Original Article

DOI: 10.14235/bas.galenos.2024.38981
Bezmialem Science 2024;12(3):309-16

The Effects of Orthosis and Exercise on The Median Nerve Morphology and Functional Status of Patients with Carpal Tunnel Syndrome: A Randomized Pilot Study

Karpal Tünel Sendromlu Hastalarda Ortez ve Egzersizin Medyan Sinir Morfolojisi ve Fonksiyonel Durum Üzerine Etkisi: Randomize Pilot Çalışma

Hakan AKKAN[1], Meltem IŞINTAŞ ARIK[2], Mehmet KORKMAZ[3], Sibel CANBAZ KABAY[4], Hasan Hüseyin GÖKPINAR[5]

[1]Kütahya Health Sciences University, Tavşanlı Vocational School of Health Services, Department of Therapy and Rehabilitation, Kütahya, Türkiye
[2]Kütahya Health Sciences University Faculty of Health Sciences, Department of Physiotherapy and Rehabilitation, Kütahya, Türkiye
[3]Kütahya Health Sciences University Faculty of Medicine, Department of Radiology, Kütahya, Türkiye
[4]Dokuz Eylül University Faculty of Medicine, Department of Neurology, İzmir, Türkiye
[5]Kütahya Health Sciences University Faculty of Medicine, Department of Physical Medicine and Rehabilitation, Kütahya, Türkiye

ABSTRACT

Objective: This study aimed to investigate the effects of orthosis, and additional nerve and tendon gliding exercises (NTGE) on median nerve morphology and functional status in patients with mild-to-moderate carpal tunnel syndrome (CTS) and to compare the effectiveness of proposed treatments.

Methods: Twenty-seven wrists of 19 patients with mild-to-moderate CTS were included in the study. They were randomized into three groups: neutral wrist orthosis alone (n=8), the combination of the orthosis with nerve gliding exercises (NGE) (n=10), and the combination of the orthosis with nerve/tendon gliding exercises (n=9). The cross-sectional area (CSA) of the median nerve (ultrasonography) and functional status (Boston carpal tunnel syndrome questionnaire and patient-specific functional scale) were evaluated at baseline and after six weeks of treatment.

Results: While the functional status of all groups improved significantly ($p<0.05$), the CSA of the median nerve significantly decreased in the combination of the orthosis with NGE group ($p<0.05$). However, there were no significant differences between the treatment groups in relation to the improvement in the intraneural edema and the functional status ($p<0.05$).

ÖZ

Amaç: Bu çalışmanın amacı, hafif-orta şiddette karpal tünel sendromlu (KTS) hastalarda ortez ile orteze ek sinir ve tendon kayma egzersizlerinin (STKE) medyan sinir morfolojisi ve fonksiyonel durum üzerindeki etkilerini araştırmak ve önerilen tedavilerin etkinliğini karşılaştırmaktır.

Yöntemler: Hafif-orta derecede KTS'li 19 hastanın 27 el bileği çalışmaya dahil edildi. Hastalar üç gruba ayrıldı: nötral el bileği ortezi grubu (n=8), ortez ile SKE grubu (n=10) ve ortez ile STKE (n=9). Medyan sinirin enine kesit alanı (ultrasonografi) ve hastaların fonksiyonel durumu (Boston karpal tünel sendromu anketi ve hastaya özgü fonksiyonel ölçek) tedavi öncesinde ve altı haftalık tedavi sonunda değerlendirildi.

Bulgular: Tüm grupların fonksiyonel durumu anlamlı şekilde iyileşirken ($p<0,05$), medyan sinirin kesit alanı ortez ile NGE kombinasyonu grubunda anlamlı şekilde azaldı ($p<0,05$). Ancak, intranöral ödem ve fonksiyonel durumdaki iyileşme açısından tedavi grupları arasında anlamlı bir fark yoktu ($p>0,05$).

Sonuç: Altı haftalık ortez tedavisine ek olarak verilen STKE KTS'li hastaların semptomlarını ve fonksiyonel durumunu iyileştirmede

Address for Correspondence: Hakan Akkan, Kütahya Health Sciences University, Tavşanlı Vocational School of Health Services, Department of Therapy and Rehabilitation, Kütahya, Türkiye
E-mail: hakan.akkan@ksbu.edu.tr **ORCID ID:** orcid.org/0000-0001-7920-1128

Cite this article as: Akkan H, Işıntaş Arık M, Korkmaz M, Canbaz Kabay S, Gökpınar HH. The Effects of Orthosis and Exercise on The Median Nerve Morphology and Functional Status of Patients with Carpal Tunnel Syndrome: A Randomized Pilot Study. Bezmialem Science. 2024;12(3):309-16

Received: 07.08.2023
Accepted: 27.02.2024

ABSTRACT

Conclusion: The 6-week orthotic treatment and additional NTGE could be effective in improving the patient's symptoms and functional status. However, the combination of a 6-week orthotic treatment and NGE could be effective in reducing intraneural edema.

Keywords: Carpal tunnel syndrome, diagnostic imaging, exercise therapy, ultrasonography, splints

ÖZ

etkili olabileceği bulunmuştur. Bununla birlikte, 6 haftalık ortez tedavisi ve SKE kombinasyonu intranöral ödemi azaltmada olabileceği tespit edilmiştir.

Anahtar Sözcükler: Karpal tünel sendromu, tanısal görüntüleme, egzersiz tedavisi, ultrasonografi, splintler

Introduction

Carpal tunnel syndrome (CTS) is the most common entrapment neuropathy in the upper extremity (1). Compression and/or irritation of the median nerve at the carpal tunnel level causes CTS. Elevated carpal tunnel pressure is responsible for the nerve's compression and/or irritation. High pressure inside the tunnel causes ischemia by affecting intraneural blood circulation (2). Prolonged ischemia leads to intraneural edema and ultimately causes intra/extra-neural fibrotic changes (3). Therefore, the median nerve can adhere to surrounding tissues, and the excursion of the nerve can reduce (4). Long-lasting ischemia also results in focal demyelination and axonal degeneration in the later stages of the disease. These pathophysiological processes are accepted as possible mechanisms for developing CTS symptoms (3).

The goals of CTS treatment are decreasing symptoms and improving hand function. Surgical treatment is superior to non-surgical treatments in improving function and reducing symptoms in six months. However, no strong evidence is found for the 12-month results (5). Surgery costs are high, and non-surgical treatments' side effects are low. Therefore, non-surgical treatments stand out as the first treatment option (6). Non-surgical treatments include patient education, orthosis (customized volar or dorsal thermoplastic orthoses, prefabricated off-the-shelf orthoses), therapeutic exercise, biophysical agents, and manual therapy techniques (7). Nocturnal orthosis is the most frequently used intervention for CTS by hand therapists. Besides, hand therapists often prefer tendon gliding exercises and nerve mobilization (8). These exercises can help reduce tenosynovial edema, improve venous return, and relieve pressure inside the carpal tunnel (9). Generally, combinations of these interventions can be prescribed in clinical practice. However, a limited number of studies have investigated the effects of these treatments on median nerve morphology (10-12). Most of the studies focused on the effects of orthosis and exercises on the function and symptoms of CTS patients (13-15). Moreover, the results are controversial. Because of these controversies and the lack of studies investigating changes in the intraneural edema of the median nerve in patients with CTS, further studies seem necessary. Therefore, this randomized study examined the short-term effects of orthosis when used alone or along with nerve gliding exercises (NGE) or nerve and tendon gliding exercises (NTGE) on the morphology of the median nerve and the functional status of CTS patients.

Methods

A pilot randomized trial was conducted in the electrodiagnostic medicine laboratory of Kütahya Health Sciences University from May 2017 to December 2018. The clinical research Ethics Committee of Kütahya Dumlupınar University approved the study (decision no: 2017-4/2, date: 22.03.2017).

Randomization was performed using an online computer program (http://www.randomizer.org accessed: April 23, 2017). Participants were randomly allocated into either orthosis (control) or orthosis + NGE, or orthosis + NTGE groups at a 1:1 allocation ratio. Both hands were included in the same treatment group for those with bilateral symptoms. Participants and the physiotherapist who delivered the treatment couldn't be blinded to the intervention. When the study was conducted, no previous study provided data on the cross-sectional area (CSA) of the median nerve after exercise and orthotic device. Therefore, a convenient sample was used. Participants signed written informed consent before their inclusion. All measurements were performed at baseline and after six weeks of intervention.

Inclusion criteria were as follows; being between the ages of 18-65 years; having clinical diagnosis (electrophysiologically confirmed) of mild-to-moderate CTS with a minimum of 2 months duration of symptoms and referred to physical therapy. Exclusion criteria were as follows; severe electrodiagnostic findings; pregnant women; comorbidities associated with CTS (rheumatoid arthritis, thyroid disease, renal insufficiency, and diabetes); diagnosis of cervical radiculopathy or osteoarthritis of the wrist or hand; history of any trauma to wrist or hand; previous surgery or injection to affected hand for CTS; prior conservative therapy for CTS in the past three months (splints or exercises or any electrophysical modalities); clinical diagnostic test score <12 (CTS-6) (16); the CSA of the median nerve at carpal tunnel inlet <10 mm^2 (17); unable to understand and speak Turkish.

Outcome Measurement

A technician (specialized in electrophysiologic study) performed NCS with the Nicolet Viking Select system device (Nicolet Biomedical Inc. Madison, USA). All hands below a temperature of 32 °C were warmed before electrodiagnostic testing. Sensory and motor NCS of the median and ulnar nerves were performed. The severity of CTS was graded as mild, moderate, and severe, according to NCS. Prolonged sensory latencies (<50 m/s) with normal motor studies were considered mild CTS. Abnormal

median sensory latencies and prolongation of median motor distal latency (≥4.2 ms) were considered moderate CTS. Severe CTS was defined as an absent or low-amplitude sensory nerve action potential and a low-amplitude or absent thenar compound muscle action potential (18). The same technician performed all NCS.

After NCS, a radiologist with over ten years of experience in musculoskeletal ultrasound measured the CSA of the median nerve with a 7-12 MHz linear-array probe (Aplio 500, Toshiba, Otawara, Japan). The patients sat in a chair with their forearms on the table and facing the radiologist during the ultrasonographic measurements. The forearm of the patient was in supination position while the wrist was in neutral position, and the fingers were in the resting position (metacarpophalangeal and interphalangeal joints in semi-flexion). The probe was placed at the distal palmar wrist crease just proximal to the level of the pisiform to obtain the cross-sectional images of the median nerve. To collect reliable images, a single radiologist took a single image at the pisiform level and analyzed this image once (19). The same radiologist performed all ultrasonographic measurements.

Then, a physiotherapist with ten years of experience in musculoskeletal physiotherapy performed a clinical evaluation with the CTS-6 diagnostic instrument. CTS-6 is a diagnostic tool that helps make a clinical diagnosis by combining history and physical examination findings. A total score of ≥12 points is considered positive-CTS (16).

The patient's functional status and symptoms were assessed using the Boston carpal tunnel syndrome questionnaire (BCTSQ), a self-reported questionnaire (20), and validated for the Turkish language (21). It consists of symptom severity scale (SSS) and functional status scale (FSS). The SSS, which includes 11 questions, evaluates symptoms. The FSS, which contains eight items, assesses difficulties in the activities of daily living. Each scale uses a 5-point Likert scale to generate a final score in the range of 1-5 (the sum of the individual scores divided by the number of items). The higher the score, the greater the disability.

The patient-specific functional scale (PSFS) was developed to evaluate the patient's functional limitations with activities determined by them (22). It allows the patients to identify their difficulty performing activities and rate their difficulty on a numerical scale. PSFS is valid and reliable in upper extremity nerve injuries (23).

All participants included in the study took part in a brief patient education session lasting ~20 minutes after clinical evaluation. The physiotherapist gave this educational session, which included the pathophysiology of CTS, symptoms, causes, diagnosis of CTS, treatment options (surgery and conservative management), and activity modification principles during daily living.

After the education session, all participants were provided a custom-made orthosis with volar support that holds the wrist in a neutral position. Patients were educated to wear the orthosis at night for six weeks. Patients were asked to log their orthotic use to assess their adherence to the prescribed treatment plan. They marked the daily hours when the splint was inserted and removed for six weeks. Patients performed NTGE in the exercise groups as a home program besides the orthosis. The physiotherapist taught the patients how to do the exercises correctly and asked them to do them five times daily, ten repetitions separated by at least 2 hours. The patients were informed that exercises should not worsen their symptoms and were instructed to keep a log of their exercise routine to monitor their progress. Patients performed NGE that provided maximum excursion and did not create tension in the median nerve (24). Patients completed NGE approximately 10 min/day. Elbow flexion and wrist extension alternated with elbow extension and wrist flexion as a first nerve gliding exercise. After completion of this movement, finger flexion and wrist extension alternated with finger extension and wrist flexion as a second nerve gliding exercise. Tendon gliding exercises were taught to the patients as suggested by Wehbé (25). Patients completed tendon gliding exercises approximately 20 min/day.

Statistical Analysis

Data were analyzed using IBM SPSS Statistics for Windows, version 25 (IBM Corp, Armonk, NY). Mean ($\overline{\chi}$), standard deviation, number (n), and percentage (%) values were calculated for descriptive variables. Kolmogorov-Smirnov and Shapiro-Wilk's tests were used to assess the distribution of data. The groups were compared with the Kruskal-Wallis test because the data didn't show a normal distribution. The Wilcoxon test was used to compare the change in variables between baseline and week 6. The Kruskal-Wallis H and z values were used to calculate Cohen's d (d), which was used to estimate effect sizes. These are interpreted as follows: "negligible" ≤0.19, "small" 0.2≤d≤0.49, "medium" 0.5≤d≤0.79, and "large" ≥0.8 (26). A p-value of less than 0.05 was considered a statistically significant result.

Results

Forty individuals diagnosed with mild-to-moderate CTS were included in the study. However, data from 19 patients (27 hands; 8 bilateral, 11 unilateral) were included in the data analysis. This study is reported according to the Consolidated Standards of Reporting Trials guidelines (27), and the flowchart is reported in Figure 1. In the baseline characteristics, there was no statistically significant difference between groups (Table 1).

The measurement of the CSA of the median nerve, SSS and FSS scores of BCTSQ, and PSFS scores at baseline were homogeneous for the three groups (Table 2). There were no significant differences between groups for the measurement of the CSA of the median nerve (p=0.238, d=0.388), SSS (p=0.758, d=0.506), and FSS scores (p=0.867, d=0.555) of BCTSQ and PSFS scores (p=0.737, d=0.496) after six weeks of treatment (Table 2).

The reduction in median CSA of the median nerve in the NGE group was statistically significant at week 6, and the effect size of this difference was large (p=0.006, d=1.101) (Table 2). However, within-group changes in the CSA of the median nerve in control

(p=0.096, d=0.917) and NTGE groups (p=0.140, d=0.743) were not statistically significant at week 6 (Table 2). The effect sizes of these differences for the groups were large and medium, respectively.

After six weeks of treatment, a statistically significant improvement was observed in SSS scores in the control (p=0.012, d=1.630) and NGE groups (p=0.005, d=1.611), with large effect sizes. The reduction in median SSS score in the NTGE group was not statistically significant, with a large effect size (p=0.097, d=0.851) (Table 2). There was a statistically significant difference in the FSS scores in all groups in the within-group comparisons (control: p=0.012, d=1.630; NGE group: p=0.012, d=1.352; NTGE group: p=0.021, d=1.303) (Table 2). All the effect sizes of these differences were large.

At week 6, within-group changes in the PSFS scores were statistically significant for the NGE (p=0.008, d=1.128) and NTGE groups (p=0.028, d=1.620) (Table 2). The effect sizes of these differences were large. However, the improvement in the median PSFS score in the control group was not statistically significant, with a large effect size (p=0.069, d=1.022) (Table 2).

All patients completed the orthosis log. There was no significant difference between groups in wearing time from baseline to post-intervention, with a medium effect size (p=0.757, d=0.506). Patients in the exercise groups also completed the exercise log. Exercise adherence was similar between NGE and NTGE groups at week 6, with a large effect size (p=0.604, d=3.001) (Table 3).

Patients in all groups reported no adverse events during or after the treatment. Additionally, the patients stated they did not use any medication during the treatment period.

Discussion

After six weeks of treatment, we found that orthosis and exercises improved symptoms and function in patients with CTS. There were no significant differences between all groups. However, education, orthosis, and NGE significantly reduced the CSA of the median nerve at week 6.

The plausible target of the treatment in patients with mild-to-moderate CTS is to prevent the transition of the median nerve to the fibrotic stage by reducing edema (28). It was shown that either orthosis or NTGE exercises reduced signal intensity of the median in patients with CTS (28). Ultrasound, which is widely used in diagnosing CTS, is another tool used to investigate the effectiveness of treatments. Twelve-week volar-supported neutral wrist splint treatment decreased the CSA of the median nerve at the pisiform level (29,30). In our study, the CSA of the median nerve at the pisiform level decreased by 3.7% after six weeks of volar-supported neutral wrist orthosis treatment. This magnitude of change in the intraneural edema did not exceed minimal detectable change (MDC) thresholds (3.8-6.2%) (31).

Hand therapists often prescribe a combination of exercise and orthosis (9). Yıldırım et al. (32) stated that the combination of the orthosis with the NTGE did not significantly affect the CSA of the median nerve. This result is consistent with our findings.

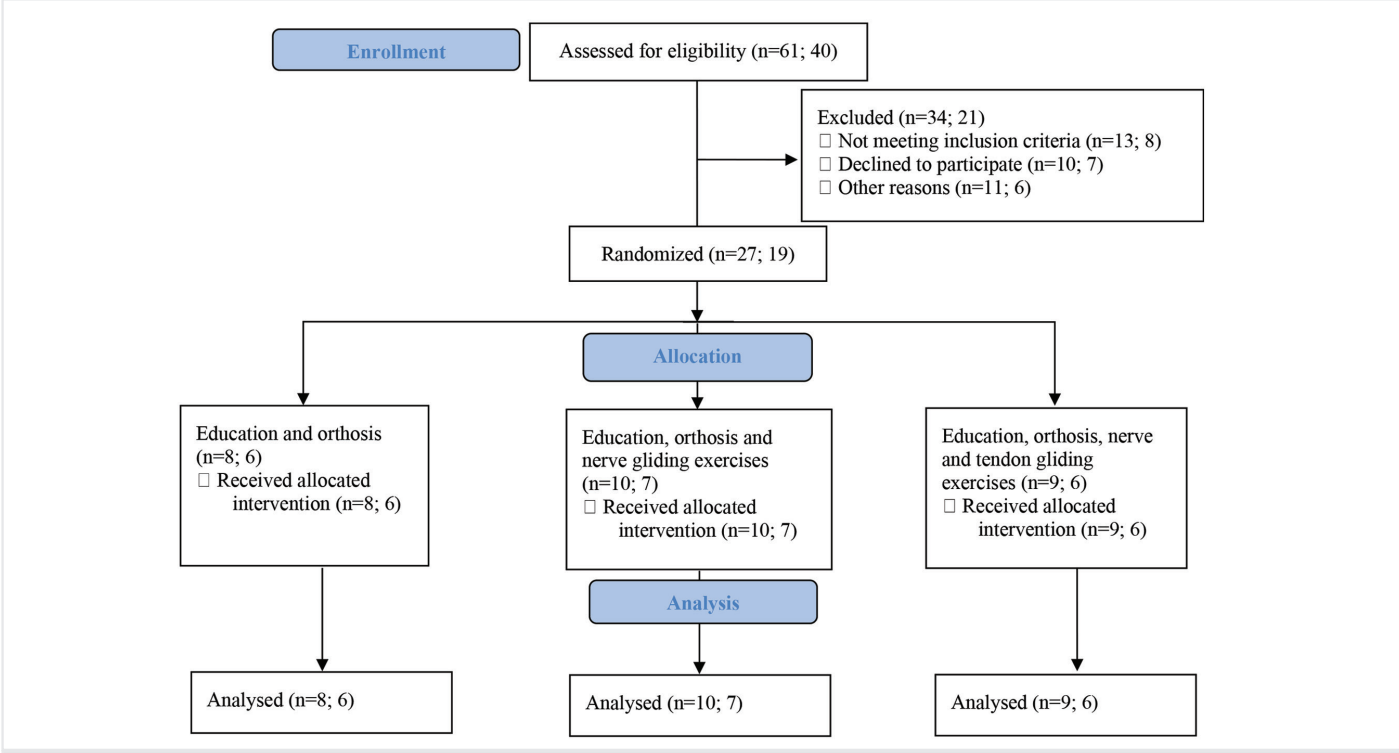

Figure 1. Flow chart of the study
n: Number of hands; the number of patients

The way the patients do the tendon gliding exercises may have led to this result. Strong fist movement performed during tendon gliding exercises causes migration of lumbrical muscles into the tunnel. This movement could have aggravated nerve compression and neutralized the effects of NGE (27). We taught them that if their symptoms worsened during these movements, they should reduce their range of motion. The patients did the exercises independently, so whether they followed the instructions during the sessions was unclear.

Polat et al. (12) reported that a combination of orthosis and NGE did not affect intraneural edema after six weeks of treatment. They didn't report which nerve gliding exercise was used in the study. However, the combination of NGE with orthosis reduced the median CSA of the median nerve by 13.6% in our study. This magnitude of change in the intraneural edema exceeded (MDC) thresholds (31). This may be due to our study's different NGE.

A significant improvement of 1.41 for SSS and 1.50 for FSS was achieved in the orthosis group in our study. This improvement was better than Gatheridge et al. (33), whose treatment protocol included a 4-week neutral wrist orthosis. The differences in orthotic designs, wearing regimes, treatment, and follow-up times used in the studies make it difficult to conclude. However, our results supported that the custom-made neutral wrist splint, worn only at night for six weeks, as suggested in the guideline (34), reduced the symptoms and improved the patients' function.

After six weeks of treatment, a significant improvement of 1.36 for SSS and 1.24 for FSS was achieved in the NGE group. Orthosis and NGE could facilitate venous return and reduce intraneural edema. This contributes to symptom resolution and improvement in function in patients with mild-to-moderate CTS.

Compared to the baseline, a significant improvement of 1.37 for FSS was achieved in the NTGE group. This improvement is better than the improvements in the studies of Figueiredo et al. (13) and Schmid et al. (28). An improvement of 1.09 for SSS in the NTGE group was also achieved, lower than the finding of the study by Figueiredo et al. (13). However, this was not a statistically significant improvement. Although the number of repetitions, treatment duration, and application method of the NTGE used in these studies differed, we had similar results to previous studies. It can be concluded that a combination of orthosis and NTGE could decrease the symptoms and improve the functions of mild-to-moderate CTS patients. However, we don't know whether these differences exceed the MCD of SSS and FSS. The MCD of SSS and FSS is only calculated for surgical treatment (35). Moreover, it is impossible to interpret these findings in terms of MCD.

The patients' PSFS scores improved in all groups, and the activities they rated were similar to those on the FSS of BCTSQ. However, there were some activities not included in BCTSQ, like "using hand and power tools as an occupational activity", "sewing stitches as a free time activity", and "using makeup tools as a personal care", where they faced difficulties. Hence, to evaluate the functional status of CTS patients in more detail, we recommend using PSFS along with BCTSQ.

Monitoring a patient's adherence to treatment is crucial, particularly in studies that involve exercise and orthosis. In our research, we had patients fill out logs for both orthosis and exercise to monitor and enhance their motivation and adherence. We found that patients complied well with the treatment, and this should be closely monitored in future studies involving exercise and orthosis.

Table 1. Baseline characteristics of patients

	Orthosis group (Group 1) (n=8; patients =6)	Orthosis, and nerve gliding exercises group (Group 2) (n=10; patients =7)	Orthosis, nerve, and tendon gliding exercises group (Group 3) (n=9; patients =6)	p-value
Age (y), mean (SD)	40.83 (13.61)	44.00 (9.87)	43.00 (6.48)	0.828
Body mass index, mean (SD)	29.56 (4.85)	26.28 (2.51)	28.30 (5.61)	0.513
Gender, n (%)				
Female	6 (100)	4 (57.1)	6 (100)	
Male	-	3 (42.9)	-	
Affected side, n (%)				
Dominant	4 (66.70)	4 (57.10)	2 (33.30)	
Non-dominant	-	-	1 (16.70)	
Bilateral	2 (33.30)	3 (42.90)	3 (50.00)	
Electrodiagnostic test grade				
Mild	3	4	4	
Moderate	5	6	5	
CTS-6 score (points)	17.94 (3.74)	17.55 (1.96)	19.38 (5.17)	0.813
Duration of symptoms (m)	44.25 (29.90)	24.25 (21.83)	24.55 (21.67)	0.119

y: Years, SD: Standard deviation, BMI: Body mass index, m: Months

Non-surgical treatments are recommended before considering surgery for patients with mild-to-moderate CTS. This study's findings can help healthcare professionals formulate treatment plans and reduce intraneural edema in the median nerve in patients with mild-to-moderate CTS. Education, night splinting, and exercise could improve mild-to-moderate CTS patients' functionality and intraneural edema in the median nerve.

The study's major strengths are the objective measurement of intraneural edema, the randomized design, and the use of valid

Table 2. Comparison of median values of outcome measures for all groups and between-group and within-group differences

Outcome measures	Group	Baseline Median (25th percentile-75th percentile)	Week 6 Median (25th percentile-75th percentile)	Between-group difference p-value	Within-group difference p-value
Median nerve cross-sectional area (mm^2)	Group 1	13.50 (10.25-16.50)	13.00 (9.25-14.75)	Baseline 0.352[a]	0.096[b]
	Group 2	11.50 (10.00-14.00)	10.00 (9.00-10.25)		0.006[b]*
	Group 3	10.00 (10.00-13.00)	10.00 (9.00-10.50)	Week 6 0.238[a]	0.140[b]
Symptom severity scale (points)	Group 1	2.99 (2.90-3.18)	1.58 (1.20-1.63)	Baseline 0.867[a]	0.012[b]*
	Group 2	2.85 (2.40-3.63)	1.49 (1.00-2.20)		0.005[b]*
	Group 3	2.54 (1.90-4.31)	1.45 (1.45-3.17)	Week 6 0.758[a]	0.097[b]
Functional status scale (points)	Group 1	3.25 (2.65-3.50)	1.75 (1.37-2.43)	Baseline 0.508[a]	0.012[b]*
	Group 2	2.81 (1.42-3.15)	1.57 (1.28-2.40)		0.012[b]*
	Group 3	2.87 (1.62-3.84)	1.50 (1.25-2.78)	Week 6 0.867[a]	0.021[b]*
Patient specific functional scale (points)	Group 1	3.80 (1.60-5.15)	6.00 (5.00-7.95)	Baseline 0.052[a]	0.069[b]
	Group 2	4.50 (2.47-5.00)	6.80 (5.60-8.42)		0.028[b]*
	Group 3	4.80 (2.75-5.10)	8.10 (7.05-8.80)	Week 6 0.737[a]	0.008[b]*

mm^2: Square millimetres, [a]: P-values determined using the Kruskal-Wallis test. [b]: P-values determined using the Wilcoxon test. *: p<0.05

Table 3. Comparison of orthosis wearing times and exercise sessions between groups

Outcome measures	Group	Mean (SD)	Median (25th percentile-75th percentile)	p-value
Orthosis wearing time (hours)	Group 1	7.26 (1.14)	6.86 (6.40-8.49)	0.757[c]
	Group 2	6.63 (1.38)	6.83 (5.58-7.78)	
	Group 3	6.87 (0.83)	7.00 (5.94-7.50)	
Number of exercise sessions in a day	Group 2	4.58 (0.35)	4.59 (4.30-5.00)	0.604[d]
	Group 3	4.22 (0.84)	4.86 (3.28-4.94)	

SD: Standard deviation, [c]: P-value determined using Kruskal-Wallis test. [d]: P-value determined using Mann-Whitney U test

and reliable measurements. Additionally, our data can be used to calculate the sample size for confirmatory studies.

Study Limitations

The major limitation of this study was the need for a follow-up evaluation. We did not perform follow-up assessments. Therefore, it is still being determined whether the effects of these proposed treatments last longer. The long-term effects of orthosis and exercise on intraneural edema and function need further investigation. Although the sample size in each group was small, most of the calculated effect sizes were medium-to-large. So, we could argue that the current sample size was sufficient to test the research hypothesis. We did not perform the classification of patients according to the severity of CTS. Further studies can also assess the effectiveness of orthosis, nerve, and tendon gliding exercises on median nerve morphology and function of CTS patients with varying degrees of CTS severity. Finally, exercise and orthosis adherence were monitored by self-reporting, which could overestimate the actual adherence rate.

Conclusion

Custom-made nocturnal wrist orthosis and a 6-week home-based nerve gliding exercise program are safe and feasible in patients with mild-to-moderate CTS. Participating in and completing the proposed CTS treatment program substantially benefits patients' intraneural edema, symptoms, and functions.

Ethics

Ethics Committee Approval: The clinical research Ethics Committee of Kütahya Dumlupınar University approved the study (decision no: 2017-4/2, date: 22.03.2017).

Informed Consent: Participants signed written informed consent before their inclusion.

Authorship Contributions

Surgical and Medical Practices: H.A., M.K., S.C.K., H.H.G., Concept: H.A., M.I.A., Design: H.A., M.I.A., Data Collection or Processing: H.A., M.K., S.C.K., H.H.G., Analysis or Interpretation: H.A., M.I.A., Literature Search: H.A., Writing: H.A., M.I.A., M.K., S.C.K., H.H.G.

Conflict of Interest: No conflict of interest was declared by the authors.

Financial Disclosure: This work was supported by the Kütahya Dumlupınar University Scientific Research Committee (2017-71).

References

1. Urits I, Gress K, Charipova K, Orhurhu V, Kaye AD, Viswanath O. Recent Advances in the Understanding and Management of Carpal Tunnel Syndrome: a Comprehensive Review. Curr Pain Headache Rep. 2019;23:70.
2. Wang L. Guiding Treatment for Carpal Tunnel Syndrome. Phys Med Rehabil Clin N Am. 2018;29:751-60.
3. Schmid AB, Fundaun J, Tampin B. Entrapment neuropathies: a contemporary approach to pathophysiology, clinical assessment, and management. Pain Rep. 2020;5:e829.
4. Ellis R, Blyth R, Arnold N, Miner-Williams W. Is there a relationship between impaired median nerve excursion and carpal tunnel syndrome? A systematic review. J Hand Ther. 2017;30:3-12.
5. Shi Q, Bobos P, Lalone EA, Warren L, MacDermid JC. Comparison of the Short-Term and Long-Term Effects of Surgery and Nonsurgical Intervention in Treating Carpal Tunnel Syndrome: A Systematic Review and Meta-Analysis. Hand (N Y). 2020;15:13-22.
6. American Academy of Orthopaedic Surgeons. Management of Carpal Tunnel Syndrome Evidence-Based Clinical practice Guideline. https://www.aaos.org/globalassets/quality-and-practice-resources/carpal-tunnel/cts_cpg_4-25-19.pdf Published February, 2016. Accessed September 15, 2020.
7. Erickson M, Lawrence M, Jansen CWS, Coker D, Amadio P, Cleary C. Hand Pain and Sensory Deficits: Carpal Tunnel Syndrome. J Orthop Sports Phys Ther. 2019;49:CPG1-CPG85.
8. Parish R, Morgan C, Burnett CA, Baker BC, Manning C, Sisson SK, et al. Practice patterns in the conservative treatment of carpal tunnel syndrome: Survey results from members of the American Society of Hand Therapy. J Hand Ther. 2020;33:346-53.
9. Horng YS, Hsieh SF, Lin MC, Chang YW, Lee KC, Liang HW. Ultrasonographic median nerve changes under tendon gliding exercise in patients with carpal tunnel syndrome and healthy controls. J Hand Ther. 2014;27:317-24.
10. Paquette P, Higgins J, Gagnon DH. Peripheral and Central Adaptations After a Median Nerve Neuromobilization Program Completed by Individuals With Carpal Tunnel Syndrome: An Exploratory Mechanistic Study Using Musculoskeletal Ultrasound Imaging and Transcranial Magnetic Stimulation. J Manipulative Physiol Ther. 2020;43:566-78.
11. Polat YD, Aydın E, Ince FS, Bilgen M. Sonoelastic response of median nerve to rehabilitation in carpal tunnel syndrome. J Ultrason. 2020;20:90-4.
12. Paquette P, Higgins J, Danino MA, Harris P, Lamontagne M, Gagnon DH. Effects of a preoperative neuromobilization program offered to individuals with carpal tunnel syndrome awaiting carpal tunnel decompression surgery: A pilot randomized controlled study. J Hand Ther. 2021;34:37-46.
13. Figueiredo DS, Ciol MA, da Conceição Dos Santos M, de Araújo Silva L, Bidin Brooks JB, Santos Diniz RA, et al. Comparison of the effect of nocturnal use of commercial versus custom-made wrist orthoses, in addition to gliding exercises, in the function and symptoms of carpal tunnel syndrome: A pilot randomized trial. Musculoskelet Sci Pract. 2020;45:102089.
14. Abdolrazaghi HA, Khansari M, Mirshahi M, Ahmadi Pishkuhi M. Effectiveness of Tendon and Nerve Gliding Exercises in the Treatment of Patients With Mild Idiopathic Carpal Tunnel Syndrome: A Randomized Controlled Trial. Hand (N Y). 2021;18:222-9.
15. Lewis KJ, Coppieters MW, Ross L, Hughes I, Vicenzino B, Schmid AB. Group education, night splinting and home exercises reduce conversion to surgery for carpal tunnel syndrome: a multicentre randomised trial. J Physiother. 2020;66:97-104.

16. Fowler JR, Munsch M, Tosti R, Hagberg WC, Imbriglia JE. Comparison of ultrasound and electrodiagnostic testing for diagnosis of carpal tunnel syndrome: study using a validated clinical tool as the reference standard. J Bone Joint Surg Am. 2014;96:e148.
17. Pan TJ, White RJ, Zhang C, Hagberg WC, Imbriglia JE, Fowler JR. Baseline Characteristics of the Median Nerve on Ultrasound Examination. Hand (N Y). 2016;11:353-6.
18. Werner RA. Electrodiagnostic evaluation of carpal tunnel syndrome and ulnar neuropathies. PM R. 2013;5(5 Suppl):14-21.
19. Junck AD, Escobedo EM, Lipa BM, Cronan M, Anthonisen C, Poltavskiy E, et al. Reliability Assessment of Various Sonographic Techniques for Evaluating Carpal Tunnel Syndrome. J Ultrasound Med. 2015;34:2077-88.
20. 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 Am. 1993;75:1585-92.
21. Sezgin M, Incel NA, Serhan S, Camdeviren H, As I, 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;28:1281-5.
22. Stratford P, Gill C, Westaway M, Binkley J. Assessing disability and change on individual patients: a report of a patient specific measure. Physiother Can. 1995;47:258-63.
23. Novak CB, Anastakis DJ, Beaton DE, Mackinnon SE, Katz J. Validity of the Patient Specific Functional Scale in patients following upper extremity nerve injury. Hand (N Y). 2013;8:132-8.
24. Coppieters MW, Hough AD, Dilley A. Different nerve-gliding exercises induce different magnitudes of median nerve longitudinal excursion: an in vivo study using dynamic ultrasound imaging. J Orthop Sports Phys Ther. 2009;39:164-71.
25. Wehbé MA. Tendon gliding exercises. Am J Occup Ther. 1987;41:164-7.
26. Fritz CO, Morris PE, Richler JJ. Effect size estimates: current use, calculations, and interpretation. J Exp Psychol Gen. 2012;141:2-18.
27. Schulz KF, Altman DG, Moher D; CONSORT Group. CONSORT 2010 statement: updated guidelines for reporting parallel group randomised trials. BMJ. 2010;340:c332.
28. 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.
29. Soyupek F, Yesildag A, Kutluhan S, Askin A, Ozden A, Uslusoy GA, et al. Determining the effectiveness of various treatment modalities in carpal tunnel syndrome by ultrasonography and comparing ultrasonographic findings with other outcomes. Rheumatol Int. 2012;32:3229-34.
30. Mansiz Kaplan B, Akyuz G, Kokar S, Yagci I. Comparison of the effectiveness of orthotic intervention, kinesiotaping, and paraffin treatments in patients with carpal tunnel syndrome: A single-blind and randomized controlled study. J Hand Ther. 2019;32:297-304.
31. Impink BG, Gagnon D, Collinger JL, Boninger ML. Repeatability of ultrasonographic median nerve measures. Muscle Nerve. 2010;41:767-73.
32. Yıldırım P, Dilek B, Şahin E, Gülbahar S, Kızıl R. Ultrasonographic and clinical evaluation of additional contribution of kinesiotaping to tendon and nerve gliding exercises in the treatment of carpal tunnel syndrome. Turk J Med Sci. 2018;48:925-32.
33. Gatheridge MA, Sholty EA, Inman A, Pattillo M, Mindrup F, Sanderson DL. Splinting in Carpal Tunnel Syndrome: The Optimal Duration. Mil Med. 2020;185:2049-54.
34. Huisstede BM, Fridén J, Coert JH, Hoogvliet P; European HANDGUIDE Group. Carpal tunnel syndrome: hand surgeons, hand therapists, and physical medicine and rehabilitation physicians agree on a multidisciplinary treatment guideline—results from the European HANDGUIDE Study. Arch Phys Med Rehabil. 2014;95:2253-63.
35. De Kleermaeker FGCM, Boogaarts HD, Meulstee J, Verhagen WIM. Minimal clinically important difference for the Boston Carpal Tunnel Questionnaire: new insights and review of literature. J Hand Surg Eur Vol. 2019;44:283-9.