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Donor site healing response to low-level laser therapy following skin graft surgery

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Abstract

Introduction. Skin grafting is an essential reconstructive technique for the healing of deep and extensive burns. Donor site problems are common complications after skin graft surgery. Speeding up the healing process at the donor site using low-level laser therapy helps avoid these problems. Objectives: The purpose of this research was to examine the efficacy of low-level laser therapy in promoting donor site healing in burn patients who underwent skin graft surgery.

Methods. Forty patients of both genders (16 male, 24 female) aged 20–40 years suffered full-thickness burns with a total body surface area varying from 20 to 35% and had undergone split-thickness skin graft surgery were selected randomly and divided into two equal groups. The low-level laser therapy group (study group) attended three sessions per week for three weeks, while the placebo group (control group) received sham laser treatments. All patients received conventional medical treatment and traditional wound care (dressing). Photography and J Image software were used to measure wound surface area before the treatment (day 1 post-operative), day 11 post-operative, and day 21 post-operative in both groups.

Results. The study and control groups demonstrated a substantial reduction in wound surface area at day 11 and day 21 post-operative compared with day 1 ($p < 0.001$), with the percentage of improvement of 88.69% and 98.73% and 50.18% and 80.22%, respectively. On day 21 compared to day 11 ($p < 0.001$), the percentage of improvement was 88.81% and 60.30%, respectively. Between-group comparisons revealed a significant decrease in wound surface area at day 11 and day 21 post-operative in the study group compared to the control group ($p < 0.001$).

Conclusions. Low-level laser therapy is an effective modality for enhancing wound healing of the donor site in burned patients undergoing skin graft surgery.

Key words: donor site, low-level laser therapy, skin graft, wound healing

Introduction

Severe burns require a recovery period spanning several months or even years, demanding a substantial amount of patience and resilience. In more severe burn cases, skin grafts and reconstructive procedures become imperative, as spontaneous repair falls short in healing wounds. In situations involving patients with severe burns, the timing of grafts becomes crucial, potentially making the difference between life and death [1].

The gold standard for treating significant cutaneous defects caused by burns, ulcers, and traumatic injuries is autografts. Remarkably, the pain experienced at the donor site during graft harvesting often exceeds that felt at the actual burn site, underscoring the significance of proper post-graft donor site care [2, 3].

Furthermore, complications during donor site healing can manifest as pain, itching, infections, dyschromia (a blend of hypo- and hyperpigmentation), and hypertrophic scarring. Managing donor sites post-graft harvesting is of paramount importance, and frequently, patients encounter more discomfort at the donor site than at the burn recipient site itself [4].

Expediting the healing process and mitigating pain during recovery yield several advantages: swifter return to work, diminished risk of wound infections, enhanced quality of life, potentially reduced need for pain relief, and increased availability of donor sites for harvesting, if required [5].

Tissue repair and skin wound healing constitute intricate procedures involving a series of dynamic events. The responsibility of attending to patients grappling with healing difficulties poses an evolving challenge, necessitating inventive strategies. An approach that stands out in addressing such injuries is low-level laser therapy (LLLT) [6].

LLLT offers a non-invasive approach that bolsters the process of healing and tissue repair, concurrently delivering reductions in pain and inflammation. Research substantiates the safety and effectiveness of this technique in promoting tissue recovery [7].

Consequently, the objective of this study is to assess the therapeutic impact of LLLT in expediting donor-site wound healing after skin graft surgery in burn patients.

Subjects and methods

Study design

This randomised controlled trial was performed in the physical therapy department for burn, Alahrar Teaching Hospital, Zagazig, Sharkia, Egypt, from where the patients were also recruited from November 2022 to April 2023. Each participant in the study had the protocol thoroughly explained to them before any procedures were performed.

Sample size determination

The number of samples needed for the investigation was determined beforehand. Test size estimation (*F*-tests – ANOVA: Repeated measures, across factors, = 0.05, = 0.10, and effect size = 0.5) using the G POWER statistical software (version 3.1.9.2; Franz Faul, Universität Kiel, Germany) indi-

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cated that $N = 32$ participants would be sufficient for this investigation. The number of participants was raised by 25% ($N = 40$) to account for potential dropouts.

Subjects

Figure 1 represents a flowchart of participants being recruited for the study. Forty-seven patients were initially screened, but seven were eliminated because they did not match the study's inclusion requirements in one way or another. Forty people were randomised into an LLLT group and a placebo group at random.

A total of 40 patients of both sexes, aged 20–40 years, suffered from 3rd-degree burns with a TBSA ranging from 20–35% and had undergone split-thickness skin graft (STSG) surgery participated in our study. Every single patient had a donor site from the thigh and began the treatment program from the 1st day post-operative. The exclusion criteria included patients with associated diseases (such as diabetes mellitus, infectious diseases, and autoimmune diseases) that might interfere with the healing process. Patients taking medications (such as corticosteroids, chemotherapy, or radiation) that interfere with the body's natural healing process, as well as the elderly, pregnant women, smokers, those with known dietary deficiencies, photosensitivity, skin diseases, histories of trauma or accidental injury, as well as those who have undergone surgery at the intended donor site previously were also excluded.

Patients were assigned to one of two groups randomly by a physical therapist who was unaware of the study's design and who opened sealed envelopes containing randomised cards generated by a computer. The study group (active laser group) received LLLT at the donor site for 1 session per day with three sessions a week for three weeks, while the control group (placebo group) received a placebo laser for 1 session per day with three sessions a week for three weeks. The standard medical procedures and wound care (dressing) were administered to both groups. Every patient provided informed consent before starting the study.

Outcome measures

Photography (digital camera Nikon D3500 and J Image 1.53e software) was used for measurement of the wound surface area of the donor site before treatment (day 1 post-operative), at day 11 post-operative, and 21 days post-operative.

ImageJ digital image analysis provided highly accurate estimates of the wound area. As a free, quick, and precise method of measuring wounds, this technique might be used consistently in clinical practice to record wound healing. The rate of reduction in wound size is the most reliable indicator of healing [8].

The digital camera was held perpendicular to the wound at a distance of 50 cm, and photographs were taken. Calibration was accomplished by positioning a ruler of known size adjacent to the wound, parallel to the uninjured skin. Photos were imported into ImageJ, and the program converted the pixel count automatically. To maintain consistency in measurements, patients and cameras were always in the same positions and at the same distances. Each wound also included a label with the subject number as well as the measurement date [9].

Intervention

Low-level laser therapy

The study group received LLLT on the donor site using a red laser (α circle, SN 1207002505, manufactured by Medical Equipment Co., made in China). The LLLT device was calibrated before the treatment. All dressings were eliminated in a controlled setting, and then LLLT was delivered directly to all donor sites by a perpendicular contact approach to all sites, shielding it from contamination with a sterile clear cover. LLLT was provided with the following settings: 650 nm wavelength, 150 mW power output, 0.25 cm^2 radiation areas, 0.6 W/cm^2 power density, continuous mode, 2 joules per cm^2, 90 s/cm^2 for three sessions per week for three weeks. Laser safety goggles were worn at all times during laser irradiation by the therapist and patient [10].

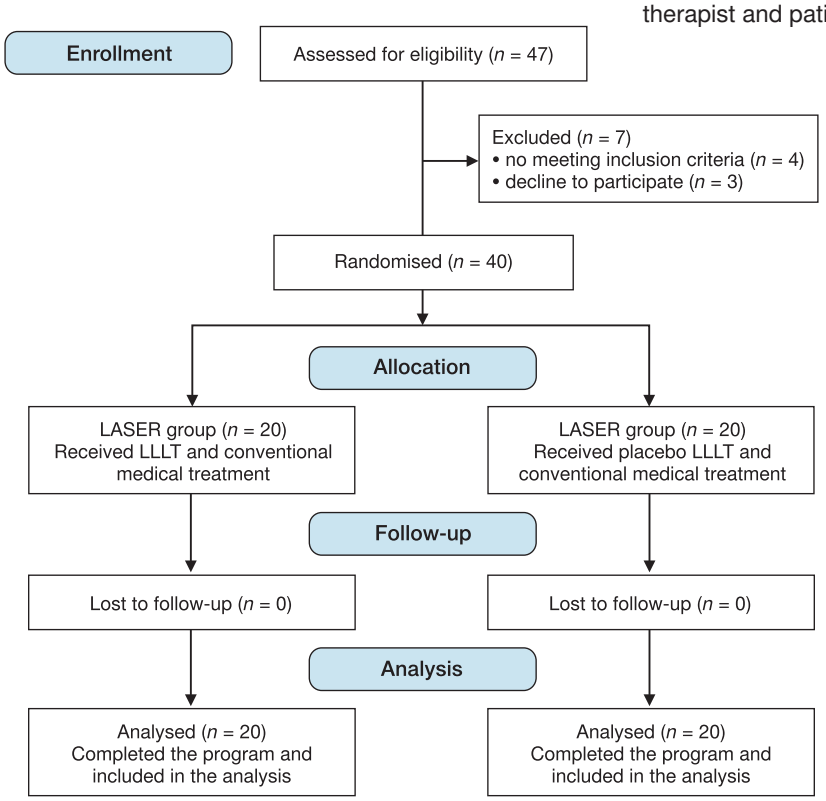

Figure 1. CONSORT flowchart of the study

The placebo group received the same procedure as the study group but with an aluminium cover on the top of the laser probe. We applied a test before the placebo procedure to ensure the aluminium cover was preventing the passage of the laser in that group. We also set the device power output at 10 mW, which is the lowest output for the device.

Statistical analysis

Subject characteristics were compared between the groups using an unpaired *t*-test. The distribution of males and females across the groups was analysed using the chi-squared test. The Shapiro–Wilk test was used to ensure that the data followed a normal distribution. To examine whether or not the groups were homogeneous, Levene's test for homogeneity of variances was performed. Wound size was compared between days 1, 11, and 21 within each group using an ANOVA with repeated measures. Wound size was compared across groups using an unpaired t-test. All statistical tests were performed at a p-value < 0.05 level of significance. The Windows version of the SPSS statistical software (version 25) was used for all analyses (IBM SPSS, Chicago, IL, USA).

Results

Subject characteristics

Data were screened for normality assumption, homogeneity of variance, and presence of extreme scores. A Shapiro–Wilk test for normality showed that the measured variables were normally distributed and the groups were homogeneous ($p > 0.05$).

Table 1. Basic characteristics of the participants

	Study group (mean ± *SD*)	Placebo group (mean ± *SD*)	*p*-value
Age (years)	28.65 ± 6.37	31.95 ± 6.7	0.11
TBSA (%)	27.9 ± 4.99	28.55 ± 3.83	0.64
WBCs count (× 10^9)	7.33 ± 1.69	7.43 ± 2.21	0.88
INR	0.98 ± 0.08	0.97 ± 0.09	0.66
Sex			
females [*n* (%)]	8 (40)	8 (40)	1
males [*n* (%)]	12 (60)	12 (60)	

TBSA – total body surface area, WBCs – white blood counts, INR – international normalised ratio

Table 1 illustrates subject characteristics for the study and placebo groups. There was no substantial difference between groups in age, total body surface area (TBSA), white blood counts (WBCs), international normalised ratio (INR), and sex distribution ($p > 0.05$).

Effect of treatment on wound size

Within group comparison

Both groups showed statistically substantial reductions in wound size on days 11 and 21 compared to day 1 ($p < 0.001$) and wound size was significantly reduced by day 21 compared to day 11 ($p < 0.001$, Figures 2 and 3).

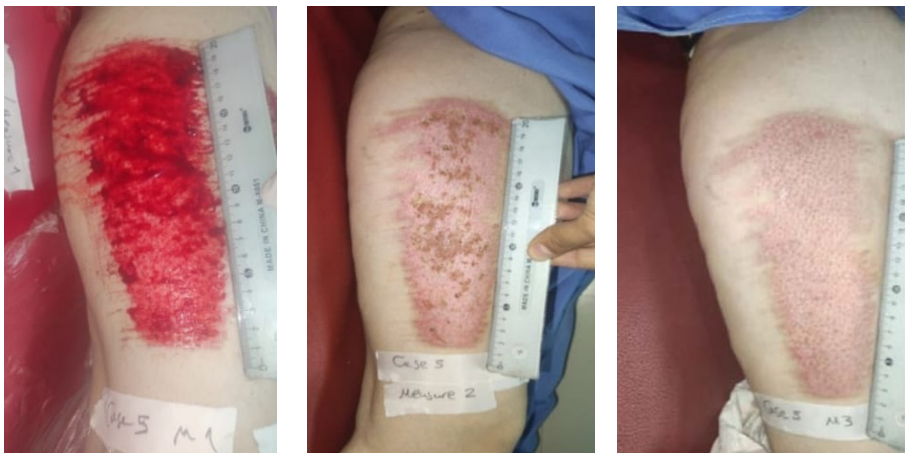

Figure 2. Progression of donor site wound healing at day 1, 11, and 21 post-operative in the laser group

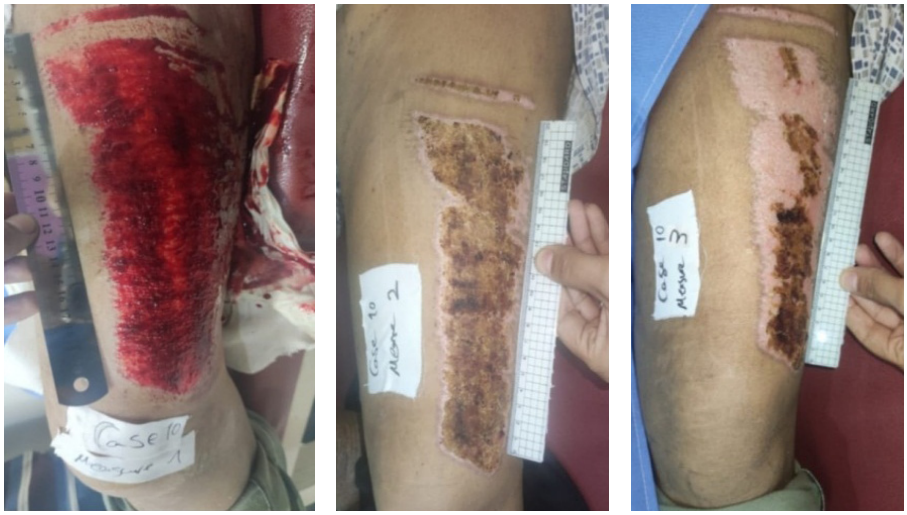

Figure 3. Progression of donor site wound healing at day 1, 11, and 21 post-operative in the placebo group

Table 2. Comparison of mean values of wound size between days 1, 11 and 21 post-operative in the study and placebo groups

Wound size (mm)	Study group			Placebo group		
	MD	% of change	*p*-value	MD	% of change	*p*-value
Day 1 – day 11	127.57	88.69	0.001	74.88	50.18	0.001
Day 1 – day 21	142.01	98.73	0.001	119.7	80.22	0.001
Day 11 – day 21	14.44	88.81	0.001	44.82	60.30	0.001

Table 3. Comparison of mean values of wound size on days 1, 11, and 21 post-operative between the study and placebo groups

Wound size (mm)	Day 1 (mean ± *SD*)	Day 11 (mean ± *SD*)	Day 21 (mean ± *SD*)
Study group	143.83 ± 30.28	16.26 ± 7.02	1.82 ± 1.52
Placebo group	149.21 ± 23.16	74.33 ± 9.55	29.51 ± 3.34
MD	–5.38	–58.07	–27.69
t-value	–0.63	–21.89	–33.69
p-value	0.53	0.001	0.001

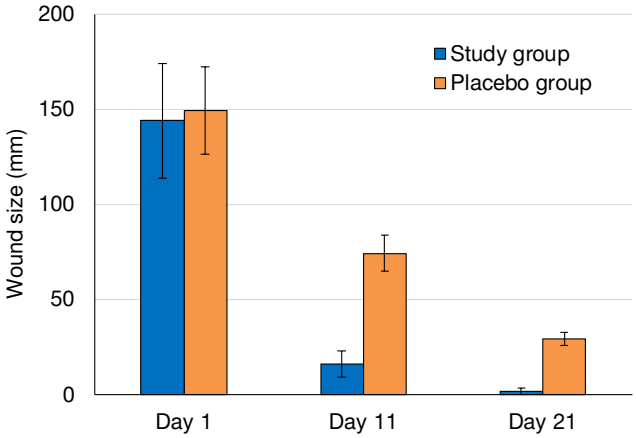

Figure 4. Mean values of wound size on days 1, 11 and 21 post-operative between the study and placebo groups

When comparing the percentage of wound size change between day 1 and day 11; day 1 and day 21; and day 11 and day 21, the percentages for the study group were 88.69%, 98.73%, and 88.81%, while for the placebo group they were 50.18%, 80.22%, and 60.30% (Table 2, Figure 4).

Between groups comparison

The size of wounds on post-operative day 1 did not change substantially between the study and placebo groups ($p > 0.05$).

On post-operative days 11 and 21, the wound size of the study group reduced substantially as compared to the placebo group ($p < 0.001$, Table 3, Figure 4).

Discussion

Donor site skin graft surgery has complications like most skin surgeries as infection, scar formation, hypertrophic scar, and hyperpigmentation delay healing and make patients less satisfied [11, 12].

Several clinical studies reported a significant effect of LLLT on burns [13], ulcers [14], and post-operative wounds [15], but there is a lack of studies about LLLT's effect on donor site wound healing. Therefore, the purpose of this investigation was to assess the efficacy of LLLT in facilitating donor-site healing in post-burn skin graft patients.

The present investigation revealed that there was a statistically substantial difference in wound size throughout the three different time points for both groups ($p > 0.001$). However, when wound size was compared between the two groups, the study group demonstrated a statistically substantial reduction in wound size on days 11 and 21 post-treatment, while the placebo group showed no such reduction ($p < 0.001$).

LLLT has been shown to accelerate wound healing by promoting the synthesis of collagen, motility of keratinocyte cells [16], release of growth factors [17], an increase in vascularisation, and the transformation of fibroblasts into myofibroblasts [18].

The current study's findings are consistent with those of Kazemikhoo et al. [19], who examined the efficacy of photobiomodulation (PBM) vs STSGs in the treatment of deep burn wounds in 40 children. In the PBM group, a 650 nm laser was applied to irradiate the burn region day after day until full healing, while STSGs were carried out in the STSG group. All wounds reportedly healed after 10–12 sessions in the PBM group, and there was a notable reduction in burn area compared to the STSG group ($p > 0.001$). The results also showed that the PBM group had a much lower rate of scar as well as hypertrophic scar formation than the STSG group, indicating that PBM can be an effective alternative to STSG.

Kazemikhoo et al. [20], who studied the effect of LLLT on patients having grade 3 burn ulcers on their hands or feet and who were eligible for STSG, confirm our findings. After skin graft surgery, the ulcer surface area was considerably less in the laser-treated group than in the control group, which received traditional dressings. They reported that LLLT is an effective and safe approach for enhancing graft survival as well as wound healing in patients with a deep burn ulcer.

Our findings concur with those of Dahmardehei et al. [21], who combined LLLT with skin graft surgery for diabetic patients having grade three burn ulcers who were amputation candidates. The results demonstrated a significant impact of LLLT on the surgical prognosis and full recovery of all amputation candidates.

In addition, Priyadarshini et al. [22] evaluated the impact of LLLT on the size, grade, but also culture status of diabetic foot ulcers in a RCT involving 100 diabetic foot ulcer patients randomly assigned to either the LLLT group or a control group. After 15 days of treatment, they observed a substantial decrease in the mean ulcer area ($p < 0.001$) with recovery of grade two ulcers to grade one. Compared to the control group, the LLLT group exhibited remarkable infection control as well as a lower mean overall cost of therapy. They determined that laser therapy is a non-painful procedure that stimulates faster granulation, wound contraction, and re-epithelialisation, hence accelerating complete wound healing and eliminating the need for additional procedures such as STSGs.

Additionally, Machado et al. [23] conducted a systemic analysis of randomised studies comparing LLLT to alternative therapies, different forms of LLLT, LLLT placebo, and controls in the management of pressure ulcers (PUs) in humans. Ulcer size, rate of healing, as well as complete recovery, were the endpoints examined. The application of LLLT at

a wavelength of 658 nm yielded significant outcomes, while higher wavelengths produced no conclusive evidence.

This study's results agreed with those of Ibrahim and Mohamady [24], who examined the effect of LLLT using laser radiation [helium-neon (632.8 nm) and gallium arsenide (904 nm)] on wound healing in patients who had upper limb second-degree thermal burn injuries. All study groups began laser treatment 72 hours after the burn injury and continued it three times weekly for three weeks. When comparing the two-laser group to the placebo group, they discovered that the two-laser group had a much lower WSA and a better wound state. The results also show that helium-neon and gallium arsenide lasers work well to speed up the healing process.

Both in vitro and in vivo studies show that laser therapy hastens wound healing by boosting epithelialisation, fibroblasts action, revascularisation, perfusion, as well as scar tensile strength [13, 25]. In a review by Zhao et al. [26], they found laser therapy to be an effective adjunct treatment for wounds.

LLLT has been shown to be an effective treatment for speeding up tissue repair and managing pain, according to a review by Enwemeka et al. [27]. LLLT has also been used effectively to treat diabetic ulcers [28], pressure ulcers [29], as well as post-surgical wounds [30].

One proposed explanation for how LLLT promotes wound healing is that it raises the activity of an enzyme called cytochrome c oxidase (COX) by stimulating the mitochondrial membrane potential of a cell. This process impacts three molecules: adenosine triphosphate (ATP), reactive oxygen species (ROS), and nitric oxide (NO). The ability of a cell to fight infection also speeds up the healing process by boosting an elevation in ATP, the main energy source for most cellular functions. Positive effects on cellular repair and healing can be seen when ROS levels are regulated by the activation of transcription factors. Natural NO is a powerful vasodilator that improves tissue oxygenation and immune cell movement by increasing blood flow [31, 32].

Limitations

The study had some flaws as the lack of a tracking system or follow-up. There is a need for follow-up in future investigations.

Conclusions

We conclude that LLLT is a promising therapeutic method for facilitating quicker recovery of the donor site after skin graft surgery for burn patients.

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Ethical approval

The research related to human use has complied with all the relevant national regulations and institutional policies, has followed the tenets of the Declaration of Helsinki, and has been approved by the Ethical Committee of the Faculty of Physical Therapy at Cairo University, Egypt (approval No.: P.T.REC/012/003623). It was retrospectively registered in the clinical trials registry (NCT05907915).

Informed consent

Informed consent has been obtained from all individuals included in this study.

Conflict of interest

The authors state no conflict of interest.

Disclosure statement

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