International Journal of Public Health Excellence (IJPHE)
Vol. 3, No. 1, December 2023, pp. 159~164
Journal Homepage: https://ejournal.ipinternasional.com/index.php/ijphe
ISSN: 2809-9826, DOI: 10.55299/ijphe.v3i1.523

The Effectiveness of Using Laser Therapy on Outcome of Carpal Tunnel Syndrome Patients: A Literature Review

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Article Info

Article history:

Received August 06, 2023
Revised August 14, 2023
Accepted August 29, 2023

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ABSTRACT

Carpal Tunnel Syndrome (CTS) is a neuropathy caused by compression of the median nerve that passes through the carpal tunnel structure in the wrist. If the CTS condition is not treated, complications will occur such as irreversible damage to the median nerve resulting in permanent impairment and disability, chronic wrist pain, and muscle atrophy and weakness. Currently there are various CTS therapies such as splinting, local injection of corticosteroids, oral medications such as prednisone, physical therapy such as carpal bone mobilization, ultrasound therapy, and nerve glides exercises, as well as surgical therapy. However, these various therapies have not provided optimal results and there are complications such as neuromas, hypertrophic wounds, dysesthesia, wrist joint stiffness, and the inability of various to reduce CTS symptoms. Therefore, more effective therapy with minimal side effects is needed. Therefore, in this literature review, an analysis of the effect of laser therapy on various outcomes of CTS patients as an innovative therapy was carried out. Study searches were performed on various databases such as Pubmed, ScienceDirect, Directory of Open Access Journal, Epistemonikos, and Cochrane Library. From the search results obtained a total of 389 studies. The 7 studies that met the inclusion and exclusion criteria were the studies that were analyzed in this literature review. Various types of laser therapy showed better outcome results than the control group, with LLLT laser therapy showing the best results in various outcomes in CTS patients. LLLT laser therapy also shows better results when combined with other types of therapy. No adverse events were reported with any type of laser therapy in all inclusion studies. Therapy is the newest type of innovative therapy with better effects and minimal side effects compared to conventional therapy in CTS patients.

Keywords: *Carpal Tunnel Syndrome, Laser Therapy, Literature Review, Outcome*

1. INTRODUCTION

Carpal Tunnel Syndrome (CTS) is a neuropathy caused by compression of the median nerve that passes through the carpal tunnel structure in the wrist. CTS is the most common nerve compression disease, accounting for approximately 90% of all neuropathies. The incidence of CTS in developed countries is 1 in 3 people per 1000 people per year with a prevalence of 50 per 1000 which is also similar to the incidence and prevalence in developing countries. If the CTS condition is not treated, complications will occur such as irreversible damage to the median nerve resulting in permanent impairment and disability, chronic wrist pain, and muscle atrophy and weakness [1]. Therefore, treatment of CTS is needed to prevent these complications [2]. Currently there are various CTS therapies such as splinting, local injection of corticosteroids, oral drugs such as prednisone, physical therapy such as carpal bone

mobilization, ultrasound therapy, and nerve glides exercises, as well as surgical therapy in the form of surgical decompression in cases of severe CTS [3]. However, these various therapies have not provided optimal results and there are complications such as neuromas, hypertrophic wounds, dysesthesia, wrist joint stiffness, and the inability of various to reduce CTS symptoms [4]. Therefore, more effective therapy with minimal side effects is needed. Various recent studies have shown various potential therapeutic modalities to treat CTS. One of the most widely used therapies today is laser therapy [5]. Laser therapy is used because it promotes nervous system regeneration and functional recovery of patients with a positive effect on clinical improvement and neuropsychological parameters of peripheral nerve lesions. Therefore, in this literature review, an analysis of the effect of laser therapy on various outcomes of CTS patients was carried out [6].

2. METHOD

Study searches were performed on various databases such as Pubmed, ScienceDirect, Directory of Open Access Journal, Epistemonikos, and Cochrane Library. Study searches were carried out using the keywords "carpal tunnel syndrome" and "laser therapy". The studies obtained were then filtered based on study inclusion and exclusion criteria. The inclusion criteria used in this sample were: 1) The study subjects were CTS patients; 2) The intervention used is in the form of laser therapy; 3) Comparator in the form of conventional therapy or placebo; 4) Outcomes in the form of VAS, motor function and sensory function. The exclusion criteria used in this study were articles published more than the last 10 years [7]. Studies that met the inclusion and exclusion criteria were then accessed in full-text to see the availability of articles. Studies that are not fully accessible will be excluded. The final results will be obtained from studies that will be used in this literature review [8]. The search for studies was carried out using keywords. From the search results, a total of 389 studies were obtained. The 7 studies that met the inclusion and exclusion criteria were the studies that were analyzed in this literature review [9].

3. RESULTS AND DISCUSSION

The effect of laser therapy on the various outcomes of CTS patients can be seen comprehensively in table 1.

3.1 Effects of Laser Therapy on Pain Outcome in CTS Patients

The use of laser therapy for CTS patients can reduce pain outcomes in CTS patients. There are 5 of the total studies that measure the pain outcome of CTS patients in the administration of laser therapy. The use of a laser with a wavelength of 830-1064nm (250 Joule/25 watts) for 100 seconds can reduce the visual analogue scale (VAS) score by 2.2 points which is greater than the control group (0.4 point decrease). [5]Another study using a Gallium-Alluminium-Arsenide (GaAlAs) laser of 18 Joules for 15 sessions also found that it reduced the VAS score by 2.81 points which was also greater than the control group with placebo laser (decrease of 2.35 points). [6]These results are in line with another study using low-level laser therapy (LLLT) with longer wavelengths providing a greater reduction in VAS points (4.43 point decrease) compared to the control group using Kinesio Taping (2.9 point decrease) [10]. The use of LLLT in reducing the visual numerical scale (VNS) in CTS patients is also supported by other studies comparing the reduction in VNS scores in the LLLT therapy group, the LLLT + kinesio taping group, and the sham laser group. The results showed that the decrease in daytime VNS scores in the LLLT group (5 point decrease) was as great as in the LLLT + kinesio taping group (5 point decrease), and greater than the sham laser (0 point decrease). Meanwhile, the reduction in night VNS scores in the LLLT therapy group (6 point decrease) was smaller than in the LLLT + kinesio taping group (7 point decrease), and higher than the sham laser group (0 point decrease). [8]However, when LLLT therapy was compared with fascial manipulation (FM) therapy, the reduction in VAS scores was smaller in the LLLT group (0.48 point decrease) compared to the FM group (5.29 point decrease) [11].

The results of these studies showed that LLLT therapy in the Akgol study provided the highest reduction in VAS in all inclusion studies, whereas LLLT + kinesio taping therapy provided the highest reduction in VNS at night . A higher decrease in VAS and VNS scores indicates a better therapeutic effect on pain. This shows that LLLT therapy gives the best results on the outcome of reducing pain in CTS patients. However, the effect of LLLT on pain outcomes in CTS patients is better when combined with other therapies such as kinesio taping. The mechanism of LLLT in reducing pain using the properties of coherent light causes fibroblastic regeneration in clinical trials and various laboratory experiments [12]. LLLT has also been found to significantly reduce pain in the acute setting by reducing biochemical biomarkers and oxidative stress, as well as reducing edema and bleeding. Various previous studies have also shown the presence of analgesic and anti-inflammatory effects through photobiomodulation mechanisms in experimental trials [13]. The pain reduction effect of LLLT therapy is better when combined with kinesio taping due to the combination of the LLLT therapy mechanism and the kinesio taping mechanism which creates coils under the skin thereby increasing the space under the skin to accelerate healing and channeling fluids to painful areas to accelerate tissue healing [14].

3.2 Effects of Laser Therapy on Motor and Sensory Latency in CTS Patients

The use of laser therapy in CTS patients in several studies also showed an effect on motor and sensory latency outcomes. Four of the total studies measured two latency outcomes , namely distal motor latency (DML) and distal sensory latency (DSL). GaAlAs laser therapy with a wavelength of 780nm showed a greater reduction in DML

(0.015ms reduction) than the placebo laser group (no reduction in DML score). [6]Another study using a laser with a wavelength of 830-1064nm showed a higher decrease in DML score (0.3ms decrease) compared to TENS therapy (0.1ms increase in DML). [5] The results of DML measurements in the study using laser acupuncture showed better results (DML reduction of 0.03 ms) compared to the placebo group (0.14 DML increase) [15]. However, studies using LLLT showed that the DML score on LLLT (0.22 ms decrease) decreased slightly compared to sham laser therapy (0.46 ms decrease) but was still better than LLLT + Kinesiotaping (0.06 DML decrease) [16]. These results show that the use of LLLT results in a higher reduction in DML than other types of laser therapy. The DSL measurements were carried out in two of the seven inclusion studies, namely the study using laser acupuncture and the study using LLLT. The results showed that the decrease in DSL in laser acupuncture was less (0.08 ms) compared to the decrease in DSL in LLLT (7.50 ms) [17].

The mechanism of LLLT in reducing DML and DSL is still not known with certainty. However, in various studies, it has long been hypothesized that increased mitochondrial function (ie, increased ATP production) in brain cells irradiated with LLLT is one of the main mechanisms involved with the beneficial effects observed after LLLT treatment [18]. Mitochondria are considered to be the powerhouses of eukaryotic cells, converting oxygen and nutrients through the processes of oxidative phosphorylation and the electron transport chain into adenosine triphosphate (ATP). Complex IV, also known as CCO is a large transmembrane protein complex found in mitochondria, which is a component of the electron transport chain of cellular respiration. CCO absorbs the same light spectrum as observed for the action spectrum for biological responses to light in the visible and near infrared light (NIR) range [19]. At the cellular level, LLLT can cause photodissociation of nitric oxide (NO) from CCO. In stressed cells, NO produced by mitochondrial NO synthase displaces oxygen from CCO, resulting in a downregulation of cellular respiration and a subsequent reduction in the production of energy storage compounds, such as ATP. By separating NO from CCO, LLLT prevents oxygen transfer from CCO and thereby promotes unhindered cellular respiration. The increase in cellular ATP produced by LLLT may contribute to the positive effect, both by increasing cellular energy levels and by increasing cyclic AMP molecules (formed biochemically from ATP) involved in many signaling pathways. It is therefore assumed that CCO acts as an important chromophore in LLLT [20]

3.3 The Effect of Laser Therapy on the Conductivity Speed of the Median Nerve in CTS Patients

CTS is entrapment neuropathy caused by compression of the median nerve as it travels through the carpal tunnel of the wrist. Compression of the median nerve causes a decrease in the conduction velocity of the median nerve. [1,14]. However, in three inclusion studies, laser therapy showed good results in increasing the conduction velocity of the median nerve [21]. Laser acupuncture therapy showed an effect in increasing the conduction velocity of the median nerve which was higher (+0.31 m/s) than the placebo control group (-0.06 m/s). In addition, laser acupuncture therapy also increased the sensory conduction velocity of the median nerve which was higher (+1.27) compared to the placebo group (+0.37). [12]. GaAlAs 780nm laser therapy was also found to have an effect in increasing the median nerve sensory conduction velocity which was higher (+). [22] 6,222) than the placebo laser group (+1,265). [8,12,15]. However, LLLT therapy increased sensory nerve conduction velocities no higher than sham laser therapy (+0.04 VS + 0.32). These results indicate that GaAlAs laser therapy is the best in increasing the conduction velocity of the median nerve in CTS patients [23].

The mechanism of GaAlAs laser therapy as the best in increasing the conduction velocity of the median nerve is due to its effect on increasing myelin cells. However, another reason that can explain this repair effect is the increased energy transport and distribution of calcium in the cytoplasm which will create an increase in functional cellular potential, accelerated injury repair, and increased scar tissue resistance, pro-inflammatory activity, as an acceleration of tissue regeneration and increased blood circulation. Increased tissue regeneration is due to the effects of GaAlAs laser therapy in the form of increased activity of leukocytes, phagocytes, and increased calcium in the cell cytoplasm. Another reason is the acceleration of cell division and growth, activation of protein and cytokine synthesis, and relaxation of blood vessel walls (vasodilation) with photolytic complexes such as NO [24].

3.4 Effects of Laser Therapy on Functional Status Scale and Symptomps Severity Scale in CTS Patients

Another effect of laser therapy that can be observed in various studies is an improvement in the Functional Status Scale (FSS) and Symptoms Severity Scale (SSS) scores. GaAlAs 18 Joule and LLLT therapy showed an improvement in FSS and SSS. Changes in FSS in LLLT therapy (-0.89) were better than the control group (-0.31). Better improvement in FSS in LLLT therapy was also followed by better improvement in SSS compared to the control group (-1.12 VS -0.49). (Akgol) GaAlAs therapy also showed better improvement in FSS scores compared to placebo laser (-0.54 VS -0.4) and better SSS score improvement than the control group (-0.61 VS -0.33). These results indicate that the best improvement in FSS and SSS is obtained with the use of LLLT therapy [25].

The mechanism of LLLT in repairing FSS and SSS values is mediated by the existence of various studies which have shown that LLLT has a significant effect on tendon repair by first activating cytochrome C oxidase and thereby carrying out the photon absorption process, secondly acting in all three phases of tendon repair, and finally repair tendons. recovery. The mechanism of LLLT repair differs in the three phases of tendon repair. In the inflammatory phase, LLLT especially activates large amounts of VEGF and promotes angiogenesis under hypoxia. During the proliferative phase, LLLT increases the amount of type III collagen by promoting fibroblast proliferation. Throughout

the remodeling phase, LLLT primarily activates M2 macrophages and downregulates inflammatory factors, thereby reducing the inflammatory response. The anti-inflammatory effect possessed by LLLT allows repair of damage that has occurred in CTS [26]. Faster improvement will reduce the symptoms experienced by the patient so that the SSS score also improves. The anatomical and biochemical improvements that occur lead to an improved functional status of the wrist [27]. Maximum wrist function will support more optimal daily activities as well. Therefore, LLLT through this mechanism also improved the FSS score better than the control group or GaAlAs laser therapy [28].

3.5 Side Effects of Using Laser Therapy in Overcoming CTS

In all inclusion studies, side effects of using laser therapy in treating CTS were not reported as side effects in CTS patients. This shows that the use of laser therapy in treating CTS is classified as safe with a better level of effectiveness than control therapy with placebo or conventional therapy [29].

Table 1. Effects of Laser Therapy on Various Outcomes of CTS Patients

Authors (Year)	Population	Intervention	Outcomes	Side effects
Casale et al. (2013)	20 Symptomatic CTS	Laser 830-1064nm (250 J/25 Watt) for 100 seconds VSTENS 100Hz for 30 minutes	VAS score change: -2.2 VS -0.4DML score change: -0.3 VS +0.1	Not reported
Fusakul et al. (2014)	66 CTS moderate to severe	Gallium-aluminum-arsenide laser (18H x 15 sessions) VS placebo laser	VAS score change: -2.81 VS -2.35 SSS score change:-0.61 VS -0.33FSS score change:-0.54 VS -0.4	Not reported
Lazovic et al. (2014)	79 CTS moderate to severe	GaAIAs diode laser 780nm VSPlacebo Laser	DML score change: -0.015 VS -0.000MNSCV score change:+6.222 VS +1.265	No side effects have been reported
Pratelli et al. (2015)	42 CTS	Low-Level Laser Therapy (LLLT) VSFascial Manipulation (FM)	VAS score change: -0.48 VS -5.29	No side effects have been reported
Guner et al. (2018)	38 CTS (12 unilateral, 26 bilateral)	Low-power laser therapy VS kinesiotaping + low-power laser therapy VS sham laser therapy	Day VNS score change: -5 VS -5 VS 0 Night VNS score change:-6 VS -7 VS 0 mSNCV score change:+0.04 VS +0.20 VS +0.32 mMDL score change:-0.22 VS -0.06 VS -0.46 Score change mSDL:-7.50 VS -10.10 VS -8.70	No side effects have been reported
Juan et al. (2019)	84 CTS	Laser acupuncture (1x1 day, 5x1 week, for 4 weeks) VS placebo	Change in DML score: -0.03 VS +0.14 Change in DSL score:-0.08VS+0.04 Change in MNCV score:+0.31 VS -0.06 Change in WP SNCV score:+1.27 VS +0.37	No side effects have been reported
Akgol G (2021)	60 CTS	Low-Power Laser Therapy VS Kinesio taping	VAS score change: -4.43 VS -2.9 Boston-SSS score change: -1.12 VS -0.49 Boston-FSS score change: -0.89 VS -0.31	No side effects have been reported

VAS: visual analogical scale; mSNCV: Median Sensory Nerve Conduction Velocity ; MNCV: Median Nerve Conduction Velocity ; SNCV: Sensory Nerve Conduction Velocity ; MDL: Motor Distal Latency ; DSL: Distal Sensory Latency ; WP SNCV: Wrist -Palm Sensory Nerve Conduction Velocity ; FSS: The Functional Status Scale ; SSS: Symptomps Severity Scale ; VNS: Visual Numeric Scale ; HGS: Handgrip Strength ; mMDL: median motor nerve distal latency [30].

4. CONCLUSION

In this literature review, the effects of laser therapy shown in various inclusion studies show that various types of laser therapy can improve outcomes in CTS patients starting from reducing pain, reducing motor and sensory latency, increasing median nerve conduction velocity, and improving FSS and SSS scores. Faster improvement will reduce the symptoms experienced by the patient so that the SSS score also improves. The anatomical and biochemical improvements that occur lead to an improved functional status of the wrist. The mechanism of GaAlAs laser therapy

as the best in increasing the conduction velocity of the median nerve is due to its effect on increasing myelin cells. However, another reason that can explain this repair effect is the increased energy transport and distribution of calcium in the cytoplasm which will create an increase in functional cellular potential, accelerated injury repair, and increased scar tissue resistance, pro-inflammatory activity, as an acceleration of tissue regeneration and increased blood circulation. In addition, no side effects were reported in all inclusion studies, so it can be concluded that laser therapy is an innovative type of therapy that is effective with minimal side effects in overcoming CTS by improving various outcomes of CTS patients.

ACKNOWLEDGEMENTS
Author thanks to Faculty of Medicine, Tarumanagara University, Indonesia. Faculty of Medicine, Trisakti University, Indonesia. Faculty of Medicine, Pelita Harapan University, Indonesia. Faculty of Medicine, Widya Mandala Catholic University Surabaya, Indonesia. And Department of Neurology, Mataram University, Indonesia

REFERENCES

[1] S. M. Rayegani, M. Moradi-Joo, S. A. Raeissadat, M. H. Bahrami, M. Seyed-Nezhad, and S. Heidari, "Effectiveness of low-level laser therapy compared to ultrasound in patients with carpal tunnel syndrome: A systematic review and meta-analysis," *J. Lasers Med. Sci.*, vol. 10, no. Suppl 1, p. S82, 2019.

[2] T. Wolny and P. Linek, "Is manual therapy based on neurodynamic techniques effective in the treatment of carpal tunnel syndrome? A randomized controlled trial," *Clin. Rehabil.*, vol. 33, no. 3, pp. 408–417, Mar. 2019, doi: 10.1177/0269215518805213.

[3] T. P. Franke, B. W. Koes, S. J. Geelen, and B. M. Huisstede, "Do Patients With Carpal Tunnel Syndrome Benefit From Low-Level Laser Therapy? A Systematic Review of Randomized Controlled Trials," *Arch. Phys. Med. Rehabil.*, vol. 99, no. 8, pp. 1650-1659.e15, Aug. 2018, doi: 10.1016/j.apmr.2017.06.002.

[4] W. K. W. Cheung *et al.*, "Low-level laser therapy for carpal tunnel syndrome: systematic review and network meta-analysis," *Physiotherapy*, vol. 106, pp. 24–35, Mar. 2020, doi: 10.1016/j.physio.2019.06.005.

[5] T. Wolny and P. Linek, "The Effect of Manual Therapy Including Neurodynamic Techniques on the Overall Health Status of People With Carpal Tunnel Syndrome: A Randomized Controlled Trial," *J. Manipulative Physiol. Ther.*, vol. 41, no. 8, pp. 641–649, Oct. 2018, doi: 10.1016/j.jmpt.2018.11.001.

[6] D. B. Piazzini *et al.*, "A systematic review of conservative treatment of carpal tunnel syndrome," *Clin. Rehabil.*, vol. 21, no. 4, pp. 299–314, Apr. 2007, doi: 10.1177/0269215507077294.

[7] J. C. Kim, S. H. Jung, S.-U. Lee, and S. Y. Lee, "Effect of extracorporeal shockwave therapy on carpal tunnel syndrome," *Medicine (Baltimore).*, vol. 98, no. 33, p. e16870, Aug. 2019, doi: 10.1097/MD.0000000000016870.

[8] G. Akgol, M. S. Elbasti, A. Gulkesen, G. Alkan, A. Kaya, and H. Ulusoy, "Comparison of low power laser and kinesio taping for the treatment of carpal tunnel syndrome: A prospective randomized study," *J. Back Musculoskelet. Rehabil.*, vol. 34, no. 4, pp. 545–553, 2021.

[9] A. Güner, L. Altan, and M. Kasapoğlu Aksoy, "The effectiveness of the low-power laser and kinesiotaping in the treatment of carpal tunnel syndrome, a pilot study," *Rheumatol. Int.*, vol. 38, no. 5, pp. 895–904, 2018.

[10] M. Asheghan, A. Khatibi Aghda, V. Sobhani, S. Ebrahim Hashemi, and M. Taghi Hollisaz, "A randomized comparative trial of corticosteroid phonophoresis, local corticosteroid injection, and low-level laser in the treatment of carpal tunnel syndrome," *LASER Ther.*, vol. 29, no. 1, pp. 11–17, 2020, doi: 10.5978/islsm.20-OR-01.

[11] M. Alam, M. Khan, S. I. Ahmed, and S. S. Ali, "Effectiveness of neural mobilization and ultrasound therapy on pain severity in carpal tunnel syndrome," *Biomed. Res. Ther.*, vol. 5, no. 4, pp. 2187–2193, 2018.

[12] K. Shem, J. Wong, and B. Dirlikov, "Effective self-stretching of carpal ligament for the treatment of carpal tunnel syndrome: A double-blinded randomized controlled study," *J. Hand Ther.*, vol. 33, no. 3, pp. 272–280, Jul. 2020, doi: 10.1016/j.jht.2019.12.002.

[13] S. Kooner, D. Cinats, C. Kwong, G. D. Matthewson, and G. Dhaliwal, "Conservative treatment of cubital tunnel syndrome: A systematic review," *Orthop. Rev. (Pavia).*, vol. 11, no. 2, Jun. 2019, doi: 10.4081/or.2019.7955.

[14] M. Hernández-Secorún *et al.*, "Effectiveness of Conservative Treatment According to Severity and Systemic Disease in Carpal Tunnel Syndrome: A Systematic Review," *Int. J. Environ. Res. Public Health*, vol. 18, no. 5, p. 2365, Feb. 2021, doi: 10.3390/ijerph18052365.

[15] S. M. Georgeto, G. L. Picharski, R. A. C. Andraus, R. A. da Silva, S. Ngomo, and K. B. P. Fernandes, "Outcomes of bilateral carpal tunnel syndrome treatment – A systematic review and meta-analysis," *J. Plast. Reconstr.*

Aesthetic Surg., vol. 75, no. 9, pp. 3250–3259, Sep. 2022, doi: 10.1016/j.bjps.2022.06.070.

[16] M. Nalbant, O. Ümit Yemişci, S. Özen, and Ş. Tezcan, "Ultrasonographic and electrophysiological outcomes of carpal tunnel syndrome treated with low-level laser therapy: A double-blind, prospective, randomized, sham-controlled study," *Arch. Rheumatol.*, vol. 37, no. 1, pp. 19–30, Mar. 2022, doi: 10.46497/ArchRheumatol.2022.8605.

[17] D. Klokkari and I. Mamais, "Effectiveness of surgical versus conservative treatment for carpal tunnel syndrome: A systematic review, meta-analysis and qualitative analysis," *Hong Kong Physiother. J.*, vol. 38, no. 02, pp. 91–114, Dec. 2018, doi: 10.1142/S1013702518500087.

[18] S. Haghighat, Z. Zabihi, and S. Khosrawi, "Effects of low-level laser therapy with wrist splinting on outcome of patients with carpal tunnel syndrome; a randomized, double-blind, placebo-controlled trial," *Int. J. Med. Investig.*, vol. 7, no. 4, pp. 5–14, 2018.

[19] S. Badıl Güloğlu, M. Bilgilisoy Filiz, K. K. Kılıç, Ş. Koldaş Doğan, İ. E. Toslak, and N. F. Toraman, "Treatment of carpal tunnel syndrome by low-level laser therapy versus corticosteroid injection: a randomized, prospective clinical study," *Lasers Med. Sci.*, vol. 37, no. 4, pp. 2227–2237, Jun. 2022, doi: 10.1007/s10103-021-03489-6.

[20] B. M. Huisstede, M. S. Randsdorp, J. van den Brink, T. P. C. Franke, B. W. Koes, and P. Hoogvliet, "Effectiveness of Oral Pain Medication and Corticosteroid Injections for Carpal Tunnel Syndrome: A Systematic Review," *Arch. Phys. Med. Rehabil.*, vol. 99, no. 8, pp. 1609-1622.e10, Aug. 2018, doi: 10.1016/j.apmr.2018.03.003.

[21] G. Choi, L. S. Wieland, H. Lee, H. Sim, M. S. Lee, and B. Shin, "Acupuncture and related interventions for the treatment of symptoms associated with carpal tunnel syndrome," *Cochrane Database Syst. Rev.*, vol. 2019, no. 9, Dec. 2018, doi: 10.1002/14651858.CD011215.pub2.

[22] L. H. A. Sousa, C. de O. Costa, E. M. Novak, and G. S. Giostri, "Complex regional pain syndrome after carpal tunnel syndrome surgery: A systematic review," *Neurol. India*, vol. 70, no. 2, p. 491, 2022.

[23] B. M. Huisstede, J. van den Brink, M. S. Randsdorp, S. J. Geelen, and B. W. Koes, "Effectiveness of Surgical and Postsurgical Interventions for Carpal Tunnel Syndrome—A Systematic Review," *Arch. Phys. Med. Rehabil.*, vol. 99, no. 8, pp. 1660-1680.e21, Aug. 2018, doi: 10.1016/j.apmr.2017.04.024.

[24] J. Du *et al.*, "Manual Therapy and Related Interventions for Carpal Tunnel Syndrome: A Systematic Review and Meta-Analysis," *J. Integr. Complement. Med.*, vol. 28, no. 12, pp. 919–926, Dec. 2022, doi: 10.1089/jicm.2022.0542.

[25] F. J. Martin-Vega, M. J. Vinolo-Gil, V. Perez-Cabezas, M. Rodríguez-Huguet, C. Garcia-Munoz, and G. Gonzalez Medina, "Use of Sonophoresis with Corticosteroids in Carpal Tunnel Syndrome: Systematic Review and Meta-Analysis," *J. Pers. Med.*, vol. 12, no. 7, p. 1160, Jul. 2022, doi: 10.3390/jpm12071160.

[26] M. R. Asadi *et al.*, "Effect of Low-Level Laser Therapy Combined with Therapeutic Ultrasound on Hand Pain and Function Following Carpal Tunnel Syndrome: A Randomized Controlled Trial," *Middle East J. Rehabil. Heal. Stud.*, vol. 8, no. 4, 2021, doi: https://doi.org/10.5812/mejrh.116063.

[27] T. Wolny and P. Linek, "Neurodynamic Techniques Versus 'Sham' Therapy in the Treatment of Carpal Tunnel Syndrome: A Randomized Placebo-Controlled Trial," *Arch. Phys. Med. Rehabil.*, vol. 99, no. 5, pp. 843–854, May 2018, doi: 10.1016/j.apmr.2017.12.005.

[28] M. R. Asadi *et al.*, "Effect of Low-Level Laser Therapy Combined with Therapeutic Ultrasound on Hand Pain and Function Following Carpal Tunnel Syndrome: A Randomized Controlled Trial," *Middle East J. Rehabil. Heal. Stud.*, vol. 8, no. 4, pp. 605–612, Sep. 2021, doi: 10.5812/mejrh.116063.

[29] E. S. Cage, J. J. Beyer, and N. A. Ebraheim, "Injections for treatment of carpal tunnel syndrome: A narrative review of the literature," *J. Orthop.*, vol. 37, pp. 81–85, Mar. 2023, doi: 10.1016/j.jor.2023.02.011.

[30] R. A. B. Lopes-Martins, R. L. Marcos, E. C. P. Leal-Junior, and J. M. Bjordal, "Low-Level Laser Therapy and World Association for Laser Therapy Dosage Recommendations in Musculoskeletal Disorders and Injuries," *Photomed. Laser Surg.*, vol. 36, no. 9, pp. 457–459, Sep. 2018, doi: 10.1089/pho.2018.4493.