decrease in VAS, Boston-SSS, and Boston-FSS in the 12th and 24th weeks in the rESWT group. The same condition was not observed in the LCI group in which there was a significant decline in Boston-SSS score in the first and fourth weeks compared with basal scores.[22] In our study, significant improvement was observed in VAS-P, VAS-N, and Boston-SSS in the first week after treatment in all three groups, and this improvement was observed in the third-month follow-up. However, in the comparison between the groups, it can be said that LCI produced better results than rESWT according to clinical scores in our study. Looking at the NCS parameters in the study of Atthakomol et al.,[22] it was observed that the peak median sensory distal latency reduction in the rESWT group was greater than that of the LCI group, and this difference was statistically significant. Contrary to the study of Atthakomol et al.,[22] in our study, significant improvement was observed in mSNCV at 12 weeks after treatment in all three groups, and no significant difference was observed between the groups. These different results in studies may be due to the lack of a significant relationship between NCS findings and symptom severity scores. This nonsignificant relationship has been shown in some studies.[23,24] In our study, there was an improvement in favor of

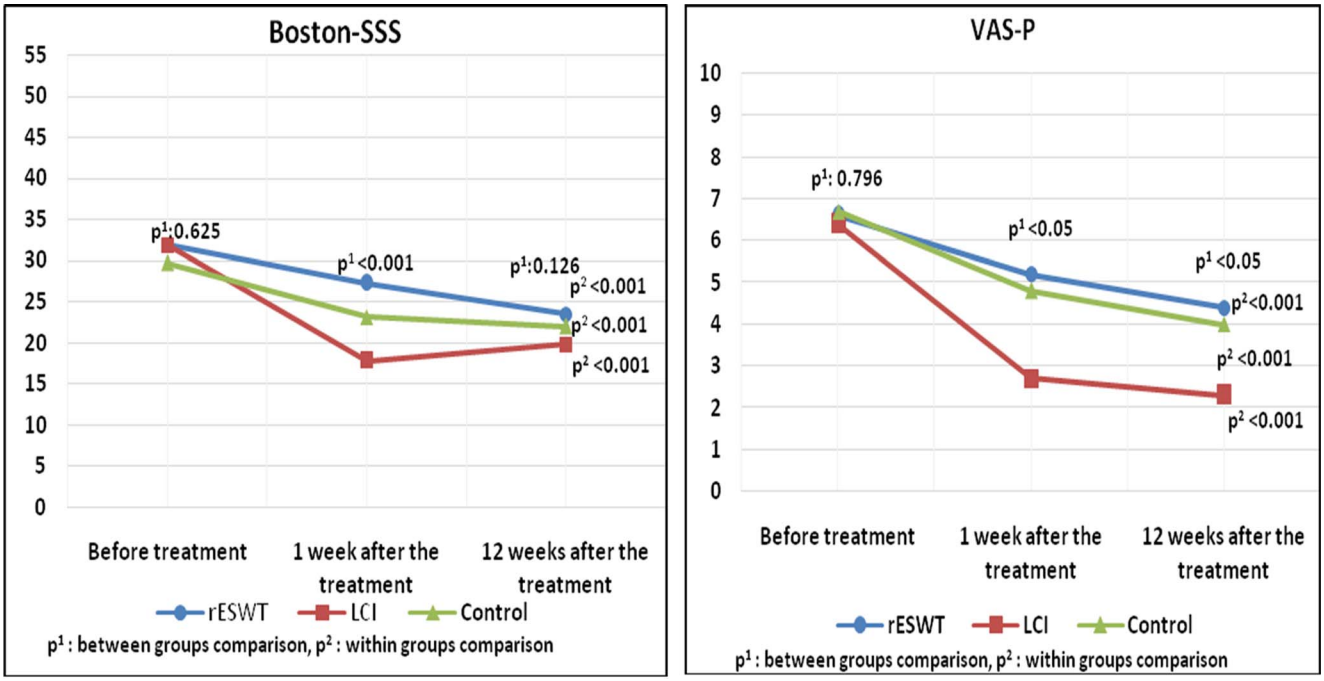

FIGURE 2. Results of the Boston-SSS and VAS-P. The significance was $P < 0.05$ compared with baseline.

improvement in both symptom severity scores and mSNCV, one of the NCS parameters. However, although NCS measurements provide results by evaluating large myelinated nerve functions in the diagnosis of CTS, it is very difficult to evaluate small unmyelinated nerves that cause symptoms of CTS with NCS.[25] Therefore, NCS findings and CTS symptom severity may not correlate with each other. In addition, the difference between the rESWT used in the study of Atthakomol et al.[22] and the rESWT protocol in our study may have led to different results. In the study of Atthakomol et al.,[22] rESWT intensity was made in the form of 3–7 mins, 4 bar, 15-Hz frequency, and 5000 shocks. Although it was a single session, the rESWT effect may have continued until the 24th week because of its intense intensity. In the study of Atthakomol et al.,[22] significant improvement in symptom severity and functional status began at week 4 compared with baseline with a single dose of rESWT. In the study of Wu et al.,[6] more than one session of ESWT was administered and significant functional and symptom improvement began in the first week. This difference may be due to the difference in the treatment protocol (single session vs. multiple sessions; single-session ESWT vs. multiple ESWT + splint).[6,7] In our study, a significant change was observed in the rESWT group in favor of improvement in VAS-P and VAS-N scores at the first follow-up (first week after treatment) with treatment. The VAS is a subjective visual assessment method, and it has been found to be an appropriate method in comparative studies with other methods of assessing pain.[26] In two studies investigating the effectiveness of ESWT in CTS and using VAS for pain assessment, it was reported that there was a significant decrease in VAS scores in the short and long term, as in our study.[5,22] A decrease in VAS scores reflects improvement in a patient's symptoms. However, in our study, a significant improvement was found in the first-week posttreatment VAS-P and VAS-N scores in the LCI group compared with the other two groups, but no significant difference was found between the control group and the rESWT group. We cannot say that rESWT in addition to splint treatment provided additional benefit to the patient. In the study of Atthakomol et al.,[22] unlike our study, 10 mg of triamcinolone was mixed with 1 ml of 1% lidocaine and administered to the LCI group. In our study, 40 mg of methylprednisolone acetate was administered without lidocaine. The type and amount of corticosteroid administered may have caused the different results in the studies.

In our study, all patients in the rESWT group reported pain during the procedure. However, it was not at a level where the patients wanted to terminate the treatment, and it did not continue after the treatment. In the LCI group, seven patients reported pain on the day of injection. Later, their symptoms did not continue. There was no pain reported in the patients in the splint group. Similar to the studies in the literature, in our study, no serious complications other than pain developed with rESWT.[5,6,27] In the literature, it is reported that there may be temporary pain, skin erythema, or a small hematoma after ESWT, and these conditions generally recover spontaneously.[28] When ESWT is used as a treatment method, these adverse effects should be kept in mind.

The limitations of our study are as follows: the patients were not followed up after the 12th week, the number of patients was not high, and imaging (e.g., ultrasonography) was not used to determine the treatment site before both injection and rESWT. There was a difference between the randomization method that we used and the number of patients distributed to the groups, and no blinding method was used. Our strengths include the presence of a control group in our study and that it is a randomized controlled study.

The results of our study indicate the efficacy of ESWT for relieving symptoms of CTS; however, there is no evidence with respect to the added benefits of the treatment when the results

TABLE 2. Intragroup and intergroup comparison of primary and secondary outcomes

	rESWT (n = 26)		LCI (n = 23)		Control (n = 23)		
	Mean ± SD	P_1	Mean ± SD	P_1	Mean ± SD	P_1	P
VAS-pain							
Pretreatment	6.6 ± 2.4		6.4 ± 2.0		6.7 ± 2.4		0.796
Posttreatment 1st wk	5.2 ± 2.4	0.002	2.7 ± 1.9	<0.001	4.8 ± 2.7	<0.001	0.001[a]
Posttreatment 12th wk	4.4 ± 2.2	0.001	2.3 ± 2.2	<0.001	4.0 ± 3	<0.001	0.011[b]
VAS-numbness							
Pretreatment	7.5 ± 2.1		7.1 ± .2.3		6.7 ± 2.7		0.671
Posttreatment 1st wk	5.2 ± 2.5	<0.001	1.9 ± 1.8	<0.001	4.2 ± 3.1	<0.001	<0.001[c]
Posttreatment 12th wk	4.7 ± 3	<0.001	3.2 ± 2.8	<0.001	4.4 ± 3.3	0.004	0.201
Boston-SSS							
Pretreatment	31.9 ± 8.7		31.9 ± 8.7		29.7 ± 7.7		0.625
Posttreatment 1st wk	27.2 ± 8.3	0.007	17.8 ± 6.7	<0.001	23.1 ± 7.5	<0.001	<0.001[d]
Posttreatment 12th wk	23.5 ± 6.1	<0.001	19.8 ± 5.2	<0.001	22 ± 8.5	<0.001	0.126
Boston-FSS							
Pretreatment	21.8 ± 7.2		21.8 ± 7.2		22.1 ± 9.1		0.495
Posttreatment 1st wk	20.4 ± 6.8	0.266	15 ± 5.9	<0.001	19.1 ± 7.9	0.060	0.011[e]
Posttreatment 12th wk	19 ± 5.5	0.013	13.7 ± 5.2	0.001	16 ± 6.1	0.002	0.008[f]
Hand grip strength, kg							
Pretreatment	22.2 ± 11.3		22.2 ± 9.6		21.9 ± 8.3		0.922
Posttreatment 1st wk	23 ± 9.4	0.143	24.7 ± 8.5	0.003	23 ± 8.2	0.248	0.525
Posttreatment 12th wk	24 ± 9.4	0.294	25.5 ± 9.3	0.005	23.8 ± 8.3	0.106	0.745
mSNAP amplitude, mV							
Pretreatment	17.3 ± 6.7		16.2 ± 5.6		21.5 ± 6.0		0.009[g]
Posttreatment 12th wk	18.4 ± 11.1	0.667	17.3 ± 5.4	0.134	25.9 ± 9.7	0.075	0.002[h]
mCMAP amplitude, mV							
Pretreatment	9.0 ± 1.9		8.4 ± 2.3		8.3 ± 2.2		0.471
Posttreatment 12th wk	8.2 ± 2	0.006	8.1 ± 2.5	0.419	8.7 ± 2.9	0.363	0.907
mMDL, ms							
Pretreatment	4.5 ± 0.6		4.5 ± 0.5		4.3 ± 0.6		0.156
Posttreatment 12th wk	4.4 ± 0.9	0.795	4.1 ± 0.3	0.014	3.8 ± 0.5	0.001	0.002[i]
mSNCV, m/sec							
Pretreatment	37.4 ± 5.1		38.5 ± 9.7		40.4 ± 5.2		0.093
Posttreatment 12th wk	40.2 ± 6.8	0.003	42.1 ± 8.7	0.028	45.2 ± 7.1	0.001	0.081[j]
mMCV, m/sec							
Pretreatment	55.1 ± 3.2		55.6 ± 2.8		56.2 ± 3.4		0.569
Posttreatment 12th wk	55.2 ± 3.8	0.967	54.8 ± 3.6	0.156	55.1 ± 4.4	0.548	0.960

P value indicates the comparison between groups, and Kruskal-Wallis test was used.

P_1: compared with the pretreatment. Wilcoxon test was used for VAS-P, VAS-N, Boston-SSS, Boston-FSS, and hand grip strength. Wilcoxon test or dependent sample t test was used for NCS parameters.

[a] $P < 0.001$ between LCI rESWT group; $P = 0.005$ between LCI control group (Mann-Whitney U test).

[b] $P = 0.003$ among LCI rESWT group (Mann-Whitney u test).

[c] $P < 0.001$ among LCI-rESWT group; $P = 0.007$ between LCI control group (Mann-Whitney U test).

[d] $P < 0.001$ among the LCI rESWT group; $P = 0.011$ among LCI control group (Mann-Whitney U test).

[e] $P = 0.003$ between LCI rESWT group (Mann-Whitney U test).

[f] $P = 0.003$ between group LCI rESWT; $P = 0.041$ among rESWT control group (Mann-Whitney U test).

[g] $P = 0.005$ between LCI control group; $P = 0.014$ among rESWT control group (Mann-Whitney U test).

[h] $P = 0.001$ between LCI control group (2-sample t test); $P = 0.006$ among rESWT control group (Mann-Whitney U test).

[i] $P = 0.002$ between LCI control group; $P = 0.003$ among rESWT-control group (Mann-Whitney U test).

[j] One-way analysis of variance for intergroup comparison.

mMCV, median motor conduction velocity.

were compared with control group. The use of the hand-wrist resting splint, which is given as the base treatment to all patients included in the study, seems to be effective in reducing the subjective symptoms of CTS. However, these results reflect a short period limited to 3 mos. For this reason, according to our study, LCI and splint should be the first choice in mild-to-moderate CTS if there is no contraindication. However, ESWT is a noninvasive method and patient tolerance is better.

For these reasons, ESWT has advantages over LCI in this regard. Moreover, the specific parameters of ESWT, such as the number of shocks, energy size, frequency, pressure, and total treatment course, may also be factors that affect subsequent changes in electrophysiologic parameters. Therefore, studies with longer follow-up periods should be conducted to standardize the dose given in ESWT. In addition, it should be kept in mind that none of these treatment methods directly remove the pressure on the median nerve in terms of rehabilitation, and surgery may be needed in future recurrences and patients with severe CTS.

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