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Original Article

The efficiency of mirror therapy in peripheral nerve injuries

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ABSTRACT

Objectives: The purpose of this study was to investigate the effectiveness of mirror therapy on pain, sensory, and functional development in addition to conventional rehabilitation and occupational practices in patients with a peripheral nerve injury in the hand.

Patients and methods: Twenty-six patients with peripheral nerve injury in the hand were included in this randomized controlled study between November 2017 and May 2018. The patients were randomly assigned to the mirror group (n=14) and the control (n=12) group. Both groups received conventional therapy in our clinic for 45 min a day during weekdays for six consecutive weeks. The mirror group received an additional 10-15 min of visual mirror therapy. Visual Analog Scale (VAS), Duruöz Hand Index, Quick Disabilities of the Arm, Shoulder, and Hand, Jebsen hand function test, and Semmes-Weinstein monofilament test were used for the assessment of pain, hand function, and sensation of the patients at baseline and after treatment. The handgrip strength of the patients was measured with a dynamometer.

Results: A total of 20 patients (17 males, 3 females; mean age 31.9±16.5, range 16 to 65 years) completed the study, with 10 in each group. Statistically significant improvement was detected in hand skill functions, such as page-turning (p=0.004), backgammon packing (p=0.023), and heavy object lifting (p=0.029) in the mirror group. A statistically significant decrease was found in total scores of VAS after treatment in both groups (p<0.05).

Conclusion: The results imply that mirror therapy integrated with conventional rehabilitation may aid additional benefits on hand functions in peripheral nerve injury. These results demonstrate that mirror therapy can be used in addition to the rehabilitation program of patients with peripheral nerve injury.

Keywords: Hand rehabilitation, mirror therapy, occupational therapy, peripheral nerve injury.

Functional losses resulting from hand injuries cause severe disability and loss of workforce in daily life.[1] It is reported in the literature that 57% of patients with hand injuries are young adults in the age group of 16-35 years. Traumatic tendon injuries or peripheral nerve cuts constitute a large group among these patients.[1-3] It has been reported that 2-3% of the patients who apply to trauma centers are those with upper extremity peripheral nerve injury.[4] It has been stated that 2.8% of nerve injuries with an annual incidence of 500,000 develop into permanent disabilities due to the prolonged regeneration process, and 25% of the patients cannot return to work for 1.5 years.[5,6]

Sensorimotor losses and neuropathic pain that develop after peripheral nerve injury cause physical and social disabilities in these patients.[1,6] Pain is the most common complication of the rehabilitation process in patients with severe hand injuries. It negatively affects functional recovery both in the acute and progressive periods.[7] In patients with peripheral

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nerve injury, the pain may be nociceptive, neuropathic, or their combination, or even complex regional pain syndrome (CRPS).[8,9]

The main goal of rehabilitation in patients with peripheral nerve injuries in the hand is to maintain the current capacity as much as possible until the recovery process is completed and to improve hand skills and functional activities.[10,11]

Mirror therapy is a cost-effective treatment method developed in the late 90s; it focuses on the movements of the healthy extremity, in addition to conventional applications. Mirror treatment is aimed to increase deep sensory input to the extremity with the help of visual stimuli.[12,13] There are randomized controlled studies showing the efficacy of mirror therapy in CRPS, dystonia, and hemiplegic upper extremity rehabilitation in the literature. There are a limited number of controlled studies showing the effectiveness of mirror therapy in addition to classical rehabilitation applications in hand tendon injuries.[14,15]

In light of current knowledge, positive effects of low-cost mirror therapy on pain, motor development, and functional recovery are reported in rehabilitation patients. There is no randomized controlled study showing the effectiveness of mirror therapy in patients with peripheral nerve injury in Türkiye. This study aimed to investigate the effectiveness of mirror therapy on pain, sensory, and functional development in addition to conventional rehabilitation and occupational practices in patients with a peripheral nerve injury in the hand.

PATIENTS AND METHODS

Thirty-six patients who were followed up in the University of Kocaeli School of Medicine, Department of Physical Medicine and Rehabilitation between November 2017 and May 2018 diagnosed with peripheral nerve damage and who completed the four-week postoperative assessment were evaluated in the randomized controlled study. Patients aged 15-65 years who underwent early surgical repair for peripheral nerve injury at the wrist and 10 cm above the wrist were included in the study. Patients with communication problems and cognitive impairment with additional neurological and rheumatologic diseases associated with the musculoskeletal system and patients with multiple traumas were not included in the study. Twenty-six patients were assigned to two groups by flipping a coin (the mirror treatment group [n=14] and the control group [n=12]) by simple random sampling. The study flowchart is shown in Figure 1.

The demographic data of all patients were recorded. After the patients' first application to the clinic and rehabilitation and during their 5- and 12-week checkups, motor and sensory examinations were performed. The pain levels in the patients were determined using the Visual Analog Scale (VAS),[16] handgrip strength with a Jamar dynamometer (Sammons Preston, Rolyan, Bolingbrook, IL, USA),[17] activity participation levels with the Duruöz Hand Index (DHI),[18] arm, shoulder, and hand injury issues with the Quick Disabilities of the Arm, Shoulder, and Hand (Q-DASH) questionnaire,[19] hand skill functions with the Jebsen-Taylor hand function test (JTHFT),[20] and the sensory threshold with the Semmes-Weinstein Monofilament Test (SWMT).[21]

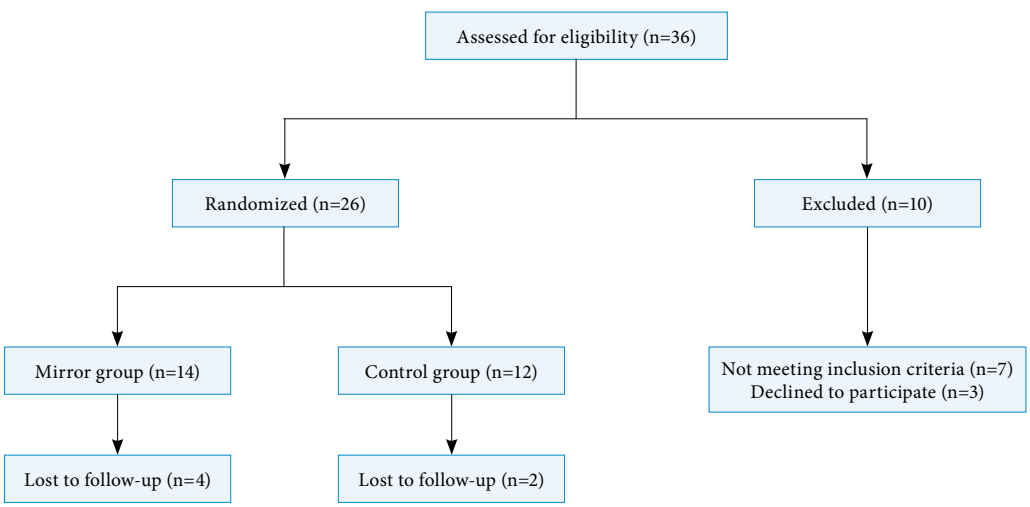

Figure 1. Study flowchart.

All evaluations except for handgrip strength were made by the same therapist before the treatment (fifth postoperative week) and after the treatment (12th postoperative week). All patients included in the study were taken to conventional treatment for 45 min every day for six weeks and to an occupational program determined according to the injured nerve after the necessary clinical follow-up was performed. In addition to these treatments, mirror therapy was applied to the patients in the mirror group for 15 min five days a week.

Mirror treatment was applied by placing the mirror assembly (45×60 cm) on the midline of the body while the patients were seated at the table. Both upper limbs were positioned so that the affected limb was behind the device (behind the mirror) and the healthy limb in front of the reflective surface of the mirror. The patients were asked to periodically perform activities determined according to the motor function of the injured peripheral nerve under observation in front of the mirror with the intact limb (Figures 2, 3). Activities and exercises were determined separately for each patient in accordance with the injury level and postoperative weeks.

Exercises were performed in the rehabilitation protocol following the injury levels and postoperative weeks of the patients (passive, active-assistive, active-resistive range of motion exercises). Stretching exercises were applied to patients who completed their sixth week and developed contracture. Before the stretching exercises, suitable superficial (paraffin, hot pack, or infrared) or deep heater (ultrasound) was applied. Hand and upper extremity strengthening exercises were performed using digiFlex (White Plains, NY, USA) in yellow, red, green, blue, and black, Thera-Band (THERABAND Proven Science, Akron, OH, USA), hand rehabilitation dough, hand exercise pulley, and a silicone ball.

Figure 2. Mirror therapy.

Statistical analysis

Statistical evaluation was conducted using IBM SPSS version 20.0 software (IBM Corp., Armonk, NY, USA). The distribution of the data was evaluated using the Kolmogorov-Smirnov test. Numerical variables not conforming to normal distribution were given as median (interquartile range) and categorical variables as frequency (percentages). Differences between groups were determined by the Mann-Whitney U test for numerical variables that do not have a normal distribution. Differences between repeated measurements were analyzed using the Wilcoxon t-test when the normal distribution assumption was not provided. Relationships between categorical variables were evaluated using Fisher exact test. For testing two-sided hypotheses, a p-value <0.05 was considered statistically significant.

RESULTS

Of the 26 patients included in the study, 20 (17 males, 3 females; mean age 31.9±16.5, range 16 to 65 years) completed the study. There was no statistically significant difference between groups in terms of age (p=0.052). Other demographic comparisons between groups could not be examined since the statistical test assumptions did not hold. The demographic information of the patients and the distribution according to the groups are given in Table 1.

There was no statistically significant difference between groups in terms of total scores of VAS, handgrip strength, DHI, Q-DASH, and SWMT both before and after treatment (p>0.05 for all) (Table 2).

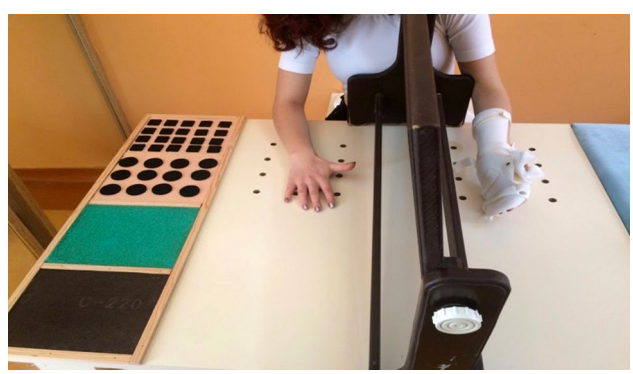

Figure 3. Exercises in the mirror.

TABLE 1
Demographic characteristics of patients

	Mirror group (n=10)					Control group (n=10)					
	n	%	Median	IQR	Range	n	%	Median	IQR	Range	*p**
Age (year)			41	20.8-60	9-65			20.5	17.8-27	16-64	0.052[a]
Sex											NA
Male	8	80				9	95				
Female	2	20				1	10				
Injured hand											NA
Right	3	30				6	60				
Left	7	70				4	40				
Mechanism of injury											NA
Glass	4	40				8	80				
Work	6	60				2	20				
Dominant hand											NA
Right	9	90				10	100				
Left	1	10				0	0				
Injured nerve											NA
Median	4	40				4	40				
Ulnar	6	60				6	60				

IQR: Interquartile range; NA: Not applicable; * Mann-Whitney U test.

TABLE 2
Pre- and post-treatment VAS, handgrip strength, DHI, Q-DASH, and SWMT total data of the mirror and control groups

	Mirror group			Control group			
	Median	IQR	Range	Median	IQR	Range	*p**
VAS							
Pre-treatment	5.5	3.8-6	2-7	5	4-6	4-7	0.971
Post-treatment	2	0.8-3	0-4	2.5	2-3	2-4	0.165
p†		**0.004**			**0.004**		
JAMAR							
Pre-treatment	13.7	7.8-19	6-37	14	10.8-21.3	8-25	0.631
Post-treatment	19.5	13.7-26.8	12-44	18.5	15.3-25.3	12.3-30	0.796
p†		**0.005**			**0.005**		
DHI							
Pre-treatment	63	42.3-75.8	7-90	65	55.5-73	21-80	0.684
Post-treatment	39.5	8.5-45.5	2-56	37	31.5-48.8	8-59	0.529
p†		**0.005**			**0.005**		
Q-DASH							
Pre-treatment	64.8	48.3-84.7	13.6-100	58	54-64.8	43.2-81.8	0.315
Post-treatment	39.8	13.1-55.1	4.5-68.2	46.6	40.9-56.8	38.6-65.9	0.247
p†		**0.005**			**0.005**		
SWMT							
Pre-treatment	3	1.8-5	1-10	4	3-5.3	2-10	0.315
Post-treatment	5.5	3.8-9.5	2-15	6	4-8	4-12	0.796
p†		**0.021**			**0.005**		

VAS: Visual Analog Scale; DHI: Duruöz Hand Index; Q-DASH: Quick Disabilities of the Arm, Shoulder, and Hand; SWMT: Semmes-Weinstein Monofilament Test; JAMAR: Jamar dynamometer; IQR: Interquartile range; *Mann-Whitney U test; † Wilcoxon signed-rank test; Bold face values indicate statistically significant differences.

A statistically significant decrease was found in VAS total, DHI and Q-DASH scores after treatment within both groups ($p<0.05$ for all). The handgrip strength and SWMT scores increased significantly within groups after treatment ($p<0.05$ for all). When the improvement percentages of both groups were examined, the improvement percentages in these parameters were higher in the mirror group, except for the DHI score. The improvement percentage in the VAS score of the mirror group was 63.6%, whereas the recovery percentage of the control group was 50%. The improvement percentage in total handgrip strength score was 42.3 in the mirror group, while it was 32.1 in the control group. Regarding the Q-DASH score, this percentage was determined to be 38.5 in the mirror group and 19.7 in the control group. As for the SWMT score, it was found to be 83.3 in the mirror group and 50 in the control group. The improvement percentage in the DHI score was 37.3 and 43 for the mirror and control groups, respectively.

The results of JTHFT evaluation between groups and within groups are given in Table 3. When JTHFT evaluation data were compared after treatment, there was a statistically significant difference in the activities of JTHFT's page-turning ($p=0.004$), backgammon stamping ($p=0.023$), and lifting large heavy objects ($p=0.029$) of the mirror group compared to the control group.

Afterward, the difference (treatment response) in the mean scores of VAS, handgrip strength, DHI, Q-DASH, and SWMT before and after the treatment was calculated to see if there was a statistical significance difference. A statistically significant

TABLE 3
Comparison of mirror and control groups according to JTHFT performance time results

	Mirror group			Control group			
JTHFT parameters (second)	Median	IQR	Range	Median	IQR	Range	*p**
Simulated page turning							
Pre-treatment	8.8	6.4-13.1	4.5-20.5	12.3	10.3-16	6.6-19.5	0.075
Post-treatment	5.7	4.3-8.5	3.9-10.4	9.7	8.4-13.3	6-15.6	**0.004**
p†		**0.005**			**0.005**		
Lifting small objects							
Pre-treatment	11.5	9.3-26.3	6.1-48.5	13.9	9.4-21.4	8.6-37.4	0.579
Post-treatment	9.2	7.2-13.5	5.2-20	12.6	7.8-15.7	5.7-21.7	0.393
p†		**0.005**			**0.005**		
Simulated feeding							
Pre-treatment	16.5	11.2-21.1	10.1-55.8	14.7	13.3-18.3	10.1-33.8	0.579
Post-treatment	12.3	8.1-14.5	6.4-17.6	11.9	10.7-14.6	9.3-21.4	0.684
p†		**0.005**			**0.005**		
Stacking backgammon pieces							
Pre-treatment	6.9	4.2-8.8	3.5-11.1	9.3	6.4-10	4.6-13.3	0.165
Post-treatment	4.7	3.4-6	3.2-7	5.8	4.4-8.5	3.4-10	**0.023**
p†		**0.005**			**0.005**		
Lifting large-lightweight objects							
Pre-treatment	6.5	4.7-9.2	4.6-29.6	6.7	5.8-9.7	5.2-16.8	0.353
Post-treatment	4.7	3.8-6.2	3.2-8.2	5.8	4.4-8.5	3.4-10	0.143
p†		**0.005**			**0.017**		
Lifting large-heavy objects							
Pre-treatment	6.5	4.7-9.2	4.6-29.6	9.4	6.2-12.7	3.4-24.6	0.247
Post-treatment	4.4	3.8-7.4	3.6-8.4	8.9	5.5-10.7	3.1-12	**0.029**
p†		**0.005**			0.059		

JTHFT: Jebsen-Taylor hand function test; IQR: Interquartile range; *Mann-Whitney U test; † Wilcoxon signed-rank test; Bold face values indicate statistically significant differences.

TABLE 4
Treatment response defined as the difference between pre- and post-treatment mean values of VAS, handgrip strength, DHI, Q-DASH, and SWMT for the mirror and control groups

	VAS	JAMAR	DHI	Q-DASH	SWMT
VAS, JAMAR, DHI, Q-DASH and SWMT treatment response	Mean±SD	Mean±SD	Mean±SD	Mean±SD	Mean±SD
Mirror group	3.10±1.10	7.10±2.46	24.80±19.00	26.70±17.93	3.60±2.01
Control group	2.44±0.88	4.40±2.17	27.10±13.1	10.00±5.3	2.00±0.81
*p**	0.123	**0.035**	0.481	**0.011**	**0.043**

VAS: Visual Analogue Scale; DHI: Duruöz Hand Index; Q-DASH: Quick Disabilities of the Arm, Shoulder, and Hand; SWMT: Semmes-Weinstein monofilament test; JAMAR: Jamar dynamometer; * Independent samples t test.

difference was found in the treatment response of handgrip strength, Q-DASH, and SWMT values in the statistical analysis (p=0.035, p=0.011, and p=0.043, respectively; Table 4).

DISCUSSION

Maximum functional gains after traumatic hand injuries depend on the level of injury, applied surgical techniques, and rehabilitation practices. The most important factors that negatively affect functional recovery in patients with a peripheral nerve injury in the hand are the use of extremities due to pain and insufficiency without learning.[13,22] It is possible to control pain, preserve joint range of motion, and restore muscle strength and sensation with rehabilitation applications in the early postoperative period of peripheric nerve injuries. A prolonged immobilization process in this period may negatively affect the somatosensory image and functional organization in the cerebral cortex.[23] Supporting the somatosensory cortex and preserving the cortical image accelerates maximum functional development. It has been reported that early sensory stimulation can contribute to the preservation of cortical images with mirror therapy.[23,24] In addition, there are case reports and a few controlled studies that show the positive effect of mirror therapy on pain.[25]

Mirror therapy provides feedback to the patient with an illusion effect during motor movement. It is reported that observing only a moving limb activates "mirror neurons" in the premotor area of the cerebral cortex. It has been reported that mirror neurons play a fundamental role in learning new motor skills.[26] Although the mechanism of action is not fully understood, for the analgesic effect of mirror therapy, it is stated that dynamic feedback is provided to the brain of the person, and the individual perceives pain as if it does not exist. As a result, an illusion effect occurs in the brain with mirror therapy, and the resulting cortical changes can be corrected.[13]

In the literature, it has been reported that while positive effects on pain are observed in approximately six weeks in early stage CRPS patients, whereas no change is observed in chronic stage CRPS patients.[22,27-29] One randomized controlled study has been found in the literature investigating the after effects of mirror therapy on pain, loss of function, skill, and range of motion in patients undergoing hand orthopedic surgery.[23,29] In this study, it was reported that mirror therapy, in addition to conventional treatment, had a positive effect on pain in patients with hand tendons, peripheral nerve cuts, and soft tissue injuries. It has been suggested that controlling pain in the early period may affect the rehabilitation process and prognosis positively.[29] In our study, it was observed that there was a decrease in the level of pain in accordance with the literature. However, due to the small number of our patients, a statistical difference could not be demonstrated. We believe that early-period mirror therapy in particular will be more effective in pain control.

In the literature, quite a few randomized controlled studies have evaluated the effect of mirror therapy on strength in patients with peripheral nerve damage in the hand, although the effect of mirror therapy on strength has been examined in studies mostly performed on patients with stroke or cerebral palsy.[30,31] In this study, in which tendon and soft tissue injuries were evaluated together in addition to peripheral nerve cuts, they could not find the effect of mirror therapy on handgrip strength. Conversely, studies have reported that it increases grip strength and improves motor performance in stroke patients and healthy individuals.[15] Furthermore, it has been reported that mirror therapy applied together with conventional treatment has positive effects on hand

functions in patients with orthopedic injuries in the hand.[28] Patients with hand peripheral nerve damage were not examined in this study. In our study, it was found that both groups had an improvement in handgrip strength, but no difference was found between the groups. However, the treatment response of the mirror group was found to be higher than that of the control group.

It is important to include the level of activity and participation in the outcome measures after peripheral nerve injuries that reduce the functional capacity of the hand, which is an important part of the individual's daily and social life and may even cause disability. In recent years, the use of scales that evaluate activity and participation in the evaluation of health problems has become widespread, and the trend has shifted in this direction.[33-35] In this sense, studies evaluating the effect of trauma on individual activity and participation in upper extremity problems are frequently encountered.[23,29] In our study, hand functions were evaluated with JTHFT, and activity participation was evaluated with DHI and Q-DASH. When the JTFHT results of both groups after the treatment were examined, it was observed that there was an improvement in all parameters in both groups. However, it was determined that there was a significant improvement in favor of the mirror group in the activities of "turning pages, arranging backgammon stamps, and lifting big-heavy objects." When the responses of both groups were examined in terms of DHI and Q-DASH treatment response, it was observed that the responses of the mirror group were higher. In the literature, there is a study investigating the early and late effects of mirror therapy in patients with median and ulnar nerve injuries.[36] In this study, although clinical improvements were observed in patients who received mirror therapy in the early period, this improvement was not statistically demonstrated.[36]

Peripheral nerve injuries of the hand seriously affect the functional capacity of the hand and cause acquired disability.[37] The sense of touch is extremely important to ensure the sensory-motor integrity required for sensitive skills and to control handgrip strength during use. Young patients constitute the most of patients with peripheral nerve injuries in the upper extremity.[36] This situation results in a significant loss of workforce and a decrease in the quality of life. In our city, which is an industrial zone, patients with traumatic hand injuries constitute an important patient group of our clinic.

The age of the patient, cognitive capacity, the timing of surgical treatment after injury, the level of nerve damage, and the type of injury are the most important factors affecting the healing process. Moreover, a patient not using their hand for a long time during the recovery period is one of the important factors that delay functional recovery. Sensory education is recommended to be added to early rehabilitation practices to prevent this issue.[36] In our study, no statistically significant difference was observed in the SMWT total score of the groups after treatment, but the treatment response was higher in the mirror group. There are limited studies in the literature investigating the effect of mirror therapy on sensory development in patients with peripheral nerve injury.[38,39] In these studies, the effect of mirror therapy on sensory development could not be demonstrated statistically. In our study, no side effects were observed in the application of mirror therapy in addition to conventional treatment, and all patients were highly adherent to the treatment. Mirror treatment does not create an additional cost in terms of treatment.

The limitations of this study are the limited number of patients and the lack of long-term follow-up.

In conclusion, the addition of mirror therapy to the medical rehabilitation programs in the early period of patients with peripheral nerve injuries has a positive effect on pain, grip strength, and sensory development and can increase the functional use of the injured hand in daily life activities thanks to the increase in sensory development and strength.

Ethics Committee Approval: The study protocol was approved by the Kocaeli University Non-Interventional Clinical Research Ethics Committee (date: 20.09.2017, no: 2017/243). The study was conducted in accordance with the principles of the Declaration of Helsinki.

Patient Consent for Publication: A written informed consent was obtained from the patients and/or parents of the patients.

Data Sharing Statement: The data that support the findings of this study are available from the corresponding author upon reasonable request.

Author Contributions: Idea/concept, writing the article: S.K., I.S.; Design, analysis and/or interpretation: I.S., S.K., Ç.Ç., N.D.; Control/Supervision: I.S., N.D.; Data collection and/or processing: S.K., G.Ö., L.B.; Literature review: I.S., S.K., G.Ö., Ç.Ç.; Critical review: N.D., L.B., G.Ö.; References and fundings: S.K., I.S., G.Ö.; Materials: L.B., S.K.

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