THE EFFICACY OF A NON-TRADITIONAL SPLINT COMBINED WITH TENDON AND NERVE GLIDING EXERCISES FOR THE TREATMENT OF CARPAL TUNNEL SYNDROME: A RANDOMIZED CONTROLLED CLINICAL TRIAL

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Carpal tunnel syndrome (CTS) is a commonly diagnosed upper extremity neuropathy with a prevalence of 3.7% in the general population. The need to identify effective and economical conservative management strategies for the treatment of CTS is critical. The purpose of this randomized controlled clinical trial was to evaluate the effectiveness of a non-traditional fabricated wrist splint combined with tendon and nerve gliding exercises for the treatment of CTS. Sixty-one subjects diagnosed with mild to moderate CTS enrolled in the study. Fifty-one subjects completed the study. After completing the CTS history and demographic questionnaire, the CTS Symptom Severity and Functional Status Scale, the Disabilities of the Arm Shoulder and Hand (DASH) questionnaire, and a physical examination subjects were randomly assigned to a group. The FAB-EX (n=13) and the FAB-NOEX (n=14) received the fabricated wrist splint, which supported the wrist and metacarpophalangeal (MCP) joints. The FAB-EX also received exercises. The OTS-EX (n=13) and the OTS-NOEX group (n=11) received an off the shelf wrist cock-up splint. The OTS-EX also received exercises. Subjects were instructed to wear either splint all night, for 4 weeks and if applicable, perform exercises 3 times a day. At 4 weeks subjects completed the same measures given at baseline. At 8 weeks, subjects were mailed the

CTS Symptom Severity and Functional Status Scale, the DASH, and an exit survey. 2 x 2 x 3 mixed analysis of variances (ANOVA) were performed on the subjective measures and 2 x 2 x 2 mixed ANOVAs were performed on the objective measures. All groups, over time, demonstrated a significant improvement on the CTS Symptom Severity ($p < .001$) and Functional Status Scale ($p < .001$), DASH ($p < .001$), tip pinch ($p < .008$), and palmar pinch ($p < .034$). Subjects randomized to the non-traditional fabricated wrist/MCP splint demonstrated significant improvement on the CTS Symptom Severity ($p < .014$) and Functional Status Scale ($p < .029$). There were no significant findings between the groups who received exercises and the groups who did not receive exercises. The results of this study support the use of a fabricated wrist/MCP splint for the treatment of CTS.

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PREFACE

I would like to thank my dissertation chair and advisor, Joan C. Rogers, PhD, OTR/L, for her never ending patience, support, and guidance. I am grateful that I had the opportunity to study under such a leader in the field of occupational therapy. You are a wonderful advisor, mentor, and educator.

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1.0 INTRODUCTION

Carpal tunnel syndrome (CTS) is a compression neuropathy of the median nerve at the carpal canal in the wrist which results in sensory and motor impairments in the median nerve distribution of the hand. Symptoms of CTS are nocturnal pain, numbness, paraesthesias, weakness, and in severe cases, atrophy of the thenar muscles in the hand. CTS is a potentially disabling disorder and if left untreated permanent damage to the median nerve may occur resulting in clumsiness, loss of hand dexterity, and loss of hand function.

CTS was first described in the medical literature in 1854 (Paget, 1854). Now a plethora of information on CTS can be found not only in the medical literature but in newspapers, magazines, and on the World Wide Web. There are over 4,500 articles published and over 700,000 websites relating to the topic of CTS. As a result of the increased familiarization with CTS and more people seeking medical attention for this disorder, CTS has become one of the most commonly diagnosed upper extremity neuropathies (Atroshi et al., 1999; Papanicolaou et al., 2001). Atroshi et al. (1999) reported a 3.8% prevalence of CTS in the general population of Sweden and in a more recent study, Papanicolaou, McCabe, and Firrell (2001) reported a 3.7% prevalence of CTS in the general population of the United States. Furthermore, occupational tasks are becoming more and more recognized as being associated with CTS. Tanaka et al. (1995) reported 53% of workers were told by a health care provider that they had CTS and approximately 50% of these cases may be attributed to work related tasks.

Currently, there are a variety of treatment options for CTS. Conservative intervention is the treatment of choice for mild to moderate CTS. Some of the most popular treatments are; splinting, anti-inflammatory medication, steroid injection, and activity modifications. Ultrasound, tendon and nerve gliding exercises, and manual therapy are also advocated. Once the patient presents with severe CTS; muscular atrophy, total sensory loss, significantly delayed nerve conduction velocities, and marked symptomatology, surgery is the treatment of choice (Duncan, Lewis, Foreman, & Nordyke, 1987).

Despite the many conservative interventions available for the treatment of CTS, surgical release of the carpal tunnel is one of the most common surgeries performed by hand surgeons. Approximately one-half million releases are performed a year with costs exceeding 2 billion dollars a year (Palmar & Hanrahan, 1995). Rising health care and indemnity costs are just a few of the many implications of CTS for modern society. Determining safe, effective, and economic conservative interventions for the treatment of mild to moderate CTS should be a high priority.

The purpose of this dissertation was twofold: 1) to evaluate and synthesize the current literature on the conservative management strategies for the treatment of CTS and 2) to evaluate the efficacy of a non-traditional splint and exercise regime for the treatment of mild to moderate CTS.

The first part of this dissertation was a systematic review of the literature. The systematic review evaluated and synthesized 18 research studies that investigated conservative interventions for the treatment of CTS. The treatments evaluated in these studies were splinting, ultrasound, tendon and nerve gliding exercises, iontophoresis, manual therapy, massage therapy, wrist traction, and aerobic exercise.

The second part of this dissertation was a randomized controlled clinical trial to evaluate the effectiveness of two conservative interventions specifically, a non-traditional splint and exercise program, to alter the clinical course of mild to moderate carpal tunnel syndrome (CTS). Four Experimental Groups were studied: 1) the FAB-EX group received a fabricated splint positioning the wrist in neutral and the metacarpophalangeal (MCP) joints between 0 to 10 degrees of flexion (see Appendix A) combined with a program of tendon and nerve gliding exercises (see Appendix B); 2) the FAB-NOEX group received a fabricated splint positioning the wrist in neutral and the MCP joints between 0 to 10 degrees of flexion with no exercises; 3) the OTS-EX group received a commercially available, off the shelf, prefabricated, wrist cock-up splint (see Appendix C) combined with a program of tendon and nerve gliding exercises; and 4) the OTS-NOEX group received a commercially available, off the shelf, prefabricated, wrist cock-up splint with no exercises.

Subjects were evaluated on measures related to impairment and function before the intervention (baseline), at 4 weeks posttest, and 8 weeks post-posttest. The null hypotheses tested were: 1) There will be no difference between the groups for the main effect of splint, 2) there will be no difference between the groups for the main effect of exercise, 3) there will be no difference between the groups for the main effect of time, 4) there will be no interaction between the groups for the main effects of splint and exercise, 5) there will be no interaction between the groups for the main effects of splint and time, 6) there will be no interaction between the groups for the main effects of time and exercise, and 7) there will be no interaction between the groups for the main effects of time, splint, and exercise.

1.1 HISTORY OF CARPAL TUNNEL SYNDROME

The phenomenon of CTS has been of concern to health care professionals for over 150 years. The clinical presentation of CTS was first described in the medical literature by Sir James Paget in 1854 (Paget, 1854). However, it was not until almost 30 years later that James Putnam (1880) presented a clinical series, evaluating 37 patients complaining of nocturnal paraesthesia in the median distribution of the hand. He prescribed phosphorus, strychnine, potassium bromide (used in the 1800's as an anticonvulsant and sedative), amyl nitrite, cannabis indica, and galvanism (direct current being passed along the arm), for the treatment of this disorder. He reported good results with the drug strychnine proceeded by phosphorus and minimal success with galvanism. However, he did not have the opportunity to properly evaluate the different treatment techniques and he was therefore unable to report on the significance of their effectiveness.

From 1909 to 1914 a series of articles published by Ramsay Hunt changed the way CTS was viewed and treated (Hunt, 1909, 1911, 1914). Hunt de-emphasized the sensory component, largely ignoring Putnam's early work, and argued that patients' complaints were purely motor in nature. Hunt's emphasis on motor findings led practitioners to believe that patients presenting with sensory deficits had a brachial plexus compression by a cervical rib. Thus, during that time, the treatment of choice for CTS was a cervical rib excision (Pfeffer, Gelberman, Boyes, & Rydevik, 1988). The many clinical failures of this procedure led to the re-examination of the purported pathophysiology of CTS. Eventually it became recognized that the sensory complaints reported by Putnam and the motor atrophy reported by Hunt were caused by a compression of the median nerve at the carpal tunnel.

In 1938 Moersch described a syndrome of spontaneous nerve compression and coined the term "tardy median thenar neuritis" (Moersch, 1938). However, it was not until 1947 when the

first paper was published describing in detail the clinical signs, diagnosis, and pathophysiology of spontaneous median nerve compression in the carpal tunnel (Brain, Wright, & Wilkinson, 1947). Inspired by the work of Brain, Wright, and Wilkinson, George Phalen, in the 1950s, published the first of a series of articles on CTS and popularized the condition (Michelsen & Posner, 2002).

Over the next 30 years, Phalen and his colleagues published a series of substantial articles further defining CTS and its clinical presentation (Lo, Raskin, Lester, & Lester, 2002; Phalen, 1951; Phalen, Gardner, & La Londe, 1950; Phalen, & Kendrick 1957). Phalen reported on the surgical intervention to decompress the nerve and also recommended splinting and corticosteroid injections as conservative therapeutic options (Phalen & Kendrick, 1957). In addition, he described the Tinel's sign as a useful tool to diagnose CTS and developed the Phalen's sign, a useful maneuver to aid in the diagnosis of CTS (Phalen et al., 1950). By 1970 the clinical presentation of CTS was well understood and the phenomenon was easily diagnosed. However the cause, prevention, and the most effective treatment for CTS are topics widely researched today.

1.2 PREVALENCE AND INCIDENCE OF CARPAL TUNNEL SYNDROME

CTS is a potentially disabling hand disorder and if left untreated permanent damage to the median nerve may occur resulting in loss of hand function. CTS is one of the most commonly diagnosed upper extremity peripheral entrapment neuropathies (Stevens, Sun, Beard, O'Fallon, & Kurland, 1988). The prevalence of clinically diagnosed CTS ranges from 3.7% to 3.8% and the prevalence of pain, numbness, and tingling ranges from 14.4% to 23.2% in the general population (Atroshi et al., 1999; Papanicolaou et al., 2001). The incidence of new cases of CTS

is 276 per 100,000 (Mondelli, Giannini, & Giacchi, 2002). Furthermore, surgery for the treatment of CTS is one of the most common hand surgeries performed in the United States, exceeding over 500,000 carpal tunnel releases a year with costs exceeding 2 billion dollars a year (Palmar & Hanrahan, 1995). CTS affects women more than men. One study reported a prevalence of 7.4% in women and 0.6% in men (de Krom et al., 1992). Another study's respective proportions were 15.6% and 11.3% (Papanicolaou et al., 2001). In addition, CTS is reported to be bilateral in 59% to 87% of patients (Bagatur & Zorer, 2001; Bendler, Greenspun, Yu, & Erdman, 1977; Padua, Padua, Nazzaro, & Tonali, 1998).

Work place factors are becoming more and more recognized as being associated with CTS. According to Tanaka et al. (1995), approximately 50% of medically treated CTS cases are attributed to work related tasks. Performing repetitive or forceful movements with the symptomatic hand may exacerbate or worsen the symptoms. A higher prevalence of CTS has been reported in occupations exposed to repetition, vibration, awkward wrist postures, and or forceful wrist and hand activities such as, computer operators, assembly line workers, butchers, dental hygienists, hair dressers, construction workers, and musicians (Armstrong & Chaffin, 1979; Atroshi et al., 1999; Cannon, Bernacki, & Walter, 1981; Feldman, Goldman, & Keyserling, 1983; Franklin, Boteler, & Nelson, 1984; Greer, Jenkins, & Roberts, 1992; Rothfleisch & Sherman, 1978; Tanaka et al., 1995; Wieslander, Norbäck, Göthe, & Juhlin, 1989). Furthermore, several surveys found that 34% to 79% of workers diagnosed with CTS associate their condition with their work (Rossignol, Stock, Patry, & Armstrong, 1997; Tountas, Macdonald, Meyerhoff, & Bihrle, 1983) and according to Herbert, Gerr, and Dropkin (2000), CTS is one of the most disabling and costly disorders representing the majority of lost work days and workers' compensation claims.

CTS keeps people out of work longer than any other disabling condition. According to the Bureau of Labor Statistics (2001), the median days away from work due to CTS have been the highest compared to all other work related injuries each year since 1994. The median days of lost work due to CTS are 25 days compared to 18 days for amputations, and 10 days for tendonitis. Furthermore, Bekkelund, Pierre-Jerome, Torbergsen, and Ingebrigsten (2001) reported 1 out of 10 workers remained permanently absent from work due to CTS. These numbers are rising and the costs are escalating. The prevention and early management of CTS is an occupational health and safety priority (Szabo, 1998) and the need to identify safe, effective, and economic conservative management strategies for the treatment of mild to moderate CTS is critical.

1.3 CONSERVATIVE INTERVENTIONS FOR THE TREATMENT OF CTS

The treatment of CTS has advanced considerably since the use of galvanism, phosphorus, strychnine, potassium, bromide, amyl nitrite, and cannabis indica in the late 1800s and cervical rib excision in the early 1900s. However, there is still no consensus on the optimal treatment of CTS (Scholten, de Krom, Berlesmann, & Bouter, 1997). Occupational therapists, physical therapists, and hand therapists use a variety of conservative interventions for managing CTS. Splinting the wrist is the most common non-invasive conservative intervention used to treat CTS (Duncan et al., 1987; Scholten et al., 1997) and there is evidence to support its effectiveness (Burke, Burke, Stewart, & Cambré, 1994; Daniel & Paul, 2000; Dolhanty, 1986; Gerritsen, de Vet, et al., 2002; Kruger, Kraft, Deitz, Ameis, & Polissar, 1991; Li, Liu, Miyazaki, & Warren, 1999; Sevim et al., 2004; Walker, Metzler, Cifu, & Swartz, 2000). Other conservative interventions used are: ultrasound (Ebenbichler et al., 1998; Oztas, Turan, Bora, & Karakaya,

1998), tendon and nerve gliding exercises (Akalin et al., 2002; Rozmaryn et al., 1998), iontophoresis (Banta, 1994), manual therapy (Manente, Torrieri, Pineto, & Uncini, 1999; Tal-Akabi & Rushton, 2000), massage therapy (Field et al., 2004), wrist traction (Respice, Chu-Andrew, Respice, & Bilski, 2004), and aerobic exercise (Nathan, Wilcox, Emerick, Meadows, & McCormack, 2001). Due to the paucity of solid evidence practice patterns vary between clinics and clinicians and there is no one intervention that is considered "best practice".

2.0 A SYSTEMATIC REVIEW OF THE LITERATURE

Systematic reviews have been found in the literature investigating conservative treatment options for carpal tunnel syndrome (CTS). However, these reviews included non-surgical interventions such as steroid injections, laser therapy, acupuncture, and medication and some were limited to randomized controlled clinical trials (Gerritsen, de Krom, et al., 2002; Goodyear-Smith & Arroll, 2004; Muller et al., 2004; O'Conner, Marshall, & Massey-Westropp, 2003). This systematic review focused on studies that investigated interventions that are generally performed or instructed by occupational therapists, physical therapists, or hand therapists irrespective of study design or the level of evidence.

2.1 SELECTION OF STUDIES

To determine the effectiveness of the conservative interventions commonly used by occupational therapists, physical therapists, and hand therapists to treat CTS a systematic review of the literature was conducted. A comprehensive computer aided search was made in MEDLINE, Cumulative Index to Nursing and Allied Health Literature (CINAHL), and the COCHRANE databases to search for journal articles. The key words used in the search were carpal tunnel syndrome, neuropathy, and nerve impingement, combined with splinting, treatment, conservative interventions, outcomes, and exercise. In addition, hand searches and reference checking in

relevant journals were conducted. To be included in the systematic review an article had to meet the following criteria: 1) the article was written or translated in English, 2) the interventions were non-invasive and could be performed, or instructed by, an occupational therapist, physical therapist, or hand therapist, 3) the interventions were clearly defined and evaluated the effects of conservative treatment for CTS, 4) subjects were electrophysiologically or clinically diagnosed with CTS, 5) subjects were over the age of 18 years, and 6) subjects were not pregnant.

Forty-two articles were evaluated and 18 articles met the inclusion criteria. Eighteen articles were excluded because the treatments were not treatments that are generally performed or instructed by an occupational therapist, physical therapist or hand therapist. These interventions were; yoga (Garfinkel et al., 1998), magnet therapy (Carter, Hall, Aspy, & Mold, 2002; Weintraub & Cole, 2000), therapeutic touch (Blankfield, Sulzmann, Fradley, Tapolyai, & Zyzanski, 2001), osteopathic manipulation (Sucher, 1994), steroid injections (Gelberman, Aronson, & Weisman, 1980; Graham, Hudson, Solomons, & Singer, 2004; Harter et al., 1993; Kaplan, Glickel, & Eaton, 1990; Weiss, Sachar, & Gendreau, 1994), laser therapy (Naeser, Hahn, Lieberman, & Branco, 2002; Padua, Padua, Moretti, Nazzaro, & Toral, 1999; Weintraub, 1997), acupuncture (Chen, 1990), chiropractic (Bonebrake, Fernandez, Dahalan, & Marley, 1993; Bonebrake, Fernandez, Marley, Dahalan, & Kilmer, 1990), and medications (Celiker, Arslan, & Inanici, 2002; Stransky, Rubin, Lava, & Lazaro, 1989). Three articles were excluded because not all subjects were clinically or electrophysiologically diagnosed with CTS (Daniel & Paul, 2000; Tittiranonda, Rempel, Armstrong, & Burastero, 1999; Werner, Franzblau, & Gell, 2005). Two articles were excluded because the conservative interventions were not clearly defined (Finestone, Woodbury, Collavini, Marchuk, & Maryniak, 1996; Katz et al., 1998) and another article was excluded because pregnant women were included (Courts, 1995).

2.2 DATA EXTRACTION

Data from the selected articles were extracted and recorded on a matrix. The information collected from the articles were: number of subjects enrolled in the study, number of subjects who completed the study, subject characteristics (age, gender, clinically or electrophysiologically confirmed CTS, duration of symptoms, and the percentage of subjects with bilateral CTS), intervention prescribed, outcome measures (symptoms, function, and physiologic), and the results of the study.

2.3 ASSESSMENT OF METHODOLOGICAL QUALITY

The studies were evaluated using a hierarchy of five Levels of Evidence with the best level of evidence ranked at Level I and the less convincing evidence ranked at Level V (Moore, McQuay, & Gray, 1995). The levels represent the type of research design and methods used to conduct the study. Studies at the top of the hierarchy are less biased and the results are more generalizable to the general population. In addition, the higher levels of evidence provide more confidence in the effect of the intervention being studied. Studies at the bottom of the hierarchy are subject to biases and are structured using a weaker methodological research design. Studies that are ranked at the lower levels of the hierarchy should be reviewed and interpreted with prudence.

2.4 EFFICACY OF CONSERVATIVE TREATMENT

The characteristics and results of each study are summarized in Tables 1 though 6. The studies are listed from the strongest evidence (Level I) to the weakest evidence (Level V). If the studies had the same rank, the most recent study was listed first. Only significant findings were annotated in the results section.

Table 1: Summary of Evidence on Splinting

n	Subject Characteristics	Intervention	Outcome Measures	Results p-values ≤.05 are significant
Citation: Sevim et al., 2004 (Turkey) Study Design: Prospective, blinded, randomized, before and after treatment Evidence Level: II				
E: 120 C: 108 withdraw rate: 10%	Clinical and Electro-physiological confirmed CTS, ages ranged from 23-71 yrs, duration of symptoms ranged from 5 mos to 5+ yrs Distal Injection Mean age 45 yrs, 83% female, 19% bilateral CTS Proximal Injection Mean age 44 yrs, 96% female, 17% bilateral CTS Wrist Splint Mean age 50 yrs, 79% female, 16% bilateral CTS Control Mean age 46 yrs, 83% female, 12% bilateral CTS	Distal Injection (n = 29) Injection of betamethasone distal to the carpal tunnel Proximal Injection (n = 28) Injection of betamethasone proximal to the carpal tunnel Splint (n = 28) Neutral wrist splint worn at night Control (n = 23) No treatment	<u>Symptoms/ Function</u> Neurologic Symptom Score <u>Physiologic</u> Sensory Nerve Conduction Distal Sensory Latency Distal Motor Latency	Neurolgic Symptom Score (baseline, 11 mos) <u>Between Groups</u> - Not reported. <u>Within Groups</u> - Splint group significantly improved from baseline to follow-up (p<.001). Sensory Nerve Conduction (baseline, 11 mos) <u>Between Groups</u> - Not reported. <u>Within Groups</u> - Splint group significantly improved from baseline to follow-up (p<.001). Distal Sensory Latency (baseline, 11 mos) <u>Between Groups</u> - Not reported. <u>Within Groups</u> - Splint group significantly improved from baseline to follow-up (p<.001). Distal Motor Latency (baseline, 11 mos) <u>Between Groups</u> - Not reported. <u>Within Groups</u> - Splint group significantly improved from baseline to follow-up (p<.001).

Note. E - enrolled. C – completed. CTS – carpal tunnel syndrome. * Primary outcome measure. BCTQ – Boston Carpal Tunnel Questionnaire

Table 1 (continued).

N	Subject Characteristics	Intervention	Outcome Measures	Results p-values ≤.05 are significant
Citation: Gerritsen, de Vet, et al., 2002 (United States) Study Design: Multi-center, blinded, randomized time series Evidence Level: II				
E: 176 C: 147 withdraw rate: 16%	Clinical and Electro-physiological confirmed CTS Surgery Mean age 49 yrs, 76% female, median duration of symptoms 40 wks ranging from 16 to 104 weeks, 55% bilateral CTS Splint Mean age 49 yrs, 87% female, median duration of symptoms 52 wks, ranging from 24 to 104 wks, 63% bilateral CTS	Surgery (n = 87) CTS release Splint (n = 89) Neutral wrist splint worn at night for 6 wks; and could wear during the day	<u>Symptoms</u> Success Rate Night Awakenings Severity Main Complaint Day Paresthesia Night Paresthesia Severity of Complaints Rated by Physiotherapist CTS Symptom Severity Scale <u>Function</u> CTS Functional Status Scale <u>Physiologic</u> Distal Sensory Latency	*Success Rate (baseline, 1, 3, 6, 12, 18 mos) <u>Between Groups</u> - Surgery significantly more effective compared to splint at 3 (p<.001), 6 (p<.001), 12 (p=.002) and 18 (p=.02) mos. <u>Within Groups</u> - Not reported. *Night Awakenings (baseline, 1, 3, 6, 12, 18 mos) <u>Between Groups</u> - Splint significantly more effective compared to surgery at 1 mos (p=.008). Surgery significantly more effective compared to splint at 6 mos (p=.03). <u>Within Groups</u> - Not reported. *Severity of Main Complaint (baseline, 1, 3, 6, 12, 18 mos) <u>Between Groups</u> - Surgery significantly more effective compared to splint at 3 (p<.001), 6 (p<.001), 12 (p=.005) and 18 (p=.02) mos. <u>Within Groups</u> - Not reported. *Day Paresthesia (baseline, 1, 3, 6, 12, 18 mos) <u>Between Groups</u> - Surgery significantly more effective compared to splint at 3 (p<.001), 6 (p<.001), 12 (p=.004) and 18 (p=.01) mos. <u>Within Groups</u> - Not reported. *Night Paresthesia (baseline, 1, 3, 6, 12, 18 mos) <u>Between Groups</u> - Splint significantly more effective compared to surgery at 1 mos (p=.02). Surgery significantly more effective compared to splint at 3 (p=.046) and, 6 (p=.02) mos. <u>Within Groups</u> - Not reported.

Note. E - enrolled. C – completed. CTS – carpal tunnel syndrome. * Primary outcome measure. BCTQ – Boston Carpal Tunnel Questionnaire

Table 1 (continued).

N	Subject Characteristics	Intervention	Outcome Measures	Results p-values ≤.05 are significant
			Median-Ulnar Distal Sensory Latency Difference	Severity of Complaints Rated by Physiotherapist (baseline, 3, 6, 12, mos) Between Groups - Surgery significantly more effective compared to splint at 3 (p=.007), 6 (p=.001), and 12 (p=.002) mos. Within Groups - Not reported.
			Distal Motor Latency	CTS Symptom Severity Scale (baseline, 3, 6, 12, 18 mos) Between Groups Surgery significantly more effective compared to splint at 3 (p<.001), 6 (p=.001), 12 (p=.003), and 18 (p=.02) mos. Within Groups - Not reported. CTS Functional Status Scale (baseline, 3, 6, 12, 18, mos) Between Groups - Surgery significantly more effective compared to splint at 6 (p=.001) and 12 (p=.03) mos. Surgery approaching significance compared to Splint at 3 (p=.07) mos. Within Groups - Not reported. Distal Sensory Latency (baseline, 12 mos) Between Groups - Surgery significantly more effective compared to splint (p=.04). Within Groups - Not reported. Median-Ulnar Distal Sensory Latency Difference (baseline, 12 mos) Between Groups – No significant difference. Within Groups – Not reported. Distal Motor Latency (baseline, 12 mos) Between Groups - No significant difference. Within Groups – Not reported.

Note. E - enrolled. C – completed. CTS – carpal tunnel syndrome. * Primary outcome measure. BCTQ – Boston Carpal Tunnel Questionnaire

Table 1 (continued).

n	Subject Characteristics	Intervention	Outcome Measures	Results p-values ≤.05 are significant
Citation: Manente et al., 2001 (Italy) Study Design: Randomized, time series Evidence Level: II				
E: 83 C: 80 withdraw rate: 04%	Clinical and Electro-physiological confirmed CTS Hand Brace Mean age 46 yrs, 90% female, mean duration of symptoms not reported, no bilateral CTS (inclusion criteria) Control Mean age 50 yrs, 83% female, mean duration of symptoms not reported, no bilateral CTS (inclusion criteria)	Hand Brace (n = 41) Hand brace that produces a mild stretch to digits 3 and 4, does not impede wrist flexion or extension, worn at night for 4 wks Control (n = 43) No treatment	<u>Symptoms</u> BCTQ Symptoms Subject's Global Impression of Change <u>Function</u> BCTQ Function <u>Physiologic</u> Distal Motor Latency Sensory Nerve Action Potential Sensory Conduction Velocity	*BCTQ Symptoms (baseline, 2, 4, wks) <u>Between Groups</u> - Hand brace significantly more effective compared to no treatment at 2 and 4 wks (p<.001). <u>Within Groups</u> - Not reported. *BCTQ Function (baseline, 2, 4 wks) <u>Between Groups</u> - Hand brace significantly more effective compared to no treatment at 2 and 4 wks (p<.001). <u>Within Groups</u> - Not reported. Subject's Global Impression of Change (baseline, 4 wks) <u>Between Groups</u> - Hand brace significantly more effective compared to no treatment at 4 wks (p=.006). <u>Within Groups</u> – Not reported Distal Motor Latency (baseline, 4 wks) <u>Between Groups</u> – No significant difference. <u>Within Groups</u> – Not reported. Sensory Nerve Action Potential (baseline, 4 wks) <u>Between Groups</u> – No significant difference. <u>Within Groups</u> – Not reported. Sensory Conduction Velocity (baseline, 4 wks) <u>Between Groups</u> - No significant difference. <u>Within Groups</u> - Not reported.

Note. E - enrolled. C – completed. CTS – carpal tunnel syndrome. * Primary outcome measure. BCTQ – Boston Carpal Tunnel Questionnaire

Table 1 (continue).

n	Subject Characteristics	Intervention	Outcome Measures	Results p-values ≤.05 are significant
Citation: Walker et al., 2000 (United States) Study Design: Prospective, randomized, before and after treatment Evidence Level: II				
E: 21 (30 hands) C: 17 (24 hands) withdraw rate: 20%	Clinical and Electro-Physiological Confirmed CTS Full-Time Splint Wear Mean age 61 yrs, 7% female, mean duration of symptoms not reported, 46% bilateral CTS Night-Time Splint Wear Mean age 60 yrs, 0% female, mean duration of symptoms not reported, 73% bilateral CTS	Full-Time Splint Wear (n = 11 hands) Full time neutral wrist splint wear Night Time Splint Wear (n = 13 hands) Night time neutral wrist splint wear	<u>Symptoms</u> CTS Symptom Severity Scale <u>Function</u> CTS Functional Status Scale <u>Physiologic</u> Distal Sensory Latency Distal Motor Latency	CTS Symptom Severity Scale (baseline, 6 wks) <u>Between Groups</u> – No significant difference. <u>Within Groups</u> - Both groups significantly improved (p =.0001) from baseline to follow-up. CTS Functional Status Scale (baseline, 6 wks) <u>Between Groups</u> – No significant difference. <u>Within Groups</u> - Both groups significantly improved (p=.0001) from baseline to follow-up. Distal Sensory Latency (baseline, 6 wks) <u>Between Groups</u> – Full time splint wear significantly more effective compared to night time splint wear (p=.05). <u>Within Groups</u> - Both groups significantly improved (p=.0037) from baseline to follow-up. Distal Motor Latency (baseline, 6 wks) <u>Between Groups</u> – Full time splint wear significantly more effective compared to night time splint wear (p=.04). <u>Within Groups</u> – No significant difference.

Note. E - enrolled. C – completed. CTS – carpal tunnel syndrome. * Primary outcome measure. BCTQ – Boston Carpal Tunnel Questionnaire

Table 1 (continue).

n	Subject Characteristics	Intervention	Outcome Measures	Results p-values ≤.05 are significant
Citation: Li et al., 1999 (Canada) Study Design: One group, quasi-experimental, time series, within-subject Evidence Level: III				
E: 25 (33 hands) C: 22 (29 hands) withdraw rate: 12%	Clinical confirmed CTS, mean age 45 yrs, 64% female, mean duration of symptoms 42 wks ranging from 1 to 260 wks, 32% bilateral CTS	Ulnar Gutter Splint Neutral ulnar gutter wrist splint worn at night and when performing repetitive wrist motion	Symptoms CTS Symptom Severity Scale Function CTS Functional Status Scale	CTS Symptom Severity Scale (1-2 wks before baseline, baseline, 2, 10-12 wks) Splint group significantly improved from baseline to 2 wks and from baseline to 12 wks (p=.0000). CTS Functional Status Scale (1-2 wks before baseline, baseline, 2, 10-12 wks) Splint group significantly improved from baseline to 12 wks (p=.0004).

Note. E - enrolled. C – completed. CTS – carpal tunnel syndrome. * Primary outcome measure. BCTQ – Boston Carpal Tunnel Questionnaire

Table 1 (continue).

n	Subject Characteristics	Intervention	Outcome Measures	Results p-values ≤.05 are significant
Citation: Burke et al., 1994 (United States) Study Design: Prospective, blinded, time series Evidence Level: III				
E: 59 (90 hands) C: 47 (71 hands) withdraw rate: 21%	Clinical confirmed CTS, mean age not reported, gender not reported, 53% bilateral CTS Neutral Wrist Splint Mean duration of symptoms 25 mos Wrist Cock-Up Splint Mean duration of symptoms 28 mos	Neutral Wrist Splint (n = 45 hands) Neutral wrist splint Wrist Cock-up Splint (n = 45 hands) Wrist splint @ 20 degrees extension Schedule of splint wear not reported	<u>Symptoms</u> Overall Symptom Relief Questions Night Time Symptom Relief Questions Day Time Symptom Relief Questions	Overall Symptom Relief (2, 8 wks) <u>Between Groups</u> - Neutral wrist splint significantly more effective compared to wrist cock-up splint (p=.017) at 2 wks. No comparison made at 8 wks between groups. <u>Within Groups</u> – Not reported. Night Time Symptom Relief (2, 8 wks) <u>Between Groups</u> - Neutral wrist splint significantly more effective compared to wrist cock-up splint (p=.034) at 2 wks. No comparison made at 8 wks between the groups. <u>Within Groups</u> – Not reported. Day Time Symptom Relief (2, 8 wks) <u>Between Groups</u> – No significant difference. <u>Within Groups</u> – Not reported. Correlation between length of symptoms and response to splinting No significant correlation. Correlation between EMG confirmed CTS and response to splinting No significant correlation.

Note. E - enrolled. C – completed. CTS – carpal tunnel syndrome. * Primary outcome measure. BCTQ – Boston Carpal Tunnel Questionnaire

Table 1 (continue).

n	Subject Characteristics	Intervention	Outcome Measures	Results p-values ≤.05 are significant
Citation: Dolhanty, 1986 (United States) Study Design: Quasi-experimental pretest posttest Evidence Level: III				
E: 12 (20 hands) C: 12 (20 hands) withdraw rate: 0%	Clinical and electro-physiological confirmed CTS Splint Mean age 49 yrs, 83% female, mean duration of symptoms 30 wks, 67% bilateral CTS Control Mean age 52 yrs, 83% female, mean duration of symptoms 26 wks, 67% bilateral CTS	Splint (n = 10 hands) Splint positioning the wrist in a few degrees of flexion worn night and day Control (n = 10 hands) No splint	<u>Symptoms</u> Morning Stiffness Numbness Pain Tingling <u>Physiologic</u> Electrodiagnostic Study	Morning Stiffness (baseline, 1wk) <u>Between Groups</u> – No significant difference. <u>Within Groups</u> – Not reported. Numbness (baseline, 1wk) <u>Between Groups</u> - Splint significantly more effective compared to no splint in decreasing intensity (p=.0028) and frequency (p=.0113). <u>Within Groups</u> – Not reported. Pain (baseline, 1wk) <u>Between Groups</u> Splint significantly more effective compared to no splint in decreasing intensity (p=.0376) and frequency (p=.0297). <u>Within Groups</u> – Not reported. Tingling (baseline, 1wk) <u>Between Groups</u> Splint significantly more effective compared to no splint in decreasing intensity (p=.0343) and frequency (p=.0173). <u>Within Groups</u> – Not reported. Electrodiagnostic study (baseline, 1 wk) <u>Between Groups</u> – No significant difference. <u>Within Groups</u> – Not reported.

Note. E - enrolled. C – completed. CTS – carpal tunnel syndrome. * Primary outcome measure. BCTQ – Boston Carpal Tunnel Questionnaire

Table 1 (continue).

n	Subject Characteristics	Intervention	Outcome Measures	Results p-values ≤.05 are significant
Citation: Kruger et al., 1991 (Canada) Study Design: Retrospective Evidence Level: IV				
E: 105 C: 105 withdraw rate: 0%	Electro-physiological confirmed CTS, ages ranged from 20 to 86 yrs, 80% female, duration of symptoms ranged from less than 1 month to over 12 mos with 35 % having symptoms for at least 1 yr, 36% bilateral CTS	Splint (n = 105) Ulnar gutter neutral angle wrist splint (schedule of splint wear not reported)	<u>Symptoms</u> Yes/No Question "Did splinting decrease your symptoms?" <u>Physiologic</u> Median Motor Median Sensory	Yes/No Question (baseline, within 17 mos of tx) 67% of subjects reported symptom relief. Median Motor (baseline, within 17 mos of tx) No significant difference. Median Sensory (baseline, within 17 mos of tx) Splint group significantly improved from baseline to follow-up (p=0.02).

Note. E - enrolled. C – completed. CTS – carpal tunnel syndrome. * Primary outcome measure. BCTQ – Boston Carpal Tunnel Questionnaire.

Table 2: Summary of the Evidence on Ultrasound

n	Subject Characteristics	Intervention	Outcome Measures	Results p-values ≤05 are significant
Citation: Oztas et al., 1998 (Turkey) Study Design: Patient-blinded, before and after treatment Evidence Level: II				
E: 18 (30 hands) C: 18 (30 hands) withdraw rate: 0%	Clinical and Electro-physiological confirmed CTS, 100% female, 67% bilateral CTS US @ 1.5W/cm² Mean age 53 yrs ranging from 45 to 61 yrs, mean symptom duration 88 mos ranging from 24 to 180 mos US @ 0.8W/cm² Mean age 51 yrs ranging from 37 to 66 yrs, mean symptom duration 89 mos ranging from 6 to 240 mos US @ 0.0W/cm² Mean age 49 yrs ranging from 41 to 59 yrs, mean symptom duration 70 mos, ranging from 6 to 240 mos	US @ 1.5W/cm² (10 hands) US @ 0.8W/cm² (10 hands) US @ 0.0W/cm² (10 hands) Continuous US applied to the carpal tunnel for 5 min, 5 days, for 2 wks	<u>Symptoms</u> Pain Visual Analog Scale Night Pain/Paresthesia Frequency of Awakening <u>Physiologic</u> Median Distal Latency Median Nerve Conduction Velocity Sensory Distal Latency Sensory Nerve Conduction Velocity	Pain Visual Analog Scale (baseline, 20 days) <u>Between Groups</u> – No significant difference. <u>Within Groups</u> - All groups significantly improved from baseline to follow-up (p<.05). Night Pain/Paresthesia (baseline, 20 days) <u>Between Groups</u> – No significant difference. <u>Within Groups</u> - All groups significantly improved from baseline to follow-up (p<.05). Frequency of Awakening (baseline, 20 days) <u>Between Groups</u> – No significant difference. <u>Within Groups</u> - All groups significantly improved from baseline to follow-up (p<.05). Median Distal Latency (baseline, 20 days) <u>Between Groups</u> – No significant difference. <u>Within Groups</u> – No significant difference. Median Nerve Conduction Velocity (baseline, 20 days) <u>Between Groups</u> – No significant difference. <u>Within Groups</u> – No significant difference. Sensory Distal Latency (baseline, 20 days) <u>Between Groups</u> – No significant difference. <u>Within Groups</u> – No significant difference. Sensory Nerve Conduction Velocity (baseline, 20 days) <u>Between Groups</u> – No significant difference. <u>Within Groups</u> – No significant difference.

Note. E – enrolled. C – completed. CTS - carpal tunnel syndrome. US – ultrasound. * Primary outcome measure.

Table 2 (continue).

n	Subject Characteristics	Intervention	Outcome Measures	Results p-values ≤05 are significant
Citation: Ebenbichler et al., 1998 (Austria) Study Design: Randomized, double blind, "sham", time series Evidence Level: II				
E: 45 (90 hands) C: 34 (68 hands) withdraw rate: 24% to 7 wk follow-up 33% to 24 wk follow-up	Clinical and electro-physiological confirmed CTS, 100% bilateral CTS (inclusion criteria) Pulsed US @ 1.0W/ cm² Mean age 51 yrs, mean duration of symptoms 8 mos Sham US @ 0.0W/cm² Mean age 51 yrs, mean duration of symptoms 7 mos	Pulsed US @ 1.0W/ cm² (n = 34) sham US @ 0.0W/cm² (n = 34) US applied to the carpal tunnel of one wrist and sham US applied over other wrist, 10 treatments performed once a day for 5 days and next 10 treatments performed twice a wk for 5 wks	<u>Symptoms</u> Main Complaint Worst Complaint Sensory Loss General Improvement <u>Function</u> Grip Strength Pinch Strength <u>Physiologic</u> Distal Motor Latency Sensory Nerve Conduction	*Main Complaint (baseline, 2, 7, 24 wks) <u>Between Groups</u> – Pulsed US significantly more effective compared to sham US at 2 (p<.015), 7 (p<.001), and 24 (p<.0005) wks. <u>Within Groups</u> - Not reported. *Worst Complaint (baseline, 2, 7, 24 wks) <u>Between Groups</u> – Pulsed US significantly more effective compared to sham US at 7 (p<.002), and 24 (p<.0005) wks. <u>Within Groups</u> - Not reported. *Sensory Loss (baseline, 2, 7, 24 wks) <u>Between Groups</u> – Pulsed US significantly more effective compared to sham US at 2 (p<.009), 7 (p<.007), and 24 (p<.0005) wks. <u>Within Groups</u> - Not reported. General Improvement (baseline, 2, 7, 24 wks) <u>Between Groups</u> – Pulsed US significantly more effective compared to sham US (p=.002) at 7 wks. <u>Within Groups</u> - Not reported. Grip Strength (baseline, 2, 7, 24 wks) <u>Between Groups</u> – Pulsed US significantly more effective compared to sham US at 7 (p<.0005) and 24 (p<.0005) wks. <u>Within Groups</u> - Not reported. Pinch Strength (baseline, 2, 7, 24 wks) <u>Between Group</u> – Pulsed US significantly more effective compared to sham US at 24 wks (p=.014). <u>Within Groups</u> - Not reported.

Note. E – enrolled. C – completed. CTS - carpal tunnel syndrome. US – ultrasound. * Primary outcome measure.

Table 2 (continue).

n	Subject Characteristics	Intervention	Outcome Measures	Results p-values ≤05 are significant
				*Distal Motor Latency (baseline, 2, 7, 24 wks) Between Groups – Pulsed US significantly more effective compared to sham US at 2 (p<.001), 7 (p=.0005), and 24 (p=.0005) wks. Within Groups - Not reported. *Sensory Nerve Conduction (baseline, 2, 7, 24 wks) Between Groups – Pulsed US significantly more effective compared to sham US at 2 (p<.0005), 7 (p<.0005), and 24 (p<.001) wks. Within Groups - Not reported.

Note. E – enrolled. C – completed. CTS - carpal tunnel syndrome. US – ultrasound. * Primary outcome measure.

Table 3: Summary of the Evidence on Tendon and Nerve Gliding Exercises

n	Subject Characteristics	Intervention	Outcome Measures	Results p-values ≤.05 are significant
Citation: Akalin et al., 2002 (Turkey) Study Design: Prospective, randomized, before and after treatment Evidence Level: II				
E: 28 (36 hands) C: 28 (36 hands) withdraw rate: 0%	Clinical and electro-physiological confirmed CTS Tendon Gliding / Nerve Gliding Exercises Mean age 52 yrs, 94% female, mean duration of symptoms 48 mos, 14% bilateral CTS Splint Mean age 52 yrs, 94% female, mean duration of symptoms 50 mos, 14% bilateral CTS	Exercise (n = 14) Neutral wrist splint, night and day wear for 4 wks, tendon gliding /nerve gliding exercises, 5x a day, 10 reps, hold for 5 sec Splint (n = 14) Neutral wrist splint	<u>Symptoms</u> Phalen's Sign Tinel's Sign CTS Symptom Severity Scale <u>Function</u> 2-Point Discrimination Grip Strength Pinch Strength CTS Functional Status Scale	Phalen's Sign (baseline, 8 wks) <u>Between Groups</u> – No significant difference. <u>Within Groups</u> - Both groups significantly improved from baseline to 8 wks. Tinel's Sign (baseline, 8 wks) <u>Between Groups</u> – No significant difference. <u>Within Groups</u> - Both groups significantly improved from baseline to 8 wks. CTS Symptom Severity Scale (baseline, 8 wks) <u>Between Groups</u> – No significant difference. <u>Within Groups</u> - Both groups significantly improved from baseline to 8 wks. 2-Point Discrimination (baseline, 8 wks) <u>Between Groups</u> – No significant difference. <u>Within Groups</u> – No significant difference. Grip Strength (baseline, 8 wks) <u>Between Groups</u> - – No significant difference. <u>Within Groups</u> - Both groups significantly improved from baseline to 8 wks. Lateral Pinch Strength (baseline, 8 wks) <u>Between Groups</u> – Splint and exercise group significantly more effective compared to control (p=.026). <u>Within Groups</u> - Both groups significantly improved from baseline to 8 wks. CTS Functional Status Scale (Baseline, 8 wks) <u>Between Groups</u> – No significant difference. <u>Within Groups</u> - Both groups significantly improved from baseline to 8 wks.

Note. E – enrolled. C – completed. CTS – carpal tunnel syndrome. TGE – tendon gliding exercises. NGE – nerve gliding exercises. NSAID – non-steroidal anti-inflammatory drugs.

Table 3 (continue).

n	Subject Characteristics	Intervention	Outcome Measures	Results p-values ≤.05 are significant
Citation: Rozmaryn et al., 1998 (United States) Study Design: Retrospective Evidence Level: IV				
E: 197 (240 hands) C: 197 (240 hands) withdraw rate: 0%	Clinical confirmed CTS, ages ranged from 30 to 39 yrs, 73% female, mean duration of symptoms ranged from less than 6 mos to 2+ yrs, 36% bilateral CTS	Exercises (n = 104) Traditional treatment (splinting, NSAIDs, injection) and TGE, NGE (3-5x a day, 5 reps, holding each position for 7 sec), contrast baths 2x a day Traditional Treatment (n = 94) Splinting, NSAIDs, injection	<u>Symptoms</u> Surgical release	Surgical Release TGE/NGE group required significantly fewer surgeries than the traditional treatment group; 43% of subjects in exercise group had surgery compared to 71% in the traditional treatment group.

Note. E – enrolled. C – completed. CTS – carpal tunnel syndrome. TGE – tendon gliding exercises. NGE – nerve gliding exercises. NSAID – non-steroidal anti-inflammatory drugs.

Table 4: Summary of Evidence on Iontophoresis

n	Subject Characteristics	Intervention	Outcome Measures	Results p-values ≤.05 are significant
Citation: Banta, 1994 (United States) Study Design: Prospective, one group, two step treatment, time series Evidence Level: III				
E: 18 (23 hands) C: 18 (23 hands) withdraw rate: 0%	Clinical and electro-physiological confirmed CTS, ages ranged from 22 to 73 yrs, 61% female, mean duration of symptoms ranged from 2 mos to 10 yrs, 28% bilateral CTS	Splint The first 3 wks neutral wrist splint full time wear, the 4th wk NSAIDS, Iontophoresis with dex-amethasone and lidocaine across the wrist every other day for 45 min	<u>Physiologic</u> Nerve Conduction Study	Nerve Conduction Study (baseline, 3 wks and 6 mos) 17% of the subjects improved with splinting and NSAIDs with normalization of nerve conduction studies at the 3 wk follow-up and remained asymptomatic at the 6 mos follow-up. 48% improved with iontophoresis with normalization of nerve conduction at 6 mos follow-up. 35% referred to surgery at 6 mos.

Note. E – enrolled. C – completed. CTS – carpal tunnel syndrome. NSAID – non-steroidal anti-inflammatory drugs.

Table 5: Summary of Evidence on Manual Therapy

n	Subject Characteristics	Intervention	Outcome Measures	Results p-values ≤.05 are significant
Citation: Tal-Akabi & Rushton, 2000 (Switzerland) Study Design: Randomized, experimental design Evidence Level: II				
E: 21 C: 21 withdraw rate: 0%	Clinical and electro-physiological confirmed CTS (Subjects were selected from a waiting list for surgery), mean age 47, ranging from 29 to 85 yrs, 67% female, mean duration of symptoms 2.3 yrs, 43% bilateral CTS	Neuro-Dynamic Mobilization (n=7) Upper limb tension test mobilization Carpal Bone Mobilization (n=7) Carpal bone mobilization (posterior-anterior and anterior posterior techniques) and flexor retinaculum stretch Control (n=7) No treatment	<u>Symptoms</u> Symptom Visual Analog Scale Modified Pain Relief Scale <u>Function</u> Functional Box Scale Active Range of Motion Upper Limb Tension Test/Median Nerve Biased Test Subject's Continuing to Surgery	Symptom Visual Analog Scale (Baseline, 3 wks) <u>Between Groups</u> – Neuro-dynamic mobilization and carpal bone mobilization significantly more effective compared to control (p<.05). <u>Within Groups</u> - Neurodynamic mobilization group significantly improved from baseline to follow-up (p<.02). Carpal bone mobilization group significantly improved from baseline to follow-up (p<.001). Modified Pain Relief Scale (Baseline, 3 wks) <u>Between Groups</u> - Neuro-dynamic mobilization and carpal bone mobilization significantly more effective compared to control (p<.05). <u>Within Groups</u> – Not reported. Functional Box Scale (Baseline, 3 wks) <u>Between Groups</u> – No significant difference. <u>Within Groups</u> – Not reported. Active Range of Motion (Baseline, 3 wks) <u>Between Groups</u> – No significant difference. <u>Within Groups</u> - Neurodynamic mobilization and carpal bone mobilization group significantly improved from baseline to follow-up (p<.05). Upper Limb Tension Test and Median Nerve Biased Test (Baseline, 3 wks) Neurodynamic mobilization – 7 out of 7 subjects tested positive at baseline compared to 2 at follow-up (71% improvement). Carpal bone mobilization – 7 out of 7 subjects tested positive at baseline compared to 3 at follow-up (57% improvement). No treatment – 7 out of 7 subjects tested positive at baseline and 7 subjects tested positive at follow-up (0% improvement)

Note. E – enrolled. C – completed. CTS – carpal tunnel syndrome.

Table 5 (continue).

n	Subject Characteristics	Intervention	Outcome Measures	Results p-values ≤.05 are significant
				Subject's Continuing to Surgery Neurodynamic mobilization – 2 subjects continued to surgery. Carpal bone mobilization – 1 subject continued to surgery. No treatment – 6 subjects continued to surgery.
Citation: Manente et al., 1999 (Italy) Study Design: Crossover Evidence Level: III				
E: 71 (112 hands) C: 71 (112 hands) withdraw rate: 0%	Clinical and electro-physiological confirmed CTS, mean age 54 yrs ranging from 28 to 76 yrs, 84% female, mean duration of symptoms 13 mos ranging from 2 wks to 7 yrs, bilateral CTS not reported	Relief maneuver Palm up, distal heads of the MCP bones (excluded the first) are gently squeezed inducing a slight adduction of digits 2 and 4, turn palm down, stretch digits 3 and 5 Phalen's Sign Place the wrist in flexion	Symptoms Abolition of Symptoms Improvement Physiologic Median Sensory Conduction Velocity Median Distal Motor Latency	Abolition of Symptoms Relief maneuver abolished symptoms in 23% of hands. Improvement (immediately after the maneuver) Relief maneuver was effective in 77% of hands, Phalen's sign caused symptoms to worsen in 76% of hands and no change in 24% of hands. Median Sensory Conduction Velocity (Baseline, 5 min) No significant difference. Median Distal Motor Latency (Baseline, 5 min) No significant difference.

Note. E – enrolled. C – completed. CTS – carpal tunnel syndrome.

Table 6: Summary of Evidence on Other Conservative Interventions

n	Subject Characteristics	Intervention	Outcome Measures	Results p-values ≤.05 are significant
Citation: Field et al., 2004 (United States) Study Design: Randomized controlled clinical trial Evidence Level: II				
E: 16 C: 16 withdraw rate: 0%	Clinical confirmed CTS, mean age 47 yrs ranging from 20 to 65 yrs, 93% female, duration of symptoms 6.7 yrs, 0% bilateral CTS	Massage Massage on the affected arm by therapist 1x a wk, self massage 1x day Control No treatment	<u>Symptoms</u> Carpal Tunnel Symptoms Tinel's Sign Phalen Test Visual Analogue Scale State Anxiety Inventory Profile of Mood States <u>Function</u> Grip Strength <u>Physiologic</u> Nerve Conduction Velocity Median Peak Latency	Carpal Tunnel Symptoms (baseline, 4 wks) <u>Between Groups</u> – Massage significantly more effective compared to control (p<.05). <u>Within Groups</u> – Not reported. Tinel's Sign (baseline, 4 wks) <u>Between Groups</u> – No significant difference. <u>Within Groups</u> – Not reported. Phalen Test (baseline, 4 wks) <u>Between Groups</u> – No significant difference. <u>Within Groups</u> – Not reported. Visual Analogue Scale (baseline, 4 wks) <u>Between Groups</u> – Not reported. <u>Within Groups</u> – Massage group significantly improved from baseline to follow-up (p<.05). State Anxiety Inventory (baseline, 4 wks) <u>Between Groups</u> – Not reported. <u>Within Groups</u> – Massage group significantly improved from baseline to follow-up (p<.05) Profile of Mood States (baseline, 4 wks) <u>Between Groups</u> – Not reported. <u>Within Groups</u> – Massage group significantly improved from baseline to follow-up (p<.05).

Note. E – enrolled. C – completed. CTS – carpal tunnel syndrome.

Table 6 (continue).

n	Subject Characteristics	Intervention	Outcome Measures	Results p-values ≤.05 are significant
				Grip Strength (baseline, 4 wks) Between Groups – Not reported. Within Groups – Massage group significantly improved from baseline to follow-up (p<.05). Nerve Conduction Velocity (baseline, 4 wks) Between Groups – No significant difference. Within Groups – Not reported. Median Peak Latency (baseline, 4 wks) Between Groups – Massage therapy significantly more effective compared to control (p<.05). Within Groups – Not reported
Citation: Respice et al., 2004 (United States) Study Design: One group, pre-test post-test Evidence Level: III				
E: 30 C: 30 withdraw rate: 0%	Clinical and electro-physiological confirmed CTS, mean age 44 yrs ranging from 25 to 60 yrs, 50% female, duration of symptoms not reported, bilateral CTS not reported	Wrist Traction Device Worn for 10 min, 2x a day for 4 wks, 10 min, 1x a day the following 4 wks	Physiologic Sensory Nerve Latency-Mid Palmar Sensory Nerve Latency-Wrist	Sensory Nerve Latency- Mid Palmar (baseline, 8 wks) Wrist traction device group significantly improved from baseline to 8 wks (p<.001). Sensory Nerve Latency-Wrist (baseline, 8 wks) Wrist traction device group significantly improved from baseline to 8 wks (p<.001).

Note. E – enrolled. C – completed. CTS – carpal tunnel syndrome.

Table 6 (continue).

n	Subject Characteristics	Intervention	Outcome Measures	Results p-values ≤.05 are significant
Citation: Nathan et al., 2001 (United States) Study Design: One group, pre-test post-test Evidence Level: III				
E: 41 C: 30 withdraw rate: 27%	Clinical and electro-physiological confirmed CTS, mean age 47 yrs, ranging from 30 to 64 yrs, 80% female, mean duration of symptoms 48 mos, bilateral CTS not reported	Aerobic Exercise (n = 30) 1 hr per day 3 days a wk	<u>Symptoms</u> Specific symptoms (numbness, tingling and nocturnal awakening) Non-specific symptoms (pain, tightness and clumsiness) <u>Physiologic</u> Median Sensory Latency Antidromic Sensory Latency	Specific Symptoms (baseline, 10 mos) No significant difference. Non-Specific symptoms (baseline, 10 mos) No significant difference. Median Sensory Latency (baseline, 10 mos) No significant difference. Antidromic Sensory Latency (baseline, 10 mos) No significant difference.

Note. E – enrolled. C – completed. CTS – carpal tunnel syndrome.

2.4.1 Splinting

Eight studies evaluated the effectiveness of splinting for decreasing symptoms and increasing function for patients diagnosed with CTS: four Level II evidence, three Level III evidence, and one Level IV evidence.

Level II Evidence

Sevim et al. (2004) used a prospective, masked, randomized, before and after treatment design with 120 subjects to determine the long term (11 months) efficacy of conservative intervention for the treatment of mild to moderate CTS. Subjects were referred from neurology, plastic and reconstructive surgery, and orthopedic outpatient clinics at a university hospital. A neutral wrist splint worn at night was compared to injection for relieving symptoms of CTS. The outcome measures were nerve conduction studies and a neurologic symptom score. The neurologic symptom score was a structured questionnaire administered by two of the authors who were masked to the patient's electrophysiologic findings and treatment methods. The questionnaire contained questions regarding symptoms of CTS such as; numbness, pain, night symptoms, and activities that aggravated these symptoms such as; housework, reading, and driving. The severity of each symptom was graded on a scale from 1 to 3 and the sum of the complaint score resulted in the neurologic symptom score. Higher scores reflected greater symptom severity. Sevim et al. (2004) reported no significant difference between the groups however subjects who wore a splint at night, for an average of 5 to 6 nights a week, for 11 months, significantly decreased CTS symptoms and improved in sensory and motor conduction velocities from baseline to follow-up. One methodological problem with this study was the absence of a standardized outcome measure to evaluate CTS symptoms; the reliability and

validity of the neurology symptom score is questionable. Another methodological problem was the absence of subjective and objective outcome measures to evaluate function.

Gerritsen, de Vet, et al. (2002) used a randomized controlled clinical trial with 176 subjects and multiple sites to compare the effectiveness of splinting versus surgery for the short term and long term for the treatment of mild to moderate CTS. Subjects were instructed to wear the neutral wrist splint at night for 6 weeks. The number of night awakenings due to CTS symptoms and night paresthesia were significantly improved compared to surgery at 1 month. In addition, the success rate and severity of the main complaint improved, however, surgery was more effective in severity of the main complaint, day paresthesia, and the CTS Symptom Severity Scale at 3, 6, 12, and 18 months.

Only one article evaluated the effectiveness of finger placement for the treatment of mild to severe CTS. Manente et al. (2001) used a randomized, before and after treatment design, with 83 subjects, comparing a hand brace that held the long finger and ring finger in extension to no treatment. The hand brace was worn at night for 4 weeks. The Carpal Tunnel Boston Questionnaire was administered at baseline, 2 weeks, and 4 weeks and the Subject's Global Impression of Change Questionnaire and the nerve conduction study were administered at baseline and 4 weeks. The hand brace was significantly more effective compared to no treatment in decreasing symptoms and increasing function at 2 and 4 weeks and was significantly more effective in the Subject's Global Impression of Change Questionnaire and improving sensory nerve action potential at 4 weeks. Manente and colleagues theorized that the reason for their excellent results may have been because the hand brace extends the long and ring finger pulling the lumbrical muscles out of the carpal tunnel and decreasing carpal tunnel pressure thus, decreasing CTS symptoms. Limitations to this study were that the hand brace did not include the

position of the wrist and the control group received no treatment. Past studies have demonstrated an association between splint wear and decreasing CTS symptoms thus, a control group with wrist splinting would have been a better comparison of the effectiveness of the hand brace.

In addition to assessing the long term and short term benefits of splinting, the schedule of splint wear has been investigated. Walker and colleagues (2000) employed a prospective, randomized, before and after treatment design, with 21 subjects, to compare full time neutral wrist splint wear to night time neutral wrist splint wear for the treatment of CTS. Outcome measures were the CTS Symptom Severity and Functional Status Scale and nerve conduction studies. Both groups significantly decreased symptoms, increased function, and improved sensory nerve conduction from baseline to 6 weeks. In addition, subjects who wore the splint full time significantly improved in distal sensory and distal motor latency compared to night time splinting. However, Walker and colleagues reported that the full time splint wear group had only a 46% adherence to splint wear during the day and a 100% adherence to night time splint wear. Thus, due to the lack of adherence to full time splint wear, the results of this study are not convincing on the benefits of full time splint wear.

Level III Evidence

Different splint designs have also been used to treat CTS. Li et al. (1999) used a one group, quasi-experimental, time series, within subject design, with 25 subjects to evaluate the effectiveness of an ulnar gutter neutral wrist splint worn at night and during day time activities for the treatment of mild to moderate CTS. Outcome measures were assessed at 1 to 2 weeks before treatment, baseline, 2 weeks post treatment, and 10 to 12 weeks post-post treatment. CTS symptoms, assessed by the CTS Symptom Severity Score, significantly decreased from baseline

to 2 weeks and from baseline to 12 weeks. Function, assessed by the CTS Functional Status Scale, significantly increased from baseline to 12 weeks.

The position of the wrist for the treatment of CTS was investigated by Burke et al. (1994). Burke evaluated 59 subjects using a prospective, masked, time series design. They compared a neutral wrist splint to a splint positioning the wrist in 20 degrees of extension. The neutral wrist splint was significantly more effective than the 20 degree wrist extension splint in overall symptom relief and night time symptom relief at 2 weeks.

One of the first studies evaluating splinting for the treatment of CTS was by Dolhanty in 1986. She studied 12 subjects using a quasi-experimental, pretest posttest design, comparing a splint positioning the wrist in a few degrees of flexion to no treatment. Outcome measures were frequency and intensity of CTS symptoms, morning stiffness, and electrodiagnostic studies. Dolhanty reported that subjects who wore the splint had significantly fewer CTS symptoms and improved on the electrodiagnostic studies compared to the subjects who received no treatment at 1 week. Limitations to this study were the small sample size, the lack of standardized measures to evaluate symptoms, and the failure to assess function.

Level IV Evidence

A retrospective, one group, pretest posttest design study conducted by Kruger et al. (1991) assessed the efficacy of a ulnar gutter splint positioning the wrist in neutral for the treatment of CTS. Outcome measures were nerve conduction and a subjective question regarding symptom relief. Their chart review indicated that 67% of 105 subjects had symptomatic relief with the use of splints and splint wear was significantly effective for improving median sensory latency.

In summary, a critical review of this literature revealed eight studies evaluating the effectiveness of splinting for the treatment of CTS. Of those eight studies, four were randomized

controlled clinical trials, three were quasi-experimental studies and one was a retrospective study.

Of the four randomized controlled clinical trials, one study did not evaluate function and did not use standardized outcome measures to evaluate symptoms for determining the long term effectiveness of splint wear (Sevim et al., 2004). Another trial evaluated the effectiveness of a hand brace, which excluded the wrist, compared to no treatment (Manente et al., 2001). The hand brace significantly decreased CTS symptoms and increased function. However, the lack of comparison to a wrist splint makes it impossible to determine if the hand brace was a more effective treatment than a wrist splint. The remaining two randomized controlled clinical trials demonstrated that splinting the wrist is an effective intervention for the treatment of CTS for the short term (Gerritsen, de Vet, et al., 2002; Walker et al., 2000). A limitation to all the randomized controlled clinical trials was the lack of reliable and valid objective measures to evaluate function. The best evidence comes from randomized controlled clinical trials, however if valid and reliable measures are not used then the results of the studies are weakened.

Moderate levels of evidence were provided by three quasi-experimental studies. However, these studies did not evaluate function and did not use standardized measures to evaluate symptom severity (Burke et al., 1994; Kruger et al., 1991; Dolhanty, 1986). In addition Dolhanty (1986) used a small sample size and a short follow-up period of 1 week. The lack of standardized measures and small sample size decreases the strength of the evidence.

Weak evidence supporting the use of an ulnar gutter neutral wrist splint was provided by the retrospective study. The methodological problems with this study were the lack of standardized measures to evaluate symptoms and the vague follow-up period (within 17 months of treatment).

Based on the review, the strongest evidence supports neutral wrist splinting, worn at night, for decreasing CTS symptoms and increasing function for the short term (Gerritsen, de Vet, et al., 2002; Walker et al., 2000). However, strong evidence supports surgery as more effective than splinting at 3, 6, 12, and 18 months (Gerritsen, de Vet, et al., 2002). Moderate evidence supports neutral wrist splinting, worn at night, for decreasing symptoms for the long term (Sevim et al., 2004) and short term (Burke et al., 1994; Li et al., 1999). Conversely, from the review, studies investigating splint schedule (Walker et al., 2000) and different types of splint designs (Kruger et al., 1991; Li et al., 1999) demonstrated that regardless of the schedule or type of splint (ulnar or volar based) all groups improved with splint wear; thus, the schedule and type of splint may not be as important as the position of the wrist and, as demonstrated by Manente et al. (2001), the position of the fingers.

2.4.2 Ultrasound

The use of ultrasound for the treatment of CTS was assessed in two Level II evidence studies.

Level II Evidence

One study, a randomized controlled clinical study, conducted by Oztas et al. (1998), compared three ultrasound interventions; 1) intensity at 1.5W/cm², 2) intensity at 0.8W/cm², and 3) no intensity (sham) for the treatment of mild to moderate CTS. There were 18 subjects and 30 hands. The outcome measures were: pain scale, night pain, number of night awakenings, and nerve conduction. All three interventions significantly decreased symptoms of CTS after 20 days. There were no significant differences between the interventions; all three treatments were effective in decreasing symptoms of CTS.

Another study investigating the efficacy of ultrasound for the treatment of mild to moderate CTS was conducted by Ebenbichler et al. (1998). Ebenbichler and colleagues used a randomized, single-blind, "sham" ultrasound treatment with 45 subjects to compare active ultrasound treatment to "sham" ultrasound treatment. Outcomes were measured by; subjective symptoms, grip strength, pinch strength, and nerve conduction. The results supported the use of ultrasound treatment at 1.0W/cm² pulsed for 15 minutes for 20 sessions compared to the "sham" treatment. Subjects significantly decreased symptoms and improved in nerve conduction at 2 weeks, 7 weeks, and 6 months. The treatment group also improved in grip strength and pinch strength at 7 weeks and 6 months. In addition, subjects' overall improvement was significantly improved at 7 weeks.

In summary, the two studies on ultrasound provided conflicting evidence that ultrasound treatment is an effective intervention. Oztas et al. (1998) reported no difference between treatment and "sham" ultrasound and the study by Ebenbichler et al. (1998) reported significant improvement with the ultrasound treatment at 2 weeks, 7 weeks, and 24 weeks. However, only 67% of the subjects were available for the 24 week follow-up thus decreasing the strength of the results for the long term effects of pulsed ultrasound for the treatment of CTS. It should also be noted that different treatment parameters were set for each study, Oztas used continuous ultrasound and Ebenbichler used pulsed ultrasound which may have influenced the results.

2.4.3 Tendon and Nerve Gliding Exercises

The efficacy of tendon and nerve gliding exercise for the treatment of CTS was assessed in two Level II evidence studies and one Level III evidence study.

Level II Evidence

Akalin et al. (2002) used a prospective, randomized, before and after treatment design, involving 28 subjects, to compare neutral wrist splinting to neutral wrist splinting and tendon and nerve gliding exercises for the treatment of mild to moderate CTS. All subjects were instructed to wear the splints every night and as much as possible during the day for 4 weeks. The subjects in the exercise group were also instructed on tendon and nerve gliding exercise to be performed 5 times a day, maintaining each position for 5 seconds and repeating each exercise 10 times. The Phalen's test, Tinel's test, 2-point discrimination, grip strength, pinch strength, CTS Symptom Severity and Functional Status Scale, and subject satisfaction were assessed at baseline and 8 weeks. Significant improvement was obtained on all outcome measures, in both groups, from baseline to 8 weeks with the exception of 2-point discrimination. In addition, the group that received tendon and nerve gliding exercises improved more than the group that only wore the splint, but the difference between the groups was not significant except for lateral pinch strength.

Level IV Evidence

A study by Rozmaryn et al. (1998) used a retrospective, before and after treatment design to compare usual conservative treatment with usual conservative treatment and tendon and nerve gliding exercises. They studied 105 charts and reported that the subjects who were prescribed tendon and nerve gliding exercises in addition to traditional treatment (splints, non-steroidal anti-inflammatory drugs and injections) underwent surgery 28% less than the subjects who were prescribed traditional treatment without tendon and nerve gliding exercises.

In summary, based on the review of the articles, the evidence is not convincing that tendon and nerve gliding exercises are effective in decreasing symptoms for the treatment of CTS. Akalin et al. (2002) reported significant improvement in both groups but no significant

difference between the groups except for lateral pinch strength. A limitation of this study was that adherence to the exercise program was not reported. Rozmaryn et al. (1998) also evaluated the efficacy of tendon and nerve gliding exercises in a retrospective design. This evidence is less convincing. This was a retrospective study and there were many confounding variables which may have influenced the results. The groups received traditional treatment ranging from splinting, non-steroidal anti-inflammatory drugs, injection, and contrast baths; thus, it is not feasible to determine if the results of this study were ultimately due to the tendon and nerve gliding exercises.

2.4.4 Iontophoresis

One Level III evidence study, evaluated the efficacy of iontophoresis for the treatment of CTS.

Level III Evidence

Banta (1994) evaluated the effectiveness of splint wear, non-steroidal anti-inflammatory drugs, and iontophoresis in a prospective, one group, time series, and two step treatment protocol. The outcome measure was nerve conduction taken at baseline, 3 weeks, and 6 months. Banta reported 17% of the 18 subjects responded to continuous splint wear and non-steroidal anti-inflammatory drugs, 48% of the hands responded to iontophoresis.

2.4.5 Manual Therapy

There was one Level II evidence study and one Level III evidence study that evaluated manual therapy for the treatment of CTS.

Evidence Level II

Tal-Akabi and Rushton (2000) used a randomized, experimental design to investigate the effectiveness of neurodynamic mobilization and carpal bone mobilization compared to no treatment for decreasing symptoms and increasing function for individuals with CTS. Twenty-one subjects were recruited from a list waiting for a carpal tunnel release. Thus, it can be assumed these subjects had severe CTS. Two different scales were used to evaluate pain; the Visual Analogue Scale and the Modified Pain Relief Scale. In addition, the Functional Box Scale, active range of motion (AROM), the Upper Limb Tension Test, and the Median Nerve Biased Test were used. Neurodynamic mobilization and carpal bone mobilization were both significant for decreasing pain and increasing AROM compared to no treatment. The authors did not do a post hoc analysis to determine which treatment was more effective.

Evidence Level III

A study by Manente et al. (1999) used a one group, crossover design, where all 71 subjects received two maneuvers, the Phalen's test and the CTS relief maneuver. The CTS relief maneuver is applied by placing the affected hand palm up, and gently squeezing the distal heads of the metacarpal bones (excluding the thumb) inducing a slight adduction of the index finger and the small finger. If the maneuver does not relieve CTS symptoms then the palm is turned down and the middle finger and ring finger are gently stretched. Immediately after the Phalen's test and the relief maneuver were performed, the subjects were asked if the symptoms improved or worsened. The relief maneuver was successful in eliminating all CTS symptoms in 23% of the hands and improving paraesthesias in 77% of the hands. The Phalen's test had no effect on CTS symptoms or worsened the symptoms. However, once the relief maneuver was released the CTS symptoms reappeared immediately in all hands.

In summary, a review of manual therapy for treating CTS provides moderate evidence that carpal bone mobilization and neurodynamic mobilization are effective for decreasing CTS symptoms and increasing AROM in individuals with severe CTS (Tal-Akabi & Rushton, 2000). However, the results may have been influenced by a placebo effect due to the lack of treatment in the control group and biases within the subject population. The subjects were sampled from a waiting list to receive a carpal tunnel release thus; it can be assumed that these subjects had severe CTS. Consequently, the results of this study cannot be generalizable to subjects with mild and moderate CTS. In addition, moderate evidence is provided for the relief maneuver for decreasing CTS symptoms during the performance of the maneuver. The relief maneuver was not effective in alleviating CTS symptoms or increasing function once the relief maneuver was released.

2.4.6 Other Conservative Interventions

Other conservative interventions were found in the literature for the treatment of CTS. There was one Level II evidence study evaluating the effectiveness of massage therapy, one Level III evidence study evaluating the effectiveness of wrist traction and one Level III evidence evaluating the effectiveness of aerobic exercise.

Level II Evidence

Field et al. (2004) used a randomized controlled clinical trial with 16 subjects to evaluate the effectiveness of massage therapy compared to no treatment. The massage therapy group was taught self-massage which they were instructed to perform on the affected arm daily. In addition a therapist provided a 15-minute massage, on the effected arm, once a week for 4 weeks. The outcome measures were carpal tunnel symptoms (loss of strength, tingling,

numbness, burning, or pain), Tinel's sign, Phalen test, nerve conduction velocity, visual analog scale, grip strength, State Anxiety Inventory and the Profile of Mood States. Fields and colleagues reported that the massage group significantly decreased symptoms and improved median peak latency by the end of treatment. In addition, the massage therapy group reported lower anxiety and depressed mood levels by the end of the study. A limitation to this study was that adherence was not reported. The investigators stated adherence was monitored using a Massage and Pain Log, however, the results of that Log were not reported.

Level III Evidence

Respice et al. (2004) using a one group, pretest posttest design with 30 subjects, evaluated a wrist traction device that combined a neutral wrist position, elongation, distraction, and decompression of the carpal tunnel. The outcome measure was sensory nerve latency at the mid palm and the wrist conducted at baseline and 8 weeks. The results demonstrated significant improvement in peak latency values from baseline to 8 weeks. A limitation to this study was the lack of standard outcome measures evaluating CTS symptoms and function.

Another Level III evidence study evaluated aerobic exercise for decreasing symptoms and improving sensory nerve latency for patients diagnosed with CTS. Nathan et al. (2001) used a one group, pretest, posttest design. All 41 subjects engaged in aerobic exercise for one hour, three times a week. After 10 months patients reported a decrease in pain, tightness, and clumsiness but these results were not statistically significant. A limitation to this study was the lack of standard outcome measures evaluating CTS symptoms and function.

2.5 SUMMARY OF THE EVIDENCE

The strongest available evidence for the treatment of CTS supports the use of neutral wrist splints, worn at night, (Gerritsen, de Krom, et al., 2002; Walker et al., 2000), the use of a hand brace positioning the middle and ring finger in extension; preventing composite finger flexion (Manente et al., 2001), pulsed ultrasound (Ebenbichler et al., 1998), and massage therapy (Field et al., 2004) for decreasing CTS symptoms and increasing functional status in the short term. Moderately robust evidence supported neutral wrist splints, worn at night, for decreasing CTS symptoms for the long term (Sevim et al., 2004) and short term (Burke et al., 1994; Li et al., 1999). In addition, there is weak and limited evidence supporting the use of iontophoresis, wrist traction device, and tendon and nerve gliding exercises for the treatment of CTS.

The most robust evidence supports the use of a neutral wrist splint and a hand brace which limits composite finger flexion. In addition, there is less robust evidence supporting tendon and nerve gliding exercises. To date, there are no known studies evaluating the effectiveness of a splint that positions the wrist in neutral and prevents composite finger flexion combined with tendon and nerve gliding exercises.

3.0 SIGNIFICANCE OF THE PROBLEM

Occupational therapists, physical therapists, and hand therapists use a variety of conservative interventions for managing mild to moderate carpal tunnel syndrome (CTS) but strong evidence supporting these interventions is lacking (Gerritesen, de Krom, et al., 2002; Goodyear-Smith & Arroll, 2004; Muller et al., 2004; O'Conner, Marshall, & Massy-Westropp, 2003). Based on this systematic review of the literature, there is strong evidence supporting the use of night time neutral wrist splints and a hand brace that position the long finger and ring finger in extension for decreasing symptoms and increasing functional status in individuals diagnosed with CTS. There is also limited evidence on the effectiveness of tendon and nerve gliding exercises for the treatment of CTS.

CTS is caused by many different mechanisms and prescribing only one intervention to these patients may not be the most effective approach for managing CTS. Combinations of effective interventions should be investigated to determine the most effective treatment regime. Studies have compared splint wear to surgery, injection, and tendon and nerve gliding exercises for the treatment of CTS. Different types of splints and different wrist positions have also been studied. In addition, one study, evaluating the effects of finger position has been reported. However, to date, there are no known research studies that evaluated the effectiveness of a splint that considers the position of the wrist and the fingers combined with tendon and nerve gliding exercises for the treatment of CTS.

3.1 SPLINTING THE WRIST

The carpal tunnel at the wrist is formed by the transverse carpal ligament volarly and the wrist bones dorsally. The transverse carpal ligament attaches from the scaphoid tubercle to the ridge of the trapezium radially and the hook of the hamate and pisiform ulnarly. Ten structures, the median nerve, the flexor pollicis longus tendon, the four tendons of the flexor digitorum superficialis, and the four tendons of the flexor digitorum profundus course through the carpal tunnel. At this level the median nerve innervates the thumb, index, long, and the radial aspect of the ring finger.

Symptoms of CTS are caused when any condition decreases the size of the carpal tunnel or any condition increases the volume of the structures contained in the carpal tunnel thus, increasing carpal tunnel pressure and resulting in median nerve compression (Phalen, 1951). Anatomical conditions can contribute to decreasing the area in the carpal tunnel. For example, the size and diameter of the carpal tunnel vary in the general population and people with CTS have smaller carpal canals compared to the normal population (Dekel, Papaioannou, Rushworth, & Coates, 1980; Papaioannou, Rushworth, & Atar, 1992). Other investigators suggest that this variation in diameter may account for the increased prevalence in women (Schuind, Ventura, & Pasteels, 1990; Slater & Bynum, 1993). Conditions that alter the fluid balance such as pregnancy (Ordeberg, Salgeback, & Ardeberg, 1987) and obesity, and inflammatory conditions such as rheumatoid arthritis (Chamberlain & Corbett, 1970; Massarotti, 1996; Stevens, Beard, & O'Fallon, 1992) and nonspecific tenosynovitis may also increase carpal tunnel pressures. Functional use such as repetitive flexion and extension of the wrist and fingers may also be a contributor to increasing carpal tunnel pressure. Regardless of the cause of the increased pressure treatment should focus on decreasing the pressure in the carpal tunnel.

Studies have demonstrated that pressure in the carpal tunnel increases with flexion and extension and the pressure in the canal is at its lowest when the wrist is positioned in neutral (Gelberman, Hergenroeder, Hargens, Lundborg, & Akeson, 1981; Weiss, Gordon, Bloom, So, & Rempel, 1995). Gelberman et al. (1981) reported that intratunnel pressures in normal people are 2.5 mm Hg at neutral, 31 mm Hg with wrist flexion and 30 mm Hg in wrist extension. In addition, Weiss et al. (1995) reported that the lowest pressure of the carpal tunnel was when the wrist was positioned in approximately 2 degrees of extension and 2 degrees of ulnar deviation. Thus, splinting the wrist in neutral will decrease pressure in the canal and help preserve the integrity of the median nerve. Conversely, the position of the wrist may not be the only consideration. There is evidence suggesting that even when the wrist is positioned at 0 degrees, the position of the fingers influences the space in the carpal canal. For example, finger flexion causes the lumbrical muscles to migrate into the carpal canal decreasing space and increasing pressure (Siegel, Kuzma, & Eakins, 1995; Ugbolue et al., 2005; Yii & Elliot, 1994).

3.2 SPLINTING THE METACARPOPHALANGEAL (MCP) JOINTS

Clinically, it has been observed that limiting finger motion in addition to splinting the wrist in neutral decreases the symptoms of CTS. Several studies have reported that when the fingers are actively flexed the lumbrical muscles migrate into the carpal tunnel (Siegel, Kuzma, & Eakins, 1995; Yii & Elliot, 1994). Siegel and colleagues (1995) demonstrated that all four lumbrical muscles lay within the carpal canal when the fingers are actively flexed and Cobb, An, Cooney, and Berger (1994) determined that the incursion of the lumbrical muscles into the canal was greatest with 50% or more active finger flexion. The effect of this incursion into the tunnel was studied by Cobb, An, and Cooney (1995), and they found that tunnel pressure increases when the

lumbrical muscles are in the canal and that intra-tunnel pressure exceeds normal pressures when making a strong fist; making a strong fist increased the pressure more than just flexing the digits.

Furthermore, actively gripping tools of different diameters and hypertrophied lumbrical muscles may further increase carpal tunnel pressure. Cobb, Cooney and An (1996) in an anatomical study measured carpal tunnel pressure with and without 1 and 2 inch tubing. They reported that actively gripping 1 and 2 inch tubing increased carpal tunnel pressure significantly more than actively gripping without the tubing. Another anatomical case report study by Robinson, Aghasi, and Halperin (1989), reported that hypertrophied lumbrical muscles were the cause of CTS in three manual workers. The muscles may have become enlarged as a result of repetitive forceful flexing and extending the digits while performing work related tasks.

Because these anatomical studies indicate that the space in the carpal tunnel can decrease by lumbrical incursion into the carpal tunnel and pressure can increase with finger flexion and actively gripping, splinting the wrist alone may not be sufficient for reducing the pressures in the carpal canal.

Theoretically, splinting the wrist at neutral, decreasing flexor and extensor excursion and positioning the MCP joints between 0 and 10 degrees of flexion preventing lumbrical incursion should maintain or decrease the pressure in the carpal canal because the lumbrical muscles will not be migrating into that limited space. Therefore, if splinting is the intervention of choice, the position of the fingers should not be ignored and splints should be designed to prevent the lumbrical muscles from migrating into the carpal canal by preventing the fingers to actively move into greater than 50% of flexion.

3.3 EXERCISES FOR THE TREATMENT OF CTS

The rationale for using nerve gliding exercises is an attempt to improve axonal transport which will improve nerve conduction (Butler & Gifford, 1989). According to Butler, (1991) mobilizing the nerve may reduce the pressure existing within the nerve which may result in an increase of blood flow to the nerve. Consequently, this increase of blood flow may result in regenerating and healing the injured nerve. In addition, nerve gliding exercises may increase nerve excursion through the canal widening the area of contact between the median nerve and the transverse carpal ligament and maximizing the relative excursion of the median nerve and the flexor tendons in the carpal tunnel. Furthermore, performing tendon gliding exercises may provide enough motion between the median nerve and the flexor tendons to prevent adhesions through the use of active finger motion (Szabo, Bay, Sharkey, & Gaut, 1994). Seradge, Jia, and Owens (1995) reported that active flexion and extension finger exercises reduce pressure in the carpal tunnel. Totten and Hunter (1991) proposed a series of tendon and nerve gliding exercises for the postoperative management of CTS to prevent adhesions. However, Akalin et al. (2002) demonstrated that these exercises, when used in a non-surgical conservative treatment program, decreased CTS symptoms compared to splint wear alone. In addition, Rozmaryn et al. (1998), in a retrospective study, demonstrated that using a comprehensive conservative treatment regime with tendon and nerve gliding exercises compared to a comprehensive conservative treatment regime that did not include tendon and nerve gliding exercises significantly decreased the number of subjects who went on to surgical intervention.

CTS can be caused by a variety of mechanisms. Different combinations of effective interventions should be investigated to develop the best treatment regime for the managing CTS. Clinical studies demonstrate that splinting the wrist, splinting the fingers, and tendon and nerve

gliding exercises decrease symptoms of CTS. Anatomical studies demonstrate that CTS symptoms increase when the pressure in the carpal tunnel increases. Carpal tunnel pressure is at its lowest when the wrist is in neutral and the fingers are less than 50% of finger flexion. Other anatomical studies demonstrated that active flexion and extension finger exercises increase blood flow to the nerve which may heal the injured nerve and decrease carpal tunnel pressure. Thus, a combination of splinting, to prevent forceful and repetitive wrist and finger flexion and extension, and an exercise program that gently mobilizes the fingers and increases blood flow to the nerve should decrease pressure in the carpal tunnel thus, decreasing CTS symptoms.

4.0 RESEARCH HYPOTHESIS

Determining the most effective conservative intervention to manage carpal tunnel syndrome (CTS) is challenging. Strong evidence-based research validating conservative interventions commonly used in the hand clinics is lacking. Current research demonstrates that the optimal angle for the wrist is 0 degrees (Burke et al., 1994) and anatomic studies have demonstrated that the least amount of lumbrical excursion into the carpal canal occurs when the fingers are held in extension; all four lumbrical muscles lie within the carpal canal when the fingers are actively flexed (Cobb et al., 1994; Siegel et al., 1995; Yii & Elliot, 1994). In addition, there is evidence suggesting that the use of tendon and nerve gliding exercises coupled with other conservative treatment options will decrease symptoms of CTS (Akalin et al., 2002; Rozmaryn et al., 1998). However no study, to date, has examined the effect of a splint which positions the wrist in neutral and the metacarpophalangeal (MCP) joints between 0 to 10 degrees of finger flexion combined with tendon and nerve gliding exercises.

The purpose of this randomized controlled clinical trial was to determine if a fabricated splint positioning the wrist at 0 degrees and positioning the (MCP) joints between 0 to 10 degrees of flexion is more effective than the traditional wrist cock-up splint. In addition, this study evaluated the effectiveness of tendon and nerve gliding exercises in conjunction with splint wear. The null hypotheses of this study were: 1) There will be no difference between the groups for the main effect of splint, 2) there will be no difference between the groups for the main effect

of exercise, 3) there will be no difference between the groups for the main effect of time, 4) there will be no interaction between the groups for the main effects of splint and exercise, 5) there will be no interaction between the groups for the main effects of splint and time, 6) there will be no interaction between the groups for the main effects of time and exercise, and 7) there will be no interaction between the groups for the main effects of time, splint, and exercise.

5.0 RESEARCH DESIGN AND METHODS

The Intuitional Review Board at the University of Pittsburgh approved the study protocol and the research was conducted in accordance with the University of Pittsburgh research standards.

5.1 STUDY DESIGN

This study was a randomized controlled clinical trial, 2 (splint) x 2 (exercise) x 3 (time) for the subjective outcome measures (see Table 7) and a 2 (splint) x 2 (exercise) x 2 (time) for the objective outcome measures (see Table 8). Time was assessed at 8 weeks for the subjective measures only to decrease subject withdrawal rate. At 8 weeks subjects were only required to complete and return questionnaires. If they had been required to meet with the primary investigator for a third time withdrawal rate may have been higher.

Mixed analysis of variances (ANOVA), repeated measures designs were used with two between subject variables (splint and exercise) and one within subject variable (time). The design involved three independent variables; splint, exercise, and time. The splint and exercise variables contained two factors and the time variable contained three factors for the subjective measures and two factors for the objective measures. The first independent variable, splint, consisted of two factors; 1) a wrist splint which included the metacarpophalangeal (MCP) joints and 2) a wrist cock-up splint. The second independent variable, exercise, consisted of two factors; 1) tendon and nerve gliding exercises and 2) no exercises. The third independent variable, time,

consisted of three factors for the subjective outcome measures; 1) baseline data, 2) 4 weeks data (posttest), and 3) 8 weeks data (post-posttest) and two factors for the objective measures; 1) baseline data and 2) 4 weeks data (posttest).

Table 7: Study Design – Subjective Measures

		Splint	
		Fabricated Wrist/MCP Splint	Off the Shelf Wrist Cock-Up Splint
Exercise	Tendon and Nerve Gliding Exercises	FAB-EX Baseline 4 weeks 8 weeks	OTS-EX Baseline 4 weeks 8 weeks
	No Exercise	FAB-NOEX Baseline 4 weeks 8 weeks	OTS-NOEX Baseline 4 weeks 8 weeks

Table 8: Study Design – Objective Measures

		Splint	
		Fabricated Wrist/MCP Splint	Off the Shelf Wrist Cock-Up Splint
Exercise	Tendon and Nerve Gliding Exercises	FAB-EX Baseline 4 weeks	OTS-EX Baseline 4 weeks
	No Exercise	FAB-NOEX Baseline 4 weeks	OTS-NOEX Baseline 4 weeks

5.2 SUBJECTS

Sixty-one subjects (47 female, 14 male) with mild to moderate CTS consented and were enrolled in the study. The subjects were recruited from the University of Pittsburgh Medical Center's Orthopedic Outpatient Hand Clinic in Oakland, Pennsylvania between March 2004 and March 2005. An orthopedic hand surgeon at the Orthopedic Outpatient Hand Clinic identified the subjects. The physician discussed the research project with the patients and if they expressed interest in participating in the study the referring physician or a member of his team obtained informed consent. Once the informed consent document was signed and the physician determined that the subject met the inclusion/exclusion criteria the subject was referred to the Primary Investigator.

To be included in the study the subjects had to meet the following inclusion criteria: be at least 18 years of age, have a positive Tinel's sign or Phalen's sign, have complaints of nocturnal numbness and tingling, and be English speaking. Subjects were excluded from the study if they: 1) had a previous neuropathy other than CTS in the past year, 2) were pregnant, 3) had a steroid injection into the carpal canal in the past 3 months, 4) had thenar atrophy, or 5) had a prior carpal tunnel release.

Electrodiagnostic tests were not used to confirm the diagnosis of CTS because the reliability and validity of these results are questionable (Glowacki, Breen, Sacher, & Weiss, 1996; Redmond & Rivner, 1988). Many investigators have queried their value as a diagnostic tool and outcome measure, finding limited or no relationship between the electrodiagnostic study and the patient's clinical status (Braun & Jackson, 1994; Concannon, Gainor, Petroski, & Puckett, 1997; Glowacki et al., 1996; Redmond & Rivner, 1988). Subjects with a previous neuropathy were excluded from the study because the symptoms of CTS might have been due to

an underlying cause, such as, diabetes mellitus or thyroid disease. Subjects with thenar atrophy were excluded from the study because weakness or atrophy of the thenar muscles are indications of severe CTS and in most cases surgical release of the carpal tunnel is recommended. Subjects who were experiencing CTS symptoms due to pregnancy were excluded because in most cases symptoms of CTS usually resolve following delivery. Subjects who had a previous steroid injection into the canal or a previous carpal tunnel release were excluded from the study because the aims of this study were to determine the effectiveness of conservative interventions for the treatment of CTS.

5.3 MEASURES

All subjects completed a demographic questionnaire for descriptive purposes and the primary outcome measure, the CTS Symptom Severity and the Functional Status Scale (Levine et al., 1993). Subjects also completed the Disability of the Arm, Shoulder, and Hand (DASH) questionnaire, an exit survey and underwent a physical examination. The physical examination consisted of evaluating grip strength, pinch strength, and functional sensibility using the Moberg Pickup Test.

5.3.1 Descriptive Measure

Demographic and CTS History Questionnaire

The demographic questionnaire (see Appendix D) was used for descriptive purposes and included questions regarding the subject's age, gender, hand dominance, ethnicity, height, weight, and occupation. Other questions involved how long the subjects had been experiencing CTS symptoms and what they felt caused their CTS. The questionnaire also contained questions

regarding their current medications and their prior treatment for CTS such as splinting, medication, ultrasound, activity modification, ergonomics, or patient education. Lastly, the questionnaire asked how confident the subjects felt that the treatment about to be provided would decrease their symptoms of CTS and increase their level of function.

5.3.2 Primary Outcome Measure

Carpal Tunnel Syndrome Symptom Severity and Functional Status Scale

The primary outcome measure, the CTS Symptom Severity and Functional Status Scale, is a self-administered, multiple choice questionnaire designed to assess symptom severity and functional status in subjects with CTS (Levine et al., 1993). There are two subscales; the 11 item symptom severity scale inquiring about CTS symptoms (e.g. numbness, tingling, pain) and the 8 item functional status scale inquiring about functional tasks (e.g. writing, buttoning). The response selections range from 1 point (mildest pain or no difficulty with activity) to 5 points (most severe pain, unable to perform activity). The subscales are scored separately by calculating the mean of each subscale. Higher scores indicate greater disability.

This outcome measure is highly reproducible (Symptom Severity Scale, r = 0.91; Functional Status Scale, r = 0.93), internally consistent (Symptom Severity Scale, Cronbach's alpha of 0.89; Functional Status Scale, Cronbach's alpha of 0.91), responsive to clinical change, and valid (Levine et al., 1993). Levine and colleagues (1993) assessed responsiveness to clinical change by comparing the preoperative and postoperative scores in two cohorts of patients who had a CTS release and reported this change as an effect size. They reported a large effect size for the CTS Symptom Severity Scale (1.4) and the Functional Status Scale (0.82). Furthermore, Levine and colleagues correlated the scores on the scales to the extent of patient satisfaction with

their outcome using the Spearman correlation coefficient. They found that greater satisfaction with the outcome was associated with greater improvement in the scores for both the CTS Symptom Severity Scale ($r = 0.52$) and the Functional Status Scale ($r = 0.29$).

Validity refers to whether a scale measures what it is supposed to measure. Currently, there is no universally accepted standard for measurement of severity of CTS symptoms or functional status. However, Levin and colleagues (1993) compared the scales to more traditional measures of CTS disability and impairment. The scores for the CTS Symptom Severity Scale had moderate significant correlations with grip strength ($r = 0.38$, $p < .05$) and pinch strength ($r = 0.47$, $p < .01$) and weak non-significant correlations with two-point discrimination ($r = 0.15$), Semmes-Weinstein monofilament test ($r = 0.17$), and median nerve sensory conduction velocity ($r = 0.11$). The scores on the Functional Status Scale had moderate significant correlations with grip strength ($r = 0.50$, $p < 0.05$), pinch strength ($r = 0.60$, $p < 0.05$), and two-point discrimination ($r = 0.42$, $p < 0.01$), and weak non-significant correlations with Semmes-Weinstein monofilament test ($r = 0.24$), and median nerve sensory conduction velocity ($r = 0.12$).

5.3.3 Secondary Outcome Measures

DASH

The DASH questionnaire was another assessment tool used to measure function (Solway, Beaton, McConnell, & Bombardier, 2002). The DASH is a self-report, Likert-type scale consisting of 30 items. Items 1 to 21 relate to functional activities (e.g., writing, turning a key, and making a bed) and the response selections range from 1 (no difficulty) to 5 (unable). Question 22 refers to the extent that arm, shoulder, or hand problem interferes with normal

activities and the response selections range from 1 (not at all) to 5 (extremely). Question 23 refers to how the shoulder, arm, or hand problem limits regular daily activities and the response selections range from 1 (not limited at all) to 5 (unable). The next section of the scale, questions 24 through 28, address the severity of the symptoms (e.g., pain, tingling, weakness, and stiffness). The response selections range from 1 (none) to 5 (extreme). Question 29 addresses difficulty with sleeping. The response selections range from 1 (no difficulty) to 5 (so much difficulty that I can't sleep). The last question addresses how the arm, shoulder, or hand problem makes them feel (e.g., less confident, less capable) and the response selections range from 1 (strongly disagree) to 5 (strongly agree). The DASH is scored by using the following formula:

$$\text{DASH DISABILITY/SYMPTOMS SCORE} = \left[\frac{\text{(sum of responses)}}{n} - 1 \right] \times 25$$

A higher score indicates greater disability. The DASH has been shown to be reliable, valid, and responsive in the shoulder (Beaton et al., 2001), elbow (Turchin et al., 1998), wrist and hand (MacDermid, Richards, Donner, Bellamy, & Roth, 2000) and in subjects diagnosed with CTS (Gay, Amadio, & Johnson, 2003; Greenslade, Mehta, Belward, & Warwick, 2003).

Grip Strength

Hand strength was measured by the hand held Jamar dynamometer (Fabrication Enterprises, Inc., Irvington, NY) which is a standard measure of grip strength measured in pounds and is recommended as the best measure of grip strength compared to other instruments (Mathiowetz, Weber, Volland, & Kashman, 1984). Subjects were positioned according to the recommendations provided by the American Society of Hand Therapists. Subjects were seated with the testing arm positioned in shoulder adduction and neutrally rotated, elbow flexed to 90 degrees, and the forearm and wrist in the neutral position (Fess & Moran, 1981). Subjects were instructed to maximally grip the handles. In addition, other recommendations by the American

Society of Hand Therapists were followed. For example, the dynamometer was set at the second handle position when evaluating grip strength and the mean of three successive trials was used as the outcome variable. Mathiowetz and colleagues (1984) reported that the highest test-retest reliability is when the mean of three trials is used (r = 0.80). The Jamar dynamometer is a sensitive and repeatable test instrument with a significant inter-rater reliability coefficient of 0.97 (Mathiowetz, et al., 1984). Scores range form 0 to 200 pounds.

Pinch Strength

Pinch strength was measured using a hand held pinch meter (B & L Engineering, Santa Fe Springs, CA), which was found to be the most accurate for measuring pinch strength (Mathiowetz et al., 1984). Subjects were given one opportunity to exert maximum force with three types of pinch; tip pinch, lateral pinch, and palmar pinch. For tip pinch the subject grasped the pinch meter between the pad of the index finger and the pad of the thumb. For lateral pinch the subject grasped the pinch meter between the pad of the thumb and the radial side of the middle phalanx of the index finger. For palmar prehension the pinch meter was grasped between the pads of the thumb, index finger, and long finger. Testing was done with the subjects sitting straight, and the testing arm positioned with the shoulder adducted, elbow flexed at 90 degrees, and the forearm pronated. Inter-rater reliability yielded a Pearson's correlation coefficient above 0.97 on all pinches (Mathiowetz, et al., 1984). Scores range from 0 to 45 pounds.

Moberg Pickup Test

The Moberg Pickup Test (Moberg, 1958) is a test commonly used in the clinic for evaluating functional sensibility. The test reflects fine motor performance and requires the ability to perceive constant touch and use precision sensory pinch. Subjects were timed on how quickly they could pick up an assortment of everyday objects, such as a coin, safety pin, and paper clip

and place them in a small box. Subjects were seated in a chair facing the test. The 12 items were randomly placed. Subjects were informed before the start of the test that this was a timed task. They were instructed to place the objects in the box, one at a time, as quickly as possible. They were also instructed not to slide the objects to the edge of the table. The dominant hand was tested first, followed by the non-dominant hand. If the subject was ambidextrous, the hand used for writing was considered the dominant hand. Based on a study by Ng, Ho, and Chow, (1999) with 14 subjects, inter-rater reliability yielded a significant Pearson's correlation coefficient of 0.67. Norms have not been established for this test (Callahan, 1995). The best comparison for the involved hand is the performance by the uninvolved hand.

Exit Survey

An exit survey (see Appendix E), designed by the Primary Investigator, was administered at the completion of the study to determine if the subjects received any additional interventions during the course of the study, and to evaluate the subjects' perceptions of their outcome and their satisfaction with the treatment provided. If the subject reported receiving additional interventions such as medication, injection, ultrasound, and or ergonomics during the course of the study the subjects were asked to rate how helpful other interventions were for decreasing their CTS symptoms. The answer selections ranged from very helpful to not at all helpful. Other questions on the exit survey were related to their symptoms at the end of the study. The answer selections ranged from no symptoms to no improvement. If the subjects reported that their symptoms returned they were asked if they would continue to wear the splint or continue to do the exercises (if applicable). The answer selections were yes, no, or maybe. Lastly, the exit survey asked what they found to be most helpful for decreasing their symptoms of CTS, such as splint exercise,

patient education, medication and or injection (the subject's were asked to select only one answer). See table 9 for a schedule of measures administered throughout the 8 week study.

Table 9: Schedule of Measures

	In-person (baseline)	In-person (4 weeks)	Mail (8 weeks)
Demographic and CTS History Questionnaire	X		
CTS Symptom Severity & Functional Status Scale	X	X	X
DASH	X	X	X
Grip Strength	X	X	
Pinch Strength (tip, lateral, palmar)	X	X	
Moberg Pickup Test	X	X	
Exit Survey			X

Note. CTS – carpal tunnel syndrome.

5.4 PROCEDURES

After informed consent was obtained and immediately following the subject's appointment with the Orthopedic Hand Surgeon at the Hand Therapy Clinic at the University of Pittsburgh Medical Center, the subject met with the Primary Investigator. All questions regarding the study were addressed at that time. After all questions were addressed subjects were randomized into 1 of 4 groups. Subjects were encouraged to contact the Primary Investigator if there were any problems with the splint or exercise program during the course of the study.

5.4.1 Interventions

There were four groups and each group received a different intervention. Subjects in the FAB-EX group received a fabricated wrist splint positioning the wrist in neutral and the MCP joints between 0 and 10 degrees of flexion and tendon and nerve gliding exercises. Subjects in the FAB-NOEX group received a fabricated wrist splint positioning the wrist in neutral and the MCP joints between 0 to 10 degrees of flexion and no exercises. Subjects in the OTS-EX group received a prefabricated, off the shelf wrist cock-up splint immobilizing the wrist in 20 degrees of extension and tendon and nerve gliding exercises. Subjects in the OTS-NOEX group received a prefabricated off the shelf wrist cock up splint immobilizing the wrist in 20 degrees of extension and no exercises. Subjects were instructed to wear the splint all night, every night, for 4 weeks. In addition, if the subjects were randomized into the FAB-EX group or the OTS-EX group then the subjects were verbally and visually educated on how to correctly perform tendon and nerve gliding exercises (Totten & Hunter, 1991). Subjects were given a handout on the exercises and were instructed to perform the exercises 3 to 5 times a day, 10 repetitions of each position and holding each position for 5 seconds. Finally, all groups received an educational brochure developed by Dr. Goitz, Dr Sotereanos, and Dr Tomaino, explaining the signs, symptoms, and treatment for CTS (see Appendix E).

5.4.2 Randomization

Subjects were randomized by selecting sealed envelopes with an experimental group (FAB-EX, FAB-NOEX, OTS-EX or OTS-NEX) assignment. The experimental group assignment was placed on an 8 ½ inches by 10 inches sheet of paper and folded so the group assignment was concealed in the fold. The paper was then placed in an envelope and the envelope was sealed.

This method ensured that the Primary Investigator could not visualize the treatment group prior to the subjects selecting the envelope. Once the envelope was opened the subjects' experimental group was revealed.

5.4.3 Appointments

At the first appointment the subjects completed the demographic and CTS history questionnaire, the CTS Symptom Severity and Functional Status Scale, and the DASH questionnaire, and a physical evaluation. The physical evaluation consisted of grip strength measured using a Jamar Dynamometer, pinch strength (tip pinch, lateral pinch and palmar pinch) measured using the pinch meter, and functional sensibility assessed using the Moberg Pickup test.

At 4 weeks the subjects returned for a posttest evaluation. At this appointment subjects completed the CTS Symptom Severity and the Functional Status Scale and the DASH questionnaire. Grip strength, pinch strength, and functional sensibility were re-evaluated using the same procedures and tools used in the initial evaluation.

At 8 weeks subjects were sent via United States postal mail the CTS Symptom Severity and Functional Status Scale, the DASH questionnaire and an exit survey. Along with the questionnaires subjects were sent pre-paid postal envelopes addressed to the Primary Investigator to facilitate returning the questionnaires.

5.4.4 Adherence to Protocol

Adherence to the splint wearing protocol and the exercise program was tracked by using a daily log consisting of a 1-week calendar (see Appendix G). Subjects were given 4 daily logs electronically or in hard copy and 4 pre-paid postal envelopes addressed to the Primary

Investigator. Subjects were instructed to check how often they wore the splint (all night, ½ the night, not at all) and how many sessions of the exercise program they performed during the day (1 session to 5 sessions). Subjects were instructed to return the completed daily log at the end of each week. In addition, the Primary Investigator called each subject at the end of each week to inquire about comfort of the splint, the frequency of wearing the splint at night, and if applicable, how often the subjects were performing the tendon and nerve gliding exercises as instructed. Adherence to the protocol was defined as wearing the assigned splint at night at least 80% of the time and if applicable performing the tendon and nerve gliding exercises a minimum of 80% during the 4 week period.

5.4.5 Statistical Analysis

The criterion for significance (alpha) was set at 0.05. A priori power analysis suggested that a sample size of 40 (10 subjects per group) was required to minimize the Type II error rate with a large effect size (f = .47), and power at .80 to yield a statistically significant result. The effect size of .47 was used in the analysis because that was the effect size of the CTS Symptom Severity Scale (the primary outcome measure used in this study) in a previous study by Akalin et al. (2002), which compared a group wearing a neutral wrist splint to a group wearing a neutral wrist splint and performing tendon and nerve gliding exercises for the treatment of CTS. The sample size was calculated using the SPSS Power Analysis program using a 2 x 2 factorial design accounting for splint and exercise. Time was not used because it was a within subject factor and would not effect the sample size needed. To account for withdrawals we over sampled by 21 subjects resulting in a total of 61 subjects.

Descriptive statistics were computed on subject demographics and baseline clinical characteristics on all subjects, by experimental group. One-way ANOVA tests were used to compare group baseline characteristics for continuous variables and Chi-Square tests were used to compare categorical variables. The null hypothesis was that there were no differences in demographic features or clinical characteristics among the four groups.

Statistical significance of an interaction effect or main effect for the groups was analyzed using a 2x2x3 mixed-model ANOVA on the subjective measures (CTS Symptom Severity and Functional Status Scale, and DASH) and a 2x2x2 mixed model ANOVA was used on the objective measures (grip strength, pinch strength, and Moberg Pickup test). Data on the 51 subjects who completed the protocol were used in this analysis. In addition, an intention-to-treat analysis was also conducted using the mean method on the 61 subjects that consented to the study.

Practical significance was analyzed using partial eta squared (η_p^2). Partial eta squared was used because it determines the strength of association and is unaffected by the number of factors used in the model. It only takes into consideration the effect of interest, eliminating the influence of other factors, thus preventing a more powerful variable from skewing the results (Olejnik & Algina, 2003). Descriptive statistics, inferential statistics, and effect sizes were computed using SPSS for Windows version 12.0.

6.0 RESULTS

Of the 79 subjects screened, 61 subjects were enrolled in the study and randomly assigned to one of four groups (see Figure 1). A total of 51 subjects completed the study (41 women and 10 men). Their mean age ± standard deviation was 49.9 ± 14.1, with a range from 21 to 86 years. CTS was bilateral in 55% of the subjects. Of the 10 withdrawals, 2 subjects in the FAB-EX group did not return for their 4 week appointment and were lost to follow-up and 1 subject received an injection before the end of the 4 week period. In the FAB-NOEX group, 2 subjects did not return for their 4 week appointment and were lost to follow-up and 1 subject became ill due to other medical problems and could not continue in the study. In the OTS-EX group, 1 subject did not return for the 4 week appointment and was lost to follow-up, 1 subject underwent surgery before the end of the 4 week period and 1 subject moved out of state and could not attend the 4 week follow-up session. In the OTS-NOEX group, 1 subject did not return for the 4 week appointment and was lost to follow-up.

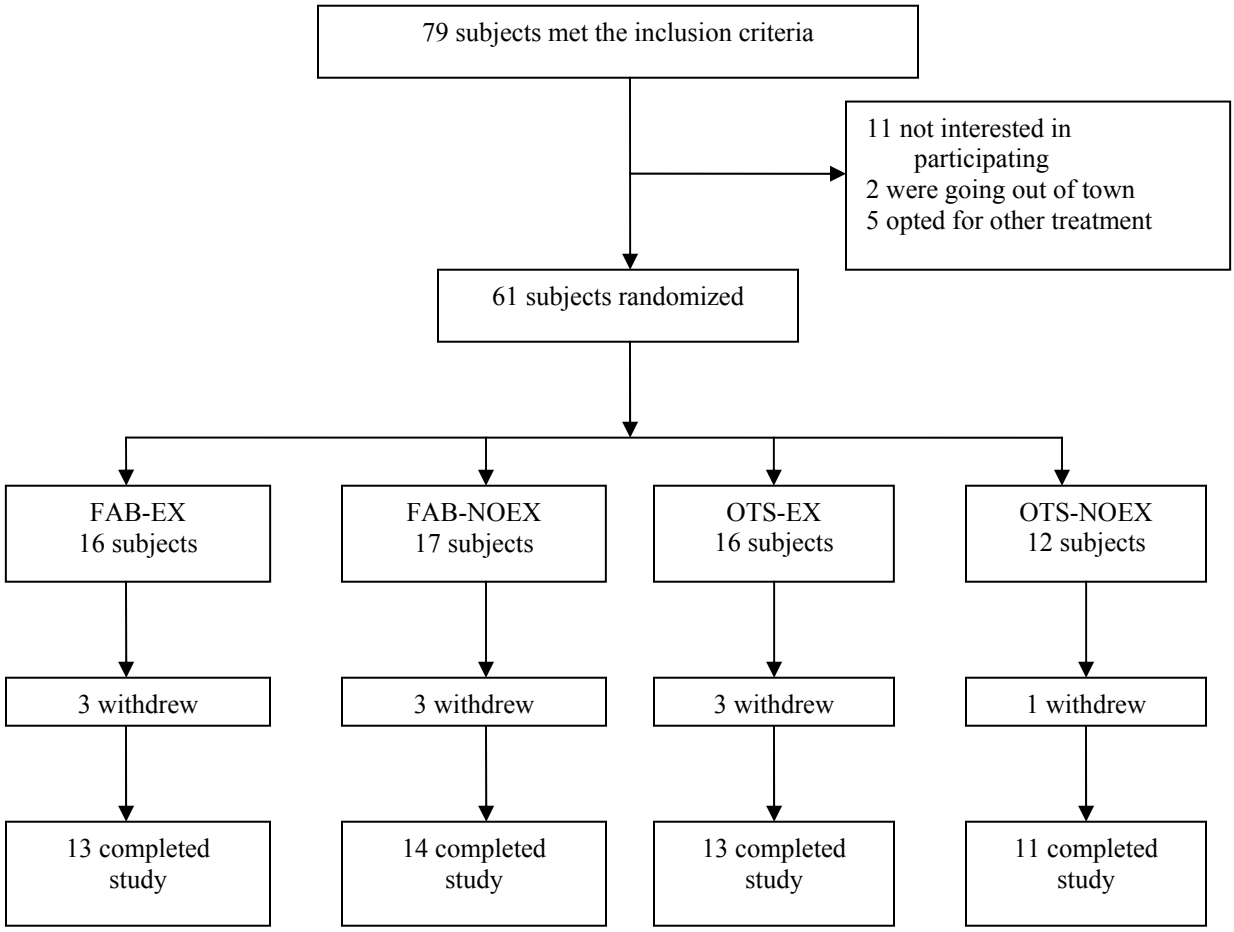


Figure 1: Trial Profile

Demographic and clinical characteristics of all groups before treatment are shown in Table 10. There were no significant differences between the groups in the demographic and clinical characteristics at baseline. In addition, there were no significant differences in the demographics and clinical characteristic at baseline between the subjects who completed the study compared to the subjects who dropped out.

Table 10: Demographic and Clinical Characteristics of Subjects who Completed the Study

CHARACTERISTICS	FAB-EX	FAB-NOEX	OTS-EX	OTS-NOEX	*P*
DEMOGRAPHIC					
Age, yr *	51.9 ± 15.7	49.0 ± 15.4	50.1 ± 13.2	46.6 ± 12.9	.83
Sex					.47
Male (%)	5.9	2.0	7.9	3.9	
Female (%)	19.6	25.5	17.6	17.6	
Hand Dominance					.09
Right (%)	17.6	25.5	25.5	19.6	
Left (%)	7.8	2.0	0.0	2.0	
Bilateral CTS (%)	15.0	15.7	11.8	11.8	.28
Race					.13
White (%)	25.5	25.5	15.6	21.6	
Black (%)	0.0	2.0	3.9	0.0	
Other (%)	0.0	0.0	5.9	0.0	
Employment Status					.83
Full time (%)	11.8	11.8	17.6	13.8	
Part time (%)	5.9	5.9	3.9	3.9	
Not working (%)	7.8	9.8	3.9	3.9	
Symptom Duration					.40
0-6 months (%)	5.9	9.7	11.8	5.9	
6-12 months (%)	3.9	5.9	2.0	7.9	
1-2 years (%)	5.9	3.9	3.9	2.0	
Over 2 years (%)	9.7	7.9	7.8	5.9	
Cause of CTS					.97
Occupation (%)	9.8	15.7	15.7	7.8	
Other (%)	15.7	11.8	9.8	13.7	
CLINICAL					
CTS SSS*	2.5 ± 0.49	2.4 ± 0.79	2.9 ± 0.86	2.8 ± 0.83	.31
CTS FSS*	1.8 ± 0.69	2.2 ± 0.75	2.4 ± 0.77	2.2 ± 0.90	.20
DASH*	19.7 ± 13.5	30.0 ± 21.7	33.4 ± 18.3	32.6 ±17.9	.22
Grip Strength, pounds*	62.3 ± 33.6	48.3 ± 16.8	58.5 ± 32.9	53.3 ± 19.7	.57
Tip Pinch, pounds*	11.4 ± 5.5	9.9 ± 3.3	12.0 ± 5.5	9.0 ± 2.9	.35
Palmar Pinch, pounds*	14.8 ± 5.9	13.2 ± 4.7	13.9 ± 5.4	12.9 ± 3.3	.79
Lateral Pinch, pounds*	16.2 ± 5.7	15.7 ± 4.7	16.5 ±7.5	14.7 ± 3.8	.87
Moberg Pickup Test, seconds*	15.2 ± 5.0	14.6 ± 5.0	16.4 ± 6.0	14.0 ± 4.2	.69

Note. * Means and standard deviations. FAB-EX – received a fabricated wrist splint which included the metacarpophalangeal joints and exercises. FAB-NOEX – received a fabricated wrist splint which included the metacarpophalangeal joints. OTS-EX – received an off the shelf wrist cock-up splint and exercises. OTS-NOEX – received an off the shelf wrist cock-up splint. CTS – carpal tunnel syndrome. SSS – Symptom Severity Scale. FSS – Functional Status Scale. CTS SSS, CTS FSS, DASH, Moberg Pickup Test - higher scores indicate greater impairment. Grip strength, pinch strength, tip pinch, palmar pinch, and lateral pinch - lower scores indicate greater impairment.

The means and standard deviations of the measurements at baseline, 4 weeks, and 8 weeks are contained in Table 11 and Table 12. The results of the mixed-model ANOVA for the on-protocol analysis are contained in Table 13 through 20. The Mauchley test of sphericity was significant indicating that the assumption of sphericity had been violated thus, the Greenhouse-Geisser correction factor was applied to the *p* values. The interaction effects (time x splint, time x exercise, and time x splint x exercise) were not significant on any of the measures.

Statistical significance was found for the main effect of splint. Subjects who received the fabricated wrist splint which included the metacarpophalangeal (MCP) joints improved more on the primary outcome measure; the CTS Symptom Severity, F (1, 47) = 6.45, $p < .014$, $\eta_p^2 = .12$ and Functional Status Scale, F (1, 47) = 5.10, $p < .029$, $\eta_p^2 = .10$ than those subjects who received the off the shelf wrist cock-up splint. The partial eta squared indicated that the fabricated wrist/MCP splint had a medium effect on CTS symptoms accounting for 12% of the variability, and a medium effect on functional status accounting for 10% of the variability. There were no significant findings for the main effect of exercise on any of the outcome measures.

Statistical significance was found for the main effect of time. All subjects significantly improved over time on the subjective measures; CTS Symptom Severity, F (1.7, 81.59) = 27.26, $p < .001$, $\eta_p^2 = .37$ and Functional Status Scale F (1.6, 75.93) = 17.39, $p < .001$, $\eta_p^2 = .27$, and the DASH, F (2, 94) = 14.83, $p < .001$, $\eta_p^2 = .24$. On the objective measures all subjects significantly improved over time on tip pinch, F (1, 47) = 7.79, $p < .008$, $\eta_p^2 = .14$ and palmar pinch, F (1, 47) = 4.75, $p < .034$, $\eta_p^2 = .09$. Post hoc testing for the main effect of time was significant for the pair-wise comparison between baseline and 4 weeks and baseline and 8 weeks on the CTS Symptom Severity and Functional Status Scale, and the DASH. However, time was

not significant between the 4 week follow-up and the 8 week follow-up. Tip pinch and palmar pinch were significant between baseline and the 4 week follow-up.

Table 11: Comparison of the Subjective Measures Baseline, Posttest, and Post-Posttest

	BASELINE MEAN ± SD	POSTTEST MEAN ± SD	POST-POSTTEST MEAN ± SD
CTS Symptom Severity Scale			
FAB-EX	2.48 ± 0.49 $_{a\,1}$	1.78 ± 0.33 $_{b\,1}$	1.87 ± 0.57 $_{b\,1}$
FAB-NOEX	2.44 ± 0.79 $_{a\,1}$	1.93 ± 0.75 $_{b\,1}$	1.77 ± 0.51 $_{b\,1}$
OTS-EX	2.92 ± 0.86 $_{a\,1}$	2.26 ± 0.90 $_{b\,2}$	2.43 ± 0.97 $_{b\,2}$
OTS-NOEX	2.77 ± 0.83 $_{a\,1}$	2.38 ± 0.85 $_{b\,2}$	2.28 ± 0.84 $_{b\,2}$
CTS Functional Status Scale			
FAB-EX	1.76 ± 0.69 $_{a\,1}$	1.38 ± 0.28 $_{b\,1}$	1.40 ± 0.30 $_{b\,1}$
FAB-NOEX	2.21 ± 0.75 $_{a\,1}$	1.69 ± 0.88 $_{b\,1}$	1.54 ± 0.62 $_{b\,1}$
OTS-EX	2.39 ± 0.77 $_{a\,1}$	1.95 ± 0.86 $_{b\,2}$	2.09 ± 1.04 $_{b\,2}$
OTS-NOEX	2.24 ± 0.90 $_{a\,1}$	2.06 ± 0.95 $_{b\,2}$	1.88 ± 0.74 $_{b\,2}$
DASH			
FAB-EX	19.69 ± 13.48 $_{a\,1}$	14.61 ± 14.63 $_{b\,1}$	10.78 ± 10.20 $_{b\,1}$
FAB-NOEX	29.98 ± 21.72 $_{a\,1}$	17.98 ± 22.77 $_{b\,1}$	16.33 ± 17.29 $_{b\,1}$
OTS-EX	33.43 ± 18.73 $_{a\,1}$	21.98 ± 18.45 $_{b\,1}$	29.58 ± 25.44 $_{b\,1}$
OTS-NOEX	32.59 ± 17.87 $_{a\,1}$	26.22 ± 23.09 $_{b\,1}$	23.57 ± 21.07 $_{b\,1}$

Note. FAB-EX – received a fabricated wrist splint which included the metacarpophalangeal joints and exercises. FAB-NOEX – received a fabricated wrist splint which included the metacarpophalangeal joints. OTS-EX – received an off the shelf wrist cock-up splint and exercises. OTS-NOEX – received an off the shelf wrist cock-up splint. CTS – carpal tunnel syndrome. Higher scores indicate greater impairment. Items in each row (the within subject variable) that share a letter are not significantly different. Items in each column (the between subject variable) that share a number are not significantly different. Higher scores indicate greater impairment.

Table 12: Comparison of the Objective Measures Baseline and Posttest

	BASELINE MEAN + SD	POSTTEST MEAN + SD
Moberg Pickup Test (seconds)		
FAB-EX	15.22 ± 4.98 $_{a\,1}$	14.24 ± 4.34 $_{a\,1}$
FAB-NOEX	14.64 ± 4.99 $_{a\,1}$	14.36 ± 8.36 $_{a\,1}$
OTS-EX	16.36 ± 5.97 $_{a\,1}$	18.45 ± 9.71 $_{a\,1}$
OTS-NOEX	13.96 ± 4.22 $_{a\,1}$	14.77 ± 4.84 $_{a\,1}$
Grip Strength (pounds)		
FAB-EX	62.26 ± 33.62 $_{a\,1}$	64.15 ± 32.37 $_{a\,1}$
FAB-NOEX	48.33 ± 16.80 $_{a\,1}$	52.38 ± 19.08 $_{a\,1}$
OTS-EX	58.54 ± 32.97 $_{a\,1}$	60.77 ± 38.73 $_{a\,1}$
OTS-NOEX	53.33 ± 19.73 $_{a\,1}$	53.48 ± 17.06 $_{a\,1}$
Tip Pinch (pounds)		
FAB-EX	11.38 ± 5.55 $_{a\,1}$	12.15 ± 4.88 $_{b\,1}$
FAB-NOEX	9.86 ± 3.28 $_{a\,1}$	11.07 ± 4.38 $_{b\,1}$
OTS-EX	12.00 ± 5.54 $_{a\,1}$	12.46 ± 4.82 $_{b\,1}$
OTS-NOEX	9.00 ± 2.86 $_{a\,1}$	9.90 ± 2.70 $_{b\,1}$
Lateral Pinch (pounds)		
FAB-EX	16.23 ± 5.70 $_{a\,1}$	17.15 ± 6.50 $_{a\,1}$
FAB-NOEX	15.71 ± 4.75 $_{a\,1}$	16.50 ± 4.15 $_{a\,1}$
OTS-EX	16.54 ± 7.47 $_{a\,1}$	16.23 ± 7.49 $_{a\,1}$
OTS-NOEX	14.73 ± 3.80 $_{a\,1}$	15.82 ± 4.42 $_{a\,1}$
Palmar Pinch (pounds)		
FAB-EX	14.77 ± 5.88 $_{a\,1}$	16.00 ± 5.83 $_{b\,1}$
FAB-NOEX	13.21 ± 4.73 $_{a\,1}$	14.14 ± 4.80 $_{b\,1}$
OTS-EX	13.92 ± 5.42 $_{a\,1}$	14.77 ± 6.18 $_{b\,1}$
OTS-NOEX	12.91 ± 3.27 $_{a\,1}$	13.27 ± 3.23 $_{b\,1}$

Note. FAB-EX – received a fabricated wrist splint which included the metacarpophalangeal joints and exercises. FAB-NOEX – received a fabricated wrist splint which included the metacarpophalangeal joints. OTS-EX – received an off the shelf wrist cock-up splint and exercises. OTS-NOEX – received an off the shelf wrist cock-up splint. Items in each row (the within subject variable) that share a letter are not significantly different. Items in each column (the between subject variable) that share a number are not significantly different. Moberg Pickup Test – higher scores indicate greater impairment. Grip strength, tip pinch, lateral pinch, palmar pinch – lower scores indicate greater impairment.

Table 13: ANOVA Summary Table -CTS Symptom Severity Scale

Source	*SS*	*df*	*MS*	*F*	η_p^2	*p*
Between Subjects						
Splint	8.127	1	8.127	6.45	.121	.014*
Exercise	0.030	1	0.030	0.024	.001	.878
Splint * Exercise	0.043	1	0.043	0.034	.001	.854
Error (Between)	59.204	47	1.260			
Within Subjects						
Time	10.734	1.736	6.183	27.257	.367	< .001*
Time * Splint	0.136	1.736	0.078	0.346	.007	.708
Time * Exercise	0.523	1.736	0.301	1.329	.028	.270
Time * Splint *Exercise	0.014	1.736	0.008	0.035	.001	.965
Error (Within)	18.508	81.591	0.227			

Note. * Significant, $p < .05$

Table 14: ANOVA Summary Table - CTS Functional Status Scale

Source	*SS*	*df*	*MS*	*F*	η_p^2	*p*
Between Subjects						
Splint	7.227	1	7.227	5.098	.098	.029*
Exercise	0.440	1	0.440	0.310	.007	.580
Splint * Exercise	1.444	1	1.444	1.018	.021	.318
Error (Between)	66.625	47	1.418			
Within Subjects						
Time	5.548	1.616	3.434	17.385	.270	< .001*
Time * Splint	0.224	1.616	0.139	0.702	.015	.470
Time * Exercise	0.410	1.616	0.254	1.285	.027	.278
Time * Splint * Exercise	0.263	1.616	0.163	0.825	.017	.420
Error (Within)	15.000	75.930	0.198			

Note. * Significant, $p < .05$

Table 15: ANOVA Summary Table - DASH

Source	*SS*	*df*	*MS*	*F*	η_p^2	*p*
Between Subjects						
Splint	3546.899	1	3546.899	3.830	.075	.056
Exercise	290.762	1	290.762	0.314	.007	.578
Splint * Exercise	502.082	1	502.082	0.542	.011	.465
Error (Between)	43523.397	47	926.030			
Within Subjects						
Time	2606.381	2	1303.191	14.832	.240	< .001*
Time * Splint	214.332	2	107.166	1.220	.025	.300
Time * Exercise	175.752	2	87.876	1.000	.021	.372
Time * Splint * Exercise	315.164	2	157.582	1.793	.037	.172
Error (Within)	8259.425	94	87.866			

Note. * Significant, $p < .05$

Table 16: ANOVA Summary Table - Moberg Pickup Test

Source	***SS***	***df***	***MS***	***F***	η_p^2	***p***
Between Subjects						
Splint	40.643	1	40.643	0.653	.014	.423
Exercise	67.692	1	67.692	1.088	.023	.302
Splint * Exercise	49.666	1	49.666	0.798	.017	.376
Error (Between)	2925.338	47	62.241			
Within Subjects						
Time	4.147	1	4.147	0.243	.005	.624
Time * Splint	27.329	1	27.329	1.602	.033	.212
Time * Exercise	0.533	1	0.533	0.031	.001	.860
Time * Splint * Exercise	6.208	1	6.208	0.364	.008	.549
Error (Within)	801.544	47	17.054			

Note. * Significant, $p < .05$

Table 17: ANOVA Summary Table - Grip Strength

Source	*SS*	*df*	*MS*	*F*	η_p^2	*p*
Between Subjects						
Splint	1.577	1	1.577	0.001	.000	.974
Exercise	2305.828	1	2305.828	1.558	.032	.218
Splint * Exercise	275.806	1	275.806	0.186	.004	.668
Error (Between)	69562.537	47	1480.054			
Within Subjects						
Time	109.659	1	109.659	1.870	.038	.178
Time * Splint	20.073	1	20.073	0.342	.007	.561
Time * Exercise	0.008	1	0.008	0.000	.000	.991
Time * Splint * Exercise	28.288	1	28.288	0.482	.010	.491
Error (Within)	2756.777	47	58.655			

Note. * Significant, $p < .05$

Table 18: ANOVA Summary Table - Tip Pinch

Source	*SS*	*Df*	*MS*	*F*	η_p^2	*p*
Between Subjects						
Splint	1.901	1	1.901	0.051	.001	.822
Exercise	105.356	1	105.356	2.849	.057	.098
Splint * Exercise	13.692	1	13.692	0.370	.008	.546
Error (Between)	1738.150	47	36.982			
Within Subjects						
Time	17.791	1	17.791	7.785	.142	.008*
Time * Splint	0.594	1	0.594	0.260	.006	.613
Time * Exercise	1.260	1	1.260	0.551	.012	.461
Time * Splint * Exercise	.000	1	.000	.000	.000	.998
Error (Within)	107.402	47	2.285			

Note. * Significant, $p < .05$

Table 19: ANOVA Summary Table - Lateral Pinch

Source	*SS*	*df*	*MS*	*F*	η_p^2	*p*
Between Subjects						
Splint	8.251	1	8.251	0.135	.003	.715
Exercise	18.217	1	18.217	0.297	.006	.588
Splint * Exercise	1.755	1	1.755	0.029	.001	.866
Error (Between)	2878.235	47	61.239			
Within Subjects						
Time	9.820	1	9.820	2.122	.043	.150
Time * Splint	1.355	1	1.355	0.293	.006	.591
Time * Exercise	2.516	1	2.516	0.544	.011	.465
Time * Splint * Exercise	3.731	1	3.731	0.806	.017	.374
Error (Within)	217.479	47	4.627			

Note. * Significant, $p < .05$

Table 20: ANOVA Summary Table - Palmar Pinch

Source	*SS*	*df*	*MS*	*F*	η_p^2	*p*
Between Subjects						
Splint	16.726	1	16.726	0.348	.007	.558
Exercise	55.469	1	55.469	1.155	.024	.288
Splint * Exercise	1.285	1	1.285	0.027	.001	.871
Error (Between)	2256.964	47	48.021			
Within Subjects						
Time	17.950	1	17.950	4.747	.092	.034*
Time * Splint	1.426	1	1.426	0.377	.008	.542
Time * Exercise	0.974	1	0.974	0.257	.005	.614
Time * Splint * Exercise	0.051	1	0.051	0.014	.000	.908
Error (Within)	177.737	47	3.782			

Note. * Significant, $p < .05$

In addition to the on-protocol analyses, an intention to treat analysis was conducted using the mixed-model ANOVA. The results were the same as the on-protocol analyses except the intention to treat analysis also demonstrated significance on the DASH for the main effect of splint. Subjects who were prescribed the wrist splint, which included the MCP joints, significantly improved more on the DASH measure ($p < .045$) compared to the subjects who

were prescribed the wrist cock-up splint. In addition, the main effect of time was also significant for the measure of grip strength ($p < .040$). All subjects significantly improved in grip strength from baseline to 4 weeks.

After the completion of the study, subjects in the FAB-EX group reported significantly fewer CTS symptoms (92%) compared to the other 3 groups ($p > .015$) (see Table 21). In addition subjects in the FAB-NOEX group, reported fewer CTS symptoms (50%) compared to the subjects in the OTS-EX group (38%) and the OTS-NOEX group (36%) but not significantly (see Table 19). Interestingly, over 80% of the subjects in all groups reported that they would continue to wear the splint at night if their symptoms increased or returned (see Table 22).

The majority of subjects found splinting to be the most helpful intervention in managing their CTS symptoms, primarily in the FAB-EX group (85%) followed by the FAB-NOEX group (64%), then the OTS-EX group (54%) and then the OTS-NO-EX group (46%) (see Table 21). In addition, 74% of the subjects who received the fabricated wrist and MCP splint reported splinting was the most helpful intervention for treating their CTS compared to 50% of the subjects who received the wrist cock-up splint (see Table 23).

Table 21: Results of Patient Reported Improvement

	FAB-EX N (%)	FAB-NOEX N (%)	OTS-EX N (%)	OTS-NOEX N (%)
No symptoms / occasional symptoms	12 (92) *	7 (50)	5 (38)	4 (36)
Frequent symptoms / no improvement	1 (8)	7 (50)	8 (62)	7 (64)
TOTAL	13	14	13	11

Note. *Significant, $p<.05$. FAB-EX – received a fabricated wrist splint which included the metacarpophalangeal joints and exercises. FAB-NOEX – received a fabricated wrist splint which included the metacarpophalangeal joints. OTS-EX – received an off the shelf wrist cock-up splint and exercises. OTS-NOEX – received an off the shelf wrist cock-up splint.

Table 22: Subjects who Would Continue Splint Wear if Needed

	FAB-EX N (%)	FAB-NOEX N (%)	OTS-EX N (%)	OTS-NOEX N (%)
Continue to wear splint at night if needed	12 (92)	13 (92)	12 (92)	9 (82)
TOTAL	13	14	13	11

Note. FAB-EX – received a fabricated wrist splint which included the metacarpophalangeal joints and exercises. FAB-NOEX – received a fabricated wrist splint which included the metacarpophalangeal joints. OTS-EX – received an off the shelf wrist cock-up splint and exercises. OTS-NOEX – received an off the shelf wrist cock-up splint.

Table 23: The Most Helpful Intervention per Subject Report

	FAB-EX N (%)	FAB-NOEX N (%)	OTS-EX N (%)	OTS-NOEX N (%)
Splint	11 (85)	9 (64)	7 (54)	5 (46)
Medication	0 (0)	0 (0)	1 (8)	0 (0)
Injection	0 (0)	0 (0)	0 (0)	3 (27)
Other	2 (15)	5 (36)	5 (38)	3 (27)
TOTAL	13	14	13	11

Note. FAB-EX – received a fabricated wrist splint which included the metacarpophalangeal joints and exercises. FAB-NOEX – received a fabricated wrist splint which included the metacarpophalangeal joints. OTS-EX – received an off the shelf wrist cock-up splint and exercises. OTS-NOEX – received an off the shelf wrist cock-up splint.

6.1 ADHERENCE TO PROTOCOL

Adherence to the splint wearing protocol for at least 80% of the time was reported in 94% of the subjects and the remaining subjects reported partial compliance. Adherence to the exercise program, at least 80% of the time, was reported in 65% of the subjects and the remaining subjects reported partial compliance.

7.0 DISCUSSION

The majority of individuals experiencing symptoms of CTS seek medical treatment to decrease their symptoms and increase their functional status. Currently, a variety of conservative interventions are used to treat CTS. However, evidence-based research on the effectiveness of these treatments is lacking. This randomized controlled clinical trial used valid and reliable measures to evaluate the effectiveness of a non-traditional splint and tendon and nerve gliding exercises for the treatment of mild to moderate CTS.

As expected, the study population was consistent with the gender and age distribution found in the literature (Atroshi, et al., 1999; de Krom, 1992; Papanicolaou et al., 2001). More women (77%) than men (23%) enrolled in the study and the majority of participants were middle aged (54%) ranging from 35 to 55 years. Furthermore, 56% of the subjects who were enrolled in the study reported bilateral CTS. These results are similar to those found by other researchers (Bagatur & Zorer, 2001; Bendler, Greenspun, Yu, & Erdman, 1977; Padua, Padua, Nazzaro, & Tonali, 1998). Tanaka et al. (1995) reported that approximately 50% of people diagnosed with CTS attribute the cause to work related tasks and in this study 49% of the study population attributed their CTS to work related tasks. The demographics in all 4 groups were comparable with no significant differences between the groups.

This study tested seven null hypotheses; 1) There will be no difference between the groups for the main effect of splint, 2) there will be no difference between the groups for the

main effect of exercise, 3) there will be no difference between the groups for the main effect of time, 4) there will be no interaction between the groups for the main effects of splint and exercise, 5) there will be no interaction between the groups for the main effects of splint and time, 6) there will be no interaction between the groups for the main effects of time and exercise, and 7) there will be no interaction between the groups for the main effects of time, splint, and exercise. Two of these hypotheses were rejected; there will be no difference between the groups for the main effect of splint and there will be no difference between the groups for the main effect of time.

We found a significant difference between the groups for the main effect of time. All groups, regardless of which splint subjects wore and regardless of whether or not they performed tendon and nerve gliding exercises, wearing a neutral wrist splint or a neutral wrist splint which supported the metacarpophalangeal (MCP) joints had significantly decreased CTS symptoms and improved functional status over 4 weeks, and that improvement was sustained over 8 weeks. These finding support those of Gerritsen, de Vet et al. (2002) and Li et al. (1999) who reported that neutral wrist splinting significantly improved symptoms for the short term. Our results, in addition to the results of other studies (Gerritsen, de Vet et al., 2002; Li et al., 1999) provide strong evidence that splinting the wrist, for the short term, is an effective intervention for decreasing symptoms and increasing function in patients diagnosed with mild to moderate CTS. Furthermore, we found that all groups significantly improved in tip pinch and palmar pinch from baseline to the 4 week follow-up.

We also found a significant difference between the main effect of splint. Between the groups, subjects who were diagnosed with mild to moderate CTS who wore the fabricated splint that immobilized the wrist in neutral and positioned the MCP joints in 0 to 10 degrees of flexion

reported a significant decrease in CTS symptom severity and a significant improvement in functional status after 4 weeks and sustained this improvement for 8 weeks. However, no significant differences were found between the 4 week and 8 week period and no significant differences were found between the groups on the DASH or the objective measures (grip strength, pinch strength, and the Moberg Pickup test).

As expected, there was a minimal difference between baseline, posttest, and post-posttest on most of the objective measures. Subjects with mild to moderate CTS generally present with sensory impairment and as the CTS progresses and becomes more severe, motor impairment is noted. The lack of significance on the objective measures may be due to the measurement tools lack of sensitivity to detect change or may be due to the patient's ability to compensate for their lack of sensation and dexterity. Clinically it is noted that many patients with mild to moderate CTS complain of sensory symptoms such as, numbness, tingling, and difficulty grasping small objects however, very few of these patients show deficiencies on objective measures assessing motor skills such as, grip strength, pinch strength, and fine motor skills.

In addition to analyzing the statistically significant differences, measures of the treatment effect were also calculated to examine whether the differences were clinically meaningful. There was a large treatment effect for time on the subjective measures indicating that both splints were effective interventions for the treatment of CTS. There was a medium treatment effect of splint indicating that the fabricated splint, which included the MCP joints, was more effective (Cohen, 1977).

Further evidence to support the use of the wrist/MCP splint was demonstrated by subject report. The subjects who were randomized to the FAB-EX group reported a significant decrease in CTS symptoms compared to the other three groups after the completion of the study and 74%

of the subjects that received the fabricated wrist/MCP splint reported that the splint was the most helpful intervention for their CTS symptoms compared to 50% of the subjects who received the traditional wrist cock-up splint.

One reason that the wrist/MCP splint was significantly more effective than the wrist cock-up splint may be due to the position of the lumbrical muscles. The neutral wrist splint that positions the MCP joint in 0-10 degrees of flexion does not allow the subjects to sleep with their wrist flexed and their hand in a fisted position thus, preventing the lumbrical muscles from entering the canal and preventing an increase in carpal tunnel pressure. Several studies have reported that when the fingers are actively flexed the lumbrical muscles migrate into the carpal tunnel increasing carpal tunnel pressure (Cobb, An, & Cooney, 1995; Siegel, Kuzma, & Eakins, 1995; Yii & Elliot, 1994). This research study supports the hypothesis that finger flexion may play a role in CTS symptoms.

Of the many studies on splinting for the conservative treatment of CTS there was only one other study that evaluated the effects of finger positioning on CTS symptoms and function. Manente and colleagues (2001) reported significant results on their primary outcome measure, the Boston Carpal Tunnel Questionnaire (same as the CTS Symptom Severity Scale and Functional Status Scale), in subjects who wore a hand brace. However, Manente and colleagues did not take into consideration the position of the wrist and they compared the splint to a control group that did not receive any treatment. Furthermore, there may have been a conflict of interest; the authors of the study were also in the process of securing a patent for the hand brace. The current study evaluated the effects of wrist and finger positioning for the treatment of CTS and compared this splint to a group that was prescribed a wrist cock-up splint.

Of the other studies of conservative treatment options for CTS only two studies evaluated the effects of tendon and nerve gliding exercises for the treatment of CTS (Akalin et al., 2002; Rozmaryn et al, 1998). Rozmaryn et al. (1998) in a retrospective study reported that the subjects who received tendon and nerve gliding exercises underwent surgery 28% less than the subjects who received traditional treatment. However, this was a retrospective study, which provides a lower level of evidence, and the groups did not receive standard treatments. The other study by Akalin et al. (2002) reported that both groups improved and a significant difference was reported in the group that received tendon and nerve gliding exercises in lateral pinch strength. However, adherence was not reported, thus, it is difficult to determine how closely the subjects followed the exercise regime.

The current study did not support the finding by Akalin and colleagues; no statistically significant or clinically significant differences between the groups that received the tendon and nerve gliding exercises compared to the groups that did not receive exercises were found. One reason that no significant findings were found between the groups may have been related to the low adherence to the exercise protocol. Other studies evaluating the effectiveness of tendon and nerve gliding exercises did not report adherence thus, we are unable to compare the results of this study to other studies.

7.1 LIMITATIONS

This study had several limitations. The subjects in this study were referred from an orthopedic hand surgeon who practices in a large academic medical center outpatient orthopedic hand clinic. Thus, many of the subjects had previously sought treatment for their CTS elsewhere and/or the cases seen by the surgeon were more severe. Approximately 41% of the subjects had been treated previously with a splint or anti-inflammatory medications before being seen by the hand

surgeon. Furthermore, 67% of the subjects who completed the study had symptoms of CTS longer than 6 months, which may have minimized the effect of treatment. Splinting has been found to be most effective if prescribed within the first 3 months of symptoms onset (Kruger et al., 1991).

Other limitations included the lack of a control group and the inability to control for other confounding variables. Ethically, a control group of no intervention could not be established because there is evidence that splinting is an effective treatment for CTS. In addition, other potential confounding variables could not be controlled. For example, other interventions such as anti-inflammatory medications and injections (after the 4 week period) could not be withheld during the study period. Of the 51 subjects 7.8% were taking anti-inflammatory medications and 17.6% of the subjects received an injection after the 4 week period. Therefore, it is not clear if the improvement is solely due to the intervention administered in this study or the effect of medication or injection. However, 62.7% of the subjects reported splinting to be the most helpful for their CTS symptoms compared to 2.0% who reported medication to be the most helpful and 5.8% who reported injection to be the most helpful treatment.

Another limitation was that the primary investigator was not masked to the subject's group assignment. The primary investigator administered all of the interventions and assessments. Because the primary investigator was aware of the group assignments the results may be biased. The inclination of the primary investigator for or against the interventions may have been transferred to the subject's attitudes and feelings, consequently reflecting on the results of the outcome measures. For example, subjects may have wanted to please the primary investigator by answering more favorably on the subjective outcome measures and trying harder on the objective outcome measures.

The short term follow-up was another limitation. This study administered subjective and objective measures at 4 weeks and only subjective measures at 8 weeks. Thus, recurrence rates and long term results are unknown.

Lastly, adherence to the exercise program was a limitation. Only 65% of the subjects followed the exercise program at least 80% of the time and the remainder had partial compliance. Of the 35% who reported partial compliance, approximately 10% of those subjects complained of increased symptoms and pain while performing the exercises. The findings of incomplete compliance in the exercise group may have affected the study outcome by limiting symptomatic and functional improvement.

The study also had many notable strengths. The study was a randomized controlled clinical trial and the outcome measures used were reliable and valid assessment tools and tools often used in the clinic.

7.2 CLINICAL IMPLICATIONS

The present study provided evidence of the effectiveness of a splint that positions the wrist in neutral and positions the MCP joints between 0 to 10 degrees of flexion for the short term. The clinical implication from this study is that occupational therapists, physical therapists, and hand therapists can entertain the possibility that the lumbrical muscles may be the cause of CTS in some patients. Therapists can effectively treat these patients by limiting lumbrical incursion into the carpal tunnel by immobilizing the MCP joints. In addition, therapists can educate their patients on activities and positions that increase lumbrical incursion into the canal which may increase their symptoms. Studies support the use of neutral wrist splints for the treatment of mild to moderate CTS, now there is evidence supporting that the neutral wrist splint should include

positioning the MCP joints between 0 to 10 degrees of flexion. However, this study does not support the use of tendon and nerve gliding exercises for decreasing symptoms of CTS or increasing function in people diagnosed with mild to moderate CTS.

7.3 FUTURE RESEARCH

Many of the studies included in the systematic review evaluated the effectiveness of conservative interventions for CTS on a mix population of mild to severe CTS. This range of CTS severity may have minimized the treatment effect. Future research should focus on separating the subjects with severe CTS from the subjects with mild and moderate CTS to determine how well conservative interventions decreases symptoms and increase functional status in subjects that have severe CTS compared to those subjects who have mild to moderate CTS.

In this study the majority of subjects had symptoms for longer than 6 months and many of the subjects had undergone some type of previous treatment for their symptoms of CTS. Future research should focus on evaluating the effectiveness of the wrist splint that positions the wrist in neutral and positions the MCP joints between 0 to 10 degrees of flexion for subjects who are newly diagnosed with CTS and have not undergone any other intervention.

This study only followed subjects for 8 weeks. Future research should focus on a longer term follow-up and more frequent evaluations to determine if this splint is effective, for the long term for decreasing symptoms and increasing function in subjects diagnosed with mild to moderate CTS.

This study did not support the use of tendon and nerve gliding exercises for the treatment of CTS. There are low and moderate levels of evidence studies that support the use of tendon and nerve gliding exercises for the treatment of CTS. However, both studies have some

methodological flaws. Future studies, with larger sample sizes, and a more strenuous adherence to the exercise arm of the protocol needs to be conducted to confirm or reject the effectiveness of tendon and nerve gliding exercises for the treatment of CTS.

8.0 CONCLUSION

Carpal tunnel syndrome (CTS) has become one of the most commonly diagnosed upper extremity neuropathies. Rising health care and indemnity costs are just a few of the many implications of CTS for modern society. Determining safe, effective, and economic conservative interventions for the treatment of mild to moderate CTS should be a high priority. The purpose of this dissertation was twofold: 1) to evaluate and synthesize the current literature on the conservative management strategies for the treatment of carpal tunnel syndrome and 2) to evaluate the efficacy of a non-traditional splint and exercise regime for the treatment of mild to moderate CTS.

The first part of this dissertation was a systematic review of the literature. Currently there is a variety of conservative interventions for the treatment of mild to moderate CTS. However, strong level of evidence supporting conservative treatment options is lacking. A systematic review of 18 research studies evaluated and synthesized the current evidence for the conservative treatment of CTS. The treatments evaluated in these studies were splinting, ultrasound, tendon and nerve gliding exercises, iontophoresis, manual therapy, massage therapy, aerobic exercise, and wrist traction. The results of the systematic review concluded that a neutral wrist splint, a hand brace, pulsed ultrasound and massage therapy were effective interventions for treating individuals diagnosed with CTS.

The second part of this dissertation was a randomized controlled clinical trial evaluating the effectiveness of a non-traditional splint and exercise program to alter the clinical course of mild to moderate carpal tunnel syndrome (CTS). Clinical and anatomical studies have reported that preventing wrist flexion and extension, limiting repetitive tendon excursion into the carpal tunnel, and preventing composite finger flexion, limiting lumbrical incursion into the carpal tunnel will decrease carpal tunnel pressure. Thus, theoretically, a splint preventing wrist flexion and extension and composite finger flexion may decrease CTS symptoms. Tendon and nerve gliding exercises have also been reported to decrease symptoms of CTS in clinical studies and are further supported in anatomical studies. Anatomical studies report that active finger flexion and extension exercises may increase blood flow to the nerve which may help heal the injured nerve.

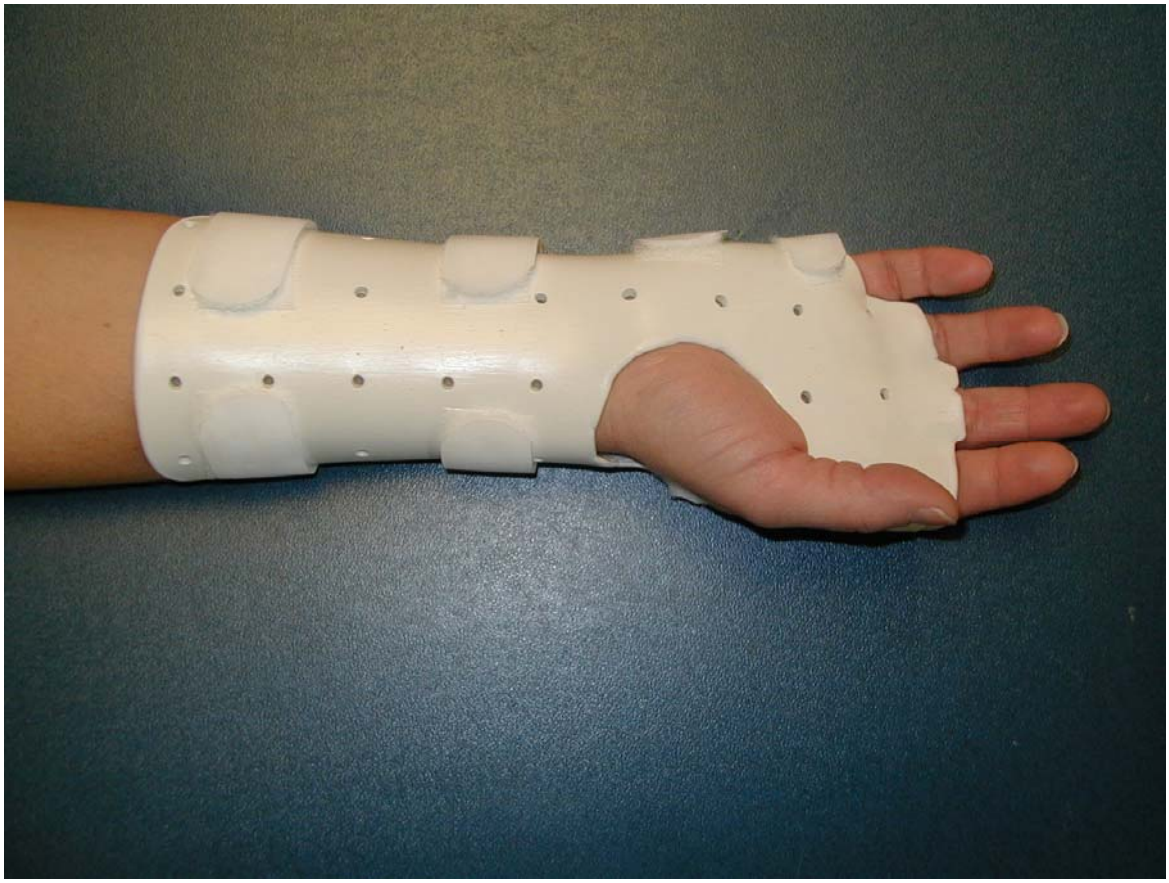
Four Experimental Groups were studied: 1) FAB-EX - fabricated splint positioning the wrist in neutral and the metacarpophalangeal (MCP) joints between 0 to 10 degrees of flexion and tendon and nerve gliding exercises, 2) FAB-NOEX - fabricated splint positioning the wrist in neutral and the MCP joints between 0 to 10 degrees of flexion, 3) OTS-EX - commercially available, off the shelf, prefabricated, wrist cock-up splint and tendon and nerve gliding exercises, 4) OTS-NOEX - commercially available, off the shelf, prefabricated, wrist cock-up splint.

The results of this study validated the use of neutral wrist splint for the treatment of CTS and provide strong evidence that wearing a splint that positions the wrist in neutral and the MCP joints in 0 to 10 degrees of flexion is effective for decreasing CTS symptoms and increasing function. Furthermore, the subjects who were randomized to the groups who received the fabricated wrist and MCP splint reported fewer symptoms, were more likely to wear the splint if

their symptoms returned, and reported the splint to be the most helpful intervention for decreasing their symptoms of CTS compared to the groups who received the wrist cock-up splint. The results of this study did not support the use of tendon and nerve gliding exercises for the treatment of mild to moderate CTS.

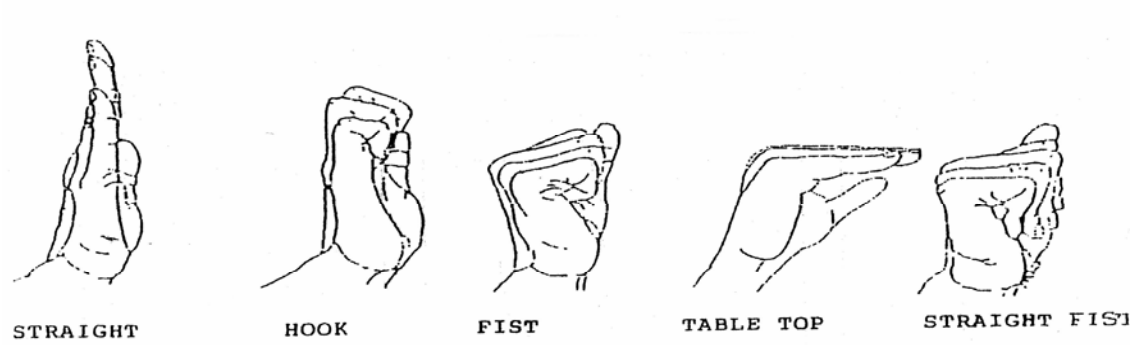
APPENDIX A

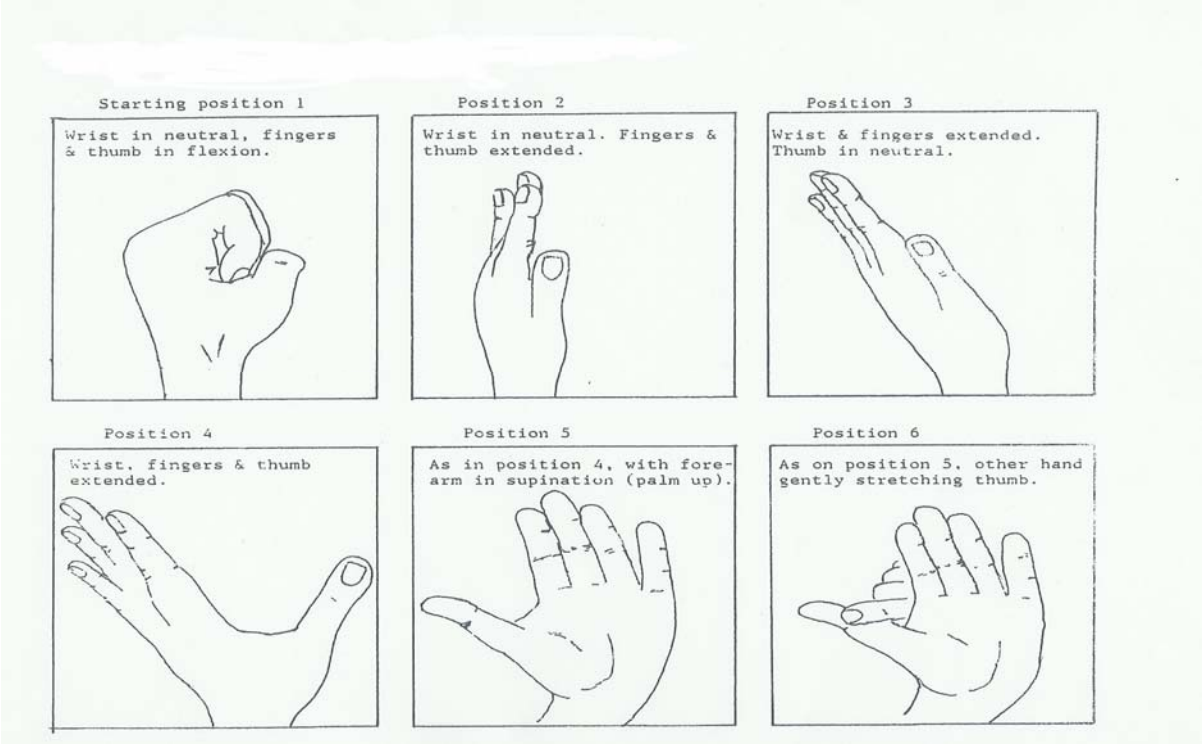
WRIST/MCP SPLINT



APPENDIX B

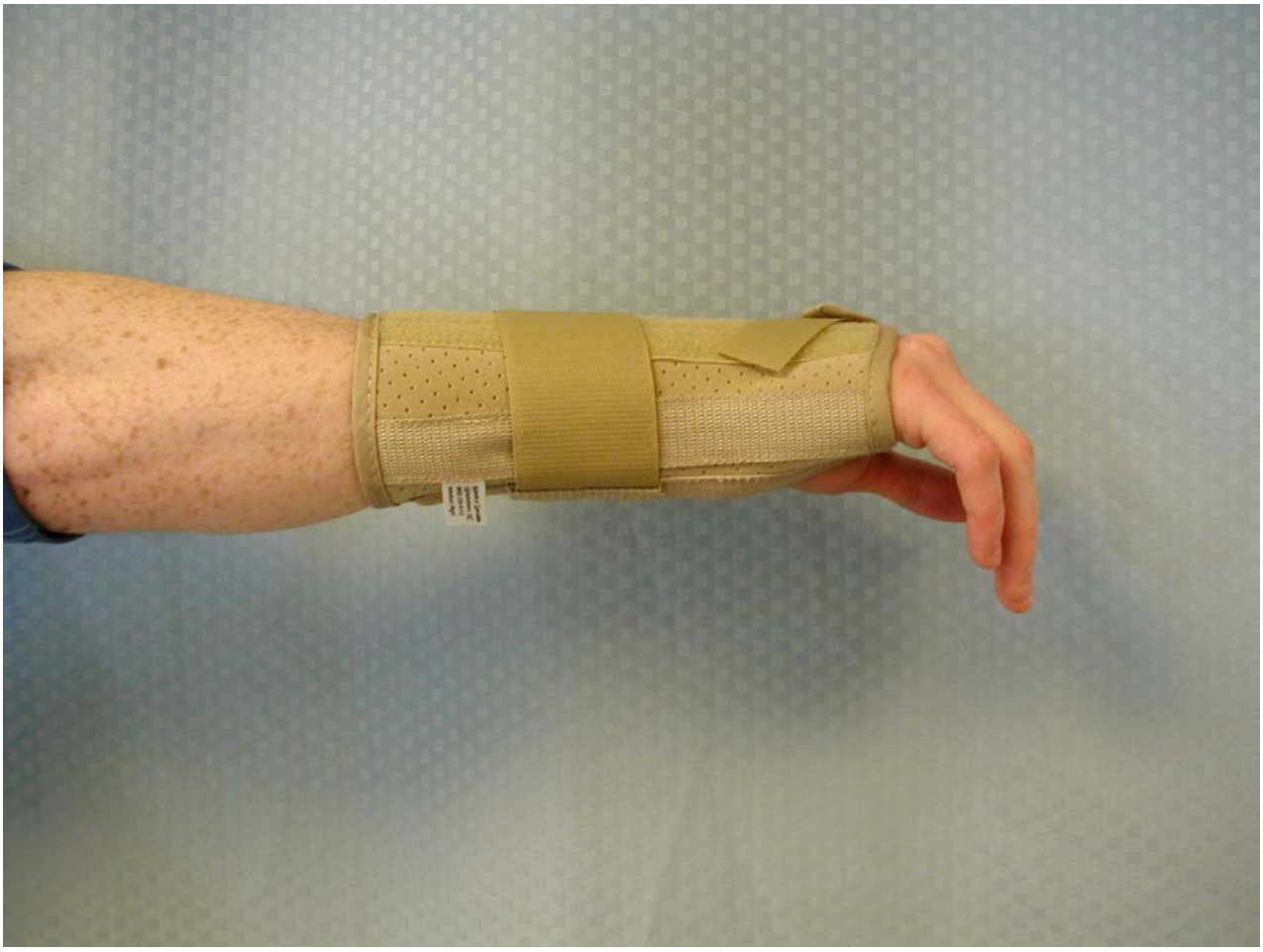
TENDON GLIDING AND NERVE GLIDING EXERCISES





APPENDIX C

WRIST COCK-UP SPLINT



APPENDIX D

DEMOGRAPHIC AND CTS HISTORY QUESTIONNAIRE

What was your age on your last birthday? _____

What is your gender?
1. M
2. F

What is your hand dominance?
1. Right
2. Left

What is your height? _____

What is your weight? _____

What is your ethnic background?
1. African American
2. Caucasian
3. Hispanic
4. Asian
5. American Indian
6. Other _____
7. Unknown
8. Refused

What is your current employment status?
1. Full-time (working at least 35 hours a week)
2. Part-time (working less than 35 hours a week)
3. Unemployed
4. Retired, not working at all
5. Retired, but working
6. Disabled/unable to work
7. Full time homemaker
8. Student
9. Other_____

How would you describe your occupation?

1. Professional, technical
2. Managerial & office (state, county, etc.)
3. Clerical & Sales
4. Crafts person (tool & die worker, etc)
5. Operative (machine operator)
6. Unskilled and domestic
7. Housewife
8. Other_____

How long have you been having symptoms of Carpal Tunnel Syndrome?

1. 0-3 months
2. 3-6 months
3. 6-12 months
4. 1 year – 2 year
5. Over 2 years
6. Unknown

What do you think caused your Carpal Tunnel Syndrome?

1. Typing
2. Occupation
3. Housework
4. Hobbies (needlework, knitting, woodworking)
5. Other

What medications are you currently taking?

Medication	dosage	frequency	duration

Did you receive any of the previous treatment listed below for your Carpal Tunnel Syndrome? If you did, please check the degree of helpfulness it was for decreasing your Symptoms?

Treatment	Received	Very Helpful	Helpful	Somewhat helpful	Not at all helpful
Splint	yes no				
Medication	yes no				
Exercises	yes no				
Ultrasound	yes no				
Activity Modification	yes no				
Ergonomics	yes no				
Patient Education	yes no				
Other (please list) _____	yes no				

My level of confidence in the ability of this treatment to decrease my symptoms of Carpal Tunnel Syndrome is:

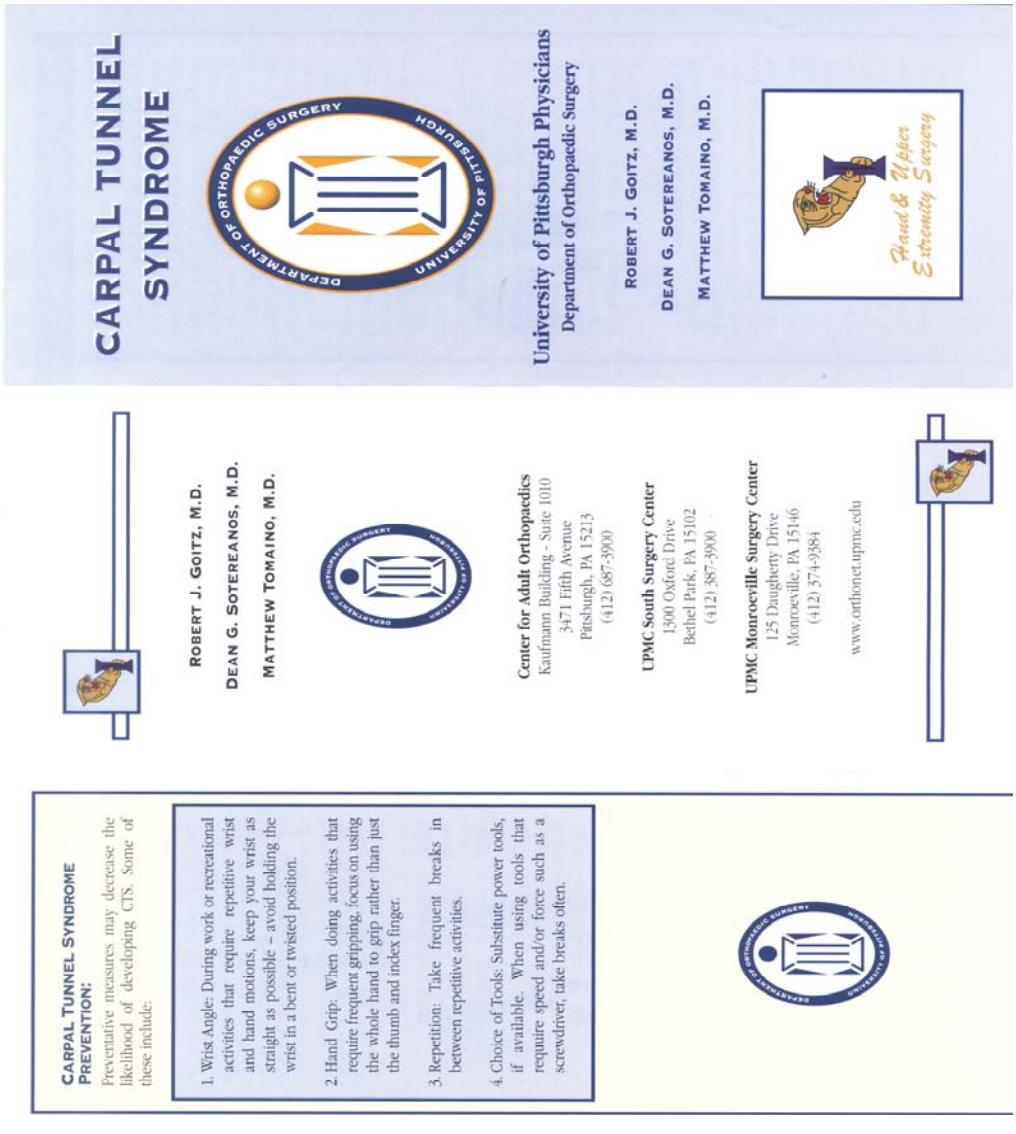
Total	Moderate	Minimal	None

My level of confidence in the ability of this treatment to increase my level of function is:

Total	Moderate	Minimal	None

APPENDIX E

EDUCATIONAL BROCHURE



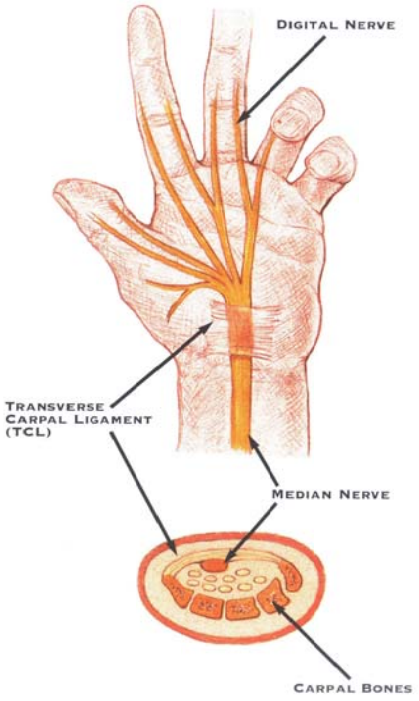
Carpal Tunnel Syndrome

Description:

Carpal Tunnel Syndrome (CTS) is a set of symptoms that result from pressure on the median nerve. Because the median nerve provides sensation to the thumb, index, middle and 1/2 of the ring finger, a person with CTS will have numbness in these same areas. Compression of the median nerve most often occurs at the carpal tunnel, under the transverse carpal ligament which is located at the wrist crease. The symptoms commonly associated with CTS are: aching, numbness or tingling in the hand and/or fingers, worsening of symptoms at night or during activities such as reading the newspaper, blow-drying hair, or driving. Other common symptoms include: weakness of the involved hand and pain traveling into the forearm. The person with CTS often finds that initially they can relieve their symptoms by rubbing or shaking their hand. However, as the process progresses, these measures fail to work. Ultimately, without treatment, the hand may become completely numb and weak. Carpal Tunnel Syndrome is diagnosed by the patient's history, physical exam and if necessary, by special nerve tests.

Treatment Options:

There are several treatment options for CTS. Conservative treatments include: adjustments to the work station and activities, use of anti-inflammatory medications, and use of wrist splints during sleep. Moderately aggressive treatment includes a steroid injection into the carpal tunnel to decrease swelling. More advanced treatment involves an outpatient surgical procedure to relieve the compression on the median nerve. Surgery is indicated for patients who have undergone conservative measures with no significant improvement, and who have persistent or worsening symptoms.



Surgical Treatment:

Carpal Tunnel Release involves a small incision on the palm of the hand. The transverse carpal ligament is released, resulting in relief of pressure on the median nerve. Once the carpal tunnel is opened, the nerve and tendons that pass through this area are inspected. The surgical wound is closed with stitches, and the hand is wrapped with soft dressings. As an out-patient procedure, patients go home within an hour of having surgery and are instructed to follow up in the doctor's office for a post-operative check-up one to two weeks after surgery.

Post-operative Care:

Those patients who choose surgical treatment for CTS will undergo a post-operative rehabilitation period. Return visits to the office for follow-up will be required. Post operative care includes: suture removal, assessment of the surgical scar, range of motion and strengthening. Additionally, the patient is taught hand and finger exercises to begin immediately following their surgery, as well as to perform several days and weeks following their operation. Within a few weeks most people are able to return to their regular activities. However, the incision may remain sore for 4-6 weeks and it may take months for strength to maximally improve.

Hand & Upper Extremity Surgery

APPENDIX F

EXIT SURVEY

Did you receive any of the treatment listed below for your Carpal Tunnel Syndrome in the past 4 weeks? If you did, please check the degree of helpfulness it was for decreasing your Symptoms?

Treatment	Received	Very Helpful	Helpful	Somewhat helpful	Not at all helpful
Injection					
Medication					
Ultrasound					
Ergonomics					
Exercises					
Other _____					

1. Concerning your Carpal Tunnel Syndrome symptoms after the completion of the study are you experiencing:
    1. no symptoms
    2. occasional symptoms
    3. frequent symptoms but had some improvement with the treatment
    4. no improvement

2. If your symptoms return will you continue wearing the splint at night?
    1. yes
    2. no
    3. maybe

3. If your symptoms return will you continue doing the exercises provided (if applicable)?
    1. yes
    2. no
    3. maybe
    4. not applicable

4. How satisfied are you with the treatment you received?

1. very satisfied
2. satisfied
3. somewhat satisfied
4. dissatisfied

5. Would you consider surgery if recommended by your physician?

1. yes
2. no
3. maybe

6. What did you find to be most helpful in treating your Carpal Tunnel Syndrome (select only one answer)?

1. splint
2. exercise
3. patient education
4. medication
5. injection
6. none of the above or other_____

APPENDIX G

DAILY LOG

	Splint Wear	**Tendon and Nerve Gliding Exercises** 5 sessions daily, hold each position for 5 seconds, repeat exercises 10 times at each session
Monday	All night ____ ½ the night ___ Not all all ___	session 1 ____session 2 ____ session 3 ____ session 4 _____ session 5 _____
Tuesday	All night ___ ½ the night ___ Not all all ___	session 1 ___ session 2 ____ session 3 ____ session 4 _____ session 5 _____
Wednesday	All night ___ ½ the night ___ Not all all ___	session 1 ____ session 2 ____ session 3 _____ session 4 _____ session 5 _____
Thursday	All night ___ ½ the night ___ Not all all ___	session 1 ____ session 2 ____ session 3 ____ session 4 _____ session 5 _____
Friday	All night ___ ½ the night ___ Not all all ___	session 1 ___ session 2 ____ session 3 ____ session 4 _____ session 5 _____
Saturday	All night ___ ½ the night ___ Not all all ___	ession 1 ____ session 2 ____ session 3 ____ session 4 _____ session 5 _____
Sunday	All night __ ½ the night ___ Not all all ___	session 1 ____ session 2 ____ session 3 _____ session 4 _____ session 5 _____

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