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Wound Healing: Clinical Evidence and Mechanisms of Action of Far Infrared Therapy

1. **Biological effect of far-infrared therapy on increasing skin microcirculation in rats**
(Yu, Chiu et al, 2006)
"FIR Therapy promoted skin blood flow through a mechanism closely related to L-arginine/NO pathway."

2. **Promotive effects of far-infrared ray on full-thickness skin wound healing in rats**
(Toyokawa, Matsui et al, 2003) "The (Toyokawa) study demonstrated the biological effects of FIR on promoting skin wound healing with histological evidence of greater collagen regeneration and infiltration of fibroblasts expressing transforming growth factor-1 (TGF-1) in wounds" (Chen 2015)
"Stimulation of the secretion of TGF-β1 or the activation of fibroblasts may be considered as possible mechanisms for the promotive effect of FIR on wound healing independent of skin blood flow and skin temperature." Toyokawa, Matsui et al, 2003

3. **Laser therapy converts diabetic wound healing to normal healing** (Al-Watban 2009)
Animal models were used to evaluate the wound healing effects of phototherapy in the forms of laser therapy and LED light therapy in the near-infrared spectrum. Animal models of full-thickness wound, burn, diabetic full-thickness wound, and diabetic burn were used. Phototherapy was shown to accelerate the healing in the diabetic animal models so they were comparable to those of the non-diabetic animal models. "633-nm laser therapy given three times per week at 4.71 J/cm(2) per dose for diabetic burns, and three times per week at 2.35 J/cm(2) per dose for diabetic wound healing are recommended as actual doses for human clinical trials, especially after major surgery in those with impaired healing, such as diabetics and the elderly."

4. **Activation of latent TGF-β1 by low-power laser in vitro correlates with increased TGF-β1 levels in laser-enhanced oral wound healing** (Arany, Nayak et al, 2007)
Low-power laser irradiation is capable of activating the latent TGF-β1 complex in vitro and its expression pattern in vivo suggests that TGF-β play a central role in mediating the accelerated healing response.

5. **Mitochondrial signal transduction in accelerated wound and retinal healing by near-infrared light therapy** (Eells, Wong-Riley et al. 2004)
"…we propose that NIR-LED photobiomodulation represents an innovative and non-invasive therapeutic approach for the treatment of tissue injury and disease processes in which mitochondrial dysfunction is postulated to play a role including diabetic retinopathy, age-related macular degeneration, Leber's hereditary optic neuropathy and Parkinson's disease."

6. **Successful treatment of diabetic foot ulcers with low-level laser therapy** (Kazemi-Khoo 2006)
A combined treatment of red light (660nm) on the ulcer bed, infrared laser (890nm) and intravenous laser irradiation (650nm) on the ulcer margins, and infrared laser acupuncture was used on 7 diabetic patients with grade II and III diabetic foot ulcers. Complete healing of the ulcers was achieved after approximately 19 sessions with reported side effects. These results suggest that "low-level laser therapy could be a safe and effective method for treatment of diabetic foot ulcers."

7. **Effects of infrared radiation on skin photo-aging and pigmentation** (Lee, Roh et al 2006)
"These results suggest that infrared radiation may have beneficial effects on skin texture and wrinkles by increasing collagen and elastin contents from the stimulated fibroblasts. Therefore, skin treatment with infrared radiation may be an effective and safe non-ablative remodeling method, and may also be useful in the treatment of photo-aged skin."

8. **Low level laser therapy for healing acute and chronic wounds - the extendicare experience** (Saltmarche 2008)
The experience of using LLLT of 785 nm on 21 acute and chronic wounds in nursing home residents was presented. Majority of the wounds achieved significant healing and some complete healing, in wounds where improvements were not measurable, their conditions did not worsen either. "The introduction of new, research based technology can potentially positively impact not only costs of chronic wounds, but may offer other indirect benefits in the nursing home settings."

9. **Effect of NASA light-emitting diode irradiation on molecular changes for wound healing in diabetic mice** (Whelan, Buchmann et al 2003)
"We believe that the use of NASA light-emitting diodes (LED) for light therapy will greatly enhance the natural wound healing process, and more quickly return the patient to a preinjury/illness level of activity."

10. **Effect of NASA light-emitting diode irradiation on wound healing** (Whelan, Smits et al, 2001) "LED produced a 47% reduction in pain of children suffering from oral mucositis. We believe that the use of NASA LED for light therapy alone, and in conjunction with hyperbaric oxygen, will greatly enhance the natural wound healing process, and more quickly return the patient to a preinjury/illness level of activity."

11. **Far-Infrared Therapy Promotes Nerve Repair following End-to-End Neurorrhaphy in Rat Models of Sciatic Nerve Injury**. (Chen TY 2015) "FIR is a potentially advantageous therapy because it requires only low-energy light emitted from a radiator; furthermore, irradiation of injured nerves requires no surgical intervention."

    Chen et al used rat model to study the effects of FIR in functional and tissue recovery after bilateral sciatic cord severing.

    (1) *A TY301N therapy unit* (WS Far-Infrared Medical Technology Co., Ltd., Taiwan) was used for the FIR therapy"….

    (2) *No evidence of pain or discomfort and infection*
    "The animal models in this study tolerated the anesthetic and surgical procedures with no sign of infection…" and all wounds healed without complication"

    (3) *Hair regrowth*
    "Our results indicated that FIR irradiation promoted increased weight gain, regrowth of denser glossier hair at 6 weeks"

    (4) *Weight gain and faster wound healing*
    "The weight-change percentages were all slightly higher in the FIR-treated group than in the NI/sham group, and a significant difference was observed at Week 8 ($P < 0.05$). We observed that FIR irradiation caused the wound healing at the site of the sutured skin to heal faster in the NI/FIR group compared with the NI/sham group at Week 1 after surgery"

    (5) *Muscle atrophy at 8 weeks following nerve injury:*
    "Figure 3(a) shows that atrophy of the gastrocnemius muscle occurred 8 weeks following nerve injury… We observed partial atrophy of the gastrocnemius muscles, which was the target muscle of the injured donor nerve in both the NI/sham and NI/FIR groups. Atrophy of the donor muscle likely occurred because of the duration of denervation before reinnervation was fully achieved.

(6) *Gastrocnemius muscle histology:* "The NI/sham group exhibited disseminated myofibril atrophy, cell denaturation and necrosis, as well as inflammatory cell infiltration and proliferation. However, the control biopsy specimens that were removed from the NI/FIR and normal groups exhibited unremarkable pathological changes …and the ultrastructure of myofibrils was clear and orderly when observed with the optical microscope. The sciatic nerve injury caused a reduction in neural innervation of the gastrocnemius muscle, leading to a decrease in muscle weight… In this study, the gastrocnemius muscle weight recovered to 63% of the contralateral side in the NI/FIR group, and it was significantly higher than that observed in the NI/sham group ($P <$ **0.05), indicating enhanced neural recovery and protection against muscle atrophy in the NI/FIR group. These data correlate with our SFI results, indicating that the gastrocnemius** muscle weight recovery might be caused by appropriated reinnervation."

(7) *Nerve regeneration and functional recovery:*
"This study employed a rat model of sciatic nerve injury to investigate the effects of postoperative low-power far-infrared (FIR) radiation therapy on nerve repair following end-to-end neurorrhaphy. Walking-track analysis results showed that the NI/FIR group exhibited significantly higher sciatic functional indices at 8 weeks after surgery ($P < 0.05$) compared with the NI/sham group. The decreased expression of CD4 and CD8 in the NI/FIR group indicated that FIR irradiation modulated the inflammatory process during recovery. Compared with the NI/sham group, the NI/FIR group exhibited a significant reduction in muscle atrophy ($P < 0.05$). Furthermore, histomorphometric assessment indicated that the nerves regenerated more rapidly in the NI/FIR group than in the NI/sham group; furthermore, the NI/FIR group regenerated neural tissue over a larger area, as well as nerve fibers of greater diameter and with thicker myelin sheaths. Functional recovery, inflammatory response, muscular reinnervation, and histomorphometric assessment all indicated that FIR radiation therapy can accelerate nerve repair following end-to-end neurorrhaphy of the sciatic nerve"

(8) *Far infrared therapy summary for nerve, muscle repair and functional return following nerve injury:* "The findings of this study show that FIR radiation treatment is a novel and noninvasive therapeutic modality to improve motor function, accelerate recovery from sciatic denervation induced gastrocnemius muscle atrophy, modulate the inflammatory process during sciatic nerve injury, and enhance nerve regeneration following end-to-end neurorrhaphy in a rat model of peripheral nerve

injury. Future studies using FIR as a noninvasive treatment modality for various peripheral nerve diseases and injuries can lead to the wide acceptance and standardization of this innovative therapy in clinics." Chen T-Y et al, Feb. 2015