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Comparison of three conservative treatment protocols in carpal tunnel syndrome

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SUMMARY

The aim of this study was to investigate and compare the therapeutic effect of three different combinations in the conservative treatment of carpal tunnel syndrome (CTS) by means of clinical and electrophysiological studies. The combinations included tendon- and nerve-gliding exercises in combination with splinting, ultrasound treatment in combination with splinting and the combination of ultrasound, splinting, tendon- and nerve-gliding exercises. A total 28 female patients (56 wrists) with clinical and electrophysiologic evidence of bilateral CTS were studied. In all patient groups, the treatment combinations were significantly effective immediately and 8 weeks after the treatment. The results of the long-term patient satisfaction questionnaire revealed that symptomatic improvement is more prominent in the group treated with splinting, exercise and ultrasound therapy combination. Our results suggest that a combination of splinting, exercise and ultrasound therapy is a preferable and an efficacious conservative type of treatment in CTS.

Keywords: Carpal tunnel syndrome; conservative treatment; nerve-gliding exercises; tendon-gliding exercises; ultrasound treatment; splinting

INTRODUCTION

The carpal tunnel syndrome (CTS), caused by compression of the median nerve at the wrist, is considered to be the most common entrapment neuropathy (1). Symptoms of CTS include pain, paraesthesia, numbness or tingling involving the fingers innervated by the median nerve. Symptoms are worst at night and often wake the patient (2). To relieve the pressure on the median nerve, several treatment options, both surgical and conservative, are available (1). The benefit of non-surgical treatment seems to be limited, although not all patients respond to surgery (3–5). Surgical treatment's complications and failures have been shown to occur in 3–19% in large series, requiring re-exploration in up to 12% for a variety of causes (6–10). Advocates of early surgery refer to its safety and effectiveness in electrophysiologically confirmed cases with no underlying reversible disorder. In addition, they point out that conservative therapy generally offers only temporary symptom relief and that surgery is unnecessarily delayed, causing further damage to the median nerve (11). Advocates of initial conservative management of CTS, however, refer to the potential benefits and safety of conservative treatment options and the potential complications of surgery (12). The current conservative treatments include splints, activity modification, non-steroidal anti-inflammatory drugs, diuretics, pyridoxine, and local injection of corticosteroids. In addition, yoga, chiropractics, ultrasound and laser treatment have been advocated (1, 6–10). Splinting is the most popular method among the conservative treatments of CTS (7, 8, 11). Immobilization of the wrist in a neutral position with a splint maximizes carpal tunnel volume and minimizes pressure on the median nerve (1). There are conflicting results on the efficacy of therapeutic ultrasound in the treatment of CTS, and only a few studies reported the benefit of ultrasound in CTS treatment (1, 2, 12–14).

Of the many studies of conservative treatment of CTS, only a few has used exercise treatment. Tendon- and nerve-gliding exercises have been used particularly for the management of postoperative CTS (15), while only two studies in the literature has used tendon- and nerve-gliding exercises in conservative management of CTS. The value of these exercises in conservative management of CTS is not well understood (16, 17)

In this study, we used different combinations of ultrasound, splinting and tendon- and nerve-gliding exercises in the conservative management of CTS. These combinations included tendon- and nerve-gliding exercises in combination with splinting, ultrasound treatment in combination with splinting and the combination of ultrasound, splinting and tendon- and nerve-gliding exercises.

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The aim of this study was to investigate and compare the therapeutic effect of these three different combinations in the treatment of CTS by means of clinical and electrophysiological studies.

MATERIALS AND METHODS

Patients

The study was conducted at the outpatient clinic of the Department of Physical Medicine and Rehabilitation. A total 36 female patients with clinical and electrophysiologic evidence of CTS were studied. All patients had bilateral involvement, and they were right handed. The local ethics committee approved the study protocol. The aim and methods of the study were explained to all patients before their informed consent was given. Patients were excluded if they had secondary entrapment neuropathies, if they had been treated with ultrasound for the syndrome or if they had required regular analgesic or anti-inflammatory drugs. Patients found to have either clinical sign for axonal degeneration of the median nerve (thenar atrophy) or evidence of denervation (abnormal spontaneous activity in the form of fibrillations and positive sharp waves) on electromyographic examination of the abductor pollicis brevis muscle were excluded from the study. They were considered to have severe CTS and were referred for evaluation by a hand surgeon (18) Patients with a history of steroid injection into the carpal tunnel, thyroid disease, diabetes, systemic peripheral neuropathy, pregnancy, or splint use were excluded as well.

Computer-generated randomization list was created by a biostatistician. It was given to the physiotherapy department in sealed numbered envelopes. When the patients qualified to enter the study, appropriate numbered envelope was opened at the reception; the card inside indicated the patient's allocation to a treatment group.

Thirty-six patients (72 wrists) were randomly assigned to one of the three groups: group I ($n = 12$), who received splinting and exercise therapy, group II ($n = 12$), who received splinting and ultrasound therapy, and group III ($n = 12$), who received splinting, exercise and ultrasound therapy. Each patient received the same treatment protocol for both wrists. Twenty-eight patients (56 wrists) completed the study. The eight dropouts are described as follows: two patients (group II) underwent surgery, two patients (group II) were lost to follow-up. In group III, two patients were lost to follow-up, and another two patients (group III) refused electrophysiologic study due to improvement of symptoms.

Intervention

A custom-made neutral volar splint was given to patients in three groups. The patients were instructed to wear the splints all night and during the day for 3 weeks.

Ultrasound treatment was administered 15 min per session to the palmar carpal tunnel area at a frequency of 1 MHz and intensity of 1.0 W/cm^2, pulsed mode 1 : 4, with a transducer of 5 cm^2 (Electronica Pagani FP-942/S) and with aquasonic gel as the couplant. The apparatus was standardized initially, and the output was controlled regularly by a simple underwater radiation balance. A total of 15 ultrasound treatments were performed once a day, five times a week, for 3 weeks.

In the exercise groups, the patients were instructed to perform nerve-and tendon-gliding exercises developed by Totten and Hunter (15). Brochures describing exercises were also given to patients. During tendon-gliding exercises, the fingers were placed in five discrete positions. Those were straight, hook, fist, table top, and straight fist. During the median nerve-gliding exercise, the median nerve was mobilized by putting the hand and wrist in six different positions. During these exercises, the neck and the shoulder were in a neutral position, and the elbow was in supination and 90 degrees of flexion. Each position was maintained for 5 seconds. The exercises were applied as five sessions daily. Each exercise was repeated 10 times at each session. Exercise treatment was continued for 3 weeks.

Outcome Measures

Patients were included in our study according to subjective symptoms, physical examination, and electrophysiologic findings. Subjective symptoms were history of paresthesia or pain in the median nerve distribution, nocturnal pain, and dysesthesia. Physical examination included Tinel's test, Phalen's test, pain measurement, two-point discrimination test, and grip and pinch strength measurement. The staff who assessed the outcomes were different from the staff administering the treatments and were blinded to the type of treatment each patient had received. Pain measurement by means of a visual scale (VAS), on which the patients could indicate their assessment along a distance of 10 cm, ranging from 0 (no pain at all) to 10 (the most intense pain that I can imagine). Measurement of static two-point discrimination was performed on the pulp of the three radial digits, and the mean value was recorded. Hand-grip strength was measured with a handheld dynamometer and pinch strength measured with a standard dynamometer between the tips of the thumb and the little finger. The patients' positioning was standardized, and the average force of three consecutive trials was calculated. The dynamometers were initially standard, and their sensitivity was controlled regularly by standard weights.

Symptoms and functional status were evaluated by the symptom-severity scale and the functional status scale, respectively (19). The symptom-severity scale had 11 questions, and the functional status scale has eight questions. The answers were rated from 1 point (mildest pain or no difficulty with

activity) to 5 points (most severe pain or cannot perform activity at all).

All electroneurographic measurements were performed with a commercially available EMG recorder (MEM-4200K, Neuropack 8, Nihon-Kohden, Tokyo, Japan). Median motor nerve conduction and distal motor latency were measured with a bipolar stimulating electrode at the wrist and a bipolar surface-recording electrode placed on the abductor pollicis muscle 7 cm from stimulus electrodes at the wrist. The active electrode was placed halfway between the metacarpophalangeal joint of the thumb and the midpoint of the distal wrist crease; hence, the recorded site was same for all recording sessions. Antidromic sensory nerve action potentials evoked at the wrist were recorded from middle finger, with surface ring electrodes placed around the proximal and distal interphalangeal joints. A standard distance (13 cm) was maintained between the stimulator and recording electrodes. At least 20 sensory nerve action potentials were averaged, and antidromic sensory nerve latencies were calculated as appropriate. A comparison with the ulnar nerve in the same hand was done in every case. Needle electromyography was performed on the abductor pollicis brevis muscle by using a bipolar needle electrode. Denervation was defined as sustained, abnormal spontaneous activity in the form of positive waves or fibrillations ranging from 0 to 4+. The skin temperature of the forearm and wrist were kept at 32–33 °C during all treatments.

All measurements were performed before the first treatment session, at the end of therapy, and after 8 weeks follow-up to compare the effects of the three treatment protocol. At the final follow-up, the patients were called by telephone, and their satisfaction was evaluated. Results were considered excellent if a patient is asymptomatic, good: rarely symptomatic, fair: symptomatic only during compelling activity and poor: continuing symptoms (without relief following treatment). Patients' satisfaction investigation was performed at an average of 11 $\pm$ 4.5 month.

Statistics

The means and standard deviations were calculated for all subjects in each group for each parameter. In each group, measurable parameters were tested with Kolmogorov–Smirnov test for evaluation of normal distribution. Because the distributions were not normal, non-parametric tests were used in statistical evaluation ($p > 0.05$). Kruskal–Wallis variance analysis was used to compare the measurable parameters before treatment. Wilcoxon and McNemar tests (discrete variables) were used to compare the parameters of each group before and after treatment. To compare the treatment groups (group I, group II and group III), Kruskal–Wallis variance analysis and Mann–Whitney *U*-tests were used. Pearson χ^2 test was used to evaluate the results of patient satisfaction questionnaire. $p < 0.05$ was considered statistically significant.

RESULTS

Baseline Evaluation

Twenty-eight patients with bilateral CTS (56 wrists) fulfilled all inclusion criteria. Twenty-four wrists treated with splinting and exercise (group I), 16 wrists treated with splinting and ultrasound therapy (group II), 16 wrists treated with splinting, exercise and ultrasound therapy (group III) completed a 3-week treatment protocol and 8-week follow-up period.

Demographic characteristics and clinical features of three groups before treatment are summarized in Table 1. No significant difference was seen between the groups regarding all clinical and electropyhsiological parameters.

Effect of Treatment

The comparison of mean values of variables in three groups, before treatment, after end of the treatment and after 8 weeks follow-up are summarized in Table 2. Table 3 summarizes the mean changes in measurements at the end of the treatment and also at 8 weeks follow-up. There were not significant differences in mean changes of all measures between the groups.

Physical Findings

Measures of tinel's sign, phalen's sign, showed significant improvement in three groups, at the end of the treatment and also at 8 weeks follow-up ($p < 0.05$), Table 2.

Measures of grip strength and pinch strength showed significant improvement in all groups at 8 weeks follow-up ($p < 0.05$), Table 2.

A significant improvement was not recorded in two-point discrimination in three groups (Table 1).

Pain

There was a significant improvement in pain at the end of the treatment and also at 8 weeks follow-up in all groups ($p < 0.05$).

Symptoms and functional status. There was significant improvement in functional status score and symptom-severity score at the end of the treatment and at 8 weeks follow-up in all groups ($p < 0.05$).

The patient satisfaction questionnaire results are summarized in Table 4. The results of group III were better than the other groups ($p < 0.05$).

Table 1 Demographic data and baseline characteristics of patiens in three experimental groups

Variable	*Treatment groups*		
	Group I	Group II	Group III
Number of wrist	24	16	16
Age, year (mean ± SD)	47.8 ± 5.5	50.1 ± 7.3	51.4 ± 5.2
Type of work (n,%)			
Housewive	11 (91)	8 (100)	7 (87)
Clerk	1 (9)	0	1 (13)
Body mass index	30.5 ± 6.9	29.7 ± 2.5	28.4 ± 5.0
Duration of symptoms, year (mean ± SD)	1.5 ± 1.6	1.4 ± 0.8	1.4 ± 0.8
Pain (Visual analogue score/10)	4.8 ± 2.9	5.1 ± 2.7	5.6 ± 3.5
Tinel's sign, positive (n,%)	20 (83.3)	13 (81.3)	11 (68.8)
Phalen's sign, positive (n,%)	20 (83.3)	13 (81.3)	13 (81.3)
2-point discrimination (mean ± SD)	3.9 ± 1.7	3.3 ± 1.3	3.9 ± 0.6
Hand grip strength (mean ± SD)	20.6 ± 7.1	20.7 ± 10.1	20.7 ± 5.5
Pinch strength (mean ± SD)	4.9 ± 2.5	4.3 ± 2.2	5.6 ± 1.4
Functional status score (mean ± SD)	20.6 ± 7.9	21.9 ± 9.1	20.5 ± 7.1
Symptom severity score (mean ± SD)	28.0 ± 9.7	29.6 ± 9.7	30.4 ± 12.1
MDL, ms (mean ± SD)	4.9 ± 1.5	4.7 ± 1.0	4.9 ± 1.9
SDL, ms (mean ± SD)	3.5 ± 0.5	3.5 ± 0.6	4.0 ± 0.9

MDL, motor distal latency; SDL, sensory distal latency.

Electroneurography

The results of electroneurography are summarized Table 2 and Table 3. Median sensory distal latency (SDL) significantly decreased in group I and group III at the end of the treatment and also at 8 weeks follow-up ($p < 0.05$). A significant improvement was not recorded in median motor distal latency (MDL) in three groups at the end of the treatment and at 8 weeks follow-up ($p > 0.05$).

Patients' work status is summarized in Table 1. A total of 11 (91%) patients in group I, eight (100%) patients in group II and seven (87%) patients in group III were homemakers.

DISCUSSION

There are variable symptoms associated with CTS. Most of these symptoms are probably due to median nerve compression at the wrist, but the variability of some symptoms suggest alternative aetiologies. Patients with CTS often complain with hand and arm pain and other sensory disturbances (13). CTS has the potential to substantially limit performance of activities of daily living for some individuals (20). The pathophysiology involves a combination of mechanical trauma and ischemic injury to median nerve within the carpal canal (21). This syndrome occurs most commonly in adults older than 30 years, particularly women and involves compression of the median nerve at the wrist, affecting both sensory and motor branches (13). The hand-intensive nature of housework and typing may contribute to higher incidence in women (22). Similarly, all patients in our study were over 30 years old, hand-intensive housewives and computer-using clerks.

To relieve the pressure on the median nerve (directly or indirectly), several treatment options, both surgical and conservative, are available (1).

There is no consensus with regard to the choice of initial treatment for CTS. The American Academy of Neurology advises non-invasive treatment first, i.e. wrist splints, modification of activities, NSAIDs or diuretics and using invasive steroid injections or open carpal tunnel release only if non-invasive treatment have turned out to be ineffective (23). Even though surgery for CTS is generally considered safe and effective, the possible risk associated with surgery and the potential for complications may contribute to the preference of some patients for non-surgical treatment (20). A lot of studies have been published concerning the efficacy of conservative treatment in CTS. The treatment choice seems controversial. There are some studies reporting the conservative treatment of CTS as ineffective (8, 24–27); however, some researchers suggested that CTS could be treated without surgery (6, 9, 16). A population-based study of CTS showed that approximately 40% of conservatively treated patients with CTS continued to experience symptoms after 30 months (27). Katz et al. reported that approximately 60–70% of conservatively managed patients remained symptomatic after 18 months (24). Kaplan et al. tried to define more accurately those patients likely to respond to non-surgical treatments by identifying five risk factors: patient age greater than 50 years, the presence of symptoms for 10 months or more, constant paresthesias, the presence of associated trigger fingers and/or positive results of phalen's test after 30s or less. In a study of

Table 2 Comparison of mean values of variables in three groups, before treatment, after end of the treatment and after 8 weeks follow-up

	Group I (mean ± SD)	*Group II (mean ± SD)*	*Group III (mean ± SD)*
Pain			
Before T	4.8 ± 2.3	5.7 ± 2.7	5.6 ± 3.5
After T I	3.3 ± 2.9*	2.2 ± 1.9*	1.3 ± 1.8*
After T II	2.6 ± 2.8†	2.5 ± 2.8†	0.8 ± 0.9†
Tinel's sign, positive, n (%)			
Before T	20 (83.3)	13 (3,81)	11 (8,68)
After T I	12 (50)*	5 (3,31)*	5 (3,31)*
After T II	7 (29.1)†	5 (3,31)†	1 (3,6)†
Phalen's sign, positive, n (%)			
Before T	20 (3,83)	13 (3,81)	13 (3,81)
After T I	11 (8,45)*	6 (5,37)*	7 (7,43)*
After T II	11 (8,45)†	5 (3,31)†	5 (3,31)†
2-point discrimination			
Before T	3.9 ± 1.6	3.3 ± 1.3	3.9 ± 0.6
After T I	3.7 ± 1.4	3.7 ± 1.0	3.3 ± 0.9
After T II	3.9 ± 1.7	3.8 ± 1.3	3.3 ± 1.1
Hand grip strength			
Before T	20.5 ± 7.1	20.6 ± 10.1	20.7 ± 5.5
After T I	21.1 ± 7.0	21.8 ± 9.7	21.7 ± 4.9
After T II	22.7 ± 7.4 †,‡	23.5 ± 2.6 †,‡	22.3 ± 5.1 †,‡
Pinch strength			
Before T	4.9 ± 2.5	4.3 ± 2.2	5.6 ± 1.4
After T I	5.6 ± 1.8	5.0 ± 2.4	6.3 ± 2.1
After T II	6.3 ± 1.7†,‡	5.7 ± 2.3†,‡	7.0 ± 2.2†,‡
Functional status score			
Before T	20.6 ± 7.8	21.9 ± 9.1	20.5 ± 7.1
After T I	14.8 ± 7.5*	16.1 ± 8.5*	11.7 ± 3.6*
After T II	14.9 ± 6.6†	16.1 ± 8.7†	12.6 ± 3.4†
Symptom severity score			
Before T	28.0 ± 9.7	29.6 ± 9.7	30.4 ± 12.1
After T I	19.7 ± 8.7*	17.1 ± 7.9*	16.1 ± 4.8*
After T II	20.2 ± 10.4†	19.1 ± 9.4†	15.6 ± 4.7†
MDL			
Before T	4.9 ± 1.5	4.7 ± 1.0	4.9 ± 1.9
After T I	4.8 ± 1.6	4.6 ± 0.8	4.6 ± 2.0
After T II	4.8 ± 1.4	4.5 ± 0.5	4.6 ± 2.3
SDL			
Before T	3.5 ± 0.5	3.4 ± 0.6	4.0 ± 0.9
After T I	3.3 ± 0.4*	3.4 ± 0.7	3.5 ± 0.6*
After T II	3.3 ± 0.5†	3.3 ± 0.6	3.5 ± 0.5†

MDL, motor distal latency, SDL, sensory distal latency, Before T, before treatmet, After T I, after end of the treatment, After T II, after 8 weeks follow-up.
*$p < 0.05$ comparison of the before T and After T I.
†$p < 0.05$ comparison of the before T and After T II.
‡$p < 0.05$ comparison of the After T I and After T II.

331 subjects with CTS, Kaplan's patients were treated with splints and anti-inflammatory agents, either with oral NSAIDs (65%) or intracanal corticosteroid injection (16%) or both, and were considered cured if their symptoms resolved for at least 6 months. Approximately 60% of patients were cured without surgery if they had only one risk factor, but 93% of those with three factors and 100% of those with four or more risk factors had unsuccessfully non-operative management (25). Regarding these risk factors, our patients mean age was over 50 years, and the duration of symptoms was over 10 months, but none of them had trigger fingers. The other possible reason for the favourable results obtained in our study could be the absence of thenar atrophy in these patients (17).

In general, conservative treatment options in patients with mild and moderate CTS have been considered as an interim measure in patients waiting to undergo surgery. Therefore, a Cohrane literature review (28) for randomized trials that compared surgical with non-surgical treatment of CTS

Table 3 The mean changes in measurements in three groups at the end of the treatment and at 8 weeks follow-up

	Group I [mean (SD)]	*Group II [mean (SD)]*	*Group III [mean (SD)]*
Pain			
Before T − after T I	−1.5 (2.7)	−2.9 (2.7)	−4.3 (3.1)
Before T − after T II	−2.2 (3.4)	−2.5 (2.5)	−4.5 (3.0)
After T I − after T II	NS	NS	NS
Functional status score			
Before T − after T I	−5.8 (7.1)	−5.8 (7.8)	−8.8 (5.6)
Before T − after T II	−6.3 (7.1)	−5.8 (7.2)	−8.2 (5.2)
After T I − after T II	NS	NS	NS
Symptom severity score			
Before T − after T I	−8.2 (10.0)	−12.5 (7.8)	−14.2 (9.6)
Before T − after T II	−7.8 (10.7)	−10.5 (6.8)	−14.4 (9.4)
After T I − after T II	NS	NS	NS
Hand grip strength			
Before T − after T I	NS	NS	NS
Before T − after T II	2.5 (4.5)	2.9 (4.9)	1.8 (3.6)
After T I − after T II	1.9 (2.7)	1.6 (2.5)	1.0 (1.7)
Pinch strength			
Before T − after T I	NS	NS	NS
Before T − after T II	1.5 (2.1)	1.5 (1.6)	1.4 (2.0)
After T I − after T II	0.8 (0.9)	0.6 (1.4)	0.9 (0.7)
MDL			
Before T − after T I	NS	NS	NS
Before T − after T II	NS	NS	NS
After T I − after T II	NS	NS	NS
SDL			
Before T − after T I	−0.2 (0.3)	NS	−0.5 (0.4)
Before T − after T II	−0.2 (0.2)	NS	−0.3 (0.3)
After T I − after T II	NS	NS	NS

NS, non-significant.

Table 4 Results of patients' satisfaction questionnaire at follow-up

	Group I [n (%)]	*Group II [n (%)]*	*Group III [n (%)]*
Excellent/good	–	3 (25.0)	8 (61.5)
Fair	10 (58.8)	8 (66.7)	5 (38.5)
Poor	7 (41.2)	1 (8.3)	–

included only one article (29). This study demonstrated significant clinical improvement in electromyography and symptoms reported at 1 year for surgical release over splinting with a cohort of 22 women. More recently, Gerritsen et al. published a second randomized study of surgical release vs. splinting in 176 patients with moderate CTS, defined by clinical and electrophysiological testing (30, 31). Surgical patients had greater improvement in the number of nights waking up due to symptoms, and severity of symptoms, as well as on a general improvement scale. However, the evidence is less clear for patients with a shorter duration of symptoms or the use of conservative therapies other than splinting, such as physical therapy and ultrasound (1, 31). Among the conservative treatment, splinting the wrist in a neutral position will help reduce and may even completely relieve CTS symptoms (32). There are many studies stressing the effectiveness of neutral angle wrist splinting in CTS. An initial trial of full-time splinting for 3–4 weeks followed by part-time night splinting is recommended similar to full-time splinting for 3 weeks in our study groups (33, 34).

Ultrasound is assumed to have thermal effects on the target tissue resulting in an increase in blood flow, local metabolism and tissue regeneration and also reducing inflammation, oedema and pain, thereby facilitating the recovery of nerve compression (1). Numerous clinical studies described the effectiveness of ultrasound in relieving pain of different types of musculoskeletal disease (35–37). However, few studies report the benefit of ultrasound treatment in the CTS under clinical conditions (12).

The underlying mechanism of tissue regeneration by ultrasound is not clear (13, 38, 39). Szumski (40) summarized the effects of ultrasound on nervous tissue as follows: it selectively heats peripheral nerves, may alter or block impulse conduction and may increase membrane permeability and tissue metabolism. He pointed out that any of the above-mentioned mechanisms may be due to the thermal effect of ultrasound

and may cause pain relief. There is an inverse relationship between fibre size and sensitivity to ultrasound: the smallest C fibers are more sensitive, and the larger A fibers are less affected. This selective absorption by smaller fibers may allow a decrease in pain transmission (13, 41). In our study, both the improvement seen in SDL of group I and III (splinting and tendon and nerve gliding exercise treatment group) and absence of improvement in SDL of group II (splinting and ultrasound group) made us think that exercise has effect on nerve conductivity of A fibers, while ultrasound does not have this effect.

Ultrasound could elicit anti-inflammatory and tissue-stimulating effects, as already shown in clinical trials (2, 36, 42) and experimentally. In this way, ultrasound has the potential to accelerate normal resolution of inflammation. The results of these studies confirm that ultrasound may accelerate the healing process in damaged tissues. These mechanisms may explain our findings including pain relief, increased grip and pinch strength, improvement in functional status and symptom-severity scale in CTS patients treated with ultrasound.

Tendon- and nerve-gliding exercises have been mostly used in the postoperative CTS (15, 43, 44). Totten and Hunter (15) proposed a series of exercises enhancing the gliding of the median nerve at the carpal tunnel for management of post-operative CTS. They also suggested these exercises for non-operative CTS. Szabo et al. (43) showed that the relationship between median nerve and flexor tendon excursion was consistently linear. They suggested active finger motion of the median nerve and flexor tendons in the vicinity of the wrist to prevent adhesion formation even if the wrist is immobilized. Seradge et al. (44) demonstrated that intermittent active wrist and finger flexion-extension exercises reduce the pressure in the carpal tunnel. Tendon- and nerve-gliding exercises may maximize the relative excursion of the median nerve in the carpal tunnel and the excursion of flexor tendons relative to one another (45).

Of the many studies of conservative treatment of CTS, only two have used exercise treatment (16, 17). Rozmaryn et al. have used nerve- and tendon-gliding exercises in conservative treatment models to decrease adhesions developed in the carpal tunnel and regulate venous return in the nerve bundles. They reviewed more than 200 hands under consideration for carpal tunnel decompression. Altogether 71% of the patients who were not offered gliding exercises went forward to surgery; only 43% of the gliding exercise group were felt to require surgery. Although they had a large number of patients and a long follow-up period, their control group's treatment was not standardized (16). Throughout the extremity movement, mobility of the peripheral nerve changes and longitudinal movement of the median nerve mostly occur in the carpal tunnel. In CTS, this physiologic mobility of the median nerve disappears (46). During the exercise, there may be redistribution of the point of maximal compression on the median nerve. This milking effect would promote venous return from the median nerve, thus decreasing the pressure inside the perinerium (45). Akalin et al. compared the group of wrist splint alone to the group with wrist splint in combination with nerve- and tendon-gliding exercises for the efficacy of the treatment. They reported significant improvement in clinical parameters, functional status scale and symptom-severity scale in both groups. They also reported significant improvement only in pinch strength in the group with wrist splint in combination with exercises compared with the wrist splint group (17). Similar to these two studies, we gave nerve- and tendon-gliding exercises to some of our patients including group I and group III.

The clinical parameters, indicating the efficacy of treatment, included pain, tinel's sign, phalen's sign, functional status scale and symptom-severity scale. In all our patient groups, we observed significant improvement in all these clinical parameters, excluding two-point discrimination. In all patients, two-point discrimination test results were measured less than 6 mm (normal sensation) before and after treatment, without significance. This result was assessed normal, since the two-point discrimination is only found in more severe cases and rarely in the early stages of CTS (21).

Regarding all parameters studied, there was no significant difference between the groups. In all groups, we observed that the efficacy of the treatment had begun just after end of the treatment and continued up to control at the 8th week. In terms of hand-grip strength and pinch strength parameters, the efficacy of treatment was observed in the control at the 8th week.

Regarding electrophysiologic study results, there was significant improvement on the SDL in groups I and III, but there was no significant improvement in MDL after treatment in all three groups. Naeser et al. (18) studied the effect of low-level laser and microamperes transcutaneous electric nerve stimulation on CTS pain and reported significant decrease in SDL and no change in MDL in real treatment group in the 1st week of the treatment. We also think that the post-treatment nerve conduction studies (NCSs) may have been obtained early before treatment (within 8 weeks) to show any effect on the motor latencies (18). For example, Harris et al., who obtained follow-up NCSs in CTS cases who had undergone surgical release of the transverse carpal ligament, observed that 'often a disturbance of conduction remained well past the time that objective and subjective complaints were cleared.' In the Harris study, patients with motor abnormalities had a more favourable result postsurgery than those with only sensory abnormalities. Often, there was a delay of 2–6 months or more before improvement, or a return to normal was observed on the NCSs. In every instance in which postoperative NCSs were done, there was rapid subjective improvement of postsurgery; however, the delay in improvement of the conduction velocity suggested that the

reperative process in the nerves was slower. Harris did not have an explanation for this delay but suggested that, post-surgery, an ischemic process may be relieved in some fibers, and some other nerve fibers are slower in their recovery (47).

The major limitation of our study is the design, having a small number of patients. We think it is better to make clinical and electrophysiological studies in the long-term follow-up instead of patient satisfaction questionnaire to decrease subjectivity. The reason why we made satisfaction questionnaire is the patient refusal due to disturbing effect of electrophysiological studies. However, there are methodologic strengths of our study. These include the prospective, randomized design, the use of valid, standard measures, the evaluation of the functional status of patients, and we also could evaluate the electrophysiologic efficacy of our treatment methods.

The result of this study emphasizes the efficacy of conservative treatment in CTS. In all patient groups, the treatment combinations were significantly effective immediately and 8 weeks after the treatment.

Long-term results obtained by the patient satisfaction questionnaire revealed that splinting, exercise and ultrasound therapy combination is more favourable compared with other combinations. Overall, our results suggest that a combination of splinting, exercise and ultrasound therapy is a preferable and an efficacious conservative type of treatment in CTS.

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