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The efficacy of ultrasound and low-intensity laser therapy in carpal tunnel syndrome

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ABSTRACT

Aim: The most frequent type of peripheral entrapment neuropathy is carpal tunnel syndrome (CTS), which is caused by compression of the median nerve at the wrist level. Ultrasound (US) and low-intensity laser therapy (LILT) are among the most commonly used physical therapy methods in the treatment of CTS. The aim of this study is to examine the efficacy of US and LILT in the treatment of CTS and their superiority to each other.

Material and Method: Patients who were admitted to the physical therapy program with the diagnosis of CTS in our clinic were retrospectively examined. A total of eleven patients (18 wrists) diagnosed with mild and moderate CTS were included in our study with the G-Power program with a 5 % margin of error and 80 % power. Patients were divided into US and LILT groups using a simple randomization method. The patients were evaluated in terms of clinical and electrophysiological parameters before and after treatment.

Results: A total of 18 wrists were included in our study, of which eight patients were diagnosed with mild CTS and the rest (n=10) with moderate CTS. The mean age of the patients was 49.66±10.68 years. When the post-treatment clinical (Boston Carpal Tunnel Syndrome Questionnaire (BCTQ), hand and pinch grip strength, measurement of wrist joint range of motion) and electrophysiological parameters were evaluated between the US and LILT groups, no significant difference was found in terms of their superiority over each other ($p>0.05$). When the LILT group was compared before and after treatment, a statistically significant difference was found in the degree of wrist extension, handgrip strength and BCTQ parameters. ($p<0.05$).

Conclusion: When US and LILT were compared in patients with mild and moderate carpal tunnel syndrome, no significant difference was found between the groups in terms of clinical and electrophysiological parameters. However, a statistically significant difference was found in the LILT group in terms of some clinical parameters before and after treatment.

Keywords: Low-intensity laser therapy, ultrasound, carpal tunnel syndrome

INTRODUCTION

Carpal Tunnel Syndrome (CTS) is the most common clinical entrapment mononeuropathy caused by compression of the median nerve at the wrist level (1). Its prevalence is around 3-6% (2). It is more common in females between the ages of 40 and 60 and is usually bilateral (3). Most patients complain of one or more of the symptoms such as weakness, pain, numbness or tingling in the hand, especially in the thumb, index and middle fingers (4). The severity of these symptoms increases at night and may wake the patient from sleep (5). CTS risk factors can be chronic diseases such as diabetes mellitus or functional disorders of the thyroid, as well as pregnancy, high body mass index, repetitive traumas (2). The most frequently used tests in the clinic for diagnosis are Tinel and Phalen tests, but the most reliable objective method is electrodiagnostic tests (6).

Conservative treatments used to manage CTS are diverse. Some of the commonly used are tendon gliding exercises, wrist splinting, local corticosteroid injections, and physical therapy modalities (7,8). The most commonly used physical therapy modalities are low-intensity laser therapy (LILT) and ultrasound (US) therapy (9). It is thought that these two methods have biophysical effects on nerve tissue and facilitate nerve healing by stimulating regeneration (10).

The aim of this study is to examine the efficacy and superiority of LILT and US therapies used in the treatment of patients with CTS, using clinical and electrophysiological parameters.

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MATERIAL AND METHOD

The study was initiated with the approval of the Research Ethics Committee of Amasya University (Date: 08/10/2020, Decision No: 2020/117). All procedures were carried out in accordance with the ethical rules and the principles of the Declaration of Helsinki.

Study Design and Participants

The study was planned as a retrospective. In the test performed with the G-Power program with 5% margin of error and 80% power, it was revealed that the groups should have at least seven people. The study groups consisted of patients who applied to the Amasya University Physical Therapy and Rehabilitation polyclinic with complaints of pain and tingling in the wrist between November 2020 and January 2021. Clinical examination and electroneuromyography (ENMG) were used to diagnose CTS. Median nerve conduction studies were performed on all patients, and patients were classified as mild, moderate, and advanced according to the American Electrodiagnostic Medical Association guidelines (11). According to this guidelines, (a) Normal means no electrophysiological abnormality (b) Mild CTS represents the reduction in sensory conduction velocity (SCV), distal motor latency (DML) is within normal limits; (c) Moderate CTS: prolongation of DML, slowing of SCV (d) Severe CTS: It means the prolongation of the DML and the absence of sensory conduction. (12-14).

Patients diagnosed with mild or moderate CTS were included in the study. Patients with advanced CTS diagnosis, surgical operation in the wrist region, fractures in the nearby region and metal or implants in the vicinity of the wrist region were not included in the study. Wrist splint was prescribed to all patients. Included patients were randomly divided into two groups, US and LILT, by simple randomization (www.randomizer.org).

After obtaining the demographic data of the patients, the Boston Carpal Tunnel Syndrome Questionnaire (BCTQ) was administered to each patient. BCTQ consists of two sub-sections as Symptom Severity Scale (SSS) and Functional Status Scale (FSS). A high score indicates the severity of symptoms and inadequate functional status (15). Turkish validity and reliability were established (16). ENMG evaluations of the patients participating in the study were made by the same physiatrist at room temperature with the Nihon-Kohden MEB-9400K (Nihon Kohden Corp, Tokyo, Japan) EMG device.

A hand dynamometer (Baseline Dynomometer, New York, USA) was used to evaluate the handgrip strength of the patients, and a pinch meter (Baseline Pinchmeter, New York, USA) was used to evaluate the pinch grip strength. While measuring the handgrip, it was measured using level 2 resistance (3.75 cm) with the elbow in 90° flexion and the forearm and wrist in neutral position. Maximum contraction was requested from the patients, adequate rest intervals were given, and the measurements were taken 3 times and the average was recorded as kilograms. Pinch grip strength was evaluated by squeezing the metal part of the pinch meter with the thumb tip on one side and the index fingertip on the other side. The average of 3 repetitions given an adequate rest interval was recorded (17).

Measurements of wrist joint range of motion are one of the measurable parameters that inform us about the functional status of the hand in CTS patients (18). When measuring wrist flexion and extension, the pivot point is taken as the styloid process of the radius and the fixed arm of the goniometer is at the radius. The movable arm followed the second metacarpal bone. While measuring the wrist radial and ulnar deviations, the forearm was kept on the table in the prone position, then the fixed arm of the goniometer was placed on the midline of the forearm and the movable arm was placed on the third metacarpal bone (19).

ROM and grip strength measurements were performed by the same physiotherapist. Evaluations (ENMG, ROM, grip strength) were made for all patients before and after treatment. The patient evaluations before the study started and on the 30th day after the treatment sessions were statistically compared.

Treatment Protocol

All patients received 10 sessions of physical therapy, 5 sessions per week. Patients in the US group were given 1 MHz frequency, 1.0 W/cm² intensity, and 3-minute pulsed type US therapy with a mobile US device (Chattanooga 2776, USA). In the LILT group, 904 Nm wavelength, 9J and 5-point application laser device was applied to the wrist for 5 minutes, with the patient and therapist taking the necessary safety precautions.

Statistical Analysis

Research data was uploaded to the computer environment and evaluated by means of SPSS® version 21.0 statistical package program (SPSS Inc., Chicago, IL, USA). In order to ensure that the selection of the patients to the study groups was random, they were divided into two groups using a simple randomization program. The conformity of the variables to the normal distribution was examined using visual (histogram and probability graphs) and analytical methods (Shapiro-Wilk Test). Descriptive statistics were presented as mean±standard deviation and median (25%-75%). The Independent Groups T-Test was used for the statistical significance between two independent groups for the variables found to have a normal distribution. Paired T Test was used as a statistical method for statistical significance between two dependent groups. For the variables that do not

show normal distribution; Mann-Whitney U Test was used for significance between two independent groups and Wilcoxon Signed Rank Test was used between two dependent groups.The results were evaluated at the 95% confidence interval, statistically at the p<0.05 level.

RESULTS

When the demographic data of the patients were examined, the mean age of the patients was 49.66±10.68 years. Bilateral CTS was diagnosed in seven of the patients included in the study. Only one of the patients were men. When the patients who received treatment were evaluated, eight patients were diagnosed with mild CTS and the rest (n=10) were diagnosed with moderate CTS. The patients were divided into two groups and US (n=8) was applied to one group and LILT (n=10) to the other group. When **Table 1** and **Table 2** were examined, a significant difference was found only in the degree of wrist radial deviation when the parameters before the treatment and at the 1st month were compared in the group receiving US treatment. On the other hand, a statistically significant difference was found in the degree of extension, handgrip strength, BCTQ in the LILT group (p<0.05). No statistically significant difference was found between the US and LILT groups before the treatment in terms of wrist flexion degrees, wrist radial and ulnar deviation degrees, hand and pinch strength values, ENMG and BCTQ parameters, except for the degree of wrist extension (p>0.05). There was no statistically significant difference between the groups in terms of clinical and electrophysiological parameters in the first month after treatment (p>0.05).

Table 1. Comparison of clinical parameters within and between groups before and after treatment

	LILT (n=10)	US (n=8)	p value
Wrist flexion pre	66.6±7.1	65.7±3.7	0.767[a]
Wrist flexion post	69.3±6.0	67.8±3.2	0.558[a]
p value	0.212[b]	0.340[b]	
Wrist extension pre	59.2±5.4	65.8±4.2	0.012[a]
Wrist extension post	66.6±7.2	68.8±9.2	0.567[a]
p value	0.013[b]	0.463[b]	
Wrist radial deviation pre	22.3±8.0	25.5±2.6	0.302[a]
Wrist radial deviation post	22.4±3.6	22.1±2.7	0.864[a]
p value	0.960[b]	0.011[b]	
Wrist ulnar deviation pre	45.3±5.9	46±4.5	0.788[a]
Wrist ulnar deviation post	46.2±6.7	43.5±2.3	0.300[a]
p value	0.718[b]	0.150[b]	
Handgrip pre	51.6±22.7	30.00 (17.0-51.75)	0.075[c]
Handgrip post	63.2±24.3	41.50 (14.0-58.00)	0.075[c]
p value	0.002[b]	0.779[d]	
Pinch grip pre	12.7±6.0	8.7±5.2	0.165[a]
Pinch grip post	13.3±6.3	8.1±3.2	0.052[a]
p value	0.541[b]	0.590[b]	
FSS pre	21.7±6.2	18.50 (13.25 - 31.25)	0.687[c]
FSS post	14.3±5.0	16.50 (12.50 – 18.00)	0.315[c]
p value	0.00[b]	0.105[d]	
SSS pre	27.4±5.8	27.6±9.8	0.953[a]
SSS post	18.1±5.0	23.6±9.5	0.133[a]
p value	0.003[b]	0.363[b]	

a: Independent t test, b: Paired t test, c: Mann-Whitney U test, d:Wilcoxon, Numerical data showing normal distribution are given as mean±standard deviation. Numerical data that do not show normal distribution are given as median(%25-%75). (LILT: Low-intensity laser therapy, US: Ultrasound therapy, Pre: Before treatment, Post: After treatment 1 month, FSS: Functional status scale, SSS: Symptom severity scale)

Table 2. Comparison of electrophysiological parameters within and between groups before and after treatment

	LILT (n=10)	US (n=8)	p value
Median nerve motor amplitude pre	12.9±4.0	12.9±3.2	1.000[a]
Median nerve motor amplitude post	10.8±3.7	11.5±2.9	0.673[a]
p value	0.123[b]	0.300[b]	
Median nerve distal motor latency pre	4.2±0.7	3.83(3.24 – 4.34)	0.360[c]
Median nerve distal motor latency post	4.1±0.5	3.48(3.24 – 4.22)	0.110[c]v
p value	0.659[b]	0.161[d]	
Median nerve sensory conduction velocity pre	37.00(33.25-44.83)	39.10(34.40-47.43)	0.762[c]
Median nerve sensory conduction velocity post	37.45(33.30-42.10)	42.35(37.50-49.03)	0.203[c]
p value	0.878[d]	0.125[d]	
Median nerve motor conduction velocity pre	54.8±5.5	57.7±3.2	0.207[a]
Median nerve motor conduction velocity post	54.5±6.0	59.9±4.7	0.055[a]
p value	0.792[b]	0.341[b]	

a: Independent t test, b: Paired t test, c:Mann-Whitney U test, d:Wilcoxon, Numerical data showing normal distribution are given as mean±standard deviation. Numerical data that do not show normal distribution are given as median (%25-%75). (LILT: Low-intensity laser therapy, US: Ultrasound therapy, Pre: Before treatment, Post: After treatment 1 month, FSS: Functional status scale, SSS: Symptom severity scale)

DISCUSSION

In this study, the efficacy of US and LILT therapies in patients diagnosed with CTS in the physical therapy outpatient clinic was compared in terms of clinical and electrophysiological aspects. Although there are many studies in the literature comparing the efficacy of US and LILT treatment in CTS (20-22), no study has been found that evaluated the measurement of wrist joint range of motion (extension, flexion, radial and ulnar deviation), BCTQ, hand and pinch grip, and ENMG.

CTS is a disease that is common in society and negatively affects people's daily living activities. Various conservative and surgical treatment methods are used in the treatment of CTS (23). Although surgery is an effective treatment option, non-invasive methods are the first choice in treatment because of the possibility of recurrence, complications, and failure. Conservative treatment methods include; splinting, injections, physical therapy and alternative therapies (24,25). LILT and US are more prominent among physical therapy modalities. Although numerous studies have been conducted in the literature, there is no consensus on the efficacy and superiority of these treatments (25).

US is one of the physical therapy agents commonly used in the treatment of musculoskeletal pain. US converts electrical energy into sound waves. As it passes through the tissues, it acts by creating heat according to the tissue resistances (26). There are numerous research on the use of US in the treatment of CTS in the literature. However, a full judgment has not been reached regarding the effectiveness of US in the treatment of CTS. Ebenbichler et al. (10) evaluated the effectiveness of US therapy in CTS with their study on 45 patients with bilateral CTS, significant improvement in treated wrists was reported at six-month follow-up. Clinical improvement and a substantial electrophysiological change were observed in all groups in another investigation comparing the effectiveness of US treatment at different doses (0 W/cm², 0.8 W/cm², 1.5 W/cm²) in CTS (27). In another study conducted on 30 wrists with mild and moderate CTS, it was found that low-intensity (0.5 W/cm²) US treatment provided clinical improvement but did not show any significant electrophysiological change (28). In a study of 40 patients with a one-year follow-up, Kamalakannan et al. (29) found that US therapy did not produce a clinically significant benefit in CTS. Similarly, in our study it was observed that US treatment did not have a statistically significant effect on clinical and electrophysiological parameters in CTS.

LILT is used to treat chronic painful conditions such as musculoskeletal injuries, arthritic conditions, and postherpetic neuralgia (30,31). The mechanism of action of LILT is thought to be an increase in ATP production, high endorphin levels, and anti-inflammatory effects. It is also known to accelerate collagen synthesis, activate angiogenesis and increase microcirculation (32). The results obtained in previous studies investigating the efficacy of LILT in CTS are contradictory. Shooshtari et al. (33) showed a significant improvement in clinical symptoms, nerve conduction studies, and handgrip strength in the laser group compared to placebo. In another study evaluating the efficacy of LILT in CTS, it was shown that laser therapy was not more effective than placebo on clinical and electrophysiological parameters (34). In our study, while clinical parameters of SSS, FSS, handgrip strength and degree of wrist extension were improved after treatment in patients who underwent LILT, it was observed that LILT had no effect on electrophysiological parameters.

When studies comparing US and LILT are examined, their effectiveness and superiority to each other are still discussed. In a study of 50 patients with CTS, US therapy was found to be more effective than LILT in all clinical and electrophysiological parameters (20). Tikiz et al. (22) suggested that the short-term and medium-term efficacy of US on clinical parameters is greater than that of LILT. However, they did not observe significant differences in electrophysiological parameters. Dincer et al. (21) showed that the combination of US or DYLT with splinting is more effective than splinting alone in the treatment of CTS. However, it has been determined that laser therapy is more effective than US therapy in terms of results such as decreasing symptom severity, relieving pain and increasing patient satisfaction. When the results were examined; however, in our study no superiority was found between US and DYLT in terms of post-treatment clinical and electrophysiological parameters.

The major limitation of our study is that it was planned to study on a small number of patients. It is also considered as not evaluating the long-term effects of US and DYLT. One of the most important limitations is that there is no placebo comparison.

CONCLUSION

US and LILT are non-invasive treatment methods that can be effective in reducing symptoms in the treatment of mild and moderate CTS. However, the advantages of these physical therapy methods over each other have not been fully clarified yet. According to our clinical study, when US and LILT were compared in patients with mild to moderate carpal tunnel syndrome, no significant difference was found between the groups in terms of clinical and electrophysiological parameters after treatment. However, a significant difference was found in the LILT group before and after treatment in terms of

degree of extension, gross grip, FDS and SSS parameters. More research is needed to compare the advantages and efficacies of US and LILT treatments.

ETHICAL DECLARATIONS

Ethics Committee Approval: The study was initiated with the approval of Research Ethics Committee of Amasya University (Date: 08/10/2020, Decision No: 2020/117).

Informed Consent: Because the study was designed retrospectively, no written informed consent form was obtained from patients.

Referee Evaluation Process: Externally peer reviewed.

Conflict of Interest Statement: The authors have no conflicts of interest to declare.

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REFERENCES:

1. Phalen GS. The carpal-tunnel syndrome: seventeen years'experience in diagnosis and treatment of six hundred fifty-four hands. JBJS 1966; 48: 211-28.
2. Kaymak B, Özçakar L. Karpal tünel sendromu. Hacettepe Tıp Derg 2007; 38: 141-6.
3. Serarslan Y, Melek İM, Duman T. Karpal tünel sendromu. Pamukkale Tıp Derg 2008: 45-9.
4. Kamolz L-P, Beck H, Haslik W, et al. Carpal tunnel syndrome: a question of hand and wrist configurations? J Hand Surg 2004; 29: 321-4.
5. Muller M, Tsui D, Schnurr R, Biddulph-Deisroth L, Hard J, MacDermid JC. Effectiveness of hand therapy interventions in primary management of carpal tunnel syndrome: a systematic review. J Hand Ther 2004; 17: 210-28.
6. Evcili G, Gül HL, Karadaş Ö, Börü ÜT. Carpal tunnel syndrome: In which ratio does electroneuromyography confirm the diagnosis? J Clin Analytic Med 2012; 3: 412-4.
7. Piazzini DB, Aprile I, Ferrara PE, et al. A systematic review of conservative treatment of carpal tunnel syndrome. Clin Rehabil 2007; 21: 299-314.
8. O'Connor D, Marshall S, Massy-Westropp N. Non-surgical treatment (other than steroid injection) for carpal tunnel syndrome. Cochrane Database Syst Rev 2003; 2003: CD003219.
9. Rayegani SM, Moradi-Joo M, Raeissadat SA, Bahrami MH, Seyed-Nezhad M, Heidari S. Effectiveness of low-level laser therapy compared to ultrasound in patients with carpal tunnel syndrome: A systematic review and meta-analysis. J Lasers Med Sci 2019; 10: S82.
10. Ebenbichler GR, Resch KL, Nicolakis P, et al. Ultrasound treatment for treating the carpal tunnel syndrome: randomised "sham" controlled trial. BMJ 1998; 316: 731-5.
11. Stevens JC. AAEM minimonograph #26: the electrodiagnosis of carpal tunnel syndrome. American Association of Electrodiagnostic Medicine. Muscle Nerve 1997; 20: 1477-86.
12. Bagga B, Sinha A, Khandelwal N, Modi M, Ahuja CK, Sharma R. Comparison of magnetic resonance imaging and ultrasonography in diagnosing and grading carpal tunnel syndrome: a prospective study. Curr Probl Diagn Radiol 2020; 49: 102-15.
13. Padua L, LoMonaco M, Gregori B, Valente E, Padua R, Tonali P. Neurophysiological classification and sensitivity in 500 carpal tunnel syndrome hands. Acta Neurologica Scandinavica 1997; 96: 211-7.
14. Hirani S. A study to further develop and refine carpal tunnel syndrome (CTS) nerve conduction grading tool. BMC Musculoskeletal Disorders 2019; 20: 1-7.
15. Levine DW, Simmons BP, Koris MJ, et al. A self-administered questionnaire for the assessment of severity of symptoms and functional status in carpal tunnel syndrome. J Bone Joint Surg Am 1993; 75: 1585-92.
16. Sezgin M, İncel NA, Sevim S, Çamdeviren H, As İ, Erdoğan C. Assessment of symptom severity and functional status in patients with carpal tunnel syndrome: reliability and validity of the Turkish version of the Boston Questionnaire. Disabil Rehabil 2006; 28: 1281-6.
17. Mathiowetz V, Weber K, Volland G, Kashman N. Reliability and validity of grip and pinch strength evaluations. J Hand Surg 1984; 9: 222-6.
18. Walker J, Sue D, Miles-Elkousy N, Ford G, Trevelyan H. Active mobility of the extremities in older subjects. Physical Ther 1984; 64: 919-23.
19. Cambridge-Keeling. ROM measurement of the hand. Rehabilitation of the Hand and Upper Extremity 5th ed Missouri.169-82.
20. Bakhtiary AH, Rashidy-Pour A. Ultrasound and laser therapy in the treatment of carpal tunnel syndrome. Aust J Physiother 2004; 50: 147-51.
21. Dincer U, Cakar E, Kiralp MZ, Kilac H, Dursun H. The effectiveness of conservative treatments of carpal tunnel syndrome: splinting, ultrasound, and low-level laser therapies. Photomed Laser Surg 2009; 27: 119-25.
22. Tıkız C, Duruöz T, Zeliha Ü, Cerrahoğlu L, Yalçinsoy E. Karpal tünel sendromunda düşük enerjili lazer ve kesikli ultrason tedavi etkinliklerinin karşılaştırılması: plasebo kontrollü bir çalışma. Turk J Phys Med Rehabil Sci 2013; 16.
23. Ekim A, Çolak E. Karpal tünel sendromunda ultrason tedavisi: plasebo kontrollü bir çalışma. Turk J Phys Med Rehabil 2008; 54.
24. Carlson H, Colbert A, Frydl J, Arnall E, Elliot M, Carlson N. Current options for nonsurgical management of carpal tunnel syndrome. Int J Clin Rheumatol 2010; 5: 129.
25. Afşar Sİ, Sarıfakıoğlu B, Yalbuzdağ ŞA. Karpal Tünel sendromu tedavisinde fizik tedavi modalitelerinin yeri: derleme. Turk J Osteoporosis 2014; 20.
26. Klaiman MD, Shrader JA, Danoff JV, Hicks JE, Pesce WJ, Ferland J. Phonophoresis versus ultrasound in the treatment of common musculoskeletal conditions. Med Sci Sports Exerc 1998; 30: 1349-55.
27. Oztas O, Turan B, Bora I, Karakaya MK. Ultrasound therapy effect in carpal tunnel syndrome. Arch Phys Med Rehabil 1998; 79: 1540-4.
28. Piravej K, Boonhong J. Effect of ultrasound thermotherapy in mild to moderate carpal tunnel syndrome. J Med Assoc Thailand=Chotmaihet Thangphaet 2004; 87: S100-6.
29. Jothi KP, Bland JD. Ultrasound therapy adds no benefit to splinting in carpal tunnel syndrome. Muscle Nerve 2019; 60: 538-43.

30. Soriano F, Ríos R. Gallium arsenide laser treatment of chronic low back pain: a prospective, randomized and double blind study. Laser Ther 1998; 10: 175-80.
31. Kemmotsu O, Sato K, Furumido H, et al. Efficacy of low reactive-level laser therapy for pain attenuation of postherpetic neuralgia. Laser Ther 1991; 3: 71-5.
32. Naeser MA, Hahn K-AK, Lieberman BE, Branco KF. Carpal tunnel syndrome pain treated with low-level laser and microamperes transcutaneous electric nerve stimulation: a controlled study. Arch Phys Med Rehabil 2002; 83: 978-88.
33. Shooshtari S, Badiee V, Taghizadeh S, Nematollahi A, Amanollahi A, Grami M. The effects of low level laser in clinical outcome and neurophysiological results of carpal tunnel syndrome. Electromyogr Clin Neurophysiol 2008; 48: 229.
34. Irvine J, Chong SL, Amirjani N, Chan KM. Double-blind randomized controlled trial of low-level laser therapy in carpal tunnel syndrome. Muscle Nerve 2004; 30: 182-7.