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EFFECTS OF DIACUTUANEOUS FIBROLYSIS ON MECHANOSENSITIVITY, DISABILITY AND NERVE CONDUCTION STUDIES IN MILD TO MODERATE CARPAL TUNNEL SYNDROME. SECONDARY ANALYSIS OF A RANDOMIZED CONTROLLED TRIAL.

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EFFECTS OF DIACUTUANEOUS FIBROLYSIS ON MECHANOSENSITIVITY, DISABILITY AND NERVE CONDUCTION STUDIES IN MILD TO MODERATE CARPAL TUNNEL SYNDROME. SECONDARY ANALYSIS OF A RANDOMIZED CONTROLLED TRIAL.

ABSTRACT

Background. Patients diagnosed with Carpal Tunnel Syndrome (CTS) present fibrosis between the soft, connective, and neural tissues that could influence the compressive situation of the median nerve. The Diacutaneous Fibrolysis (DF) technique may release tissue adhesions and increase the mobility of connective tissues.

Objective. The purpose of this study was to compare the outcomes of DF in patients with mild to moderate CTS, on: mechanosensitivity, disability, and nerve conduction studies.

Design. This was a secondary analysis of a double-blinded, randomized placebo-controlled trial.

Settings. Patients were recruited between April to September 2016 from the Department of Neurophysiology at the Hospital [redacted] Zaragoza, Spain.

Participants. Thirty-nine people (52 wrists) diagnosed with mild to moderate CTS were included.

Intervention. Participants were randomly assigned to the DF group (n=26) or the Sham group (n=26). Both groups received 5 therapy sessions, two per week.

Measurements. Mechanosensitivity with Upper Limb Neurodynamic Test 1 (ULNT1), symptoms severity and functional status with Boston Carpal Tunnel Questionnaire (BCTQ), and median nerve sensory conduction velocity with nerve conduction studies were the outcomes measured. Assessments were undertaken at baseline and after the intervention.

Results. DF group showed significant improvements between-group on mechanosensitivity, 28.46º elbow extension ROM (95% CI = 19.2-37.7); on the mean difference for BCTQ symptoms severity and functional status score, 1.0 points (95% Confidence interval (CI) = 0.7-1.4); and for sensory conduction velocity of median nerve, 5.8 m/s (95% CI = 2.5-9.2).

Limitations. Patients with severe CTS were not included, and no long-term effects were assessed.

Conclusion. Patients with mild to moderate CTS experience benefit with five sessions of DF on symptoms severity, functional status, mechanosensitivity, and nerve conduction studies.

Key Words: Carpal Tunnel Syndrome; Physical Therapy Modalities; Outcomes.

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INTRODUCTION

Carpal Tunnel Syndrome (CTS) is the most common entrapment neuropathy of the human body,[1,2] with an estimated prevalence between 6.3% and 11.7%.[3,4]

The impairment of the median nerve in the CTS could be secondary to mechanical compression and local ischemia.[5] Clinically, patients with CTS suffer paresthesia and numbness symptoms, in the first three fingers and upper limb disability.

Besides the compressive signs, patients with CTS also present biomechanical changes in the transverse carpal ligament (TCL), and degenerative changes in the neural connective tissue and adjacent tenosynovium.[6–8] Also, there is increasing evidence that has shown fibrosis in the wrist and forearm soft tissues nearby the median nerve.[9–13]

The fibrosis between the soft, connective, and neural tissues could influence the compressive situation of the median nerve. **This compression generates an edematic condition, which results in a nerve conduction velocity alteration. In addition, these impairments could decrease nerve mobility and increase mechanosensitivity.[11,12,14] Upper Limb Neurodynamic Test 1 (ULNT1) is used to assess the mechanosensitivity of the median nerve, according to the movements performed and the range of motion (ROM) achieved.[15,16]**

Recently, several authors have proposed soft tissue mobilization to decrease the compressive situation, improving clinical signs and symptoms in patients with CTS.[17–19] Diacutaneous Fibrolysis (DF**) is a physiotherapeutic technique, developed from Cyriax deep friction massage principles, that uses a set of metallic hooks to achieve a deeper and more precise application than the manual treatment. DF** is a novel technique that mechanically tries to release tissue adhesions and increase the mobility of connective tissues. This technique has shown an improvement in the mobility of other human body structures in musculoskeletal disorders, such as shoulder **pain,[20,21] lateral**

epicondylalgia,[22] and triceps surae tendon muscle reflexes.[23,24] In this sense, the improvement of the mobility between tissues with the DF technique could alleviate the mechanical compression of the median nerve in the carpal tunnel. **The reduction of the epineurial tethering in the forearm could improve the median nerve gliding in the carpal tunnel during the movement of the wrist, fingers or elbow.**

We hypothesize that the application of DF in patients with mild to moderate STC will reduce severity symptoms and increase functional status, reduce mechanosensitivity and improve nerve conduction velocity, by restoring the connective, muscle, and tendon tissue movement.

Therefore, this secondary analysis hypothesized that the effect of DF compared with Sham fibrolysis, would be greater on symptom severity and functional status, mechanosensitivity, and nerve conduction test, in patients with mild to moderate CTS.

METHODS

Trial design

This study was a secondary analysis of data from a double-blind, randomized, placebo-controlled trial[19] (ClinicalTrials.gov Identifier: C.I.PI14/00086), and was approved by the Ethics Committee of Aragón, Spain (CP13/2014). All patients provided written informed consent before enrollment in the study. The analysis in the present study was not included in the original protocol for the randomized controlled trial. **Cases included in this secondary analysis were those who completed the entire ULNT1 until the elbow extension phase from the sample analyzed in the primary study.** The study was carried out according to CONSORT guidelines.[25]

Participants and Setting

The trial was carried out in the Department of Neurophysiology at the Hospital [redacted], Zaragoza, Spain. Participant recruitment period was between April to September 2016. The participants were volunteers diagnosed with mild to moderate CTS by a neurophysiologist.

The inclusion criteria were as follows: aged 18 to 65 years, symptoms **(numbness, tingling, burning, or pain)** in the median nerve distribution, diagnosed with mild to moderate CTS, according to the American Academy of Physical Medicine and Rehabilitation criteria,[26] completed the entire ULNT1 until elbow extension phase, capable of providing information to complete questionnaires and understand the instructions, and complete all treatment sessions.

The exclusion criteria were as follows: previous surgery in the affected upper extremity or cervical spine, a specific cause of CTS (i.e. trauma, infectious process, cervical radiculopathy, alcoholism, vitamin deficiency, systemic diseases), pregnancy, previous physiotherapy treatment or corticosteroid injections in the upper limb in the last 3 months, and contraindications for the DF treatment (anticoagulant therapy or vascular alterations, wounds or skin disorders) in the elbow, forearm or hand region.

Outcomes

Two examiners blinded to the patients' allocation performed the measurements. The therapist could not be blinded to the group assignment, but he was not involved in any of the outcome measures. **The outcomes were measured at baseline and after treatment. The primary outcome variable was symptoms severity and functional status.** The secondary outcome variables were mechanosensitivity and nerve conduction studies of the median nerve at the carpal tunnel.

The symptoms severity and functional status were assessed using the Spanish version of the Boston Carpal Tunnel Questionnaire (BCTQ).[27] BCTQ has shown to be valid and reliable in patients with CTS.[27] **This questionnaire has shown an excellent reliability with an intraclass correlation coefficient (ICC [2,k]) ranged from 0.91 to 0.94. The 95% confidence interval (95%CI) ranged between 0.84 to 0.99 and the minimal detectable change at the 95% confidence level (MDC_{95}) has been stated in 0.74 in patients with CTS.[28]**

Mechanosensitivity was measured using the **ULNT1.** The ULNT1 consists of a sequence of passive movements to test the brachial plexus through the median nerve.[29–32] In the present study, the ULNT1 was sequenced by examiner 1, as follows **(Figure 1):** 90º shoulder abduction, 90º shoulder external rotation with the shoulder girdle maintained in neutral, the forearm in maximum supination, the wrist and fingers maximally extended. Patients were instructed to communicate the first symptoms. Elbow extension was performed at the onset of symptoms.[32–35] In that point, the examiner 2 performed the structural difference maneuver to classify the response.[16] **Structural differentiation maneuver is defined as a movement of a distant body part that further loads or unloads the nervous system[32]. In the ULNT1, if the symptoms are in the distal part of the upper limb, the structural differentiation consists of performing contralateral neck side bending, without changing tension in the adjacent structures, such as muscles or tendons of the forearm and the hand area (Figure 1). If the symptoms are in the proximal part of the upper limb, the structural differentiation consists of performing wrist palmar flexion. When the symptoms change with the structural differentiation maneuver, the response is classified as a neurodynamic response.**

The ULNT1 was registered at the onset of symptoms, as the following variables:

- Elbow ROM, measured with a universal goniometer.[36] **The measurement of elbow extension ROM at pain onset during ULNT1 has shown an ICC(2,1)=0.85 with the 95%CI ranging from 0.84 to 0.99.[36,37] The MDC_{95} has been determined in 10.47º.[36,37]**
- Type of symptoms, classified in stretching, pain, tingling, pricking, numbness, or burning sensation.[38]
- Symptoms intensity, measured with a 10cm visual analogue scale (VAS), where 0 represented "no symptoms" and 10 "the most intense pain imaginable".
- Location of the symptoms, registered in a body chart divided into 7 areas: forearm, wrist, three first fingers, hand, elbow, arm, and ulnar area.[38]

The sensory conduction velocity (SCV) of the median nerve at the wrist was measured with nerve conduction studies,[26,39] by a neurophysiologist, blinded to the patient's assigned group.

Randomization and Interventions

The participants were randomly assigned to the DF group or the Sham group. The randomization sequence was computer-generated (research randomizer version 4.0) by an external clinical assistant before patient recruitment. Both the examiners and the patients were blinded to the assigned group. In bilateral cases, the same intervention was performed on both sides to maintain blinding.

DF and the Sham intervention were applied by the first author, blinded to the measurements, who had received training in DF and had 5 years' clinical experience. All cases participated in 5 sessions of treatment (20 minutes each, 2-5 days between sessions). In the DF group, the hook was applied with the necessary pressure for covering the

structure, to move and traction in the transverse direction. These procedures were performed with the hook fixed on the skin and underlying soft tissues. The position of the patient was in supine with the forearm on a stable support to allow access to the muscular tissue. With the forearm of the patient positioned in supination, the DF was applied as deeply as possible following the intermuscular septum between the ventral muscles of the forearm: pronator teres, flexor carpi radialis, palmaris longus, flexor carpi ulnaris, and finger flexors. The finger flexor tendons and palmar fascia were also treated. **The cases included presented symptoms in the distal part of the upper limb (wrist and hand), so the intervention was applied from the elbow and proximal forearm to wrist, hand, and fingers, according to the centripetal approach** (Figure 2A).

In the Sham group, the hook was applied over the same forearm and hand area and in the same direction, but only at a superficial level and without any mechanical action taking place on the deep tissue layers. **A pinch of skin was held with the thumb of the palpatory hand and the tip of the hook, so that, the patient could feel the hook distinctly (Figure 2B).**

Both interventions lasted 5 sessions (20 minutes each, 2-5 days between sessions). **No other treatment modality was added to the intervention.**

Sample size

Of the 60 cases analyzed in the primary study, 52 cases met the inclusion criteria for this secondary analysis. The secondary sample sizes were n=26 cases in the DF group (18 subjects) and n=26 cases in the Sham group (21 subjects), for a sample size of 52 cases with CTS.

Because of the sample size has not been estimated for this secondary study, the statistical power of the sample for the primary outcome has been calculated. The

observed statistical power demonstrated by the sample was 99.9%, with an α error of 5%, with a consequent β error (type II) of 0.1 %.

Data Analysis

SPSS 20.0 software was used for all statistical analyses. Frequencies and percentages were calculated for qualitative variables: the quality and the location of the patients' responses during ULTN1.

Mean and standard deviations were calculated for quantitative variables: elbow extension ROM and the intensity of the patients' responses during the ULTN1, and SCV of the median nerve at the wrist. The Shapiro-Wilk test was used to assess the normal distribution of quantitative data. Differences between groups at baseline were analyzed by Student´s t-test or the Mann-Whitney U test, for normally distributed data or non-normally distributed data respectively. Chi-square test (x^2 test) or Fisher´s exact test was used for the demographic nominal variables. A two-way analysis of variance (ANOVA) was used to investigate the differences in outcomes with time (baseline and end of the treatment) as the within-subjects factor and group (FD, Sham) as the between-subjects factor. A p-value <0.05 was considered statistically significant.

The effect size was calculated with Cohen coefficients (d) and interpreted as follows: large effect sizes, d>0.8; moderate effect sizes, d=0.5-0.79; and small effect sizes, d=0.2-0.49.[40]

RESULTS

Fifty-two cases met the inclusion criteria for this secondary analysis (39 subjects, 13 bilateral and 26 unilateral). The study flowchart is shown in Figure 3.

Baseline characteristics among the groups were similar for demographic characteristics (Table 1). Adverse events or side effects were not reported nor observed for any participant.

The symptoms in ULNT1 appeared in the distal part of the upper limb and the responses obtained in all cases, at baseline and after treatment, were neurodynamic. At baseline, no significant differences between the DF and Sham groups for elbow extension ROM (p=0.51), the intensity of the sensations in ULTN1 (p=0.06), SCV of the median nerve at the wrist (p=0.34) and **BCTQ** score (p=0.33) were found.

Table 2 provides at baseline, post-intervention data, and effect sizes as well as within-group, and between-group differences for ROM in ULNT1, the intensity of the sensations in ULTN1, for SCV and **BCTQ** score. A two-way ANOVA revealed a significant Group by Time Interaction for the ULTN1 elbow extension ROM (***df*** **=1;** F=37.191, p<0.01), and the intensity of symptoms during ULTN1 **(*df*** **=1;** F=5.777, p=0.02). A significant Group by Time interaction was also detected for SCV median nerve (***df*** **=1;** F=12.227, p<0.01), and **BCTQ** symptoms severity and functional status score (***df*** **=1;** F=14.914, p<0.01). Mechanosensitivity, symptoms severity and functional status, and the SCV median nerve improved in the DF group (p>0.05). The results achieved for all the variables in the DF group showed a large effect size (d ≥ 0.9).

At baseline, the main descriptors of the type of symptoms in ULNT1 were stretching (65.4% in the Sham group, 73.1% in the DF group) and pain (23.1% in the Sham group, 19.2% in the DF group). The DF group increased the tightness sensation (80.8%) and decreased the pain sensation (15.4%) in ULTN1. However, in the Sham group decreased the stretching sensation (50.0%) and increased the pain sensation (38.5%) in ULTN1 (Table 3).

At baseline, in ULNT1, the location of symptoms (stretching, pain or tightness), independently of the type of symptoms, had no differences between groups (Figure 4). After the intervention, in the DF group, the symptoms provoked by the ULTN1 decreased in the wrist (30.8%), the elbow (3.8%) and increased in the forearm (53.8%) and hand (7.7%). The Sham group did not show differences after treatment in the location of symptoms in ULTN1 (Figure 4).

DISCUSSION

To our knowledge, this is the first study to evaluate the short terms effects of DF treatment on symptoms severity and functional status, **mechanosensitivity**, and nerve conduction studies in patients with mild to moderate CTS. The results demonstrated that DF treatment compared with Sham DF significantly improved the severity of symptoms and functional status, and mechanosensitivity in patients with mild to moderate CTS. Also, an improvement in the nerve conduction studies was found in favor of the DF group. This result **is in agreement with** a previous study.[19]

Strengths and Weakness in Relation to Other Studies

Based on our findings, DF had positive effects on hand symptoms and functional status. The results obtained on **BCTQ** severity symptoms and functional status scores were higher than the MDC.[28] The elbow extension ROM in ULNT1 increased after treatment in the DF group, suggesting a decrease of mechanosensitivity.[38,41] The improvement in elbow extension ROM in ULNT1 was superior to the MDC reported for ULNT1 in previous studies.[36,37,42,43] Also, the effect size values were greater than 1, in favor of the DF group, indicating a large effect.

Previous systematic reviews and clinical trials have studied different conservative non-invasive treatments, such as manual therapy, soft tissue mobilization, splinting, laser, ultrasounds, thermotherapy, or its combination.[18,44–49] The studies that applied non-invasive treatments, focusing on carpal tunnel area, showed positive effects on the **BCTQ** score,[44,45] however, they did not achieve positive effects on nerve conduction studies.[46–48] The studies that applied the intervention in the soft tissues of the entire upper limb demonstrated positive clinical effects on **BCTQ** score and nerve conduction study.[18,49,50] Thus, the treatment of the tissues of the specific structures related to the median nerve improved the symptoms severity and the nerve conduction studies. This is the first clinical trial that considers a deep instrumental intervention, focusing on the specific structures related to the median nerve. Additionally, it has achieved clinically relevant and statistically significant changes on **BCTQ**, nerve conduction studies and on mechanosensitivity, measured by ULNT1.

Concerning ULNT1, the mean value obtained in elbow extension ROM after DF treatment was minor than the mean ROM described as the normal response in asymptomatic subjects.[51] This difference could be related to the point where the movement was stopped. In our study, the test was stopped when the patients felt the first onset of any symptoms, whereas in other studies the test was stopped at the point of maximal tolerance. Boyd et al.[52] showed a mean difference higher than 20º of ROM between the point of the first report of symptoms and the point of maximal tolerance in neurodynamic tests.

Besides, in this study, other secondary variables of ULNT1, such as sensory responses, location, type, or intensity of symptoms, were measured. Also, these variables have been used for the CTS diagnosis.[16,38,41,42,53,54] In the present study, all the sensory variables of the ULNT1 showed significant changes after DF treatment. Stretching in the forearm was

the main symptom in ULNT1 after DF treatment. This outcome was similar to the response described in asymptomatic subjects during ULNT1.[38,51,53,55]

Explanation of Findings

The treatment of the structures surrounding the median nerve appears to be important in patients with mild to moderate CTS. Previous studies have reported that soft tissue mobilization techniques improved the CTS symptoms.[56,57]

The positive results achieved in BCTQ and nerve conduction studies could be related to the soft tissue mobilization and the release of the adherences.

It has been demonstrated that the median nerve glides directionally in the carpal tunnel during movement of the wrist, fingers or elbow, and that epineurial tethering in the forearm may reduce the nerve excursion in the tunnel, resulting in transverse contraction of the nerve and a resultant increase in intraneural pressure.[56,57]

Improvements in mechanosensitivity detected with ULNT1 reflected that patients improved mechanical tolerance. The fact of having treated soft tissues related to neural compression could have indirectly generated an improvement in the function of the nervous system. This outcome could have generated better tolerance to the tension. This fact could explain the positive results achieved by other authors that treated soft tissues around the nerve.[18,49,58]

Strengths and Limitations of the Trial

From a clinical perspective, the approach based on DF applied in the soft and connective tissue around the median nerve showed that the DF technique improves the severity of symptoms and functional status and **reduces the mechanosensitivity of the median nerve in patients with mild to moderate CTS.**

Changes in mechanosensitivity could be a relevant clinical sign in the assessment of the patients with minor peripheral nerve injuries.[59] In patients with mild to moderate CTS, **the neurodynamic test** could be an important tool, because nerve conduction studies are not always clear in minor nerve disorders.[36,41,60–62]

The present study has some limitations. Firstly, it was not a preplanned secondary subgroup analysis, that may condition a type 1 error, neither was the elbow extension phase of ULNT1 used as a selection factor at randomization. This factor could have created unbalanced groups that could have influenced the outcomes. Another potential limitation is that the study did not include severe CTS, which limits the generalization of the results. Also, the lack of studies assessing mechanosensitivity has not allowed comparing with our results. **Also, the fact that a single therapist provisioned of all treatment, reduces the generalizability of the findings to treatments by other practitioners.** Finally, no long terms effects were assessed.

Future research should study the medium and long terms of DF treatment in patients with mild to moderate CTS, the effects of DF treatment in severe CTS and the combination of DF treatment with other techniques, which have reported clinical benefits in patients with CTS, such as neurodynamic mobilizations. Finally, it could be interesting to assess the appropriate dosage and the cost-effectiveness of DF treatment in CTS patients.

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Figure 1. ULNT1 sequence and structural differentiation maneuver.

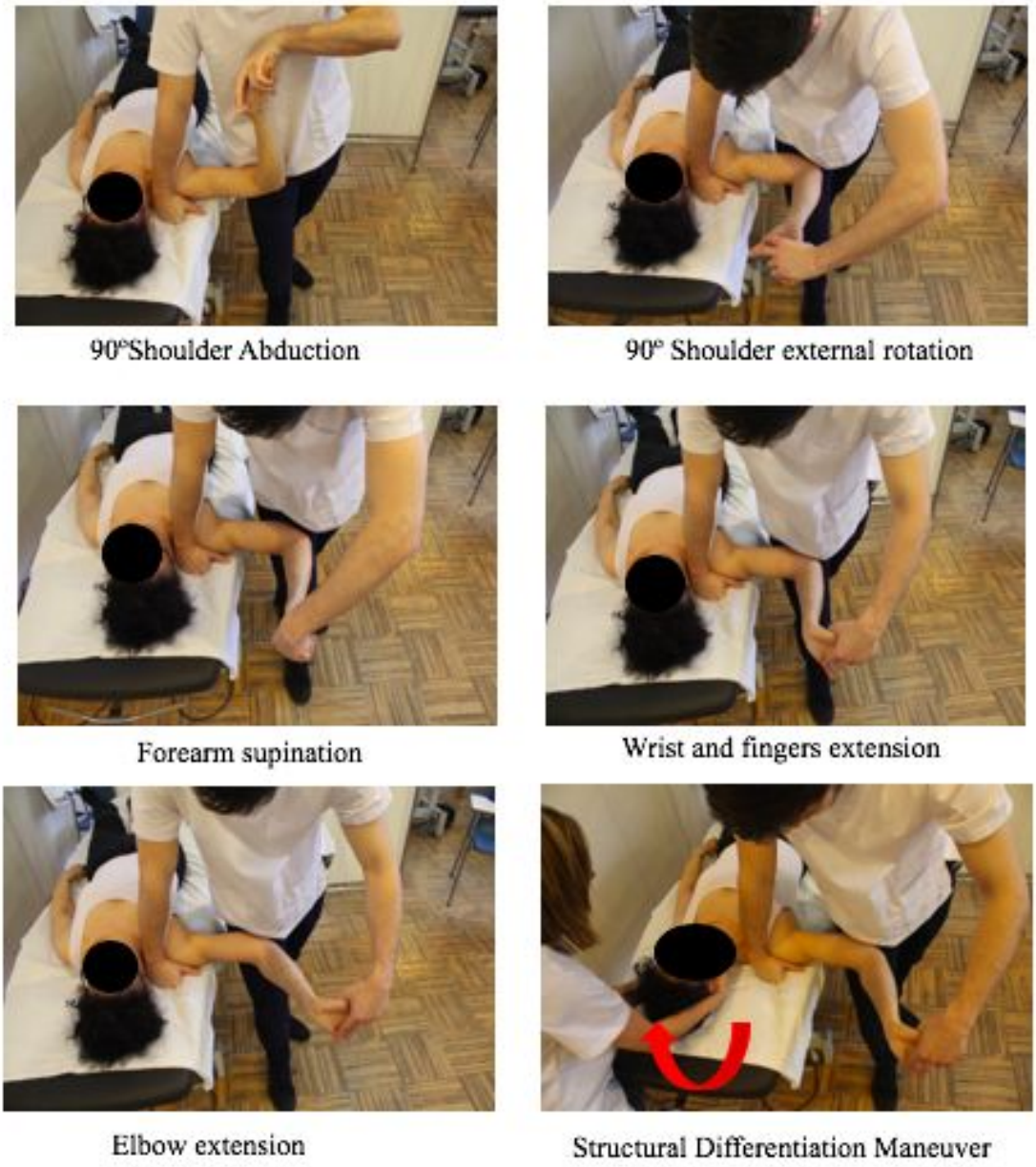
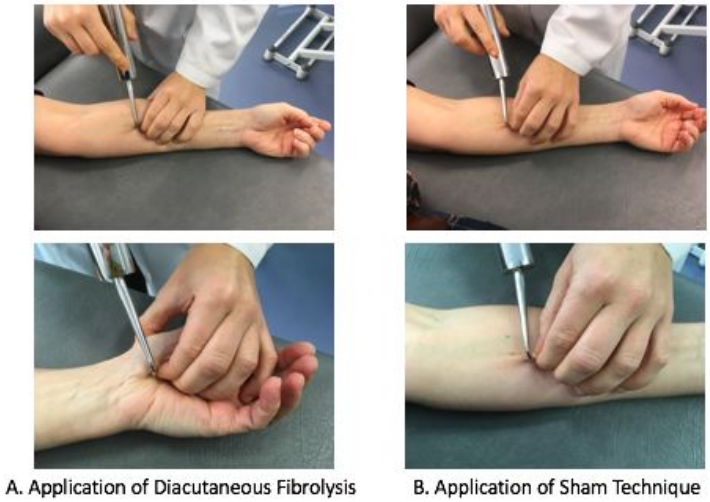


Figure 2. Independent variable application



A. Application of Diacutaneous Fibrolysis B. Application of Sham Technique

Figure 3. Flowchart of patient recruitment.

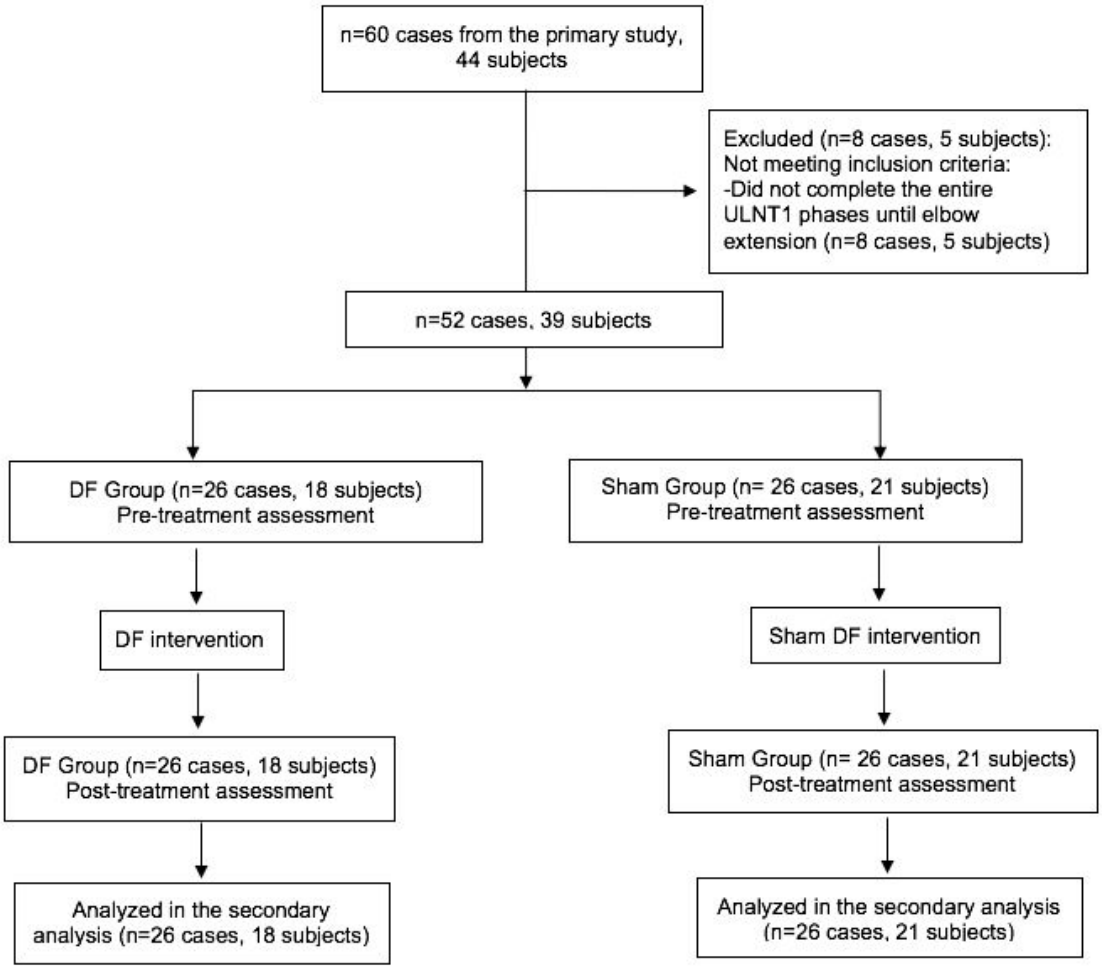


Figure 4. Symptoms´ location (stretching, pain or tightness) in ULNT1. Body chart. Pre: Baseline; POST; end of treatment.

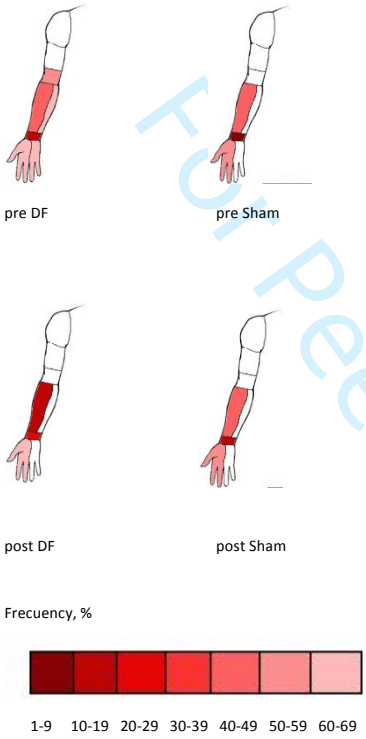


TABLE 1. Descriptive baseline characteristics of study sample [a].

Demographics[b]	**DF group (n=26)**	**Sham oroup (n=26)**	**Significance**
Gender (male/female)	5/21	4/22	p= 0.10[c]
Age (years) Mean (SD)	45.5 (9.6)	49.6 (7.6)	U = 253.5; p = 0.12[d]
BMI (kg/cm^2) Mean (SD)	24.9 (2.8)	25.6 (2.9)	t= -0.85; p = 0.40[e]
Symptoms duration (months) Mean (SD)	25.8 (23.9)	27.6 (39.2)	U = 322.0; p = 0.77[d]

[a] BMI = body mass index, DF = diacutaneous fibrolysis

[b]Continous variables are reported as mean (SD) and categorical variables are reported as n.

[c] Chi-square test, [d]U-Mann Whitney test, [e]Student-t test.

TABLE 2. Baseline, final values, differences and effect sizes for the elbow extension ROM, the intensity of the response during ULNT1 and sensory conduction velocity of median nerve in wrist[a].

Outcome group[b]	Baseline	End of treatment	Within group changes (95%CI)	Within group effect sizes	Between-group differences in change scores (95%CI)	Between-group effect sizes
ULNT1 elbow extensión (º)						
Sham group (n=26)	97.3 (10.1)	96.8 (7.8)	-0.4 (-5.2, 4.2)	0.0	28.46 (19.2, 37.7)	1.7
DF group (n=26)	97.8 (7.4)	125.3 (22.1)	27.4 (19.6, 35.2)	-1.6		
ULNT1 VAS (0-10)						
Sham group (n=26)	4.8 (2.0)	4.2 (2.0)	-0.5 (-1.2, 0.0)	0.3	-2.0 (-2.9, -1.0)	-1.2
DF group (n=26)	3.8 (1.7)	2.2 (1.2)	-1.6 (-2.2, -1.0)	1.0		
SCV median nerve (m/s)						
Sham group (n=26)	41.2 (5.5)	40.8 (5.8)	-0.3 (-1.8, 1.1)	0.0	5.8 (2.5, 9.2)	0.9
DF group (n=26)	42.7 (5.9)	46.7 (6.0)	3.9 (1.8, 6.0)	-0.6		
BCTQ						
Sham group (n=26)	2.4 (0.7)	2.3 (0.8)	0.1 (-0.5,0.3)	0.1	1.0 (1.4,0.7)	1.5
DF group (n= 26)	2.4 (0.4)	1.3 (0.4)	1.2 (0.9,1.5)	2.75		

[a] DF: diacutaneous fibrolysis; ULNT1: Upper Limb Neurodynamic Test 1; SCV: sensory conduction velocity; BCTQ: Boston Carpal Tunnel Questionnaire

[b]Values are expressed as mean ± SD for baseline and final means and as mean (95% confidence interval) for within-group and between-group change scores.

TABLE 3. Baseline, final, differences between groups and effect sizes between groups of the type of sensation provoked in ULTN1[a].

ULNT1[b]		Stretching	Pain	Tingling	Pricking	Numbness	Burning
Baseline	Sham group (n=26)	17 (65.4)	6 (23.1)	0	0	3 (11.5)	0
	DF group (n=26)	19 (73.1)	5 (19.2)	0	0	2 (7.7)	0
Final	Sham group (n=26)	13 (50.0)	10 (38.5)	0	0	3(11.5)	0
	DF group (n=26)	21 (80.8)	4 (15.4)	0	0	1 (3.8)	0

[a]ULNT1: ULNT1: Upper Limb Neurodynamic Test 1; DF: diacutaneous fibrolysis

[b]Values are frequency (%).

Original Article

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Effects of diacutaneous fibrolysis in patients with mild to moderate symptomatic carpal tunnel syndrome: a randomized controlled trial

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Abstract

Objective: To compare the effects of diacutaneous fibrolysis with sham in patients with mild to moderate carpal tunnel syndrome.

Design: Double-blind (patient and evaluator) randomized controlled trial.

Setting: Miguel Servet University Hospital, Zaragoza, Spain.

Subjects: A total of 52 patients (72 wrists) with carpal tunnel syndrome, 41 women and 11 men, mean age was 46.9 (8.8) years. They were divided into two groups: diacutaneous fibrolysis group and sham group.

Interventions: Real diacutaneous fibrolysis in diacutaneous fibrolysis group and sham diacutaneous fibrolysis in sham group. Both groups received five sessions in the forearm, wrist and hand.

Main measures: Neurophysiological parameters assessed at baseline and at the end of the treatment. Intensity of nocturnal symptoms (visual analogue scale (VAS)) and upper limb functional capacity (Disabilities of the Arm, Shoulder and Hand (DASH) questionnaire) at baseline, at the end of the treatment and one month after treatment.

Results: Diacutaneous fibrolysis group (n = 30 wrists) improved in nerve conduction distal motor latency (mean difference: –0.26, 95% confidence interval (CI): –0.49/–0.26), sensory conduction velocity (mean difference: 6.52, 95% CI: 3.52/9.51), intensity of nocturnal symptoms (mean difference: –2.24, 95% CI: –4.08/–2.04) and upper limb functional capacity (mean difference: –19, 95% CI: –26.1/–11.9) compared to the sham group (n = 30 wrists) ($P < 0.02$, $P < 0.01$, $P < 0.01$ and $P < 0.01$, respectively). At one-month follow-up, improvements in the nocturnal symptoms and upper limb functional capacity were maintained compared to the sham group ($P < 0.01$).

Conclusion: Diacutaneous fibrolysis provides short-term and one-month follow-up, improvements in sensory conduction velocity, motor distal latency, symptoms and functional capacity in patients with mild to moderate carpal tunnel syndrome.

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Carpal tunnel syndrome, physical therapy modalities, pain and randomized controlled trial

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Introduction

Non-surgical treatment is generally prescribed as the first-line approach to patients with mild to moderate carpal tunnel syndrome.[1] Current treatments in the mild and moderate stages in carpal tunnel syndrome involve the use of orthotics such as splints or orally administered drugs.[2–4] However, the negative consequences arising from their continued use must be taken into account.[5–8] Other conservative techniques have also been proposed, such as electrotherapy,[1,9] mobilization of the carpal bones, ultrasound and even combinations of techniques, but their effectiveness cannot be confirmed because of the lack of studies with an adequate methodological quality.[9–17] Recent studies propose techniques with approaches that integrate the treatment of structures taking the continuity of the nerve into account, not only at a local level.[18,19] These results, coupled with the clear involvement of adjacent tissues in the path of the nerve, justify an approach dealing with the soft tissue in the adjacent regions and not only locally in carpal tunnel structures in the wrist.

In addition to compressive signs on the median nerve at the carpal tunnel, biomechanical changes of the transverse carpal ligament and degenerative changes to the connective tissue and tenosynovium have been shown in carpal tunnel syndrome patients.[20–22]

Diacutaneous fibrolysis is a physiotherapeutic technique developed from Cyriax deep friction massage principles, but a set of metallic hooks are used to achieve a deeper and more precise application than manual. Diacutaneous fibrolysis has been proven to be effective improving symptoms and function in other musculoskeletal disorders such as shoulder pain,[23,24] lateral epicondilalgia and triceps surae tendon muscle reflexes.[25,26] To our knowledge, they are no studies on diacutaneous fibrolysis technique effectiveness in carpal tunnel syndrome. Our hypothesis is that this technique could be effective for improving alterations in the connective tissues adjacent to the nerve and could improve the function and symptoms in mild to moderate carpal tunnel syndrome patients.

The aim of this study was to evaluate the effect of five sessions of diacutaneous fibrolysis on the myofascial tissues of the forearm, wrist and hand in carpal tunnel syndrome patients with mild and moderate involvement of the upper limb in terms of nerve conduction, symptoms and functional capacity.

Methods

Design

A double-blind (patient and evaluator) randomized controlled trial was carried out between April to September 2016. The study was registered in ClinicalTrials.gov (C.I.PI14/00086) and was approved by the Clinical Research Ethics Committee of Aragón with registration number (CP13/2014).

Recruitment procedures

Subjects with mild to moderate carpal tunnel syndrome diagnosed by neurophysiological test were recruited from the neurophysiology service of the Miguel Servet Hospital (Zaragoza, Spain). The sample size was calculated for all dependent variables, estimating a two-tail test, a level of significance of 0.05, a power of 0.8 and a follow-up loss rate of 15%. The highest value (36 affected wrists per group) was obtained with data of the sensory conduction velocity (expected size 4 and SD: 5.3) previously reported in a pilot study. As there were two groups in this study (diacutaneous fibrolysis group and sham group), the total sample size was

Table 1. Inclusion and exclusion criteria.

Inclusion criteria	Exclusion criteria
Having been medically diagnosed with CTS after electrophysiological tests and presenting mild to moderate involvement. This test was performed according to the standards established by the "American Academy of Physical Medicine and Rehabilitation"	Previous surgery in the carpal tunnel in the same limb Other pathologies that may be associated with CTS: traumas, pathologies or disorders of the upper limb or cervical spine (cervical radiculopathy, cervical sprain, etc.) or prior cervical surgery Concurrent comorbidities that may be the cause and interfere with the treatment of the CTS: diabetes mellitus, hypothyroidism, rheumatoid arthritis, fibromyalgia, reflex sympathetic dysfunction, obesity, renal disease, alcoholism, significant vitamin deficiency and associated viral or bacterial processes
Being between 18 and 65 years old	Pregnancy
Having sufficient understanding and capacity to communicate their symptoms and to complete the questionnaires	Oral drugs, physiotherapy treatment or infiltrations in the upper limb in the last three months
The ability to maintain a supine position without triggering symptoms or altering the patient's condition	Presenting red flags, such as processes of malignancy, inflammation, fever etc. or psychological contraindications that could interfere with the normal progress of the study
Voluntarily accepting and consenting to participate in the study	Specific contraindications for the diacutaneous fibrolysis treatment, such as skin disorders (such as diaphanous and hypotrophy (or) ulcerous skin (or) dermatosis), a poor trophic state of the circulatory system or an overdeveloped network of surface veins or the consumption of antiplatelet agents

CTS: carpal tunnel syndrome.

72 affected wrists. The inclusion and exclusion criteria are listed in Table 1. All participants were randomly classified either into the diacutaneous fibrolysis group or the sham group. For the randomization process, an external evaluator randomized the intervention to each participant using the research randomizer (version 4.0) computer software. Both evaluators and patients were blind to the group assignment. In bilateral affectations, the same intervention was performed in both sides, in order to maintain blinding.

Data collection

The sensory conduction velocity and the motor distal latency of the median nerve at the wrist was measured by neurophysiological assessment[27,28] at the beginning and after five sessions of treatment. Neurophysiological tests were measured by a neurophysiologist. The intensity of nocturnal symptoms was also measured using a visual analogue scale (VAS) of 100-mm length, where 0 was "no pain" and 100 was "maximum pain" with no intermediate marks,[29] at baseline, at the end of the treatment and after one-month follow-up. The functional capacity of the upper limb was also evaluated with the Disabilities of the Arm, Shoulder and Hand questionnaire (DASH)[30,31] at baseline (T0), at the end of treatment (T1) and at one-month follow-up (T2). All these functional measures were performed by two physiotherapists. To determine the degree of masking, each patient was asked which technique (sham or real diacutaneous fibrolysis) they thought that they had received.

Interventions

All patients participated in five sessions of real or sham treatment 20 minutes each. All intervention lasted an average of 17.77 days (SD: 0.8) with an interval of two to five days between each session, according to a person's availability. The diacutaneous fibrolysis group received the real technique. The technique was applied using the hook on the intermuscular septa of the ventral musculature of the forearm: the pronator teres, the flexor carpi

radialis, the palmaris longus, the flexor carpi ulnaris and the finger flexors, from the proximal to the distal region, toward the wrist and ending at the approach to the flexor tendons and palmar fascia. The hook was applied with necessary pressure for covering the structure to be moved, and a short and fast traction in transverse direction made with the hook remains fixed in the skin and the underlying soft tissues[23,24] (Figure 2).

The sham group received simulated technique. The hook was applied in the same regions and in the same direction, but at a superficial level without generating mechanical traction on the deep fibers of the soft tissue[23] (Figure 2).

Both real and sham techniques were provided by the same physical therapist, who was the only person aware of patients allocation.

Data analysis

SPSS version 20.0 software for MAC was used for the statistical analysis.

A descriptive analysis was performed on the first measurement of all the variables considered. The assumption of normality was assessed using the Shapiro–Wilk test. In the between group comparisons, the chi-square test was used for qualitative variables. For quantitative variables, Student's t-test was performed if the criteria for its applicability were met; otherwise, the Mann–Whitney U test was used. The differences between groups were calculated. The level of significance was set at alpha = 0.05.

Results

The study flowchart is reported in Figure 1. A total of 52 patients (72 wrists) affected by mild to moderate carpal tunnel syndrome consent to participate in the trial and were randomly allocated to either the diacutaneous fibrolysis group (n = 25, 36 wrists) or the sham group (n = 27, 36 wrists). Of the 52 patients, 41 were female (78.85%) and 11 were male (21.15%) with a mean age of 46.9 years (SD: 8.8). Eight subjects dropped out of the study during treatment sessions. No adverse events or side-effects were reported nor observed for any participant. At baseline, the two groups showed similar demographic characteristics. The baseline demographic and clinical characteristics of the enrolled participants are shown in Table 2.

Statistically significant differences were observed after treatment (T1) in the intensity of nocturnal symptoms in the diacutaneous fibrolysis group with a significant reduction compared to the sham group ($P < 0.01$; Table 3). There was a statistically significant improvement in functional capacity with the upper limb in the diacutaneous fibrolysis group compared to the sham group ($P < 0.01$; Table 3). This improvement also persisted significantly at one-month follow-up (T2), as shown in Table 3.

After treatment (T1), the diacutaneous fibrolysis group achieved a statistically significant improvement in sensory nerve conduction velocity ($P < 0.01$) and in motor conduction latency ($P < 0.01$), in comparison to the sham group, as shown in Table 3.

No statistically significant difference ($P = 0.57$) for the degree of masking (Table 4).

Discussion

In this study, five diacutaneous fibrolysis sessions produced short-term improvements in nocturnal symptoms, functional capacity with upper limb and neurophysiological parameters compared with sham diacutaneous fibrolysis, and those improvements persisted after one-month follow-up.

The comparison with our study is difficult for several reasons: the sample characteristics, the severity of the pathology and the treatment applied.[32,33] However, this finding is highly relevant if we consider the possible adverse effects and iatrogenic lesions that may occur, such as infections, damage to the adjacent tendons and nerves or inflammation.[7,8] This shows that an analgesic effect can be achieved without taking oral drugs, thereby avoiding their negative consequences. Other conservative techniques with a solely local treatment also fail to achieve better results for pain.[34–36] Furthermore, our results are similar to those obtained in other studies that used a more global approach.[19,37] These previous researches even obtained superior results, although

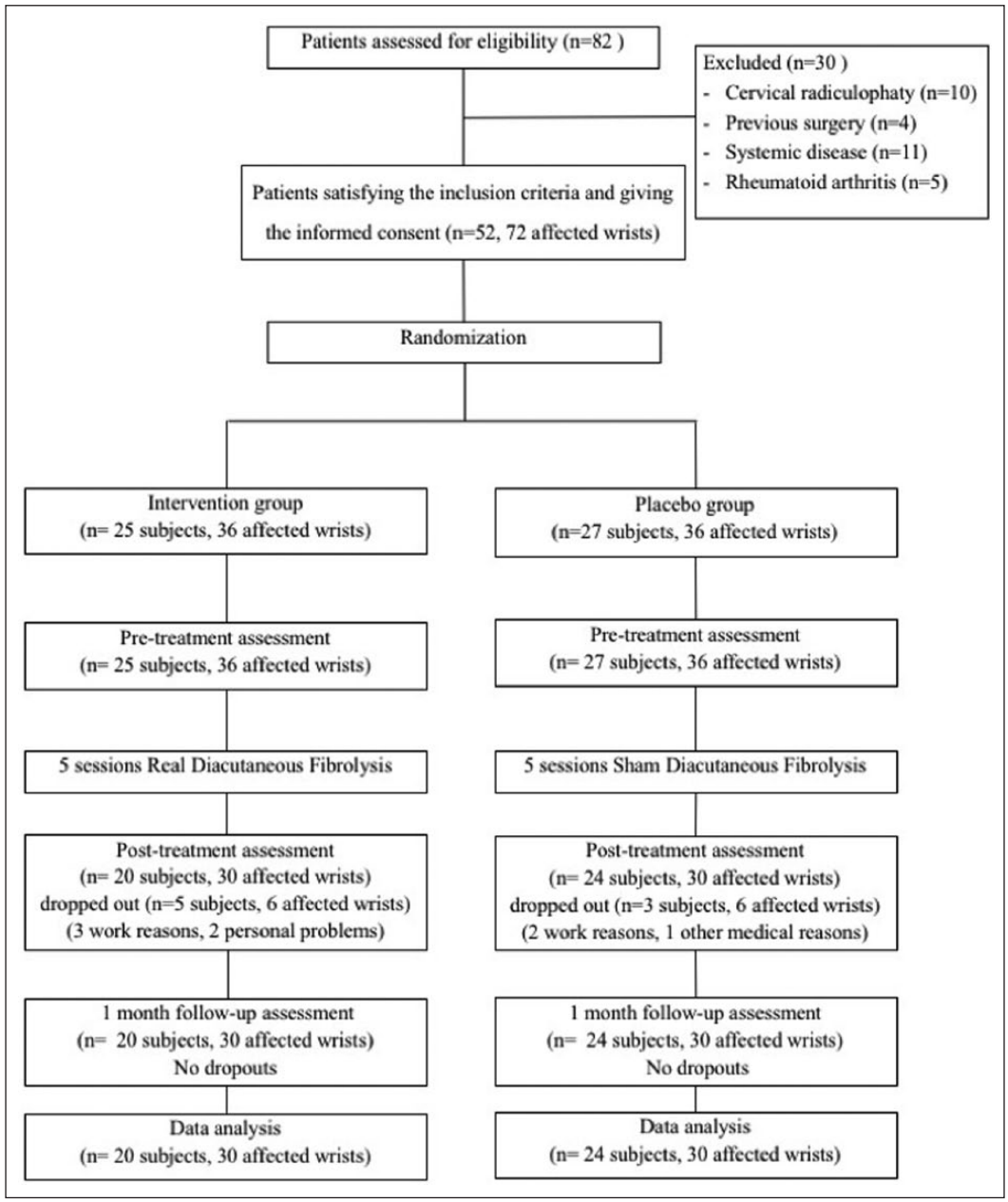

Figure 1. Flowchart of patient recruitment. FD: diacutaneous fibrolysis; CTS: carpal tunnel syndrome.

it must be emphasized that these studies included patients with severe involvement and with more intense symptoms at baseline. It should be noted that these studies adopted a broader approach,[19,37] including regions such as the cervical spine and the shoulder girdle. Importantly, in our study, the approach began with the insertion of the palmar flexors muscles of the carpus, and no techniques

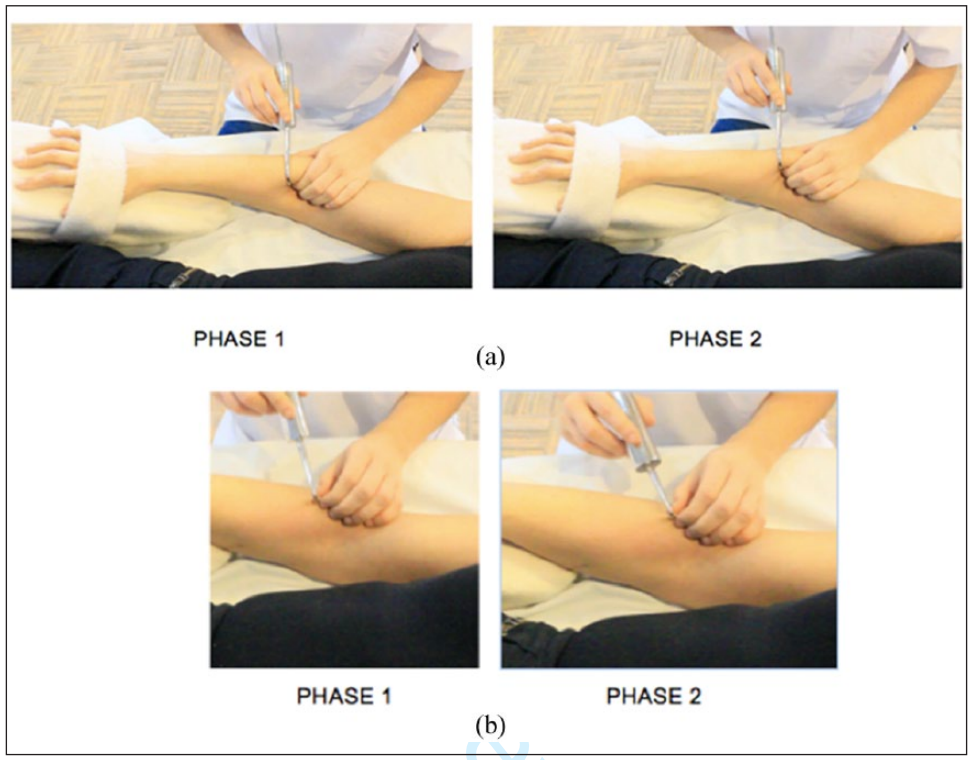

Figure 2. (a) Application of real diacutaneous fibrolysis, (b) application of sham diacutaneous fibrolysis.

were performed for more proximal regions because proximal compressive syndromes such as radiculopathy and thoracic outlet syndrome were excluded. However, a broader approach may not be justified if the possible coexistence of other associated compressive syndromes has not been evaluated beforehand.

Functional capacity in the upper limb improves after diacutaneous fibrolysis technique and after one-month follow-up and it achieved the minimal clinically relevant difference for this questionnaire.[38–40] The improvements achieved were superior to those in studies in which a conservative treatment was performed, in combination with various treatment techniques that focused on more local splint and paraffin structures,[41] and they were also superior to those obtained with neural gliding techniques.[42,43]

The improvements not only were in clinical variables but also in neurophysiological parameters values. It is a very important factor because electroneurogram is the gold standard test and is considered an appropriate measure to assess the state of the median nerve in patients with carpal tunnel syndrome after surgery.[44] Although we found no previous studies that provide data on the minimum detectable difference in the values obtained in the neurophysiological parameters, we obtained statistically significant improvements in our study. Previous studies have determined positive effects in neurophysiological parameters with some oral steroids[45] or other local treatments such as infiltrations.[32] However, it is necessary to consider the adverse effects resulting from continuous application of these treatments.[7,8] Other studies only focusing on treatment with local structures, such as splints, electrotherapy or the combination of several techniques failed to lead to improvements in the neurophysiological parameters.[9,41,46] Improvements have been achieved in nerve conduction only in some cases,

Table 2. Patients' baseline characteristics.

Variables	Diacutaneous fibrolysis group, n = 25 (36 wrists)	Sham group, n = 27 (36 wrists)	*P* value
Age in years (mean and SD)	44.97 (9.34)	48.83 (7.98)	0.08[a]
Sex			0.77[b]
Male	6 (20)	5 (16.7)	
Female	19 (80)	22 (83.3)	
BMI (Kg/m^2) (mean and SD)	24.78 (2.65)	25.32 (2.97)	0.57[a]
Wrist circumference (cm) (mean and SD)	15.94 (1.18)	15.77 (1.14)	0.36[a]
Work activity (outside home), n (%)	21 (84)	25 (92.59)	0.34[b]
Active	4 (16)	2 (7.41)	
Not working			
Use of the wrist in sports (n and %)			0.5[b]
Yes	7 (28)	6 (22.2)	
No	18 (72)	21 (78.8)	
Duration of symptoms in months (mean and SD)	25.68 (28.35)	25.06 (20.8)	0.49[c]
Affected wrist (n and %)			0.072[b]
Right	19 (52.7)	26 (72.2)	
Left	17 (47.3)	10 (27.8)	

BMI: body mass index.
[a]Mann–Whitney U test.
[b]Chi-square test.
[c]Student's t-test.

involving a combination of several treatment techniques and with more sessions than in our study.[36,41,46]

The techniques that treated adjacent soft tissues include manual therapy techniques, consisting of mobilization of the soft tissue and the fascia, similar to our study.[19,47] The possible explanation for the better results obtained using this kind of approach are the relationships between the different musculoskeletal structures, which have been demonstrated for between the palmar fascia, transverse ligament, flexor retinaculum and antebrachial fascia.[22,48] As has been demonstrated, there is not only an alteration in the nerve tissues, but also in the adjacent soft tissues.[22,49,50]

However, in our study, we obtained improvements superior to other studies in which these adjacent tissues were treated. This may suggest that despite the similarities in the type of approach used in this study and ours, diacutaneous fibrolysis may be crucial in obtaining the best results.

This study has some limitations, first the relatively small number of patients and strict inclusion criteria in the sample included, that the data cannot be extrapolated to all patients with carpal tunnel syndrome. Also, our sample comprised mild to moderate affectation with carpal tunnel syndrome, so the findings cannot be generalized to patients with severe carpal tunnel syndrome. Second, the relatively slight loss of patients and the lack of long-term follow-up. Third, it has not been compared with other conservative treatments previously used. Finally, although all the participants were asked to maintain any pharmaceutical treatments, there were using for carpal tunnel syndrome during the duration of the study, we did not specifically monitor.

Given the results of this study, we believe that diacutaneous fibrolysis will improve the prognosis of patients in the mild and moderate phases of carpal tunnel syndrome. This has a very important clinical implication, since if this approach is undertaken at an early stage, it could avoid progression of the syndrome and thereby prevent the need for surgery, which as mentioned above, has major complications and risks.

Table 3. Outcome variable values by group: at baseline, at the end of treatment and at short-term follow-up.

Variable	T0			T1 (17.77 days, SD:0.8)				T2			
	Diacutaneous fibrolysis group	Sham group	Diacutaneous fibrolysis vs sham	Diacutaneous fibrolysis group, 17.93 days (SD: 0.89)	Sham group, 17.6 days (SD: 0.67)	Diacutaneous fibrolysis vs Sham	*P* value	Diacutaneous fibrolysis group	Sham group	Diacutaneous fibrolysis vs sham	Diacutaneous fibrolysis vs sham
	Mean (SD), (n = 25) 36 wrists	Mean (SD), (n = 27) 36 wrists	*P* value	Mean (SD), (n = 20) 30 wrists	Mean (SD), (n = 24) 30 wrists	Mean (95% CI)		Mean (SD), (n = 20) 30 wrists	Mean (SD), (n = 24) 30 wrists	Mean (95% CI)	*P* value
VAS nocturnal pain (0–10)	3.32 (2.1)	3.6 (2.29)	0.53	0.42 (0.82)	3.48 (2.67)	−2.24 (−4.08/−2.04)	<0.01[a]	0.93 (1.78)	3.99 (2.42)	−3.05 (−4.07/−2.03)	<0.01[a]
DASH Questionnaire (0–100)	17.62 (8.89)	22.79 (13.49)	0.1	4.64 (5.6)	20.47 (15.16)	−19.00 (−26.1/−11.9)	<0.01[b]	5.17 (8.01)	23.11 (14.8)	−21.53 (−28.6/−14.4)	<0.01[b]
DML (m/s)	3.92 (0.52)	3.97 (0.33)	0.23	3.74 (0.49)	3.99 (0.39)	−0.26 (−0.49/−0.26)	0.029[b]				
SCV (m/s)	42.69 (5.2)	41.26 (4.81)	0.27	46.91 (5.78)	40.39 (5.82)	6.52 (3.52/9.51)	<0.01[b]				

T0: pretreatment assessment; T1: posttreatment assessment; T2: one-month follow-up; VAS: visual analogue scale; DASH: Disabilities of the Arm, Shoulder and Hand; DML: distal motor latency; SCV: sensory conduction velocity.

[a]Mann–Whitney U test.

[b]Student's t-test.

Table 4. Measurement of blinding technique. Chi-square test.

	Blinding of the technique			*P* value
	Do not know/no answer	Diacutaneous fibrolysis	Sham	
Diacutaneous fibrolysis group (n = 20, 30 wrists)	10	14	6	0.572[a]
Sham group (n = 24, 30 wrists)	14	11	5	

[a]Chi-square test.

Clinical messages

- Diacutaneous fibrolysis provides short-term and one-month follow-up improvements in sensory conduction velocity and motor distal latency.
- The application of five sessions of diacutaneous fibrolysis in the region of the forearm, wrist and hand in patients with mild and moderate carpal tunnel syndrome improves symptomatology and functional capacity and is reflected in the improvement of nerve conduction.

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