# Accelerated Wound Healing Through Photobiomodulation

Ronald J. Riegel, DVM
February, 2013

Many types of wounds cross the exam table each day. Some are intentional (surgical), some traumatic, others dermatological, a percentage infected, and all painful. Each wound is unique, yet they all have one entity in common: they all benefit from laser therapy.

All three phases of wound healing: inflammatory, proliferative, and remodeling are influenced by the biochemical cascade of events inititiated by photobiomodulation. With laser therapy, each phase of the dynamic process of restoring the individual cellular structures and organizing tissue repair is accelerated resulting in a restoration to the earlier natural state.

Photonic energy stimulates the photoreceptors on the mitochondria resulting in a decreased reaction time for cytochrome c to become cytochrome c oxidase. As a result of this reaction, there is a release of Nitric oxide and an increase in ATP synthesis.[1] In conjunction with all of the actions of NO, i.e. pain relief, the increased levels of ATP provide energy at the cellular level to initiate a return to normal metabolic function within the compromised cells.

The inflammatory phase is the body's natural response to injury. After the initial infliction of a wound, the blood vessels in the wound bed contract and a clot is formed. Once hemostasis has been achieved, through the use of ice and/or pressure, laser therapy should be applied. This will cause an immediate vasodilatation within the vasculature which allows essential cells, antibodies, white blood cells, growth factors, enzymes, and nutrients to reach the wound.[2,3,4]

It is in this inflammatory stage that the characteristic signs of inflammation can be seen. These may include erythema, edema, heat, pain, and swelling of the surrounding tissues. Photobiomodulation of the tissues relieves pain,[5] reduces swelling, and causes vasodilatation which allows the phagocytic cells, neutrophils and macrophages to invade the area to autolyse and devitalize any damaged cells or tissues.[6,7]

In summary, the effects of photobiomodulation on the inflammatory phase of wound healing are:

- Decreased duration of this phase
- Vasodilation
- Increased phagocytic activity

The proliferative phase is characterized by angiogenesis, collagen deposition, granulation tissue formation, epithelialization, and wound contraction. Application of photonic energy accelerates the process of angiogenesis.[8] In fibroplasia and granulation tissue formation, fibroblasts grow and form a new, provisional extracellular matrix through the formation of collagen. Photobiomodulation of these regenerative cells results in an increased activation rate which allows tendons, ligaments, bone, muscle, and other tissues to heal at an accelerated rate.[9,10,11] Concurrently, re-epithelialization of the epidermis occurs, in which epithelial cells proliferate and migrate atop the wound bed. [12]

The effects of photobiomodulation on the proliferative phase of wound healing are:

- Decreased duration of this phase
- Production of growth factors
- Fibroblast growth and migration
- Formation of collagen
- Epithelialization

When the levels of collagen production and degradation equalize, the remodeling or maturation phase of tissue repair begins. The application of laser therapy accelerates mitosis and collagen synthesis.[13,14] During maturation, type III collagen, which is prevalent during proliferation, is replaced by type I collagen. Originally disorganized collagen fibers are rearranged, cross-linked, and aligned along tension lines.[15] This event results in an increase in the tensile strength of the wound and a reduction of scar tissue formation.[16]

Dosage requirements are unique to each wound. Very superficial wounds may need only .5 to 2.5 J/cm$^2$ to respond. Deeper wounds may require 2.5 to 5 J/cm$^2$.[14,17] These dosages should be administered aggressively initially, i.e. every day or at least every other day and then followed by successive treatment until the wound is completely healed.

All phases and stages of wound healing benefit from laser therapy. Each type of wound will heal at an accelerated rate due to the biochemical cascade of events induced by photonic energy at the cellular level. This versatile modality is becoming the standard of care for wounds and many other maladies.

References:

1. Jiang, N.,Cooper, B.Y., Nemenov, M.I. Non-invasive diode laser activation of transient receptor potential proteins in nociceptors. Proc. Of SPIE Vol. 6428, 64809, 2007.

2. Chow R. Phototherapy and the peripheral nervous system. Photomed Laser Surg. 2011 Sep;29(9):591-2

3. Yan W, Chow R, Armati PJ. Inhibitory effects of visible 650-nm and infrared 808-nm laser irradiation on somatosensory and compound muscle action potentials in rat sciatic nerve: implications for laser-induced analgesia. J Peripher Nerv Syst. 2011 Jun;16(2):130-5.

4. Chow R, Armati P, Laakso EL, Bjordal JM, Baxter GD. Inhibitory effects of laser irradiation on peripheral mammalian nerves and relevance to analgesic effects: a systematic review. Photomed Laser Surg. 2011 Jun;29(6):365-81.

5. Chow RT, Johnson MI, Lopes-Martins RA, Bjordal JM. Efficacy of low-level laser therapy in the management of neck pain: a systematic review and meta-analysis of randomized placebo or active-treatment controlled trials. Lancet. 2009 Dec 5;374(9705):1897-908. Epub 2009 Nov 13. Review. Erratum in: Lancet. 2010 Mar 13;375(9718):894.

6. Eells, J. T. et al. Proceedings National Academy of Science 2003; 100:3439-3444

7. T.I. Karu. Low power laser therapy. In: Biomedical Photonics Handbook. Ch. 48, Editor-in-chief Tuan Vo-Dinh, Boca Raton: CRC Press. 2003.

8. Huang Y-Y, Chen A C-H, Carroll JD. Hamblin MR. Biphasic dose response in low-level light therapy. Dose Response, 2009, 7, 358-383.

9. Chung H, Dai T, Sharma SK, Huang YY, Carroll JD, Hamblin MR. The Nuts and Bolts of Low-level Laser (Light) Therapy. Ann Biomed Eng. 2012 Feb;40(2):516-33.

10. Montesinos M 1988, 'Experimental effects of Low Power Laser in Encephalon and Endorphin Synthesis LASESR', Journ Eur Med Laser Ass., vol. 1, no. 3, pp. 2-7.

11. Oswald Steward: Functional neuroscience (2000), page 116

12. Hamblin, M. R., Demidova-Rice, T. N. Cellular Chromophores and Signaling in Low Level Light Therapy. Wellman Center for Photomedicine, Mass. General Hospital. Proc. of SPIE Vol. 642802, 2007

13. Huang Y-Y, Chen AC, Carroll JD, Hamblin MR. Biphasic Dose Response in Low Level Light Therapy, Sep 1; 7(4): 358-83.

14. Hopper RA, Garthwaite J. J Neurosci. 2006 Nov 8;26(45):11513-21

15. Rochkind S. and Ouaknine GE.(1992) "Review: new trend in neuroscience: low-power laser effect on peripheral and central nervous system (basic science, preclinical and clinical studies)". Neurological Research 14:2-11.

16. Rochkind S., Nissan M., Barr-Nea L., Razon N., Schwartz M., Bartal A . (1987) "Response of peripheral nerve to HeNe laser: experimental studies" Lasers in Surgery and Medicine 7:441-443.

17. Rochkind S.(1992) "Spinal cord and brain transplantation benefitted by low-power laser irradiation." Lasers in Medical Science 7:143-151.

18. Pomeranz, B. and Chiu, D. “Naloxone Blockade of Acupuncture Analgesia: Endorphin Implicated.” Life Sci 1976 Dec. 1; 19(11) 1757-62.

19. Chow, R.T. and Barnsley, L, 2005. Systematic Review of the Literature of Low-Level Laser Therapy(LLLT) in the Management of Neck Pain. Lasers Surg Med 2005 Jul; 37(1): 46-52.

20. Huang Y-Y, Chen AC-H, Wu Q, Sharma SK, Hamblin MR. Comparison of cellular responses induced by low level light in different cell types. In: Hamblin MR, Anders JJ, Waynant RW, Editors. Mechanisms for Low-Light Therapy V, Bellingham, WA, The International Society for Optical Engineering,. Proc SPIE 2010, Vol. 7552: 75520A-1

21. Chow RT, David MA, Armati PJ. 830 nm laser irradiation induces varicosity formation, reduces mitochondrial membrane potential and blocks fast axonal flow in small and medium diameter rat dorsal root ganglion neurons: implications for the analgesic effects of 830 nm laser. J Peripher Nerv Syst. 2007 Mar;12(1):28-39.

22. OHNO-SHOSAKU, T., SAWADA, S. & YAMAMOTO, C. (1995). Presynaptic modulation of glutamatergic and GABAergic transmissions in rat cultured hippocampal neurons. 4th IBRO World Congress of Neuroscience, Kyoto, Japan, Abstract P176.

23. Nicolau, R.A., Martinez, M.S., Rigau, J. and Tomás, J. Neurotransmitter release changes induced by low power 830 nm diode laser irradiation on the neuromuscular junctions of the mouse. Lasers Surg Med 2004: 35(3): 236-41.

24. Xingjia, W.U., Alberico, S., Erbele, I., Moges, H., Pryor, B., Anders, J. Differential Response of Neurons to Light Irradiation in an in vitro Diabetic Model. Dept. of Anatomy, Physiology and Genetics, USUHS, Bethesda, MD. ASLMS proceedings 2010.

25. Huang YY, Tedford CE, McCarthy T, Hamblin MR. Low level laser therapy reduces oxidative stress in cortical neurons in vitro. In : Hamblin MR, Anders JJ, Waynant RW, Editors. Mechanisms for Low-Light Therapy VII, Bellingham, WA, The International Society for Optical Engineering, Proc SPIE 2012

26. Naeser, M. A., Neurological rehabilitation: acupuncture and laser acupuncture to treat paralysis in stroke, other paralytic conditions, and pain in carpal tunnel syndrome. J Alt Compl Medicine. 1997;3:425-428

27. Chow, R., Armati, P., Laakso, E-Liisa, Bjordal, J.M., Baxter, D.G. Inhibitory Effects of Laser Irradiation on Peripheral Mammalian Nerves and Relevance to Analgesic Effects: A Systematic Review. Photomedicine and Laser Surgery. Volume X, Number X, 2011. Pp. 1–17

28. Anders, J.J., Geuna, S., Rochkind, S. Phototherapy promotes regeneration and functional recovery of injured peripheral nerve. Neurological Research, 2004, Volume 26, March.

29. Bjordal J. M., Johnson M.I., Iversen V., Aimbire F., Lopes-Martins, R.A.B. Photomedicine and Laser Surgery. 2006, 24(2): 158-168. doi:10.1089/pho.2006.24.158.

30. Weersink, R., White, R., Lilge, L. Light dosimetry for Low Level Laser therapy: Accounting for difference in tissue and depth. Proc. of SPIE Vol. 6428,642803. 2007.

31. Chow, R.T., Johnson, M., Lopes-Martins, R., Bjordal, J.M.. Efficacy of low-level laser therapy in the management of neck pain: a systemic review and meta-analysis of randomized placebo or active-treatment controlled trials. Lancet 2009; 374: 1897-908.