Introduction

Carpel tunnel syndrome (CTS) is the most commonly seen entrapment neuropathy of the upper limb (1), with a prevalence of 9.2% -15.6% in females and 6% -11.3% in males (2), (3). This type of condition can occur in all age groups but the prevalence of bilateral CTS is most frequent seen in subjects between the ages of 40 to 60 years(4) . The prevalence of CTS has been reported in the United States (US) and United Kingdome (UK) as being 5% and 7-16% respectively(5, 6).

Compression of the median nerve classically produces the symptoms typically presented. It also results in a reduction in the ability to perform activities of daily living (ADLs). The symptoms commonly occur at night and usually cause sleep disturbance(7). Splinting, exercises, and ultrasound therapy are commonly-used conservative approaches for the treatment of mild-to-moderate CTS (8-10). Surgery is performed in patients with severe symptoms which is in turn associated with muscular atrophy and sensory loss(11). However, wrist splinting is the most frequent conservative method used in the treatment of CTS(12). Pain in the hand, tingling and numbness in the thumb, index finger, middle finger and the radial side of the ring finger are commonly-seen symptoms in people with CTS(13). This can often be accompanied by an increase in pain at night and during activities which induce wrist flexion(14). Grip strength and hand function may also be reduced (15).

Previous studies have suggested that wrist splints can produce positive effects in patients with CTS. After two weeks using a wrist splint which placed the wrist in a neutral position, Connor et al noted a significant improvement in symptoms reported by CTS patients compared to one which placed the wrist in 20 degrees of extension. It is thought that wrist splints support the wrist in an anatomic position and prevent flexion and extension, which in turn can reduce pressure within the carpel tunnel (16, 17).

A flexed position of the metacarpophalangeal (MCP) joints causes an increased pressure in the carpal tunnel (18-22). Manente et al (23) reported that CTS symptoms decreased and the function of patients increased when patients with CTS used a hand brace; however, the position of the wrist was not considered in their study. In addition, only the third and fourth digits were supported in an extended position. In a randomized controlled trial, De Angelis et al reported no significant differences between a wrist splint and hand brace when analyzing the resulting symptom severity scores(24).

From an anatomical perspective, the lumbrical muscle is a structure which makes up part of the carpal tunnel. Baker et al. noted that a combination of wearing a cock up splint with concurrent intensive lumbrical stretches was the most effective approach compared to a lumbrical splint/lumbrical stretch group, lumbrical splint/ general stretch group or cock up splint/ general stretch group(25). Whilst this appeared to be a positive result, additional evidence on the effectiveness of a night hand and wrist splint for the treatment of CTS is needed. Moreover, more effective conservative methods are required for treatment of mild-to-moderate CTS.

In a comparison of the effect of a neutrally positioned splint which covered both the wrist and MCP joints with a neutral splint covering the wrist only, and with and without exercises for the treatment of CTS, Brininger et al. reported that a splint which supported the wrist and MCP joints may be more effective than a wrist splint alone in treatment of patients with long standing CTS symptoms (26). The aim of this current study was therefore to compare the effect of a neutral wrist splint and also a wrist splint with an extended trim line to control the MCP joints on pain, function, grip and pinch strength in newly diagnosed patients presenting with mild-to- moderate CTS.

Materials and methods:

Twenty four patients (4 men plus 20 women) who were referred by an orthopedic hand surgeon to the orthotics clinic participated in this study. Nerve conduction studies (NCS) were used to diagnose CTS in the subjects, who were classified as suffering from mild, moderate, or advanced CTS according to the American Association of Electro-diagnostic Medicine guidelines(27). However, only patients with mild or moderate CTS were invited to participate in the study. Each patient met the following criteria: being over the 18 years of age, having a positive Tinel sign or Phalen manoeuvre, and having reported with night time pain, numbness and tingling during the previous 12 months. In addition, patients who presented with neuropathy (e.g, due to diabetes mellitus or thyroid disease), thenar atrophy, or those having had a steroid injection into the carpal canal within the previous 3 months or a carpal tunnel release procedure were excluded from the study. All subjects therefore had a history of CTS. The Xxxxxxxxxx xx xxxxxx xxxxxxx xxx xxxxxxxxxxxxx xxxxxxxx approved the study. Written informed consent was obtained from all patients prior to participation in this study.

Interventions

Patients in this study were divided into two groups (those who wore a neutral wrist splint and those who wore a wrist splint with an extended trim line to control the MCP joints) using a randomised allocation. In this study, a neutral wrist splint was used as a control intervention. This splint was custom made according to the dimensions of the MCP joints, wrist and forearm regions, but not moulded. The wrist splint with an MCP unit was custom moulded according to the patient's hand casting in the mentioned position. The fit of both test conditions on the hand and wrist was checked prior to testing at baseline. The splints were custom fabricated for each subject in order to position the wrist in neutral alignment(0°) according to the dimensions of their MCP joints, wrist and forearm and a plaster cast. The wrist splint with an MCP unit incorporated was custom molded with the wrist in a neutral (0°) position and the MCP joints positioned between 0° to 10° of flexion). The distal edge of the neutral wrist splint ended proximal to the 2-5th MCP joints, so that these joints could flex freely and extend without movement limitation (figure 1, A). In the other splint, (i.e a wrist splint with an MCP unit), the distal edge of splint ended just proximal to the PIP joints, so that MCP joints were restricted, but PIP joints had unlimited movement (Figure 1, B). Both splints were checked for correct fitting prior to testing. The MCP joint of the thumb was free to move in either of the splints.

The orthoses were fabricated for each patient using 4 mm thick thermoplastic material (polypropylene, Xxxxxx Xxxxx company, Inc Xxxx). After the splint was prepared and manufactured, non-elastic Velcro © closures were added (figure1) to reduce relative movement between the hand and wrist and the splints. All patients were advised to report any discomfort when using the splint. The patients were asked to use the splints during the night and also at daytime whenever possible for 6 weeks. Patient comfort when wearing each splint was checked on a weekly basis.

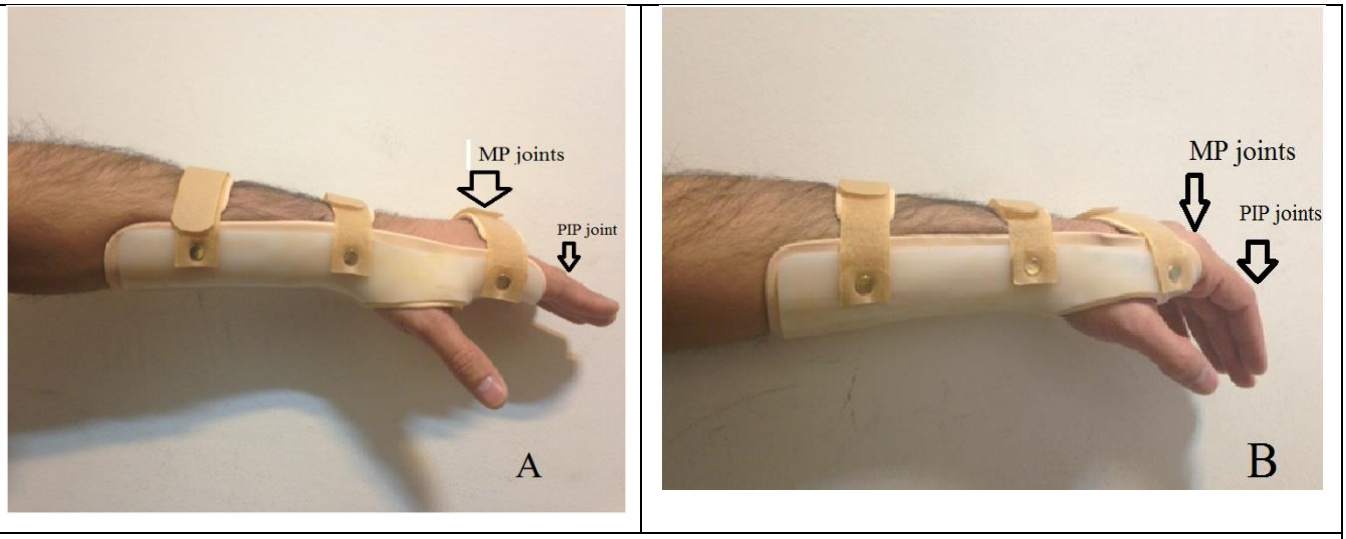

Figure1: The neutral wrist splint (A) and the wrist splint with an MCP unit (B) used in this study

Outcome measures:

A visual analog scale (VAS) was used to evaluate pain(28, 29). The VAS was based on a 100-mm straight line scale (0 = no pain, 10 = the most severe pain). Patients were requested to report on the maximum pain that they had experienced for the activities over the last week at baseline and after 6 weeks of orthosis use. Patients indicated the intensity of the sensation being experienced by placing a mark on the VAS line.

The Disability of the Arm, Shoulder and Hand (DASH) questionnaire was used to determine function (28-30). The questionnaire was completed by each patient one day before beginning the orthotic intervention and again after six weeks after orthosis use. The DASH score has 30 questions which assess function and symptoms. The following themes are included: physical function (2 questions), symptoms of disease (6 questions), social aspects (3 questions), plus two optional modules (4 questions) for workers and athletes.

Grip strength and key pinch were measured using a dynamometer (Jamar Hydraulic Hand Dynamometer - PC 5030 J1) and Pinch Gauge (Jamar Hydraulic Pinch Gauge, model PC 7498-05). For assessment of grip and pinch strength, patients were seated with the elbow flexed at 90 degrees, and with the wrist in a neutral position between pronation and supination(28-30). Pain, function, grip strength and lateral pinch were measured at baseline and at 6 weeks in the two groups. All tests conducted were by an orthosist who was trained to

administer the tests. The extent of splint use during the test period was recorded via patients self reporting the data.

Statistical analysis;

The Kolmogorov–Smirnov technique was used to determine the normal distribution of the data. To evaluate the effect of the two splints on pain, function, grip and pinch strength, a paired t-test (according to the normality of the data) was used to analyze the effects and differences in the selected outcome measures between the baseline and after 6 weeks splints using. An independent t test was applied to determine differences in the selected outcome measures between the two splints. SPSS statistical software was used for analysis of the data. The level of significance was set at 0.05.

Results

There were no significant differences in the age, weight, height, time of splint use, dominant hand, affected hand, duration of injury, pain, function or grip strength between the two groups at baseline. All patients continued their contribution to the end of the study period. Patient characteristics of the patients in this study are presented in Table 1.

Table 1: The characteristics of patients participated in this study.

	Neutral wrist splint group	Wrist splint with MCP unit group	P-Value
Number of subjects	12	12	
Age	46.42(14.11)	49.58(11.46)	0.552
Gender(Female)	10	10	1.000
Weight(kg)	78.08(15.76)	74.25(9.096)	0.473
Height(cm)	163.33(6.71)	166.92(4.85)	0.148
Index Hand(dominant hand used to perform activities of daily living)			0.558
Right	11	10	
Left	1	2	
Affected hand			0.117
Right side	3	6	
Left side	7	6	
Bilateral involvement	2	0	
Average time of splint use(hours/day)	7.25(1.54)	6.75(1.21)	0.388
Symptom duration (weeks)	5.67(2.06)	4.67(1.72)	0.210
Pain	8.08(1.78)	8.42(0.99)	0.577
Grip	5.47(1.77)	4.94(1.42)	0.429
Pinch	1.63(0.41)	1.50(0.41)	0.464

DASH	57.07(21.37)	63.26(11.65)	0.458

Table 2: Inter and intra group comparison between neutral wrist splint and wrist splint with MCP unit groups for the selected parameters after 6 weeks of use.

	Neutral wrist splint group			Wrist splint with MCP unit group			
	Baseline	After 6 weeks of use	p-value 1	Baseline	After 6 weeks of use	p-value 2	p-value 3
Pain	8.08(1.78)	4.42(2.19)	0.000	8.42(0.99)	3.17(1.11)	0.000	0.022
Grip	5.47(1.77)	7.26(3.54)	0.040	4.94(1.42)	7.30(0.37)	0.002	0.675
Pinch	1.63(0.41)	2.27(0.39)	0.000	1.50(0.41)	2.30(0.50)	0.000	0.650
DASH	57.07(21.37)	27.91(14.97)	0.000	63.26(11.65)	25.19(4.28)	0.000	0.027

P1: Comparison between baseline and after 6th week splints using in neutral wrist splint group.
P2: Comparison between baseline and after 6th week splints using in wrist splint with MCP unit group.
P3: Intra groups comparison between neutral wrist splint and wrist splint with MCP unit groups after 6 weeks splint using.

Parameters values compared to baseline at the end of week 6

Using the neutral wrist splint and wrist splint with an MCP unit significantly decreased pain (P =0.000), (P=0.022), and increased pinch (P =0.000), (P=0.000), grip strength (P =0.040), (P=0.002) and function (P =0.000), (P=0.000) respectively compared to base line at the end of the 6th week of splint use; (Table 2).

Comparisons between splint types

When comparing the two types of splints on grip (P =0.675) and pinch strength (P =0.650), there were no significant differences between the neutral wrist splint and wrist splint with MCP unit after 6 weeks of splint use. However there were significant differences in pain levels (P =0.022) and DASH score (P =0.027). The wrist splint with the MCP unit therefore demonstrated a better effect in decreasing pain and improvement of function (Table 2).

Discussion

Different types of splints have been used as a conservative intervention to improve symptoms in patients with CTS (8). Although a number of studies have been undertaken to compare different splints, information and understanding of the influence of these interventions is lacking. In this present study, the authors used four important outcome measures to evaluate the effectiveness of a traditional splint and wrist splint with MCP unit to

treat mild-to-moderate CTS. According to the prevalence of CTS, the present study was matched with previous studies for patient demographics. More women than men participated in their study and on average, the subjects were middle-aged (2, 31, 32). In this study, 83 % of participated subjects were female.

The main result of this study was the improvement noted by all patients over the six week period with the use of the two types of splints. Both splints produced limitation of wrist joint motion, which in turn appeared to improve pain, function, grip and strength parameters in following six weeks of splint use. These results were consistent with other studies in this field(33, 34).

In comparison, it was noted that for the two types of splints there were no significant differences between grip and pinch strength at end of the 6 week period, but there were significant differences between pain and DASH score. Restriction of migration of lumbrical muscles in the carpal tunnel may cause pressure relief in this tunnel and provide more pain reduction compared to a neutral wrist splint.

According to the position of the lumbrical muscles, there was a significant difference between the patient group that wore the neutral wrist and MCP extension compared to the group that wore the neutral wrist splint. Using the wrist splint with the MCP unit placed the MCP joint in 0° to 10° of flexion. Wearing the splint in this position prevents displacement of the lumbrical muscles in the carpal tunnel and therefore may have decreased pressure in the carpal tunnel. This observation supports previous findings that demonstrated the flexion of MCP joints cause migration of lumbrical muscles in to the carpal tunnel and provide carpal tunnel pressure(20, 22). .

Synergistic performance of intrinsic and extrinsic muscles of the hand can provide grip power. The median nerve is proximal to the carpal tunnel, and the ulnar or radial nerve innervate these muscles(35). The strength of the flexor pollicus longus which is innervated by the median nerve proximal to the carpal tunnel and the flexor pollicis brevis which has inconsistent innervations with variable contribution from the median and ulnar nerve can affect key pinch strength (32). In addition, abductor pollicis brevis or opponens pollicis weakness or pain may be compensated for during key pinch by synergistic muscle action or 'trick' movements(36, 37).

Strength in the affected hand has been shown to be reduced by as much as 10% to 30% compared to normal values seen in the subjects with CTS (32). Although wearing both types of splints improved strength in this study, six weeks of splint use did not return the hand to the normal mean value of strength shown in healthy participants. There was no significant difference in this variable between the two groups. Long term follow-up of the effect of wearing a wrist splint with a lumbrical unit may provide an increase in grip and pinch strength. A guideline about the time required for grip strength to return to the pre-operative level after carpal tunnel release has not been published. However, Gellman *et al*. noted that grip strength may require up to 3 months post-operatively before returning (38).

Since this study followed patients for only 6 weeks, future research should focus on evaluating the effectiveness of these types of splints over a longer term to provide more information for the long-term treatment of CTS. The results of this study do not support the superiority of the wrist splint with MCP unit over neutral wrist splint in improvement of grip and pinch strength in treating CTS. Unfortunately muscle testing and testing of different functional grips were not used in this study. Additional study in this field will be beneficial for measuring the impact of the splints. Future studies, with larger sample sizes and combination using of splints and upper limb exercising program is required to determine the effectiveness of these splints in the treatment of CTS over a longer period of time. In addition, the use of elastic Velcro strapping may have increased the circular effect of the splints in controlling motion.

Conclusion

CTS has been reported as being the most prevalently diagnosed upper-extremity dysfunction. Providing effective conservative interventions for the treatment of mild-to-moderate CTS should be given superiority. The aim of this study was to compare the effects of a neutral wrist splint and wrist splint with MCP unit, for the treatment of mild-to-moderate CTS. The results of this present study provide additional evidence of the effectiveness of splinting for decreasing symptoms and improving hand performance in patients with mild-to-moderate CTS.

Both splints (a neutral wrist splint and a wrist splint with an MCP unit) reduced pain and increased function, pinch and grip strength when compared to baseline and after 6 weeks.

There were no statistical significant differences in grip and pinch strength between the two splints, but the wrist splint with MCP unit was significantly more effective than the neutral wrist splint in pain reduction and improvement of function. Whilst further research is required, this study suggests that both splint designs are helpful in the short-term for patients with CTS.