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Original Article

The Effectiveness of Limited Dynamic Wrist Splints on the Symptoms, Function, and Strength of Women with Carpal Tunnel Syndrome: A Controlled Trial Study

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ABSTRACT

Background: Splinting is the most common conservative method of treating patients with mild and moderate Carpal Tunnel Syndrome (CTS). The aim of this study was to determine the effectiveness of the limited dynamic wrist splint on the symptoms, function, and strength of women with CTS. In this controlled trial study, the subjects wore a splint of a new design called the "limited dynamic wrist splint", which allowed the wrist motion in the range (between 15-degree flexion and 15-degree extension) that exerts minimum pressure on the median nerve and prevents extra pressure on the nerve by limiting the range of motions out of the allowed range.

Methods: In this study, 24 women diagnosed with mild to moderate CTS were initially evaluated on the basis of the Boston questionnaire, the dexterity test of the Purdue pegboard, grip and pinch strength, distal sensory latency, and sensory nerve conduction velocity. The subjects were randomly divided into two groups, control and treatment. Both groups received routine rehabilitation treatment for six weeks. The treatment group received the limited dynamic wrist splint for about six to eight hours a day. After six weeks, the initial examinations were repeated. The SPSS-16, independent t, and paired t-tests were used for data analysis.

Results: All the variables in the treatment and the control groups showed improvement. The function test of the Boston questionnaire, the Purdue pegboard test, and the pinch strength were significantly improved in the treatment group. The "severity of the symptoms" test of the Boston questionnaire and the pinch strength in the control group showed a statistically significant difference ($P < 0.05$). In a comparison of the two groups, the function test of the Boston questionnaire showed a significant difference.

Conclusion: This study showed that the use of the limited dynamic wrist splint for about six weeks for six to eight hours a day could have a significant effect on the function, dexterity, and the pinch strength of patients with CTS. Not only can the patients receive treatment by this method, but they can also perform their daily activities to some extent.

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Introduction

Carpal Tunnel Syndrome (CTS) is a compression

neuropathy in the carpal tunnel of the wrist joint which causes motor and sensory impairment in the median nerve distribution of the hand. The symptoms of CTS include nocturnal pain, tingling, paraesthesia, weakness, and thenar muscle atrophy in severe cases. CTS can be a disabling disorder if left untreated, and can cause permanent damage to the median nerve and even the loss of the hand's function [1]. The prevalence of CTS in the general population in the United States is 3.72% with an annual incidence of 139.4 per 100,000 females and 67.2 per 100,000 males [2]. Among the patients with upper extremity disorders and suspected CTS pain who were referred to a hospital in Iran, the prevalence of this syndrome was 25% in 1,000 cases [3]. CTS etiology is considered to be multifactorial. A lot of activities can evoke CTS or worsen its symptoms. CTS can be treated with both conservative and surgical interventions. The conservative treatment includes lifestyle modification, avoiding frequent movement, and the use of ergonomic equipment, splints, and tendon- and nerve-gliding exercises. Oral or injectable medication is mostly utilized in mild and moderate CTS [1, 4]. The most common conservative treatment of mild to moderate CTS in rehabilitation is to use an appropriate splint. The rationale for using a wrist splint is based on observations that CTS symptoms are relieved with rest and evoked with activity and reduced carpal tunnel pressure [5, 6]. Multitude splints have been employed to reduce the symptoms of CTS. Nevertheless, questions have always existed about which positions are the best for splinting the hand. The authors have focused on designing functional wrist splints. Some prefabricated splints set the wrist in a 20-degree extension, which is known as the functional position of the wrist [7]. Another study revealed that the carpal tunnel exerts the lowest pressure in the neutral position of the wrist. However, the optimal position is different for different people. According to sonographic examinations, the lowest compression on the median nerve was found in the 15-degree flexion and the 15-degree extension of the wrist [8]. However, no study has attempted to include all these aspects of splinting the wrist under the CTS and consider the patient's ability to perform daily activities. Therefore, in this study, the subjects wore a splint of a new design which allowed the wrist motions in the range of the lowest pressure on the median nerve: 15-degree flexion to 15-degree extension without deviations. This splint prevented extra pressure on the nerve by limiting the motions that are not in the permissible range so that the patients could perform their daily activities as they received treatment.

Methods

This interventional study was designed as a randomized controlled trial to explore the effects of limited dynamic wrist splint on the symptoms, function, and strength of women with CTS. This study was approved by the Ethics Committee of Tehran University of Medical Sciences. The protocol has been registered in the Iranian Registry of Clinical Trials (registration code: IRCT2015061522753N1).

Based on a statistical counselor's advice, 24 women (mostly homemakers), who met the inclusion criteria, were selected from two educational rehabilitation centers. The patients were included if they were female, diagnosed with CTS by the physiatrist, had mild or moderate CTS according to Table 1 [9], and could understand and perform instructions. Patients with a history of surgery, systemic diseases, pregnancy, wrist-fracture histories, a lack of cooperation, and a lack of nerve-conduction velocity results were excluded. After an electro-diagnostic test and before being diagnosed with mild or moderate CTS, the patients filled out the consent forms of participation in the study and the demographic questionnaires. The initial evaluations included the Boston questionnaire, the Purdue pegboard test of dexterity, grip and thumb-pinch strength test, sensory distal latency, and sensory nerve conduction velocity. Thereafter, the patients were randomly divided into control and treatment groups. Each group had 12 subjects. In both groups, the subjects could have routine rehabilitation treatments, including activity/ergonomic modifications, nerve and tendon gliding exercises, massage, carpal bones and nerve mobilizations, stretches of upper extremity and flexor retinaculum [7]. The treatment group received a thermoplastic customized limited dynamic wrist splint, which they had to wear for six to eight hours a day. This limited dynamic splint allows the wrist joint to move between the range of 15-degree flexion and 15-degree extension without radial or ulnar deviation by a small cogwheel at the radial side of the splint (Figure 1). The patients were taught how to use the splint correctly. The initial evaluations were repeated after six weeks for both groups and data was gathered. The test of normality, independent t and paired t-tests with 95% confidence interval (α=0.05) were used for data analysis using SPSS-16 software.

The Boston questionnaire is a validated instrument to measure the outcomes of treatment. It has the following two sections: symptoms' severity (BQ-SS) and functional status (BQ-FS). It is a suitable instrument for less educated and barely literate patients. The BQ-SS section has 11 questions about the severity and frequency

Table 1: Classification of NCV findings to a cluster of mild, moderate, and severe CTS

	SDL	S NCV	MDL	M Amp	CL	C Amp
Mild	>3.7	<40	>4.5	-	>2.4	<50%
Moderate	>4.5	<35	>5.5	<50%	>2.8	-
Severe	>5.3	<30	>6.5	-	>3.2	-

SDL: Median Nerve Sensory Distal Latency; S NCV: Median Nerve Wrist Sensory Nerve Conduction Velocity; MDL: Median Nerve Motor Distal Latency; M Amp: Median Motor Response Amplitude Compared To Other Hand; CL: Median Nerve Compound Latency; C Amp: Median Nerve Compound Amplitude Compared To Other Hand

Figure 1: Limited dynamic wrist splint; a) 15-degree extension, b) neutral position, c) 15-degree flexion

of the symptoms, including nocturnal numbness and pain, burning sensation, and muscle weakness during the day. The BQ-FS section has eight questions about the difficulties that the patient faces while performing activities such as writing, holding a book, buttoning up shirts, bathing, carrying a packet, etc. Using a Likert scale, each question has five choices and each choice has a score of 1 to 5. The patients were asked to score themselves on these parameters over two weeks. The scores of each section were then added up [10].

The Purdue pegboard is used to assess the dexterity of the hand and the fine motor skills. The validity of this test has been accepted over time. The Purdue pegboard comprises 50 holes arranged in two parallel columns, and pegs, washers, and collars are placed in four cups on top of the board. The pegboard was located on a table crosswise and the subjects sat comfortably in front of it. They were instructed to start the test on a verbal cue while an examiner timed the test with a stopwatch. The test comprised four subsets. In the first three subsets, the subjects had 30 seconds to fill the holes with pegs: first with the dominant hand, then, with the non-dominant hand, and finally, with both hands simultaneously. In the last subset, the subjects had one minute to assemble a peg, a washer, a collar, and finally, another washer in sequence, with alternating hands, starting with the dominant hand first. Each subset was repeated three times to obtain an average. The test scores equaled the number of filled holes or pieces assembled depending on the test subset. In this study, only the first step of the Purdue pegboard test was used [11, 12].

The grip and thumb-pinch strength was evaluated by the digital Pinch/Grip Analyzer of the Measurement Is Evidence (M.I.E) Company (Digital analyzer from Measurement Is Evidence company). The patients were asked to press the handle three times and the mean score of the three compressions of the device was calculated. The power unit was kilogram.

The electrodiagnostic assessments (performed by a physiatrist) were carried out by a "MEDLEC SYNERGY VIASIS" electromyography device with two 6-mm felt-tip bar electrodes as the stimulators and recorders (with diameter of pads 23 mm apart). The antidromic sensory nerve action potentials evoked at the wrist were recorded from the middle finger. Standard distances (7 cm from the recorder at mid-palm and 14 cm from the recorder at the wrist) were kept between the stimulator and the recorder electrodes. The skin temperature during all the electro-diagnostic studies was at least 31°C; the room temperature was between 23 and 25°C [13]. The sensory nerve conduction velocity was recorded in meters per second and the sensory distal latency was recorded in milliseconds.

Results

The mean age of the control group was 45.76 years and the mean age of the treatment group was 47.42 years. All the subjects in the treatment group were right-handed. In the control group, there was only one left-handed person. Of the affected limbs, 66.7% involves the right hand in the treatment group, whereas 50% in the control group involves the right hand.

The participants' descriptive statistics are summarized in Table 2.

The summary of the mean differences of the variables before and after the treatment and their significance level is presented in Table 3.

As shown in Table 3, the BQ-FS, the Purdue pegboard test of dexterity, and the pinch-strength variables in the intervention group, and the BQ-SS and the pinch-strength variables in the control group were significantly improved.

As shown in Table 4, in a comparison of the mean differences of the variables between the intervention and the control groups, only the BQ-FS variable was

Table 2: Mean scores of the pre-test and the post-test in both groups

Variable	Intervention group Mean±SD		Control group Mean±SD	
	Pretest	Posttest	Pretest	Posttest
BQ-SS	32.08±10.04	24.83±8.61	27.5±10.57	24.75±8.63
BQ-FS	20.25±6.18	14.58±4.62	15.91±7.64	15.16±6.89
Purdue pegboard	12.58±1.88	14.25±1.81	13.08±2.06	13.75±2.37
Grip strength(kg)	12.81±4.57	14.03±3.27	12.86±3.36	13.8±3.06
Pinch strength(kg)	4.91±1.31	5.77±1.24	5.74±1.61	6.62±1.62
SDL (ms)	4.15±0.35	3.92±0.57	4.00±0.36	3.92±0.4
SNCV (m/s)	35.9±4.46	39.61±8.63	34.68±4.44	36.79±5.37

SS-BQ: symptoms' severity of the Boston questionnaire; FS-BQ: functional status of the Boston questionnaire; SLD: sensory distal latency; SNCV: sensory nerve conduction velocity

Table 3: Comparison of the mean differences of the variables before and after the treatment

Variable	Intervention			Control		
	Mean difference±SD	P value	Percentage of changes	Mean difference±SD	P value	Percentage of changes
BQ-SS	-7.25±12.6	0.073	22/5%	-2.75±3.01	0.009	10%
BQ-FS	-5.66±0.14	0.005	28%	-0.075±0.06	0.38	1%
Purdue pegboard	1.66±1.49	0.003	13/27%	0.66±1.07	0.54	5%
Grip strength(kg)	1.22±2.51	0.12	9%	1.93±1.98	0.13	7%
Pinch strength(kg)	0.85±1.02	0.015	17/5%	0.88±0.09	0.006	15%
SNCV(m/s)	3.71±6.96	0.091	10%	2.1±6.69	0.29	6%
SDL(ms)	-0.22±0.39	0.072	5%	-0.07±0.49	0.59	2%

SS-BQ: symptoms' severity of the Boston questionnaire; FS-BQ: functional status of the Boston questionnaire; SLD: sensory distal latency; SNCV: sensory nerve conduction velocity

Table 4: A comparison of the mean differences between the intervention and the control groups

Variables	P value
BQ-SS	0.25
BQ-FS	0.01
Purdue pegboard	0.1
Grip strength	0.76
Pinch strength	0.71
SDL	0.41
SNCV	0.57

SS-BQ: Symptoms' severity of the Boston questionnaire; FS-BQ: Functional status of the Boston questionnaire; SLD: Sensory distal latency; SNCV: Sensory nerve conduction velocity

significantly different (P=0.01), and there were no statistical differences between the other variables.

Discussion

The results of this study show that the use of the limited dynamic wrist splint for six to eight hours per day for six weeks has a significant effect on the function, dexterity, and pinch strength of women with CTS. There has been no study on the use of this kind of splint, but the studies mentioned in this paper show various similarities with this research.

In this study, we proposed a new method of splinting for patients with CTS. It is a modified form of a splint that was first described by Williams et al. According to electrodiagnostic and sonographic studies, the lowest compression on the median nerve was found in the 15-degree flexion and 15-degree extension of the wrist in some people. Therefore, we limited the dynamic range of motion of Williams' splint and the radial and ulnar deviations of the wrist [8, 14, 15]. By preventing the compression on the median nerve, this dynamic splint could not only help the patients with CTS to perform their daily activities but also had positive effects on the symptoms, function, dexterity, and the power of their upper extremities.

Comparing the night splint and the full-time splint, Walker concluded that patients with the night-only splint had a more improved functional state than those with a full-time splint. Aside from this, patients with a full-time splint preferred not to wear it. This implies that interference with function is a possible contributing factor to suboptimal compliance [5]. The significant improvement in the functional state of patients who wore the limited dynamic wrist splint in line with this study confirmed the findings of Walker and Manente [16]. Improved dexterity skill of the intervention group is not unexpected when the functional state had improved too. Another study also revealed that static splints are not very effective in making functional improvements [17]. The results of this study demonstrate that the mean difference on the symptom severity scale of the Boston questionnaire improved in both groups. Despite the higher mean difference in the intervention group after the treatment, the control group showed significant improvement in BQ-SS. This was probably due to the small sample size.

Some studies have revealed that splinting can affect the grip and the pinch strength of patients with CTS [1, 6]. In this study, although significant improvement was seen in the pinch strength of the intervention group, and the mean difference of the grip strength in both groups increased after treatment, no statistically significant difference was found in the strength variables between the two groups. This shows that the use of the limited dynamic wrist splint could enhance pinch strength in patients with CTS.

The results of this study show that there was no significant difference in the sensory distal latency and sensory nerve conduction velocity between the two groups. This may have been due to the small sample size of the subjects. Patients who wore the limited dynamic wrist splints, however, had more physiological improvements.

As mentioned in other studies [18, 19], the limited dynamic wrist splint, with a range of motions between 15-degree flexion to 15-degree extension of the wrist joint, does not compress the median nerve. As shown in the results of this study, not only does it not worsen the symptoms or the SNCV and the SDL, it could actually help them improve. This is because the mean of the SNCV and the SDL variables in the patients with the limited

dynamic wrist splint demonstrated a greater increase compared to the patients without the splint.

Conclusion

This study shows that the use of the limited dynamic wrist splint for six to eight hours a day, for about six weeks could have a significant effect on the function, dexterity, and the pinch strength of patients with CTS. Moreover, they can receive the treatment while performing their daily activities to some extent at the same time.

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Conflict of interest: None declared.

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