Tri-wave laser therapy for spinal cord injury, neuropathic pain management, and restoration of motor function

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ABSTRACT

A laser therapy device using three combined wavelengths 532nm, 808nm, and 1064nm has been demonstrated in clinical studies. Primarily, therapeutic lasers have used wavelengths in the ranges of 632nm through 1064nm, where the optical density (OD) < 5, to achieve pain relief and tissue regeneration. Conventional wisdom would argue against using wavelengths in the region of 532nm, due to poor penetration (OD ~ 8); however, the author's observations are to the contrary. The 532nm light is efficiently absorbed by chromophores such as oxyhemoglobin, deoxyhemoglobin, and cytochrome c oxidase thereby providing energy to accelerate the healing process. The 808nm light is known to result in Nitric Oxide production thereby reducing inflammation and oxidative stress. All three laser wavelengths likely contribute to pain relief by inhibiting nerve conduction; however, the 1064nm has the deepest penetration. Through the use of this device on over 1000 patients with a variety of acute and chronic neuro-musculoskeletal disorders, the author observed that a majority of these individuals experienced rapid relief from their presenting conditions and most patients reported a tingling sensation upon irradiation. Patient testimonials and thermal images have been collected to document the results of the laser therapy. These studies demonstrate the ability of laser therapy to rapidly alleviate pain from both acute and chronic conditions.

Keywords: laser therapy, tri-wave laser, spinal cord injury, diabetic neuropathy, neuropathic pain, photobiomodulation, laser biostimulation,

1. INTRODUCTION

1.1 Laser therapy history

The first medical application of the laser is reported by Goldman in 1962, the first clinical applications by Choy and Ginsburg in 1983.[1] Low level laser therapy (LLLT) or photobiomodulation has also been used in clinical practice and the cellular and molecular mechanisms of LLLT have also been studied for many years now. Several reviews have been published of these studies toward understanding the action mechanisms on cellular and molecular levels.[2] LLLT has been demonstrated to accelerate tissue healing, relieve pain, and reduce inflammation. In a review of LLLT applied to treating traumatic brain injuries, Y.Y. Huang notes that this spectral dependence of transcranial LLLT for traumatic brain injury is correlated with the absorption spectrum of the photoreceptor cytochrome C oxidase, and furthermore concludes that LLLT may stimulate neurogenesis and synaptogenesis or synaptic plasticity.[3] More recently, it has even been suggested that pre-conditioning where tissue damage may be expected, may be effective in mitigating damage caused by surgery, heart attack, or stroke and possibly to increase athletic performance.[4] In biological tissue the "optical window" where penetration depth is maximized is reportedly from 600nm to 1200nm.[5] Although photobiomodulation is still not a part of mainstream medicine, and the photobiological mechanisms are still a topic of research, therapeutic lasers have primarily used wavelengths in this optical window, to achieve pain relief and tissue regeneration. Conventional wisdom would argue against using wavelengths in the region of 532nm, due to poor penetration (OD ~ 8) compared with the infrared (OD < 5).[6] It should also be mentioned, that it is commonly assumed that in order for light to result in photobiostimulation it must be absorbed by the tissue Recent developments in the field have included research establishing an increase in proliferation rates and membrane potential after 532 nm irradiation of adipose tissue-derived stem cells.[7]

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1.2 Laser therapy mechanisms

Infrared has a deeper penetration in tissue compared to visible light due to the combined absorption spectra of the dominant chromophores along with the photon scattering being inversely proportional to the wavelength. The 532nm light is outside the optical window in tissue because it is efficiently absorbed by chromophores such as oxyhemoglobin, deoxyhemoglobin; however it is also absorbed by cytochrome c oxidase as well as other biomolecules thereby providing energy to accelerate the healing process. Photons that are absorbed in cytochrome(c) oxidase increase electron transport, respiration, oxygen consumption and ATP production.[4] Many studies regarding the biostimulation effects of green laser light have been reported. Modifying metabolic activity in rat myocardial cells, while absorption of green band light by fibroblasts lead to DNA synthesis activation.[8] Frequency-doubled Nd:YAG laser at 532 nm wave-length was used to induce biostimulation of dermal fibro-blasts and increased chicken fibroblast proliferation was induced using an LED at the wavelength 570 nm.[9] Proliferation and viability of stem cells improved following 30 and 45 second irradiation by 532 nm laser using different exposure times at 0.15 mW/cm 2, but decreases with exposures of 60 seconds.[10] Laser light at 532 nm also produced power-dependent activation of TRPV1.[11] Another study found 532 nm laser irradiation significantly improved the maintenance of muscle tension compared with the 808 nm group. In contrast, 808 nm significantly improved the recovery from muscle hardness compared with the other groups.[12] The use of a mixed 532 nm and 1064 nm laser has been demonstrated to have therapeutic effects, and one article discusses treating precancerous lesions resulting from overexposure to sunlight.[13] The 810 nm light is known to result in Nitric Oxide (NO) production thereby reducing inflammation and oxidative stress.[14] It has also been demonstrated by measuring NO levels in the blood that LLLT dose correlates with increases in NO levels.[15] The efficacy of different wavelengths of LLLT for traumatic brain injury was studied in mice using 665nm, 730nm, 810 nm , and 980 nm. While 665nm and 810 nm showed significant beneficial effects while, 730nm and 980nm did not.[16] All three laser wavelengths likely contribute to pain relief by inhibiting nerve conduction. Low level laser irradiation has been shown to suppress bradykinin evoked action potentials in neurons associated with C-fibers.[17] Additionally, it has also been suggested that the electric field induced by light may be responsible for some cellular responses and that there may be more numerous primary mechanisms than previously suggested.[18] Modeling and simulation of beam propagation for infrared neural stimulation has also been studied.[19] The understanding of the mechanisms for low level laser therapy at the bimolecular and cellular level is still evolving and the optimum wavelength for various treatments is unknown. It is important at this stage to include both visible and infrared laser radiation as having the potential for therapeutic applications.

1.3 Tri-wave laser

The device used in the clinical studies presented is a unique triple wavelength laser whose beams are co-propagated from a single source so that all 3 wavelengths strike the target tissue simultaneously. Chariff, who has been using lasers therapeutically since the 1980s, pioneered this three-wavelength, low-level laser for tissue regeneration and pain mitigation. This laser device was developed and patented specifically to be used on living tissue for photobiomodulation, with the idea that by incorporating the 532nm, 808nm, and 1064nm wavelengths together, better, faster therapeutic results could be achieved. Clinical use has shown that this device is capable of stimulating the spinal cord and other deep tissue. Before and after thermography images show the effects of spinal cord stimulation. In addition to other applications, this laser has consistently demonstrated the ability to rapidly alleviate pain from both acute and chronic conditions without any adverse events associated.

2. METHODOLOGY FOR CLINICAL STUDIES

2.1 Treatment protocols

The following protocol was used for spinal cord injury induced neuropathic pain: the spine was irradiated primarily at the location of injury directly over the spinous processes for approximately 3 minutes and then the remainder of the spine from C-1 to L-5 was irradiated for an additional 3 minutes. The anatomical area of neuropathic pain complaint was also irradiated for approximately 2 minutes per area. All of the patients treated in Aspen Colorado area were treated 6 times a week for 2 weeks. The first patient was a quadriplegic in FL who was treated 3 times a week for the first 2 weeks, followed by weekly treatments for approximately 8 months. The last patient was treated approximately once a week for 6 weeks.

2.2 Laser irradiance levels

The laser used in these clinical studies was a battery powered pen laser with a total output power of approximately 150 mW. Unlike a typical green pen laser where the infrared is blocked, the spectral filters were such that all three wavelengths contributed similar power levels.

2.3 Thermal imaging

Body temperature is a known indicator of sickness and injury and infrared thermography is an accepted diagnostic technique.[20] Thermal images (before and after treatment) have been collected showing reduced temperature at the location of injury after treatment. The thermal image shown in Figure 1 is of the patient with spinal cord injury to C-6/7 who provided the second testimonial.

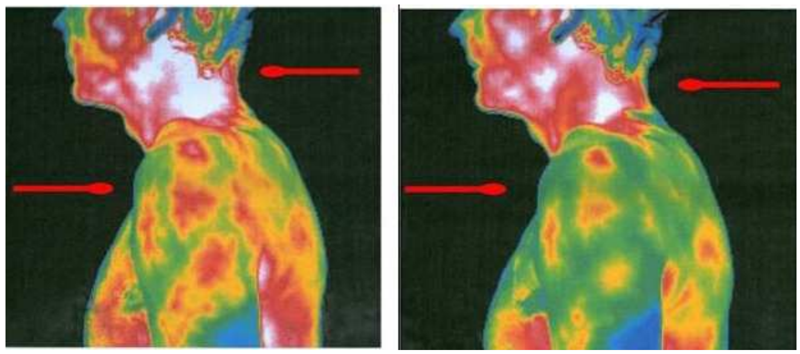


Figure 1. Thermography images before (left) and after (right) laser therapy from patient with spinal cord injury to C-6/7.

2.4 Video testimonials

Video testimonials were recorded to document the reported pain relief and increased motor function of the patients.

Table 1. Information on video files that accompany this manuscript.

Item	Video
File name	ANDRINI, TOM, DAVID, RICHARD, DENNIS, CHERYL, CHRISTINE 1, CHRISTINE 2
Number of files	8
Size of each file	4,377 KB; 2,673 KB; 3,417 KB; 2,992 KB; 2,330 KB; 3,977 KB; 5,164 KB; 4,902 KB
File type	.wmv (Windows Media Player)

3. TESTIMONIALS FROM CLINICAL STUDIES

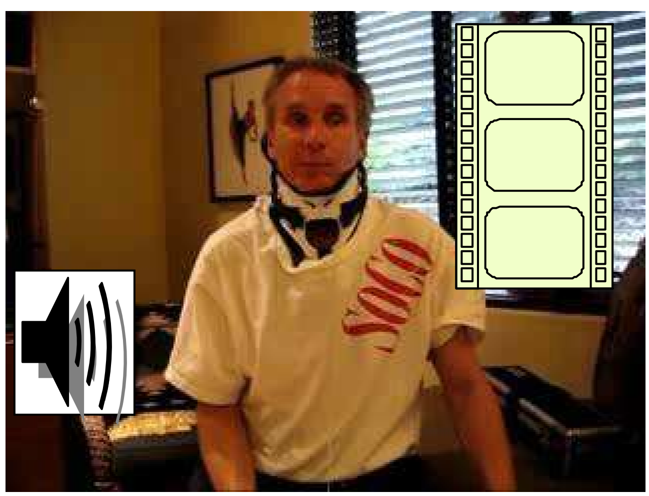
The following testimonials are primarily from patients who participated in a clinical study in the Aspen Colorado area; however, the first testimonial is from a patient in Florida who was paralyzed from the clavicle down after suffering a gunshot wound at the C-5 level in August 2008. The man was in severe pain after surgery, taking six Percocet a day among other treatments. In October 2008, two weeks after start of laser therapy, the patient went completely off his pain medication and started to regain some mobility in his arms and left thumb. As treatment continued once a week, the patient continued to regain strength and mobility, and by May 2009, he was able to raise both arms and bring his hands to his face with more control. In July through September of 2009, he regained the ability to move and lift his left leg and also regained the use of his left thumb and index finger enabling him to hold and throw a small football, as well as feed himself. By June of 2010, the patient was able to drive his own wheel chair and write again. Video documentation of this progress and his testimonial along with many others was recorded and has been made publicly available.[21]

Below is a video of patient's testimonial recorded in May 2009:

Video 1. ANDRINI.wmv Testimonial from quadriplegic patient. http://dx.doi.org/10.1117/12.2076925.1

The second testimonial is from a 51 year old male in Colorado who was in a bicycle crash on August 2, 2009. He fractured the facet of C-6, subluxated C-7 and the next day had surgery to remove the disk on C-7 and fuse with a plate. Initially after the accident the left leg and both arms were paralyzed. Feeling in he left leg came back after approximately an hour with return of motor function. Immediately after surgery the left hand presented numbness and a severe burning sensation with pain described as an 8 out of 10. Four weeks after surgery, physical therapy was administered including manual manipulation of the arm. Pain level had reduced to 5 out of 10. On October 3, 2009 after 2 days of laser therapy pain level was reported to be reduced to 3 out of 10. After 2 weeks the patient reported an increase in both the range of motion and muscle strength. The patient demonstrated his progress by his regaining the ability to snap his fingers.

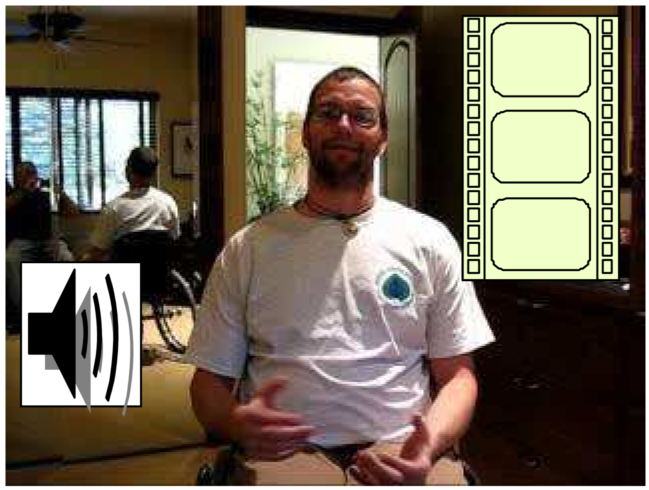
Below is a video from Oct.15, 2009 of this patient's testimonial recorded after 2 weeks of LLLT:



Video 2. TOM.wmv Testimonial from patient with spinal cord injury to C-6/7. http://dx.doi.org/10.1117/12.2076925.2

The third testimonial is from an adult male in Colorado who was injured July 3, 2005 with spinal cord injury in proximity to T-6 and T-7. He was diagnosed complete paraplegic. Five years after the injury and before laser therapy pain was reported to be at a consistent 5 out of 10. He reported feeling the best he ever had in almost 5 years after his first laser treatment. After 2 weeks, his pain was reportedly reduced to 4 out of 10.

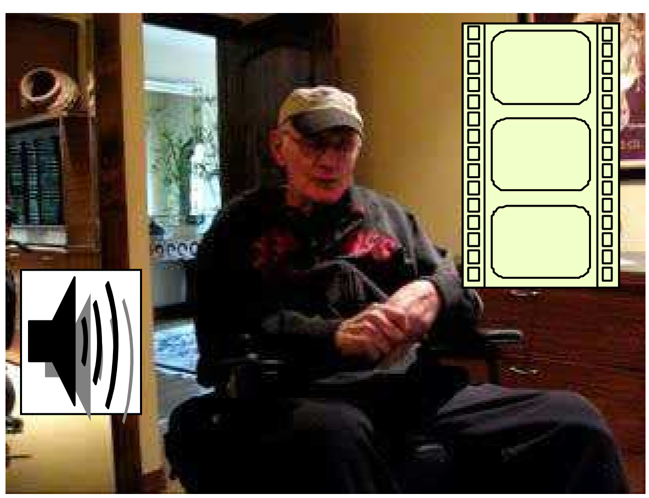
Below is a video from Oct.12, 2009 of this patient's testimonial recorded after 2 weeks of LLLT:



Video 3. DAVID.wmv Testimonial from patient with spinal cord injury to T-6/7. http://dx.doi.org/10.1117/12.2076925.3

The fourth testimonial is from an adult male in Colorado who was in a plane crash and sustained an L-1 spinal cord injury. After receiving laser therapy he reported feeling prolonged tingling in his feet, where he had complete loss of sensation in his feet previous to laser therapy. After laser therapy he had reduced pain in his hand, and intermittently reduced pain in his leg and index finger of his left hand. After 2 weeks of laser therapy the patient reduced his daily pain medication 50%.

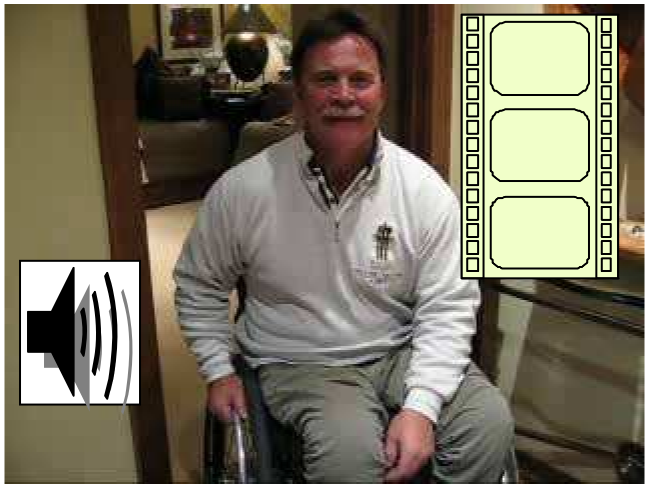
Below is a video from Oct.13, 2009 of this patient's testimonial recorded after 2 weeks of LLLT:



Video 4. RICHARD.wmv Testimonial from patient with spinal cord injury to L-1. http://dx.doi.org/10.1117/12.2076925.4

The fifth testimonial is from an adult male in Colorado who had a T-12 spinal cord injury in 1999 rendering him paraplegic. After 2 days of laser therapy, the patient reported tingling in his right foot, reduced pain in his right thigh, and reduced hypersensitivy at the location of the injury.

Below is a video from Oct. 4, 2009 of this patient's testimonial recorded after 2 days of LLLT:



Video 5. DENNIS.wmv Testimonial from patient with spinal cord injury to T-12. http://dx.doi.org/10.1117/12.2076925.5

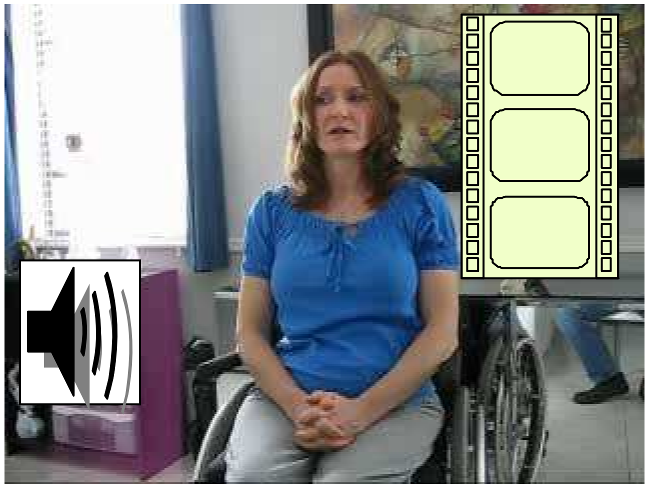
The sixth testimonial is from an adult female in Colorado who was in an accident in 2005 injuring her neck and had a double cervical fusion followed by a third fusion surgery. The patient reported debilitating pain in the neck muscles and pain due to scoliosis in her lower back. After 2 days of laser therapy, her lower back pain was reduced from 7 out of 10 to 5 out of 10, and improved range of motion in her neck.

Below is a video from Oct.16, 2009 of this patient's testimonial recorded after 2 days of LLLT:

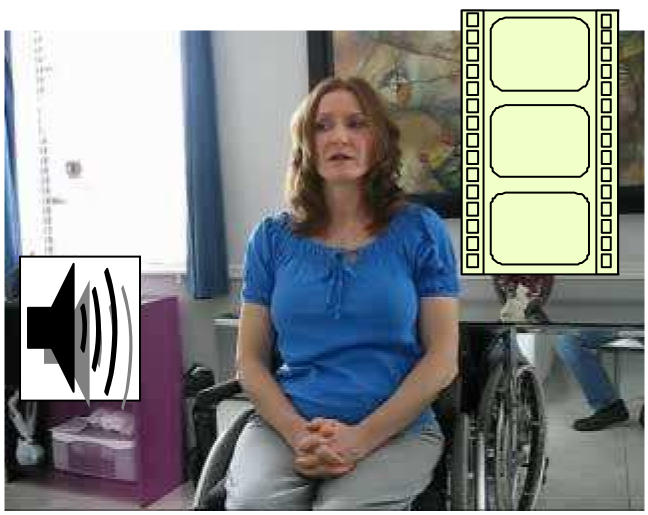
Video 6. CHERYL.wmv Testimonial from patient with cervical injury and scoliosis. http://dx.doi.org/10.1117/12.2076925.6

The seventh testimonial is from an adult female in Florida who sustained a T-12 spinal cord injury from a gunshot and crush injury from being run over by a sport utility vehicle rendering her paraplegic. The patient reported being in pain for two and a half years without any successful pain relief until a dorsal root entry zone ablation procedure resulted in a 50% reduction in pain. The patient reported tingling in her feet and legs, reduced pain, and increased quality of life after 4 weeks of laser therapy.

Below is a video of this patient's testimonial recorded after 4 weeks of laser therapy:



Video 7. CHRISTINE 1.wmv Testimonial from patient with spinal cord injury to T-12 (part 1)
http://dx.doi.org/10.1117/12.2076925.7



Video 8. CHRISTINE 2.wmv Testimonial from patient with spinal cord injury to T-12 (part 2)
http://dx.doi.org/10.1117/12.2076925.8

4. PRELIMINARY RESULTS ON DIABETIC NEUROPATHY

During recent diabetic peripheral neuropathy studies using the tri-wave laser it was observed that patients have not only had reduced neuropathic foot pain but blood sugar was measurably reduced. One recent publication on laser therapy applied to diabetic neuropathy performed at 850nm suggests that microcirculation and thereby neurovascular function is improved by laser therapy.[22] Diabetic neuropathy patients in this study were treated with a 360 mW tri-wave laser, time averaged around 3 minutes per foot, 3 minutes over the pancreas, thyroid and posterior thoracic spine. It was empirically deduced that there was a causal connection of lowered blood sugar levels resulting from the treatment method outline above.

Patient 1 was a 70 year old female type 2 diabetic. Her onset in 1988 was due to pituitary and adrenal tumor surgery to remove tumors. Her plantar feet pain and sensitivity was reported to be 10 out of 10. She was unable to manually touch toes without patient withdrawing foot and wincing. After her first LLLT treatment, her pain was reduced to 3 out of 10 and then to 0 out of 10 after the second treatment.

Patient 2 was a 67 year old female type 2 diabetic with onset at age 38. She reported severe 10 out of 10 tactile pain in both lower legs and difficulty walking. Her feet were asymptomatic. After her second treatment with LLLT her pain was reduced to 5 out of 10.

Patient 3 was a 78 year old male type 2 diabetic with non insulin dependent for a 16 year duration. Both feet, pancreas, thyroid and entire posterior spine were irradiated by laser on a daily basis for a period of 4 weeks. The treatment results included a reduction of fasting blood glucose levels from 220 mg/dl in the first week to 145 mg/dl in the second week. Measured sugar levels were then consistently at approximately that same level.

Patient 4 was a 52 year old female type 2 diabetic who is an oral medication and insulin dependent. She was diabetic for 14 year duration. She received 4 laser treatments over a two week period. Prior to treatment, fasting blood sugar levels were typically over 300 mg/dl. After the first treatment, fasting blood sugar dropped to 220 mg/dl. Two weeks after the last treatment, her fasting level was 125 and 162 mg/dl the following morning.

Patient 5 was a 55 year old female type 2 diabetic who was an insulin dependent and on oral medication. She was diabetic for 15 year duration. She also suffers from peripheral neuropathy of both feet. Prior to laser treatment, her typical fasting blood sugar level was around 300 mg/dl. She was treated 3 times a week with laser for 2 weeks. During those 2 weeks, her fasting levels were reduced to 200 or less and sometimes even as low as 117. In addition, her feet and legs felt much better after LLLT.

Patient 6 was a 30 year old male type 1 diabetic who is insulin dependent. He was diabetic for 16 year duration. He suffers from severe peripheral neuropathy of the feet. He was treated once with the laser and later that day experienced a blood sugar level reduction to 100 mg/dl, necessitating the ingestion of fruit juice to elevate the level. His neuropathy complaints were also substantially mitigated for the next 24 hours.

All patients with peripheral neuropathy experienced reduction in their neuropathy symptoms. It is theorized that the pancreatic beta cells were stimulated to produce insulin by the 3 wavelength irradiation, via direct impact on the pancreas and irradiation of the parasympathetic neurons and ganglia. The above method of treatment uses combined beams with wavelengths of 532 nm, 808 nm, and 1064 nm to provide improved beneficial therapeutic and palliative effects of laser therapy. The use of LLLT at the heretofore unused combined 532 nm, 808 nm, and 1064 nm wavelengths in the treatment of type 1 and 2 diabetes mellitus is currently patent pending.

5. CONCLUSIONS

5.1 Summary of observations from clinical studies using the tri-wave laser

Although visible light has not been widely used in combination with infrared laser therapy, in this clinical study patients observed pain reduction, improvement in physical function, improved quality of life, without any adverse events associated. Further research is necessary to expand the action spectrum for low level laser therapy to include the visible spectrum. The photochemical sensitivity of human tissue can be defined as the product of the quantum yield for the photochemical reaction with the absorption spectrum. The reduced penetration of visible light through human tissue are due to larger absorption and scattering coefficients compared to infrared and may not preclude a therapeutic effect which may even be induced by absorption in peripheral tissue. Additionally, by using various combinations of wavelengths simultaneously, for example 532nm, 808nm, and 1064nm, it is hypothesized that some synergistic affect may be produced.

5.2 Future work with tri-wave laser therapy for spinal cord injury and diabetic neuropathy

Stronger evidence is required to meet the evidenced based guidelines of the Agency for Healthcare Research and Quality including more objective outcome measurement such as calibrated quantitative sensory testing.[23] A double blind Class I clinical trial, where each of these three wavelengths are used individually in parallel with a sham laser, and tri-wave laser, would help test the hypothesis of this study. A Class I clinical trial is a randomized controlled clinical trial of the intervention of interest with masked or objective outcome assessment, in a representative population. Relevant baseline characteristics are presented and substantially equivalent among treatment groups or there is appropriate statistical adjustment for differences.[24] Objective outcomes in future laser therapy studies for diabetic neuropathy should include nerve conduction and blood sugar.

Table 2. Class I clinical trial guidelines.[24]

Additional clinical trial guidelines
a. Concealed allocation
b. Primary outcome(s) clearly defined
c. Exclusion/inclusion criteria clearly defined
d. Adequate accounting for drop-outs (with at least 80% of enrolled subjects completing the study) and cross-overs with numbers sufficiently low to have minimal potential for bias
e. For non-inferiority or equivalence trials claiming to prove efficacy for one or both wavelengths, the following are also required:
f. The authors explicitly state the clinically meaningful difference to be excluded by defining the threshold for equivalence or non-inferiority.
g. The standard treatment used in the study is substantially similar to that used in previous studies establishing efficacy of the standard treatment (e.g., for a drug, the mode of administration, dose and dosage adjustments are similar to those previously shown to be effective).
h. The inclusion and exclusion criteria for patient selection and the outcomes of patients on the standard treatment are comparable to those of previous studies establishing efficacy of the standard treatment.
i. The interpretation of the results of the study is based upon a per protocol analysis that takes into account dropouts or crossovers.

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