DOI: 10.14744/ejmi.2019.43136
EJMI 2020;4(3):320–326

Research Article

Comparing the Efficiencies of Ultrasound and Phonophoresis with Mucopolysaccharide Polysulphate Treatments in Patients with Carpal Tunnel Syndrome

Sevil Okan,[1] Ahmet Inanir,[2] Fatih Celikyay,[3] Betul Cevik[4]

[1]Department of Physical Therapy and Rehabilitation, Tokat State Hospital, Tokat, Turkey
[2]Department of Physical Therapy and Rehabilitation, Pain and Hernia Center, Samsun, Turkey
[3]Department of Radiology, Gaziosmanpasa University, Faculty of Medicine, Tokat, Turkey
[4]Department of Neurology, Gaziosmanpasa University, Faculty of Medicine, Tokat, Turkey

Abstract

Objectives: The aim of the present study was to compare different conservative treatments in patients with carpal tunnel syndrome.

Methods: Forty patients with idiopathic carpal tunnel syndrome were included in the present quasi-experimental study. Patients were randomized into phonophoresis (n=20 hands) and ultrasound (n=20 hands) groups. Phonophoresis group had phonophoresis treatment at the rate of 1.5 w/cm^2 with mucopolysaccharide polysulphate (MPS) gel as conductivity agent, while ultrasound group had ultrasound treatment at the rate of 1.5 w/cm^2 only. Both groups received hand-wrist orthosis, tendon and nerve gliding exercises. All patients were evaluated based on physical examination findings, electroneurophysiological parameters, MR imaging, visual analoge scale, Algometer, Jamar Hand Dynamometer and Boston Severity Scale and Functional Status Scale at the beginning of and three months after the treatment.

Results: Based on clinical findings, significant improvements were observed in both groups for all symptoms except for hand grip strength in phonophoresis group and except for hand grip strength and motor deficit in ultrasound group. While median nerve conduction velocity increased in both groups (p=0.001 for phonophoresis group and p=0.229 for ultrasound group), significant improvement in electromyography staging was observed only in phonophoresis group (p=0.037). Significant decreases in cross-sectional area in MR measurements were observed at two levels (p<0.005) in ultrasound group, and significant decreases were observed for all measurements in phonophoresis group (p<0.05).

Conclusion: It could be stated that MPS phonophoresis has positive effects on nerve conduction studies, MR findings and clinical outcomes in treatment of carpal tunnel syndrome.

Keywords: Carpal tunnel syndrome, mucopolysaccharide polysulphate, phonophoresis

Cite This Article: *Okan S, Inanir A, Celikyay F, Cevik B. Comparing the Efficiencies of Ultrasound and Phonophoresis with Mucopolysaccharide Polysulphate Treatments in Patients with Carpal Tunnel Syndrome. EJMI 2020;4(3):320–326.*

Carpal Tunnel Syndrome (CTS) is the most frequent trap neuropathy of upper extremity with an incidence rate of about 3.8%. Findings supporting CTS diagnosis are sensory loss in lateral half of hand, motor deficit, atrophy in abductor pollicis brevis muscle, and positivity in Phalen and Tinel tests. Nerve conduction studies are the most prominent diagnostic tests.[1] It has been mentioned in literature that ultrasound and Magnetic Resonance (MR) could be

Address for correspondence: Sevil Okan, MD. Tokat Devlet Hastanesi, Fizik Tedavi ve Rehabilitasyon Klinigi, Tokat, Turkey
Phone: +90 530 821 17 97 **E-mail:** doctorsevil@yahoo.com

Submitted Date: May 02, 2019 **Accepted Date:** June 21, 2019 **Available Online Date:** June 05, 2020

used as additional screening tools for CTS diagnosis especially in patients with diagnostic dilemmas.[2]

The first method of choice in treatment of especially mild and moderate CTS is conservative treatment. However, efficiency of conservative methods in CTS treatment has been debated.[3] Conservative treatment methods of CTS include resting, ultrasound, laser therapy, orthosis, non-steroidal anti-inflammatory drugs, oral steroids and local corticosteroid injections. For surgical treatment, median nerve decompression is used.[4] Another conservative treatment method is phonophoresis. It has been reported that phonophoresis of dexamethasone could accelerate normal resolution process of inflammation through its anti-inflammatory and tissue stimulant effects in CTS.[5] Local anesthetics and anti-inflammatory drugs (both steroid and non-steroid) are employed in phonophoresis treatment.[6] MPS phonophoresis has been suggested for the treatment of patients with heel pain. It has been thought that MPS inhibited degenerative, ischemic and inflammatory reactions, thereby improving local tissue metabolism.[7]

There are no studies in literature evaluating the efficiency of MPS phonophoresis in CTS and comparing it with US treatment to our best knowledge. The aim of the present study was to evaluate MPS phonophoresis for treatment of patients with CTS using clinical findings, electroneurophysiological parameters and MR findings and to determine whether it is superior to US treatment.

Methods

The present study was carried out on 40 patients who applied to Department of Physical Therapy and Rehabilitation at University Hospital with the complaints of numbness, burning and tingling in hands and had carpal tunnel syndrome diagnosis which was confirmed by Electromyography (EMG) during April-September 2014 period. The study was approved by local ethical board. Patients were informed about the procedure before the study, and they filled consent forms. The patients who had paresthesia, pain and/or vasomotor symptoms in region fitting median nerve distribution in hand, who had positivity for at least one of Tinel, Phalen and carpal compression tests in physical examination, and who were determined to have mild or moderate CTS in nerve conduction studies were included. The patients who had etiological factors which were not predisposing for CTS (diabetes mellitus, acute trauma, rheumatological diseases, pregnancy, hypothyroidy, hyperthyroidism, etc.), who had atrophy in thenar region, who had excluded parameters used in differential diagnosis of CTS such as cervical radiculopathy or polyneuropathy, who had medicines such as oral steroids or non- steroidal anti-inflammatory drugs and steroid injection within the last thirty days, who had physical therapy program and who had CTS surgery were excluded. All patients were subjected to electrophysiological evaluation, MR examination, pain evaluation, provocation tests, sensory and motor evaluation and Jamar Hand Dynamometer and algometry tests before and three months after the treatment. They also completed Boston Carpal Tunnel Questionnaire (BCTQ). Patients were randomly divided into two groups. For the patients in the first group, 3 ml of contact gel used in daily routine (aquasonic gel) was applied at 10 sessions on a single hand wrist using an ITO US-750 Ultrasound machine with a 5 cm^2 header and 1 MHz frequency at 1.5 w/cm^2 for five minutes. The patients in the second group had 10 sessions of 3 ml gel containing MPS applied on hand wrist using the same machine and procedure as in the first group. The patients in both groups were given neutral hand wrist orthoses during the night and also during the day as much as they can for a period of three months. In addition, tendon and nerve gliding exercise program was prepared for each patient. Patients carried out exercises as five sets of 10 repeats of each position for five seconds each for three months at their homes.[8,9]

Visual analogue scale (VAS) was used to evaluate pain status of the patients. Pain thresholds of patients were measured using pressure algometry (JTECH, Commander TM). Jamar Hand Dynamometer (Baseline hydraulic hand dynamometer, Irvington, NY, USA) was used to determine hand grip strength. Before and after the treatment, all patients completed BCTQ. BCTQ consists of 19 questions. Eleven questions measure the severity of the symptom and eight questions evaluate functional capacity.[10] Developed by Levine et al.[11] in 1993, BCTQ was verified for Turkish population in terms of validity and reliability by Sezgin et al.[12]

Electrophysiological evaluations of all patients were performed by the same person using Neuropack ε (Nihon Kohden) electromyography machine. Temperature of hand skin was measured before the electrodiagnostic examination and was maintained at 32 °C or over using an infrared lamp during nerve conduction studies. For motor conduction study, recording electrodes were located on abductor pollicis brevis and abductor digiti minimi muscles, respectively, during the stimulation of median and ulnar nerves. Reference electrodes were located on distal tendon insertion. Distal latency longer than 3.8 ms, nerve conduction velocity less than 49.7 m/s and Compound muscle action potential (CMAP) amplitude lower than 4.3 mV were considered normal values for median nerve. For the evaluation of nerve conduction velocity of median and ulnar nerves, warning electrodes were located on the 1st, 2nd, 3rd and 5th fingers, while active stimulation electrode was placed on proximal phalanx and reference electrode was placed on middle phalanx. Sensory conduction velocities of median

Table 1. Demographic features of patients

Feature	Phonophoresis (n=20) Mean±SD	Ultrasound (n=20) Mean±SD	Significance (p)
Age (years)	43.80±7.79	43.55±9.28	0.927
Height (cm)	159.10±5.72	159.55±5.77	0.806
Weight (kg)	83.05±13.85	83.25±20.26	0.971
BMI (kg/m²)	32.92±5.93	32.60±7.37	0.879
Duration of the symptom (months)	2.10±0.83	2.10±0.83	1.000

SD: Standard deviation. BMI: Body mass index. Significance Test for the Difference between Two Means.

nerve lower than 32.9 m/s for the first finger, 34.9 for the second finger, 39.6 for the third finger and 35.2 for palm-wrist were considered normal. Based on electrophysiological findings, patients with CTS diagnosis were classified as mild, moderate and advanced stage CTS.[13]

MR examination was performed on 40 hand wrists of 40 patients. Radiologist who performed the examination blind evaluated all cases irrespective of ultrasound or phonophoresis classification. Hand wrist MR examinations were carried out with hand wrist wrapping using a 1.5 tesla MR machine (Signa Excite, HDx12.0, M5B software; GE Milwaukee, WI, USA, 2005). Axial, coronal fat suppressed PD (TR/TE, 2800/30) axial coronal T1 (TR/TE, 400/10) and axial T2 (TR/TE, 4500/80) sequences were used in imaging. Other MR parameters were: FOV 12c, slice thickness: 3 mm, slice gap: 1 mm and matrix: 320x256. MR examinations were evaluated using Advantage Workstation 4.2 GE. Using axial sections, cross-sectional area of median nerve was measured at three different levels (radiocarpal joint, pisiform and hamate hook levels) and arithmetic average was calculated. In addition, signal intensity was evaluated in fat suppressed weighed series of median nerve and was classified as elevated or normal.

Statistical Analyses

Analyses were conducted to evaluate the general characteristics of study groups. Numeric variables were expressed mean±standard deviation, while categorical ones were expressed as n (percentage). Two-way variance analysis was used in repeated measurements when comparing the mean of quantitative variables between groups. p values <0.05 was considered significant. Relationships between independent categorical variables EMG Stage and Clinical Stage were tested using Fisher's Exact Test and expressed as n (%). Statistical analyses were carried out using a statistical software (IBM SPSS Statistics 19, SPSS Inc., an IBM Co., Somers, NY).

Results

Forty-eight hands were studied. Age of the patients varied from 26 to 55 years. Eight hands were excluded since the patients did not show up for treatment or follow-up, and study was completed with 40 hands (26 right and 14 left). CTS of 27 patients was in dominant hand. There were no differences between the two groups for age, height, weight, BMI and duration of symptoms (p>0.05) (Table 1).

There were no significant differences between the two groups for starting symptoms, physical examination findings and clinical and EMG stages (p>0.05). Starting measurements of BCTQ, VAS, Algometry and Jamar Hand Grip Strength were similar in both groups (p>0.05). In terms of starting MR and EMG findings, the third finger amplitude, the third finger sensory conduction velocity and the second finger sensory conduction velocity were significantly lower in ultrasound group, but the two groups were similar for other parameters (p>0.05). Significant improvements were observed in both groups for BCTQ and VAS scores after treatment (p<0.05). Considering algometry values, pain threshold increased more after treatment in phonophoresis group, though the difference was not significant (p>0.05). Hand grip strength increased after treatment in phonophoresis group but decreased in ultrasound group (p>0.05) (Table 2).

When the values from follow-up examination three months later were compared to starting values, significant improvements were observed in both groups for vasomotor symptoms, pain and flick sign (p<0.05). Strength loss evaluation improved in both groups, but improvement in phonophoresis group were more pronounced for this outcome (p<0.001). Physical examination findings revealed that significant improvements were also observed in both groups for carpal compression, Tinel, Phalen and reverse Phalen tests (p<0.001). Similarly, phonophoresis treatment was more efficient. Four patients in phonophoresis group were found to have motor deficit before the treatment and all of these patients recovered from this condition after the treatment. On the other hand, significant improvement was not observed for motor deficit in ultrasound group. Sensory deficit improved in both groups, but again phonophoresis treatment was more effective for this parameter.

Table 2. Comparison of groups before and after treatment

Variables	Phonophoresis (n=20)			Ultrasound (n=20)		
	Before treatment Mean±SD	After treatment Mean±SD	p	Before treatment Mean±SD	After treatment Mean±SD	p
Algometry	16.55±4.33	17.03±4.28	0.298	17.88±2.87	17.91±1.73	0.965
Boston FSS	2.27±0.57	1.41±0.41	<0.001	2.51±0.58	1.37±0.41	<0.001
Boston SSS	2.74±0.58	1.65±0.54	<0.001	2.89±0.67	1.67±0.58	<0.001
Jamar HD	47.7±15.54	48.55±15.87	0.713	41.2±22.45	40±21.88	0.604
VAS	5±3.32	1.2±1.79	<0.001	5.5±3.03	1.25±1.77	<0.001

SD: Standard deviation; FSS: Functional status scale; SSS: Symptom severity scale; HD: Hand dynamometer; VAS: Visual analogue scale.

Table 3. EMG and MR parameters of groups before and after treatment

Variables	Phonophoresis (n=20)			Ultrasound (n=20)		
	Before treatment Mean±SD	After treatment Mean±SD	p	Before treatment Mean±SD	After treatment Mean±SD	p
Palm wrist Amp.	39.54±3.82	38.6±7.92	0.747	38.45±14.15	40.39±3.05	0.465
Palm wrist mSNCV	28.29±6.91	31.96±6.85	0.010	28.01±4.11	29.35±6.74	0.229
mMDL	4.12±0.73	4.19±1.5	0.717	4.55±1.03	4.36±1.18	0.310
mMNCV	56.88±4.01	55.51±4.76	0.202	55.65±4.29	55.02±3.12	0.551
1st finger amp.	17.76±4.47	17.08±4.08	0.618	15.52±4.01	17.54±3.55	0.074
1st finger mSNCV1	28.32±4.51	31.03±5.36	0.006	26.32±4.5	27.81±5.37	0.057
2nd finger amp	17.62±4.71	15.57±4.06	0.053	15.71±4.42	16.6±3.87	0.400
2nd finger mSNCV	35.66±4.71	37.47±5.83	0.075	31.93±4.93	34.13±5.6	0.006
3rd finger Amp.	17.1±3.96	15.42±4.8	0.182	13.81±5.43	14.92±3.44	0.364
3rd finger mSNCV	34.86±5.58	37.01±6.38	0.062	30.75±5.35	32.66±5.97	0.017
5th finger mSNCV1	49.35±3.74	48.72±3.27	0.302	49.37±3.13	50.14±2.25	0.380
MR1	15.7±6.17	13.55±4.21	0.016	17.7±7.16	15.65±5.31	0.022
MR2	13.05±2.35	10.65±2.21	<0.001	13.4±4.58	11.65±3.99	0.006
MR3	16.4±6.37	14±4.23	0.002	15.75±7.08	14.5±5.15	0.093
MR4	15.05±3.88	12.73±2.52	<0.001	15.62±5.51	13.93±3.94	0.004

EMG: Electromyography; MR: Magnetic resonance; SD: Standard deviation; MR1: Pisiform bone level median nerve cross-sectional area; MR2: Hamate bone level median nerve cross-sectional area; MR3: Radiocarpal joint level median nerve cross-sectional area; MR4: (MR1+MR2+MR3)/3.

Electrophysiological parameters before the treatment and at follow-up three months later showed significant increases in phonophoresis group for sensory nerve conduction velocity of the first and third fingers ($p<0.05$). In ultrasound group, motor distal latency of median nerve decreased, amplitude of the first finger increased, and sensory nerve conduction velocity of the second and third fingers increased ($p<0.05$). MR parameters before and after treatment showed that all median nerve cross-sectional area measures significantly decreased in phonophoresis group, while significant decrease was observed for only two levels in ultrasound group ($p<0.05$). However, average of median nerve area measurements significantly decreased in both groups ($p<0.001$) (Table 3).

A comparison of before and after treatment EMG stages showed that EMG findings of seven patients completely disappeared in phonophoresis group, number of patients in moderate stage decreased from 12 to 9, and number of patients in mild stage decreased from 8 to 4. These changes were significant ($p<0.05$). Although EMG findings of three patients were obliterated in ultrasound group, changes in EMG findings of this group were not significant ($p>0.05$) (Table 4). Significant improvement was observed for clinical staging in both treatment groups ($p<0.05$). Clinical staging of five patients returned to normal in phonophoresis and ultrasound groups.

An evaluation of EMG staging together with MR findings in all patients showed that cross- sectional area at the entrance of median nerve into carpal tunnel and average of all measurements significantly increased in later stages of

Table 4. Change of EMG staging after treatment

Before treatment	Phonophoresis (n=20)							Ultrasound (n=20)						
	After treatment						p	After treatment						p
	No		Mild		Moderate			No		Present		Moderate		
	n	%	n	%	n	%		n	%	n	%	n	%	
EMG stage														
Mild	4	50	3	37.50	1	12.50	0.037	2	28.57	5	71.43	0	0	0.366
Moderate	3	25	1	8.33	8	66.67		1	8.33	1	8.33	11	83.33	

EMG: Electromyography; Marginal Homogeneity Test.

EMG ($p<0.05$). No significant change was observed for median nerve intensities before and after treatments in any group ($p<0.05$).

Discussion

Significant differences were observed in both phonophoresis and ultrasound groups for VAS and BCTQ scores. Although there was no significant difference before the treatment between the two groups, pain threshold and hand grip strength significantly improved in phonophoresis group. In contrast, hand grip strength decreased in ultrasound group.

Holding hand in neutral position would lead to optimal decrease in pressure and produce more benefit for alleviation of the symptoms.[14] There were different levels of benefit (31-67%) related to orthosis use in different studies.[14,15] It has been reported that use of orthosis especially for whole day could be an effective treatment method.[16] Orthosis use during both daytime and night was preferred for the patients in the present study.

Efficiencies of tendon and nerve gliding exercises are controversial.[17] Longitudinal excursion of median nerve could be improved through tendon gliding exercises, because these exercises allow gliding of flexor tendons which play significant role in elimination of adhesion formation.[8] Use of orthosis and exercise treatments together were reported to produce better improvement of hand grip strength.[18] However, another randomized study reported no difference with combined use of two methods.[17]

In phonophoresis group, improvements were observed in all patients who had been found to have motor deficit, while significant improvement was not observed in ultrasound group. In terms of clinical staging, significant improvements were found in both groups, but improvements in sensory deficit was observed only in phonophoresis group. Ultrasound, one of the physical therapy modalities, has long been used for treatment of tenosynovitis, epicondylitis, bursitis and osteoarthritis.[19] US is assumed to be an anti-inflammatory agent.[3] Dincer et al.[20] compared the efficiencies of orthosis use alone, continuous ultrasound (1.0 w/cm^2) plus orthosis use and laser plus orthosis use combinations, and found clinical and electrophysiological improvements in combined treatments. A study with placebo control, found clinical and electrophysiological improvements from different ultrasound doses. In addition, a slight decrease in nerve conduction velocity and an increase in distal latency were observed in ultrasound group. These effects were hypothesized to arise from the fact that ultrasound could cause a selective heating in peripheral nerves which in turn might lead to temporal conduction blocking in median nerve.[21] Weak evidence and limited amount of data indicated that therapeutic ultrasound is more effective than placebo in short and long term symptomatic recovery of patients with CTS.[22]

It was shown that phonophoresis with ketoprofen was more effective to alleviate pain in eighth week compared to ultrasound and orthosis use in treatment of CTS.[23] In the present study, median nerve conduction velocity of palm-wrist, the first and third fingers increased in phonophoresis group, while median nerve distal latency decreased and median nerve conduction velocity of the second and third fingers increased in ultrasound group. Electrophysiological parameters, on the other hand, improved in both groups. In terms of EMG staging, only phonophoresis group had significant improvements. Aygul et al.[24] evaluated the efficiency of phonophoresis using dexamethasone sodium phosphate in CTS treatment. They found significant improvements in follow-ups two months later for ulnar and median distal latency of the fourth finger, sensory median distal latency of the second finger and ulnar distal latency of the fifth finger. In a study where efficiency of phonophoresis using a gel containing MPS, flufenamic acid and salicylic acid combination was evaluated, heel pain of all patients decreased and did not recur for at least a year.[7]

Recently, imaging methods such as ultrasound and MR have been used for CTS diagnosis.[25] Median nerve cross- sectional area of patients in phonophoresis group significantly decreased in all MR measurements, while in ultrasound group decrease was observed only in hamate and pisiform levels. Median nerve cross-sectional area of CTS patients was 14.1 mm^2 in pisiform level and 13.3 mm^2 in hamate hook level. The same study reported the same areas as 10.9 and 9.1 mm^2, respectively, in healthy individuals.[26] Median nerve cross-sectional area in the present study was higher than that of healthy individuals, as well as in average of all measurements. In a recent study,[27] median nerve cross-sectional area in CTS patients was reported to be higher at all three levels (distal radioulnar 13.8-18.7 mm^2; proximal carpal tunnel 16.8-20.7 mm^2; distal carpal tunnel 10.2-13.9 mm^2) than that of control group (distal radioulnar 8.0-8.8 mm^2; proximal carpal tunnel 9.5-10.0 mm^2; distal carpal tunnel 8.8-9.7 mm^2). It was mentioned in the same study that median nerve signal intensity was elevated in CTS patients compared to control group and that this intensity could be a reliable imaging finding for the evaluation of CTS.[27] Similarly, median nerve intensities in MR imaging were elevated in 60% of CTS patients in the present study. Hyperintense signal change in T2 weighed series are MR findings of neuropraxia with mild nerve damage.[28] Nevertheless, Radack et al.[29] reported that elevated signal intensity in T2 weighed images was a non-specific finding in CTS since it was positive in 49% of asymptomatic individuals. In a study evaluating the effect of treatment on MR findings of CTS patients, signal intensity of median nerve weakened in carpal tunnel entrance region after one-week orthosis use or tendon-nerve gliding exercises, but no change was observed at more distal area.[30] Significant change was not observed in either group in the present study. EMG and MR findings were correlated in later stages of EMG because of increasing cross-sectional area of median nerve in later stages.

In conclusion, considering the clinical and laboratory outcomes of both treatment modalities, it could be concluded that MPS phonophoresis treatment is efficient and promising in CTS treatment.

Disclosures

Ethics Committee Approval: The Gaziosmanpasa University Clinical Research Ethics Committee granted approval for this study (date: 27.03.2014, number: 83116987-121).

Peer-review: Externally peer-reviewed.

Conflict of Interest: None declared.

Authorship Contributions: Concept – S.O., A.I., B.C., F.C.; Design – S.O., A.I., B.C., F.C.; Supervision – A.I., B.C., F.C.; Materials – S.O., A.I., B.C., F.C.; Data collection and/or processing – S.O., A.I., B.C., F.C.; Analysis and/or interpretation – S.O., A.I., B.C., F.C.; Literature search – S.O., A.I., B.C., F.C.; Writing – S.O., A.I., B.C., F.C.; Critical review – S.O., A.I., B.C., F.C.

Financial Disclosure: This work was supported by research fund of the Local University. Project Number: 2014/65.

References

1. Aroori S, Spence RA. Carpal Tunnel Syndrome. Ulster Med J. 2008;77:6–17.
2. Koyuncuoglu HR, Kutluhan S, Yesildag A, Oyar O, Guler K, Ozden A. The value of ultrasonographic measurement in carpal tunnel syndrome in patients with negative electrodiagnostic tests. Eur J Radiol 2005;56:365–369.
3. Gerritsen AA, de Krom MC, Struijs MA, Scholten RJ, de Vet HC, Bouter LM. Conservative treatment options for carpal tunnel syndrome: a systematic review of randomized controlled trials. J neurol 2002;249:272–280.
4. Keith MW, Masear V, Amadio PC, Andary M, Barth RW, Graham B et al. Treatment of carpal tunnel syndrome. JAAOS-Journal of the American Academy of Orthopaedic Surgeons 2009;17:397–405.
5. Bakhtiary AH, Fatemi E, Emami M, Maleak M. Phonophoresis of dexamethasone sodium phosphate may manage pain and symptoms of patients with carpal tunnel syndrome. Clin J Pain 2013;29:348–53.
6. Ay S, Doğan ŞK, Evcik D, Başer ÖÇ. Comparison the efficacy of phonophoresis and ultrasound therapy in myofascial pain syndrome. Rheumatol Int 2011;31:1203–8.
7. Deshpande MM, Patil CB. Heelpain and phonophoresis. J Indian Med Assoc 2010;108:365.
8. Wehbe MA, Hunter JM. Flexor tendon gliding in the hand. Part II. Differential gliding.J Hand Surg 1985;10:575–9.
9. Totten PA, Hunter JM. Therapeutic techniques to enhance nerve gliding in thoracic outlet syndrome and carpal tunnel syndrome. Hand Clin 1991;7:505–20.
10. de Carvalho Leite JC, Jerosch-Herold C, Song F: A systematic review of the psychometric properties of the Boston Carpal Tunnel Questionnaire. BMC Musculoskelet Disord 2006;7:78.
11. Levine DW, Simmons BP, Koris MJ, Daltroy LH, Hohl GG, Fossel AH et al. A self-administered questionnaire for the assessment of severity of symptoms and functional status in carpal tunnel syndrome. J Bone Joint Surg 1993;75:1585–92.
12. Sezgin M, Incel NA, Sevim S, Çamdeviren H, As İ, Erdoğan C. Assessment of symptom severity and functional status in patients with carpal tunnel syndrome: Reliability and functionality of the Turkish version of the Boston Questionnaire. Disabil Rehabil 2006;28:1281–6.
13. Aulisa L, Tamburrelli F, Padua R, Romanini E, Monaco ML, Padua L. Carpal Tunnel Syndrome; indication for surgical treatment based on electrophysiologic study. J Hand Surg 1998;23:687–91.
14. Burke DT, Burke MM, Stewart GW, Cambre A. Splinting for carpal tunnel syndrome: In search of the optimal angle. Arch Phys Med Rehabil 1994;75:1241–4.

15. Gerritsen AA, Korthals-de Bos IBC, Laboyrie PM, de Vet HCW, Scholten RJPM, Bouter LM. Splinting for carpal tunnel syndrome: prognostic indicators of success. J Neurol Neurosurg& Psychiatry 2003;74:1342–4.
16. Walker WC, Metzler M, Cifu DX, Swartz Z. Neutral wrist splinting in carpal tunnel syndrome; a comparison of night only vs full-time wear instruction. Arch Phys Med Rehabil 2000;81:424–9.
17. Akalin E, El Ö, Peker Ö, Senocak Ö, Tamci S, Gülbahar S et al. Treatment of carpal tunnel syndrome with nerve and tendon gliding exercises. Am J Phys Med Rehabil 2002;81:108–13.
18. Pinar L, Enhos A, Ada S, Güngör N. Can we use nerve gliding exercises in women with carpal tunnel syndrome? Adv Ther. 2005;22:467–75.
19. 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.
20. 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.
21. Oztas O, Turan B, Bora I, Karakaya MK. Ultrasound therapy effect in carpal tunnel syndrome. Arch Phys Med Rehabil 1998;79:1540–4.
22. Page MJ, O'Connor D, Pitt V, Massy-Westropp N. Therapeutic ultrasound for carpal tunnel syndrome. The Cochrane Library. 2013;28:CD009601.
23. Yildiz N, Atalay NS, Gungen GO, Sanal E, Akkaya N, Topuz O. Comparison of ultrasound and ketoprofen phonophoresis in the treatment of carpal tunnel syndrome. J Back Musculoskelet Rehabil 2011;24:39–47.
24. Aygül R, Ulvi H, Karatay S, Deniz O, Varoğlu AO. Determination of sensitive electrophysiologic parameters at follow-up of different steroid treatments of carpal tunnel syndrome. J Clin Neurophysiol 2005;22:222–30.
25. Horng YS, Chang HC, Lin KE, Gou YL, Liu DH, Wang JD. Accuracy of Ultrasonography and Magnetic Resonance Imaging in Diagnosing Carpal Tunnel Syndrome Using Rest and Grasp Positions of the Hands. J Hand Surg 2012;37:1591–8.
26. Beck JD, Jones RB, Malone WJ, Heimbach JL, Ebitt T, Klena JC. Magnetic resonance imaging after endoscopic carpal tunnel release. J Hand Surg 2013;38:331–5.
27. Cha JG, Han JK, Im SB, Kang SJ. Median Nerve T2 Assessment in the Wrist Joints: Preliminary Study in Patients With Carpal Tunnel Syndrome and Healthy Volunteers. J Magn Reson Imaging 2014;40:789–95.
28. Chhabra A, Andreisek G, Soldatos T, Wang KC, Flammang AJ, Belzberg AJ et al. MR neurography: past, present, and future. Am J Roentgen 2011;197:583–91.
29. Radack DM, Schweitzer ME, Taras J. Carpal tunnel syndrome: are the MR findings a result of population selection bias? Am J Roentgenol 1997;169:1649–53.
30. Schmid AB, Elliott JM, Strudwick MW, Little M, Coppieters MW. Effect of splinting and exercise on intraneural edema of the median nerve in carpal tunnel syndrome--an MRI study to reveal therapeutic mechanisms. J Orthop Res 2012;30:1343–50.