POST-OP REHAB RESEARCH ABSTRACTS

THE PHOTOTHERAPY EXPERTS

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Post-Op Rehab

Bone Stimulation by Low Level Laser – A Theoretical Model for the Effects

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Presented at the WALT annual conference, Japan.

The anecdotal and researched evidence for the effects of Low Level Laser Therapy (LLLT) on the stimulation of bone have been reported for over 20 years. This has been in the form of local as well as systematic effects – including contra-lateral effects. Reports of stimulation of rabbit radii fractures and mice femurs were made as early as 1986 and 1987 with irradiated bones healing faster than controls and contra-lateral non-treated fractures similarly demonstrating faster healing times. Over the following decade and a half, further studies have also investigated and demonstrated that LLLT is effective for the stimulation of bone tissue.

The reasons for this have been attributed to the general effects of LLLT and its ability to increase the rates of healing through mitochondrial ATP production and alteration in the cellular lipid bi-layer. Additional hypothesis include the subsequent capacity of irradiated cells to alter their ion exchange rate and thus influence the catalytic effects of the specific enzymes and substrates. These in turn initiate and promote the healing process completing the cascading cycle of events.

In the area of bone specific research, Dr. Tony Pohl of the Royal Adelaide Hospital in South Australia has provided a new theory that postulates that the majority of fluid transfer and exchange within living bone is predominantly influenced by the lymphatic circulation.

LLLT is well documented and known as having effects that influence the lymphatic circulation and wound healing process. A coupling of these two areas of theory can demonstrate a positive description and explanation of the predominant effects of LLLT in bone stimulation. In reality, LLLT's effects on bone may well be a further consequence of its actions on the lymphatic circulation.

Reports of stimulation of Rabbit radii fractures were made by Tang in 1986 and similar reports by Trelles in 1987 on mice femurs. In both situations the irradiated bones healed faster than the controls. In another study by Hernandez-Ros, in 1987, LLLT demonstrated stimulation of fresh fractures on Sprague-Dawley rats that were fractured bilaterally. The unexpected results of this study were that the contra-lateral fractured non-treated limb also healed faster than the control group. Over the following decade and a half further studies (Yamada 1991; Pyczek, Sopala et al. 1994; Ozawa 1995; Horowitz 1996; Yaakobi 1996; Saito and Shimizu 1997) have also investigated and demonstrated that LLLT is effective for promoting the stimulation of bone healing. Recently Nicolau and colleagues (2002) from Brazil demonstrated the positive effect of LLLT on the stimulation of bone in mice with latent promotion of bone remodulation at injury sites without changes in bone architecture, increased bone volume and increased osteoblast surface through increased resorption and formation of bone with higher apposition rates. A positive effect on bony implants has been demonstrated by Dörtbudak (2002) and Guzzardella (2003). The effect of laser irradiation on osteoblastic cells has been reported by Yamamoto (2001) and Guzzardella (2002).

The reasoning for this amelioration in all experimental circumstances, based on electron microscopy as well as macroscopic histological evidence, was concluded to be due to i.e. improved vascularisation as a consequence of blood vessel formation, absorption of the haematoma, macrophage action, fibroblast proliferation, chondrocyte activity, bone remodeling from increased osteoblastic activity and deposition of calcium salts.

These changes and evidence based studies attribute the macro- and microscopic effects to the known and accepted general actions of LLLT and its ability to increase rates of healing through stimulation of ATP production, (Karu 1989; Smith 1990) promoting repair and polarization of the cellular lipid bilayer (Fenyo 1990) as well as LLLT's capacity to affect cells through alterations in their exchange rate of ions (Robinson and Walters 1991) and influences the catalytic effects of the specific enzymes and substrates (Pouyssegur 1985; Karu 1988) which in turn initiate and promote the healing process.

More recent work by Dr. Tony Pohl, an internationally renowned Orthopaedic Surgeon from the Royal Adelaide Hospital in South Australia and lecturer at the Adelaide and South Australian Universities, has given rise to a new theory on bone circulation through reconsideration of fluid and protein transfer within bone (Pohl 1999). This theory suggests that the general understanding of the circulatory action within bone has been incorrect. Pohl postulates that the majority of fluid transfer and exchange within the living bone is predominantly influenced by the lymphatic rather than the vascular circulation. This is justified through studies on bone fluid input and output levels that have demonstrated that the venous and arterial aspect of circulation alone cannot account for the demonstrated levels of output nor the presence of free radical molecules which exceed those of the vascular input. Furthermore, the diameter of large protein cells within the bone exceed the diameter of the vessels that form the terminal aspects of the circulatory system making it impossible for them to have been delivered via this system. Consequently, an additional circulatory system must be present that will account for both the increased output and the presence of the large diameter protein cells as well as the free radicals.

If LLLT is then considered within the context of this new theory on bone circulation and the contribution of the lymphatic circulation then a further logical reasoned deduction for the action of LLLT on bone stimulation can be made. LLLT has a well documented and known effect influencing the lymphatic circulation. This has been demonstrated from the early works of Lievens, (1985) that demonstrated the influence of "Laser Irradiation" on the motricity of the lymphatic system and on the wound healing process. This is supported by several wound studies that demonstrate that the levels of protein rich exudates in non-healing wounds increase markedly from exposure to LLLT. This demonstrated action is determined to be as a result of the increase in lymphatic circulation (Robinson and Walters 1991; Gabel 1995). More recent work at the Flinders Medical Center in Adelaide South Australia has been completed and presented at the World Association of Laser Therapy conference in Tokyo Japan (Anderson, Carati et al. 2002). This study has demonstrated the positive effects of LLLT on the lymphatic circulation and its consequential benefits to the post mastectomy patient.
An understanding of the existing knowledge of the effects of LLLT on the lymphatic system combined with the hypothesis of bone fluid transport provides a coupled theory that would demonstrate a positive description and explain of the predominant effects of LLLT in bone stimulation.

In the trauma situation of direct or indirect damage to the bone, including fractures and periosteal induced damage such as stress fractures, the tissue damage leads to compromises that include but are not limited to, physical blockage from the trauma and waste / debris, increased fluid and circulatory viscosity from added cellular content within the lymphatics, lower speed motility and energy deficit in the tissue and cells from the loss of ATP production as a general effect from the trauma, cell changes and inability of mitochondria to function at the normal higher level to promote self repair and regeneration.

LLLT with its known general effects and specific direct effects on the lymphatic system would act to stimulate mitochondria ATP that increases cellular and circulatory motility as well as directly influencing lymphatic flow. LLLT also promotes increased permeability in interstitial tissue and fascial layers (Gabel 1995) reducing stagnation and blockage. These actions would assist the increase in lymphatic flow and consequently the circulation within the affected bone. There is also a hypothetical potential that the presence of LLLT by increasing lymphatic circulation does so by virtue of an increase in the diameter of the lymphatic vessels, not just by increased flow rates within the vessel at an unchanged diameter. This diameter increase, if definitively present, would also explain the presence of large diameter protein cells within the normal bone circulation that cannot be attributed to the vascular circulation and would additionally explain a facilitated process for removal of debris and larger protein cells passing out of traumatized areas that is additionally stimulated by the use of LLLT.

Stimulation of bone healing by LLLT has till now has been generally classified as a consequence of the general healing effects of LLLT. In reality LLLT's effect on bone may well be a further consequence of its actions on the lymphatic circulation.

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The Effects of Infrared Diode Laser Irradiation on the Duration and Severity of Post Operative Pain: A Double Blind Trial

Laser Therapy 1992, 4(4): 145 – 9.

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The trial was designed to test the hypothesis that LLLT reduces the extent and duration of post operative pain. Twenty consecutive patients for elective cholecystectomy were randomly allocated for either LLLT or as control. The trial was double blind. Patients for LLLT received 6 - 8 minutes treatment (GaAlAs: 830 nm: 60 mW CW) to the wound area immediately following skin closure prior to emergence from GA. All patients were prescribed on demand post operative analgesia (IM or oral according to pain severity). Recordings of pain scores (0 - 10) and analgesics requirements were noted by an independent assessor. There was a significant difference in the number of doses of narcotic analgesics (IM) required between the two groups. Controls n = 5.5; LLT n =2.5. No patient in the LLLT group required IM analgesia after 24 hours. Similarly the requirement for oral analgesia was reduced in the LLLT group. Controls n = 9; LLLT n = 4. Control patients assessed their overall pain as moderate to severe compared with mild to moderate in the LLLT group.

The results justify further evaluation on a larger trial population.

Preoperative Low Level Laser application to reduce post-operative pain in patients receiving winograd type of partial matrixectomy surgery of hallux.

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Introduction: Low level laser was introduced as a part of our surgical regime to assist with post operative healing following digital surgery. It was observed that fewer patients returned for post-operative redressings complaining of post operative pain. A pilot study has been undertaken to report the level of pain experienced by patients who received a Winograd type partial matrixectomy of the hallux. To reduce the number of extraneous variables the surgery was undertaken in the same setting with the same surgeon and staff with the same operative instructions provided. Laser Therapy was used within 30minutes of surgery.

Methodology: Each patient was placed on the operating table in the supine position. The laser probe was placed against the epidermis and applied at 1.8J/cm 2 ,5.7Hz, with wavelength 830 nm and output power 40mW. from a "Maestro", laser manufactured by Medicom, Praha , Czech Republic . The probe was applied at 2 points at each surgical site and at one point at each of the two sites for undertaking the digital anaesthetic block at the proximal aspect of the great toe. A mixture 5cc of 50/50 2% plain xylocaine and 0.5% Marcaine was injected dorsal to plantar into the proximal aspect of the great toe. The feet were prepped and draped in the normal sterile manner. A partial nail plate avulsion was achieved with removing 2-3mm of the fibular and/or tibia nail borders. A Betadine scrub was then undertaken. This was followed with an incision proximal to the proximal end of the matrix along the course of the new nail edge to the distal end of the nail. A second incision was made in a semi elliptical fashion from the proximal end of the first incision along the course of the original nail border joining with the distal end of the first incision. Both incisions were made down to bone and all tissue was removed. Matrix within the cavity was removed. Saline irrigation was applied to the cavity. The cavity was closed with Proline sutures at proximal and distal ends with steristrips across the nail section. The tourniquet was released and blood flow was observed to return to the area. A dressing of Betadine and Bactagras was applied with 4 x 4 sterile gauze, followed by gauze bandage and Coban.

Each patient was given oral and written instruction and an appointment for redressing in 5 to 7 days. Instructions included the suggestion that the patient take Panadol. Each patient appeared tolerated the procedure well and left the surgery ambulated.

One returning to the surgery after five to seven days for re-dressings, each patient scored on a 10cm Visual Analogue Scale, the level that best illustrated the highest level of pain that they experienced following the operation.

Results: Those in the Laser group (N=12) scored an average of 2.1 whereas those in the Non laser group scored an average 7.2 (N=3).

Conclusion: The level of self medication for pain relief was not monitored and no breakdown of ethnicity, age or sex was recorded for any patients. The authors note the small number of subjects in this study, in particularly the “No Laser” group. Given the low pain scores of the laser group reporting low pain scores, it is expected that these authors will afford all future eligible patients the opportunity of pre-operative laser therapy for this and other types of surgery. Other practitioners who do not use laser, who use like surgical techniques are encouraged to conduct a similar study on their patients, to make a comparison with the current study and to report their findings.

Advances in Laser Therapy for Bone Repair

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During the last decade, it was discovered that low-power laser irradiation has stimulatory effects on bone cell proliferation and gene expression. The purposes of this review are to analyze the effects of low- power laser irradiation on bone cells and bone fracture repair, to examine what has been done so far, and to explore the additional works needed in this area. The studies reviewed show how laser therapy can be used to enhance bone repair at cell and tissue levels. As noted by researchers, laser properties, the combinations of wavelength and energy dose need to be carefully chosen so as to yield bone stimulation.

Effects of Visible NIR Low Intensity Laser on Implant Osseointegration In Vivo.

Laser Med Surg Abstract issue, 2002: 11.

Blay A, Blay C C, Groth E B et al.

The effects of 680 and 830 nm lasers on osseointegration was studied by Blay. 30 adult rats were divided into three groups; two laser groups and one control. The rats in the two laser groups had pure titanium Frialit-2 implants implanted into each proximal metaphysis of their respective tibias, inserted with a 40 Ncm torque. The initial stability was monitored by means of a resonance frequency analyzer. Ten irradiations were performed, 48 hours apart, 4 J/cm2 on two points, starting immediately after surgery. Resonance frequency analysis indicated a significant difference between frequency values at 3 and 6 weeks, as compared to control.

At 6 weeks the removal torque in the laser groups was much higher than in the control group.

Biomodulatory Effects of LLLT On Bone Regeneration

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Tissue healing is a complex process that involves local and systemic responses. The use of Low Level Laser Therapy (LLLT) for wound healing has been shown to be effective in modulating both local and systemic response. Usually the healing process of bone is slower than that of soft tissues. The effects of LLLT on bone are still controversial as previous reports show different results. This paper reports recent observations on the effect of LLLT on bone healing. The amount of newly formed bone after 830nm laser irradiation of surgical wounds created in the femur of rats was evaluated morphometricaly. Forty Wistar rats were divided into four groups: group A (12 sessions, 4.8J/cm2 per session, 28 days); group C (three sessions, 4.8J/cm2 per session, seven days). Groups B and D acted as non-irradiated controls. Forty-eight hours after the surgery, the defects of the laser groups were irradiated transcutaneously with a CW 40mW 830nm diode laser, (f~1mm) with a total dose of 4.8J/cm2. Irradiation was performed three times a week. Computerized morphometry showed a statistically significant difference between the areas of mineralized bone in groups C and D (p=0.017). There was no significant difference between groups A and B (28 days) (p=0.383). In a second investigation, we determined the effects of LLLT on bone healing after the insertion of implants. It is known that dental implants need four and six months period for fixation on the maxillae and on the mandible before receiving loading. Ten male and female dogs were divided into two groups of five animals that received the implant. Two animals of each group acted as controls. The animals were sacrificed 45 and 60 days after surgery. The animals were irradiated three times a week for two weeks in a contact mode with a CW 40mW 830nm diode laser, (f ~1mm) with a total dose per session of 4.8J/cm2 and a dose per point of 1.2J/cm2.

The results of the SEM study showed better bone healing after irradiation with the 830nm diode laser. These findings suggest that, under the experimental conditions of the investigation, the use of LLLT at 830nm significantly improves bone healing at early stages. It is concluded that LLLT may increase bone repair at early stages of healing.

Bone Repair of Periapical Lesions Treated or Not With Low Intensity Laser (λ, =904 NM)

American Society for Laser Medicine and Surgery Abstracts
Annual Conference Dallas, Texas 2004 p. 81,303

G.R. Sousa,. M.S.Ribeiro,and E. B. Groth

Mestrado Profissionalizente Lasers em Odontologia,

The purpose of this study was to evaluate the influence of low intensity laser on the bone repair over periapical lesions of dental elements. Fifteen patients with a total of eighteen periapical lesions were selected and divided into two groups. The University of Sao Paolo, Dentistry School's Research Ethics Committee, granted ethical approval. Lesions of the control group was submitted to endodontic treatment and/or periapical surgery and the lesions of the experimental laser group, were submitted to the same procedures of the first group but also irradiated by low intensity laser. It used a 904 nm wavelength laser GaAs, employing 11 mW of power delivered by a fiber optic system, irradiation continuous and contact mode, using a fluency of 9 J/cm2. The aforementioned treatment was repeated for 10 sessions with intervals of 72 hours between each session. Bone repair was evaluated through lesion measurements, which were accessed from the X ray pictures. These were statistically analyzed.

Results showed a significant difference between the laser and control groups ($p<0,10$), emphasizing that the laser group presented a significant reduction of the lesion areas. X-ray confirmed this.

Low-level laser therapy stimulates bone-implant interaction: An experimental study in rabbits

Clin Oral Implants Res. 2004 Jun; 15 (3):325-32.

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The aim of the present study was to investigate the effect of low-level laser therapy (LLLT) with a gallium-aluminium-arsenide (GaAlAs) diode laser device on titanium implant healing and attachment in bone. This study was performed as an animal trial of 8 weeks duration with a blinded, placebo-controlled design. Two coin-shaped titanium implants with a diameter of 6.25 mm and a height of 1.95 mm were implanted into cortical bone in each proximal tibia of twelve New Zealand white female rabbits (n=48).
The animals were randomly divided into irradiated and control groups. The LLLT was used immediately after surgery and carried out daily for 10 consecutive days. The animals were killed after 8 weeks of healing. The mechanical strength of the attachment between the bone and 44 titanium implants was evaluated using a tensile pullout test.
Histomorphometrical analysis of the four implants left in place from four rabbits was then performed. Energy-dispersive X-ray microanalysis was applied for analyses of calcium and phosphorus on the implant test surface after the tensile test. The mean tensile forces, measured in Newton, of the irradiated implants and controls were 14.35 (SD+/-4.98) and 10.27 (SD+/-4.38), respectively, suggesting a gain in functional attachment at 8 weeks following LLLT (P=0.013). The histomorphometrical evaluation suggested that the irradiated group had more bone-to-implant contact than the controls. The weight percentages of calcium and phosphorus were significantly higher in the irradiated group when compared to the controls (P=0.037) and (P=0.034), respectively, suggesting that bone maturation processed faster in irradiated bone.

These findings suggest that LLLT might have a favorable effect on healing and attachment of titanium implants

Laser Therapy - Positive Double Blind Studies

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