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Low-level Laser Treatment Relieves Pain and Neurological Symptoms in Patients with Carpal Tunnel Syndrome

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Abstract. [Purpose] This placebo-controlled study investigated the therapeutic effects of low-level laser treatment (LLLT) on the transverse carpal ligament in carpal tunnel syndrome (CTS). [Subjects and Methods] Idiopathic CTS patients were recruited and were randomly assigned to two groups. The laser group (n = 45) received laser treatment (10 Hz, 60 mW, 9.7 J/cm^2, 830 nm), and the placebo group (n = 42) received sham laser treatment. The visual analog scale (VAS), Boston Questionnaire scale, neurological symptoms and nerve conduction study (NCS) were conducted before, immediately after and 5 weeks after the treatment. [Results] After LLLT, there was statistically significant decrease in VAS in the laser group ($p<0.05$). Especially, the effect of LLLT on pain alleviation in the mild CTS group continued after five weeks. Regarding the Boston Questionnaire scale neurological symptoms and NCS, only mild CTS patients in the laser group showed statistically significant improvements after treatment ($p<0.05$). [Conclusions] LLLT with 830 nm diode lasers on the transverse carpal ligament had verifiable therapeutic effects for mild CTS patients.
Key words: Low-level laster treatment, Carpal tunnel syndrome, Nerve conduction study

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INTRODUCTION

Carpal tunnel syndrome (CTS) is a median nerve lesion due to compression in the carpal tunnel. The median nerve and tendons of the hand pass through the carpal tunnel and the transverse carpal ligament is located on the palm side of the carpal tunnel. The tendons and transverse carpal ligament become inflamed and swollen because of the pressure imposed on the median nerve below it[1)]. Abnormal sensation and weak muscle strength of the hand are common clinical symptoms and signs. The diagnosis of CTS is usually based on physical examination and electromyography. These symptoms need to be differentiated from the neural paralysis caused by diabetes or other metabolic diseases[2)]. The neurological symptoms are usually caused by high pressure on the median nerve inside the carpal tunnel instead of neuropathy of the median nerve.

Many studies[3–5)] have already reported the effectiveness of low-level laser treatment (LLLT) for CTS since Anderson's study involving 100 employees of the General Motors Company[2)]. Some studies have suggested that conservative treatments for the initial onset of CTS are safer than surgery[3,4)]. LLLT is one of the choices of conservative treatments for CTS[5)]. The efficacy of LLLT in treating CTS is controversial. The beam energy of LLLT was more than 9 J in studies[6–8)] which found the treatment to be effective, while the energy was less than 6 J in a study which found it ineffective[9)]. Besides, regarding pain, there are several reports of the effectiveness of LLLT on physiological factors and it has been shown to be an effective treatment by meta-analysis[3,5)]. Recently, some researchers used LLLT to treat CTS and irradiated the transverse carpal ligament of the wrist[8)]. Based on that research, we tried to research the specificity of LLLT for CTS by investigating the clinical outcomes and neurophysiological results in cases of mild to moderate CTS.

SUBJECTS AND METHODS

This study was approved by the Institutional Review Board on Human Subjects Research. Volunteers were the patients from the rehabilitation center of a teaching hospital and they were recruited from the out-patient clinic. The

patients with CTS were diagnosed in accordance with published guidelines[10]. For all patients, nerve conduction studies (NCS) on the ipsilateral ulnar nerve were normal for both the motor and sensory conduction.

The inclusion criteria in our experiments were the patients with idiopathic CTS who had experienced repeated pain for more than a year. The exclusion criteria were medical histories of systemic diseases (rheumatoid arthritis, diabetes, and metabolic diseases), surgery and other treatments such as anti-inflammatory medicine, acupuncture, and physical therapy. For the sample size of our study, a type I error of 0.05 ($\alpha = 0.05$) was chosen and the power was set to 0.8 ($\beta = 0.2$). The required the number of samples, which was calculated based on the literature, was at least 14 for each group[8]. The 90 patients were randomly assigned to two groups based on the criterion of a double blind experiment. The laser group received LLLT, and the placebo group received sham laser treatment. The sham laser treatment followed the same procedure as the laser treatment in order to avoid any psychological effect, but its power supply was cut off and it did not generate energy output.

The laser instrument, Painless Light PL-830 (Advanced Chips & Products Corp., USA) was used in this study. The operation parameters of the PL-830 were as follows: wavelength = 830 nm; output frequency = 10 Hz, average power = 60 mW (2 × 30mW); and the treatment dosage = 9.7 J/cm^2. The two diode lasers emitted a laser beam (irradiated area = 370mm^2) on the palm side of the wrist (between the pisiform and navicular bones). LLLT was executed for 10 minutes, 5 times per week for two weeks.

Each patient was assessed before, immediately after the treatment, and five weeks after the treatment (follow-up). The four assessments, pain, symptoms, neurological signs, and NCS, were blind to one evaluator (test-retest reliability = 0.96). All data after the treatments and in the follow-up were collected and compared with the baseline before the treatments.

Pain intensity was assessed on a visual analog scale (VAS). The most painful sensation is scored 10 and a painless sensation is scored 0. The patients who participated in the study used their past experience of pain as the criterion and scored their pain intensity at present. A self-administered questionnaire, the Boston Questionnaire scale, was used to describe the discomfort symptoms of CTS[11]. There are eleven questions which assess the symptoms. The scale of each item is quantified to range from 1 (mildest) to 5 (most severe), and all scales of individual items are calculated and averaged. Two clinical tests for neurological signs of CTS, Phalen's maneuver and Tinel's sign tests, were also used. In Phalen's maneuver, patients put their hands back-to-back with the wrists in maximum flexion for 60 seconds. If there is a pricking or abnormal sensation in the radial side of the thumb, index finger, middle finger and ring finger, then the test result is positive. In Tinel's sign test, the physician taps the top of the carpal tunnel on patients' wrists. If the tapping causes a pricking or abnormal sensation in the radial side of the thumb, index finger, middle finger and ring finger, then the test result is positive. The NCS was performed with a portable electromyograph (Medelec Synergy, Oxford, UK), and the stimulating electrodes were placed on the wrist proximal to the carpal tunnel. As recommended[10], a pair of surface recording electrodes was placed on the abductor pollicis muscle to record compound muscle action potentials. The distal motor latency and sensory peak latency of the median nerve were measured by stimulating the nerve action potential. The room temperature remained at around 26~29 °C. The NCS for the CTS patients were conducted and diagnosed by the same physician, and the treatments were conducted by the same physical therapist. Both were blind to the aims of this study.

All data collected from the patients were analyzed by SPSS13.0. Because the distributions of all parameters were not normal according to the Kolmogorov-Smirnov test ($p>0.05$), non-parametric tests were used in our statistical analysis. The Mann-Whitney U Test was used to test the difference between the parameters of the basic data before the treatment. Wilcoxon's test was used to compare the differences in VAS, symptom, neurological signs, and NCS values of distal motor latency and sensory peak latency between the groups. Wilcoxon's test was also used to analyze the differential values of two assessments (after treatment minus before treatment; follow-up minus after treatment). For categorical variables of Phalen's maneuver and Tinel's sign tests, the Fisher exact test was used to compare the score before the treatment with that after the treatment, and the scores in follow-up. In all of the analyses, a two-tailed test was adopted and the α value was set at 0.05.

RESULTS

In this study, there were 90 patients with CTS, but 3 patients of placebo group dropped out during the experiment. In the laser group (n = 45), 27 patients were diagnosed as mild CTS, and 18 patients as moderate CTS. In the placebo group (n = 42), 27 patients were diagnosed as mild CTS and 15 patients as moderate CTS. In the baseline of age, duration, VAS, symptom, neurological signs, and NCS, there were no statistically significant differences between two groups before the treatment ($p>0.05$). The basic data were summarized in Table 1.

For the patients with either mild or moderate CTS, there was an obvious statistical difference ($p<0.05$) in VAS decrease between the laser group and the placebo group after the treatment. In addition, there was a significantly statistical difference ($p<0.05$) in pain relief for the mild CTS patients during follow-up.

After the treatment, there was a statistically significant decrease in the Boston Questionnaire scale for the patients with mild CTS in the laser group ($p<0.05$), but not for the placebo group (Table 2). In the neurological signs for CTS (i.e., Phalen's maneuver and Tinel's sign), if those signs occurred after the treatment, the assessment would be marked as a positive one. And if no signs occurred, the assessment would be scored as a negative one. After the statistical analysis, as shown in Table 3, we found that the amount of positive neurological signs in the Phalen's

Table 1. The basic data in two groups

	Laser group		Placebo group	
	Mild CTS	Mod CTS	Mild CTS	Mod CTS
Number of samples	27	18	27	15
L't / R't wrist	3/24	0/18	3/24	0/15
Age (y/o)	46.44 ± 10.12	48.76 ± 14.57	51.10 ± 12.19	44.60 ± 9.60
Duration of re-onset (months)	2.13 ± 0.86	3.02 ± 0.67	2.07 ± 0.30	2.89 ± 0.97
VAS	5.07 ± 0.76	7.91 ± 1.12	5.16 ± 0.79	7.10 ± 0.55
Boston Questionnaire scale	2.68 ± 0.68	2.89 ± 0.90	2.50 ± 0.52	2.49 ± 0.43
SPL (ms)	3.84 ± 0.24	4.05 ± 0.15	3.79 ± 0.11	3.96 ± 0.21
DML (ms)	4.10 ± 0.17	4.34 ± 0.45	4.09 ± 0.09	4.49 ± 0.69

All data are expressed as mean ± standard deviation, except for items of samples and L't / R't wrist, which are presented as n. VAS: Visual Analog Scale, SPL: Sensory Peak Latency, ML: Motor Latency.

Table 2. Mean changes from baseline scores of parameters, and analysis of changes after treatment and five weeks follow-up

	Differential value 1		Differential value 2	
	Laser group	Placebo group	Laser group	Placebo group
VAS				
Mild CTS	– 2.76 ± 1.48	– 0.50 ± 0.83***	– 1.01 ± 0.91	0.01 ± 0.71*
Mod CTS	– 3.17 ± 1.81	– 2.01 ± 0.91**	– 1.25 ± 0.78	– 0.51 ± 0.86
Boston Questionnaire scale				
Mild CTS	– 0.78 ± 0.31	– 0.12 ± 0.25***	– 0.06 ± 0.53	0.31 ± 0.49
Mod CTS	– 0.91 ± 0.32)	– 0.29 ± 0.76	– 0.47 ± 0.41	0.31 ± 0.72
SPL (ms)				
Mild CTS	– 0.24 ± 0.12	– 0.08 ± 0.13**	– 0.02 ± 0.23	0.01 ± 0.04
Mod CTS	– 0.08 ± 0.05	– 0.05 ± 0.04	– 0.14 ± 0.06	– 0.04 ± 0.07
DML (ms)				
Mild CTS	– 0.29 ± 0.21	– 0.16 ± 0.14**	0.01 ± 0.11	– 0.03 ± 0.25
Mod CTS	– 0.07 ± 0.04	– 0.04 ± 0.13	– 0.07 ± 0.03	– 0.02 ± 0.06

Data are expressed as mean ± standard deviation. Differential value 1: after – before treatment; Differential value 2: follow-up – after treatment. Laser group VS. placebo group, *p<0.05; **p<0.01; ***p<0.001.

Table 3. Number of participants (%) with positive neurological signs

	Phalen's maneuver			Tinel's sign test		
	Before treatment	After treatment	Follow-up	Before treatment	After treatment	Follow-up
Laser group						
Mild CTS (n = 27)	27 (100)	12 (44)***	9 (33)***	27 (100)	9 (33)***	9 (33)**
Mod. CTS (n = 18)	18 (100)	15 (83)	9 (50)	18 (100)	15 (83)	15 (83)
Total (n = 45)	45 (100)	27 (60)**	18 (40)***	45 (100)	24 (53)***	24 (53)*
Placebo group						
Mild CTS (n = 27)	24 (89)	24 (89)	21 (78)	24 (89)	21 (78)	18 (67)
Mod. CTS (n = 15)	15 (100)	12 (80)	12 (80)	15 (100)	15 (100)	12 (80)
Total (n = 42)	39 (93)	36 (86)	33 (79)	39 (93)	36 (86)	30 (71)

Data are expressed as number of positive cases (percentage). *p<0.05; **p<0.01; ***p<0.001.

maneuver and Tinel's sign for the laser group was reduced greater than that for the placebo group after the treatment and in the follow-up. This difference was statistically significant ($p<0.05$). The laser group with mild CTS was particularly statistically reduced in Phalen's maneuver and Tinel's sign. ($p<0.05$). In the NCS for mild CTS, there was a statistically difference between the laser group and the placebo group after the treatment ($p<0.05$).

During the whole course of this study, no patient complained about any side effect and dropped out from LLLT.

DISCUSSION

This research was a controlled study that tried to treat CTS via providing contact band irradiation on transverse

carpal ligament. After two weeks of LLLT with 830 nm laser, the VAS of the mild CTS patients in the laser group was decreased to 2.32 ± 0.78. The VAS of the moderate CTS patients was decreased to 3.76 ± 1.81. The results of our study were similar to the previous researches[3,5] and confirmed immediate pain alleviation of LLLT. We also found that LLLT could not maintain this effect for the next five weeks, and thus further research with longer follow-up periods were required. The analgesic effect of LLLT is still controversial, but the clinical effect is confirmed[4,8]. Many researchers have discovered that LLLT could promote the production of adenosine triphosphate from the mitochondria[5,7,8,12], and enhance the respiration metabolism of the cells[13]. Those metabolisms reduce the wastes from the inflammation including leukotrienes and metabolite which could improve the healing process. Fulop et al. found that the pain alleviation might be caused by serotonin and endorphins[14] which could effectively raise the pain threshold[15]. The CTS patients who had neurological symptoms and pain due to the inflammation and swelling of the wrist often interfered with functional hand activities. In the result of our study, we found that a decrease of symptoms in the Boston Questionnaire scale accompanied a reduction of VAS. Although our study did not provide a direct proof regarding the changes of biochemical reaction in the affected wrist, we believed that LLLT had a positive effect on CTS.

The inflammation effect of the CTS wrist often causes neurological signs and median nerve injury. In the electromyography, the mechanism of pain alleviation was better understood and the reduction of pain could also be explained. In the previous research, LLLT was found to enhance the conduction velocity of sural nerve after diode laser irritation on the normal nerve[16].Our research found that after the 830 nm LLLT, the NCS values of distal motor latency and sensory peak latency were reduced. We conjectured that nerve conduction velocity increased due to the repair of nerves. This contention is same as that in the past research[17]. Applied to clinical treatments of CTS, LLLT was more effective than other conservative treatments[18,19]. It was apparent based on their results as well as ours, especially for the improvement in symptom severity and neurological signs. Elwakil et al. compared LLLT with the standard open carpal tunnel release surgery, and found that LLLT could improve hand weakness and the atrophy of thenar muscles[7]. The velocity of neural conduction also showed statistical significance after the treatment ($p<0.05$). Some studies found that LLLT performed better than other conservative treatments in reducing neurological signs and nerve conduction velocity[18,19]. Although the effect on neural tissues generated by LLLT is not clear yet, the NCS of CTS were found to be related to the degree of severity of the symptoms in our research. In our study, irradiation area of LLLT was not the distribution of median nerve. We also found that the NCS of the laser group were statistically less than those of the placebo group after applying LLLT to transverse carpal ligament ($p<0.05$). Accordingly, this result indicated that using the LLLT with an 830 nm diodes laser on the injured nerve is effective.

In an animal research, Gigo-Benato et al. used laser irradiation (wavelength: 808 nm; dosage: 29 J / cm^2; duration: 39 seconds) for the end-to-side neurorrhaphy of mouse, and irradiated directly on the exposed axon of median nerve. They found that this approach could enhance the growth and healing of the injured nerve[20]. However, it is difficult to apply to CTS patients. Because of median nerve of human beings is located at the palm side of the wrist, and LLLT should target and reach the nerve in the soft tissue under the skin. Thus, the laser energy might be absorbed by the soft tissue, and insufficient energy reaches the injured nerve. Bakhtiary and Rashidy-Pour tried to use an 830 nm point-like LLLT (1.8 J / point) to irradiate 5 points on the distribution of median nerve[9], and they obtained an unsuccessful result. The reason was that the nerve dispersion is different from each patient, and this method is very hard to provide an appropriate dosage for the injured section of the nerve[21]. Naeser et al. also tried to mark the hand and wrist with a square cm grid to treat each marked area with the same dosage, and it resulted in an average dosage on each squares[6]. They found that the patients experienced a pain alleviation of 50 %, but statistical difference was not seen ($p>0.05$). Naeser et al. asserted the reason for no obvious statistically difference in the assessment might be that the injured nerve did not absorb enough treatment dosages[6]. Hence, the approach of point-like LLLT seemed ineffectively to treat the CTS. Chang et al. thought that the main pathophysiology for CTS is the inflammation and swelling of transverse carpal ligament, and essayed a beam-like diodes laser to irradiate on transverse carpal ligament[8]. An identical 830 nm LLLT (9.7 J/cm^2) on the injured transverse carpal ligament were imitated in our study. We also found that the pain alleviation for the mild CTS patients was higher than that for the moderate CTS patients, and the reduction of symptoms for the laser group was higher than that for the placebo group after two weeks of LLLT. As mentioned in the previous research, it would take 4 to 5 weeks of LLLT to treat the mild and moderate CTS in order to achieve statistically significant reductions of neurological symptoms ($p<0.05$)[6]. We considered that 830 nm diodes LLLT (9.7 J / cm^2) is a referable parameter for CTS, and a beam-like laser irradiated on transverse carpal ligament is a practical method. Therefore, this kind of treatment is effective, especially for mild CTS. The limitation of this study is that this LLLT do not compare with other conservative treatments, and that will be necessary to study this issue in the future.

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