Advances in Laser Therapy for the Treatment of Work Related Injuries

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Abstract: Laser Therapy has been used as a therapeutic modality for many years and has yet to become a standard of care. This modality has great potential to be used in the clinic for the reduction of pain, inflammation and to aid in the healing process. For years many studies have been done showing the benefits of laser therapy but implementation of this technology into clinically successful products has been lagging behind. This chapter will briefly review the science behind laser therapy, the traditional systems which were used and new technologies, Class IV lasers, now being used to treat injuries seen in the workplace. New advances in this technology are being made which are leading to improved and consistent clinical outcomes. The mechanisms of action for pain relief, reduction of edema and tissue healing will be presented as well as important parameters to use in order to succeed when choosing this exciting therapeutic modality. Included are brief reviews of laser therapy when treating epicondylitis, carpal tunnel syndrome, neck and back pain as well as in post surgical rehabilitation applications. Laser therapy is a tool which can have great benefit when treating both acute stage injuries as well improving some chronic conditions.

INTRODUCTION

Lasers have been used for many years for a variety of medical applications. Applications such as laser hair removal and vision correction have aided in popularizing this high tech innovation in the field of medicine. Surgical lasers are also now being used to perform surgeries which previously would have been very difficult with traditional techniques. Lasers also have been used in rehabilitation and occupational therapy clinics for many years, especially in some European counties. This technology is now getting integrated more and more into everyday practices in the United States, as good products with sound science are being introduced to the marketplace.

Over 30 years ago, Andre Mester first observed that a very low level of laser energy was causing cellular changes in mice (Mester 1967). Since that first observation there have been thousands of studies done on using lasers to influence cellular repair, reproduction or inhibition (Hode & Turner 2002). Many of these studies have utilized very low output power, laser systems.

For the past 10 or more years, the lasers used in physical therapy and occupational therapy have been low power devices, typically between 5 mW to 500 mW of output power. These devices have been called "low level lasers" or "cold lasers." These terms arose to differentiate these types of therapeutic applications from more powerful laser systems which are used to ablate tissue for surgical or cosmetic applications. Most of these terms have been inspired more by marketing than by science. The term cold laser was first used by the early scientist in this field performing in vitro studies since many skeptics claimed that heat and not laser light was the cause of the cellular changes they were reporting. Being diligent scientists, they measured the insignificant temperature changes during their experiments and proved that the laser light was causing cellular changes. The entire field then took on the term, cold laser therapy. In fact almost all lasers when used clinically for any significant amount of time will produce a small temperature change in tissue. The important thing to acknowledge is that the rise in temperature is not the cause of the cellular changes. The stimulation of cellular activity is caused by a photochemical response to the laser light.

The reservation of many therapists to integrate laser therapy into their clinic has resulted from conflicting findings in the literature. Often times these studies have been done with very low dosages which have shown inconsistent or even poor results. The studies performed on more superficial conditions such as wounds have shown very good clinical results. The challenge has been with more complex conditions or those with a deep tissue component. Newer laser systems with higher output power are now available and gaining acceptance in the market due to the ability to treat deep tissue such as a hamstring injury. Results are more consistent and due to the ability to deliver a larger amount of energy, broad areas can be treated in a short time assuring a therapist won’t “miss” the troubled area.
New scientific studies are proving positive outcomes on challenging conditions using these higher powered laser systems (Alaskym et al 2010; Charles et al 2010).

MECHANISM OF ACTION

Photochemical effects can occur when laser light is absorbed by a chromophore and a biochemical change is inspired. Photobiomodulation, which is the term the industry has decided upon, is an example of a photochemical process in which photons from a laser source interact with cells and cause a stimulation or a biochemical change. The mechanism of action of laser therapy or photobiomodulation has been debated for some time. To this day there are various thoughts to the exact mechanism. In fact there may be several potential mechanisms and even slightly different mechanisms depending on the type of cell being stimulated. The most supported mechanism is that cytochrome c, which is found in the mitochondria inside the intercellular membrane, acts as the photoreceptor. Cytochrome c absorbs light from 500 nm to 1100 nm due to specific properties of this large molecule (Karu 1995). Once light is absorbed cytochrome c is excited and can more readily bond with oxygen and become cytochrome c oxidase which is critical to the formation of ATP. ATP is critical for energy production in the cell and leads to host of biologic responses or secondary mechanisms. These mechanisms lead to the reduction of pain, inflammation and healing of tissue.

REDUCING PAIN

Pain management has been one major indication for laser therapy. How does this work? There have been extensive studies looking various mechanisms resulting from photobomodulation and resulting pain relief (Hode & Turner 2007; Faegapani et al 2008).

Upon laser interaction with cells the following processes have been seen to occur. There is an increase in serotonin (5-HT) levels (Cassone et al 1993; Walker 1983; Cassone et al 1990). Serotonin acts as a chemical messenger that transmits nerve signals between nerve cells. Serotonin levels impact mood.

There are also increases in Beta Endorphins, which decrease pain sensation.

These increases (Montesinos 1988; Labajos 1988; Cramond et al 1994), can act to abolish pain at the receptor site.

Nitric Oxide which is critical for normal action potential in impulse transmission activity in nerve cells is also increased upon laser stimulation (Mrowiec 1997). NO also has an effect on vasodilatation which enhances oxygenation.

Bradykinins which can be prevalent in injured tissue, induce pain sensation by stimulating nociceptive afferents. Laser therapy has been shown to decrease these peptides reducing pain levels (Jimbo et al 1998).

Therapeutic lasers have also shown the following positive effects:

Normalization of Ion Channels, Ca++, Na++, K+ proven to reduce pain levels (Alvarez-Leefmans et al 2005; Friedman & Lubart 1911).

Blocked Depolarization of C-Fiber Afferent Nerves (Wakabayashi 1993): Therapeutic lasers can suppress the excitation of these fibers, particularly in low velocity neural pathways from nociceptors (Kawatani et al 1993).

Increase Nerve Cell action potential: Injury or trauma can impair the resting potential of nerve cells leading to a very low threshold for pain. Laser treatment has shown to increase the resting potential closer to the norm of ~70 mV (Blom et al 2000).

Increase release of Acetylcholine(Lupy & Sergienko 1986; Mester et al 1977): Acetylcholine helps normalize nerve signal transmission in the autonomic and somatic pathways.

Axonal Sprouting and Nerve Cell regeneration: Several studies have shown the lasers positive effects in nerve repair which can have a dramatic effect in pain relief (Anders et al 1993; El-Ani et al 2009; Anders et al 2005).
All of these proven cellular responses contribute to pain relief upon therapeutic laser treatment. These mechanisms, together with the anti-inflammatory and the tissue healing benefits make the laser an integral modality in both making patients feel better and get better.

Reducing Inflammation

In addition to the above mentioned mechanisms for reducing pain, laser treatments have been shown to reduce inflammation. The following actions have been proven to produce key elements which aid in the reduction of edema.

- Enhancement of ATP (Friedman & Lubart 1911; Cui et al 2002; Casanassima et al 1984)
- Stimulation of Vasodilatation (NO) (Gladwin & Shiva 2009)
- Reduction in Interkeukin-1 (Albertini et al 2005)
- Stabilization of the Cellular Membrane (Greco et al 2001)
- Acceleration of Leukocytic Activity (Greguss et al 1978)
- Enhanced Lymphocyte Response (Karu 1991)
- Increased Angiogenesis (Krispel et al 2002; Belkin et al 1994)
- Temperature Modulation (Kurokawa et al 1991; Maeda 1990)
- Enhanced Superoxide Dismutase SOD levels (Eichler et al 2003; Eichler et al 2005)

PROMOTING HEALING

Wound healing has been the area where most of the traditional laser therapeutic studies have been completed. The results in these studies have been very encouraging and the mechanisms of tissue healing are important for other injuries; such as tears and contusions, as many of the same mechanisms are needed to promote tissue healing.

Below is a list of important physiological changes upon laser treatment along with references to the studies which measured these modifications.

- Enhanced Leukocyte Infiltration (Karu 1991)
- Increased Macrophage activity (Bansal et al 2003; Qin et al 1992; Bolton et al 1990)
- Increased Neovascularization (Gladwin & Shiva 2009)
- Increased Fibroblast Proliferation (Cagnie et al 2003; Abrahamse & Hawkins 2006)
- Keratinocyte Proliferation (Graves et al 1990)
- Early Epithelialization (Bayat et al 2005)
- Growth Factors Increase (Benayahu et al 2005; Abrahamse et al 2008)
- Greater wound tensile strength (Mester et al 1967)

The combined effect of pain relief, reduction of edema and promotion of tissue healing makes laser therapy a valuable tool in all aspects and stages of treatment of injuries. Treatments can be performed soon after an injury and help with both pain relief and healing.

HOW MUCH LASER LIGHT IS NEEDED?

Certainly there is a threshold, or an optimal amount of light which is needed to turn on the therapeutic effects listed above. Hundreds of the scientific studies have been done in vivo and have characterized the optimal dosage or range of dosages need to achieve a cellular response (Hode & Turner 2007).
These studies are imperative, since they give a baseline for the amount of laser energy we need to deliver in a given area to achieve results at the cellular level. However, if we were to use this same dosage which had an effect when exposed in a Petri dish, on the surface of the skin, we would get considerably less dosage at the tissue in which we want to achieve therapeutic results.

When using a therapeutic laser in vivo, we need to consider many additional parameters. If most of the laser light is absorbed in the dermis, for example, then we cannot achieve an optimal effect. When laser light hits tissue, it can be absorbed, scattered (including reflection), or transmitted. The main components in tissue that we need to consider are: melanin, oxyhemoglobin, deoxyhemoglobin, and water. We can get light into the body with wavelengths from 600 nm (red end of the spectrum) to 1100 nm (near infrared end of the spectrum). The range is often referred to as the "therapeutic window" for laser applications.

Although these wavelengths can penetrate, each wavelength has unique penetration characteristics.

If we put an ordinary white light source, a flashlight, into the palm of our hand, we will see a red glow out the other side. Longer wavelengths such as red penetrate deeper. The amount of red light visibly seen through the hand is dependent on the color of the skin. Melanin absorbs light strongly, so dark skin will absorb more light, especially wavelengths from 500 nm to 800 nm. Wavelengths longer than 1200 nm absorb in water very strongly and therefore it is difficult to get much penetration in tissue. These longer wavelength lasers are typically used in ablative procedures such as surgery or skin resurfacing.

The important parameter for a therapy laser system to have is the appropriate wavelength to allow penetration to deep tissue. Wavelengths longer than 800 nm can typically achieve appropriate depths to treat most musculo skeletal conditions. When dealing with wounds or more superficial conditions shorter wavelengths such as 635 nm can be used effectively, since penetration is less important.

Since all wavelengths have a probability of scattering, absorbing, or transmitting, the more power, or the greater number of photons you have, the greater depth of penetration as a function of time. (See Fig. 1) Let's assume that we get 2.5% of the total laser light delivered to the skin actually reaching the patella tendon. If we use a 250 mW laser source, we are only getting 6.25 mW at the tendon or 0.00625 J per second of exposure.

If we use a 10 W laser source, we will get 250 mW at the tendon or 0.25 J in a second. By using a lower powered laser source for a longer time you can potentially achieve a large dosage to deep tissue. Using the example above, for the 250 mW laser to achieve the equivalent amount of energy as the 10 W laser puts out in 1 second it would take almost 1 minute. (See Table 1)
Table 1: Treatment time for various output power laser systems

<table>
<thead>
<tr>
<th>Output Power</th>
<th>Dosage</th>
<th>Size of treatment area</th>
<th>Treatment Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 mW</td>
<td>4 J/cm²</td>
<td>5 in x 5 in</td>
<td>35 hours</td>
</tr>
<tr>
<td>100 mW</td>
<td>4 J/cm²</td>
<td>5 in x 5 in</td>
<td>1 hour 47 min</td>
</tr>
<tr>
<td>250 mW</td>
<td>4 J/cm²</td>
<td>5 in x 5 in</td>
<td>43 min</td>
</tr>
<tr>
<td>500 mW</td>
<td>4 J/cm²</td>
<td>5 in x 5 in</td>
<td>21.5 min</td>
</tr>
<tr>
<td>5 W</td>
<td>4 J/cm²</td>
<td>5 in x 5 in</td>
<td>2 min 9 sec</td>
</tr>
<tr>
<td>10 W</td>
<td>4 J/cm²</td>
<td>5 in x 5 in</td>
<td>1 min 5 sec</td>
</tr>
</tbody>
</table>

In principle a lower power unit with the appropriate wavelength for good penetration (800nm to 1000nm) used for a long period of time, ultimately will be able to get to the same depth and yield therapeutic results. However, one study showed that results were not the same by using a very low power density. It was shown that under $10^5$ W/cm² even when exposed for a long period of time, had no measurable results (Andreichuck et al 1993).

Many conditions are very hard to diagnose to a very precise afflicted area, or often times conditions have other involved muscles contributing to the pain. Therefore it is important to treat as broad of an area as possible. This is where newer, higher power laser units can have a great advantage. Since you can get a therapeutic dosage of light deep into tissue, in a short treatment time, it is possible to treat a very broad area. This enables the affected area and satellite areas of pain to be effectively treated.

A good example of this, is when treating a patient with carpal tunnel syndrome. Carpal tunnel is typically associated with an impairment associated at the carpus/wrist. Often times the pain may be associated with a nerve impairment in the area around the elbow, or possibly at the cervical spine. As discussed previously, a typical range for effective dosage is on the order of 4 to 10 J/cm². Since the target area is not extremely deep, in the case of carpal tunnel we would use approximately 5 J/cm². If we assume we want to treat the entire wrist area (3"x 6" or 116 cm²) it would take approximately 580 J (5 J/cm² * 116 cm²). When treating with a typical lower power laser with 250 mW output, it takes approximately 38 minutes. Treating the same area using a higher power, 10 W, laser would only take 58 seconds. The older, lower powered laser systems make it very hard to treat a broad enough area to get consistent results in an everyday clinic. Treating carpal tunnel effectively and consistently, takes a treatment protocol which can address the possible involvement of the nerve route all the way to the cervical spine area. (see Fig. 2) This type of comprehensive approach is not practical when using a lower power laser system. If using a 10 W laser, treating this entire area will take 4 to 6 minutes depending on the size of the patient and there will be positive and consistent outcomes.

Figure 2: Nerve route to treat when treating carpal tunnel syndrome
THE FOLLOWING SECTIONS WILL GO OVER SOME TREATMENTS AND STUDIES DONE ON SEVERAL OF THE MOST COMMON, WORK RELATED INJURIES.

**Epicondylitis**

Laser Therapy can be a very effective modality in treating epicondylitis. Some of the early studies done using laser therapy showed negative to moderate results (Haker *et al.* 1987; Haker & Lundeberg 1990; Basford *et al.* 2000).

All of these studies used very low dosages and only treated small, very select areas. Other studies using a more comprehensive treatment area, with a larger dosage, show significant results in blinded studies (Simunovic & Trobonjaca 2001; Simunovic *et al.* 1998; Adamek *et al.* 1997; Terashima 1990; Damjanova & Manolov 2000).

One study compares the treatment of laser, corticosteroid injections, and a combination therapy of laser and injections. The combined treatment had a significant higher analgesic effect over the other two (Konstantinovic 1997). This study reminds us that using appropriate adjunctive therapies can often lead to much enhanced outcomes.

A summary of studies on the effect of laser therapy on tendonitis was done by Bjordal (Bjordal 1997). This review concluded that laser therapy was an effective treatment both at reducing the inflammation, as well as stimulating tendon regeneration. Optimal dosages were between 0.2 - 4 J/cm² for regeneration and 3-8 J/cm² for reduction of inflammation. A recent double blind study using a higher power class IV laser has shown significant results at 3 month follow up of the laser treated group over a sham group, when measuring grip strength, pain with grip and lateral palpation. The treatment technique used a very comprehensive protocol and relatively short treatment times (Alaskym *et al.* 2010).

With a comprehensive treatment approach, laser therapy is an effective modality in treating medial and lateral epicondylitis with long lasting results.

**Carpal Tunnel Syndrome**

Carpal Tunnel syndrome is another very common work related condition which can be improved by treatment with laser therapy. The key to getting success when treating this condition is to use a broad approach to treatment. Just treatment of the carpal area may not yield results, as often this condition can stem from irritation of the cervical spine region. One study showed by treating the spinous processes, the pain and tingling was alleviated (Chermanz *et al.* 1997).

A very nice study showing long term results was done by Neaeser, *et al.* This study showed significant decreases in Melzack pain score, median nerve sensory latency, Phalen sign and Tinel sign, post-real treatment series but not seen post-sham treatments. Patients were able to perform prior work (computer typist, handyman) and their condition remained stable for 1-3 years (Naeser 2002).

As with many conditions, laser treatment of carpal tunnel syndrome, should be complimented by exercise and other standard protocols. Conditioning and changes in work habits are imperative to success and full resolution. As mentioned earlier, treating a broad area and including the nerve route, when treating carpal tunnel will ensure rapid and consistent results.

**NECK AND BACK PAIN**

Neck and back pain are very common, often difficult to find a specific cause to the pain and always difficult to treat. The pain can often be nonspecific, making both diagnostics and treatments very challenging. Lasers have been shown to be effective when used in the treatment regime for these areas (Barnsley *et al.* 2006; Bjordal *et al.* 2003). A recent meta-analysis of clinical studies using lasers, concluded that laser therapy reduces pain immediately after treatment in both acute and chronic neck pain and pain relief lasted up to 22 weeks after treatment (Bjordal *et al.* 2009).

A recent pilot study, being done by the Health Sciences Department of Colorado University, Denver, compared the pain relief obtained for nonspecific lower back pain between manipulation with Class IV laser therapy versus manipulation alone. The manipulation + laser group had significantly less pain at week 4. With both neck and back pain it is important to use a laser system which has appropriate penetration to reach deep tissues.
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Since laser therapy can relieve pain and increase blood flow, it will help to increase mobility for neck and back patients. Acute neck and back pain will respond to laser treatments very quickly, many times a positive response is seen after the first treatment. For more chronic conditions, it can take longer to see an effect, 3 to 5 treatments to even see a small benefit, and it may take up to 12 treatment sessions, in order to see a significant improvement. Working soft tissue while delivering therapeutic laser will also help to improve outcomes in these challenging cases. (See Fig. 4) This treatment approach is the key to having prolonged results. The combination of laser treatments, stretching, and exercise can have a major effect when treating patients with neck and back pain.

**POST SURGICAL APPLICATIONS**

Integrating laser therapy into post-surgical rehab can lead to much quicker and better overall outcomes. By using the laser immediately post-surgery, you will be able to reduce inflammation and pain. Since the laser also has tissue healing effects, the surgical site will improve faster, and there may be less scarring from the surgical incisions. Post rotator cuff repair and post anterior cruciate ligament repair are two procedures which adding laser therapy to the post-surgical rehabilitation plan, can dramatically improve the healing rate.

Patients will be more compliant to exercise, stretching, etc. since after the laser treatment they will have much better range of motion and less pain. Most surgical rehab programs can benefit greatly by adding laser therapy.

**TREATMENT BASICS**

When treating patients, it is critical to understand the overall diagnosis and work laser therapy into the rehabilitation program. A broad area should be treated as well as treating any potentially contributing muscle or joint. Fig. 3 shows a typical area which would be treated in the case of epicondylitis. When using a laser with output power of greater than 4W, or anytime the patient feels any warmth, a scanning method should be used. The patient should feel soothing warmth during treatment, this sensation should never be more than a pleasant warmth. If the temperature is uncomfortable, the output power should be reduced. These higher power laser units will allow for a broader and faster treatment.

**Figure 3:** Comprehensive treatment area for laser treatment of epicondylitis

Scanning of the area with the laser should be done in a grid type pattern in order to ensure comprehensive coverage of the affected area. Some laser systems allow the handpiece to be placed in contact with the patient’s tissue. In this case some manual manipulation or massage can be done while delivering therapeutic laser treatment (see Fig. 3). This can be a very effective approach when treating deep tissue conditions such as muscle or tendon tears or strains. Slight passive range of motion should be used when possible, during the last few minutes of treatment. Treatment of any associated trigger points with the laser is also a very effective way to enhance therapeutic results. Many therapists will combine soft tissue work after laser therapy. Another common adjunct therapy is to use TENS or e-stim after completing laser therapy.
It is typically recommended that laser therapy be done every other day for a three week period, for a total of 6 to 9 treatments, depending on the condition, and if it is acute or chronic. When appropriate, laser treatments can be given on a daily basis. If patients are in an environment where treatment is given every day, then it is recommended to treat with the laser on a daily basis. Acute conditions will respond very quickly to laser treatment and a significant benefit may be realized after the initial treatment. Typically a total of 6 treatments will be needed to see major improvement. Chronic conditions will take longer to respond and may take up to 3 treatments to realize any benefit and as many as 12 treatments to see significant outcomes.

Another advantage of using laser therapy is that there are very few contraindications. The contraindications which most manufacturers lists are, don't treat pregnant patients, don't treat patients who are taking any photosensitive medication; don't treat patients with cancer, don't treat over open growth plates, don't treat the eyes, don't treat the testicles, don't treat over any active hemorrhaging. Eye safety is the biggest precaution when performing laser therapy. Appropriate eye wear supplied with the laser should be worn by the clinician and the patient when treating. The eye should never be treated and when treating conditions around the face, specific eye wear, like metal eye shields must be utilized. Most contraindications listed for laser therapy are based on prudence and not on the results of studies. For comparison, cosmetic lasers such as skin resurfacing or hair removal systems, are very powerful, hundreds of times more power than even the most powerful therapeutic lasers. Even at these high powers and large dosages used in these types of ablative procedures, there have been very few side effects out of millions of treatments.

Laser therapy treatments are very easy to administer, and depending on the power level of the laser being used, treatment times take less than 10 minutes for most peripheral conditions and less than 15 minutes when treating a large area like the back or hip. The laser is easy to integrate into standard treatment protocols in a clinic. Uniform administration is achieved without requiring a high level of technical skill. Patients enjoy treatments, and will mostly respond very quickly, leading to faster more effective outcomes and enhanced compliance.

CONCLUSION

The future of laser therapy will be an exciting one. Preliminary studies are showing promising results when treating conditions such as peripheral neuropathies, strokes, and many other debilitating conditions. Fundamental studies in laboratories are continuing to refine our understanding of the mechanisms of action of laser therapy. The results of these laboratory studies need to be followed up with the appropriate animal models and then followed through to good scientifically sound, clinic based studies with measurable outcomes. As we learn more, we will be able to refine device specifications and protocols for clinicians to have the appropriate tool for treating specific conditions. The field of biophotostimulation is growing, and will continue to find new applications where lasers and other light devices can be used to address a variety of medical issues. Multidisciplinary collaboration will lead to faster discoveries and better therapeutic tools.

When implementing laser therapy in the clinical environment, you need to make sure you use the right tool for the right job. You need to take into account the types of conditions you are treating and the time you can afford treating those conditions. Lasers can be an integral tool for treating the majority of rehab and workman’s compensation
related conditions. This tool, like all others, must be used appropriately in your treatment regime to maximize overall outcomes. As discussed above, the laser will help compliance with other parts of your treatment program, helping to expedite positive outcomes and getting people back to in the game and back to work. Laser therapy can be an important modality when treating both acute and chronic work related injuries.

REFERENCES


