Effects of Low-Level Laser Therapy on Pain and Scar Formation After Inguinal Herniation Surgery: A Randomized Controlled Single-Blind Study

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Abstract

Objective: The aim of this study was to investigate the efficacy of an infrared GaAlAs laser operating with a wavelength of 830 nm in the postsurgical scarring process after inguinal-hernia surgery. Background: Low-level laser therapy (LLLT) has been shown to be beneficial in the tissue-repair process, as previously demonstrated in tissue culture and animal experiments. However, there is lack of studies on the effects of LLLT on postsurgical scarring of incisions in humans using an infrared 830-nm GaAlAs laser. Method: Twenty-eight patients who underwent surgery for inguinal hernias were randomly divided into an experimental group (G1) and a control group (G2). G1 received LLLT, with the first application performed 24 h after surgery and then on days 3, 5, and 7. The incisions were irradiated with an 830-nm diode laser operating with a continuous power output of 40 mW, a spot-size aperture of 0.08 cm² for 26 s, energy per point of 1.04 J, and an energy density of 13 J/cm². Ten points per scar were irradiated. Six months after surgery, both groups were reevaluated using the Vancouver Scar Scale (VSS), the Visual Analog Scale, and measurement of the scar thickness.

Results: G1 showed significantly better results in the VSS totals (2.14/C6 1.51) compared with G2 (4.85/C6 1.87); in the thickness measurements (0.11 cm) compared with G2 (0.19 cm); and in the malleability (0.14) compared with G2 (1.07). The pain score was also around 50% higher in G2.

Conclusion: Infra-red LLLT (830 nm) applied after inguinal-hernia surgery was effective in preventing the formation of keloids. In addition, LLLT resulted in better scar appearance and quality 6 mo postsurgery.

Introduction

Hypertrophic scars and keloids result from an abnormal fibrous wound-healing process in which tissue repair and regeneration regulating mechanism control is lost. These abnormal fibrous growths present a major therapeutic dilemma and challenge to the plastic surgeon because they are disfiguring and frequently recur.1 Approximately 100 million people per year acquire new scars, caused by traumas, burns, and surgery. According to literature data, the prevalence of hypertrophic scars among Caucasians ranges from 15% to 63%.1

The final aspect of the scar can have various consequences, such as aesthetic discomfort, psychological problems, pain and difficulty in the activities of daily life, and lowered self-esteem and quality of life.2,3 The study of therapies that promote better wound healing attenuate these problems and improve the aesthetic aspects, both morphological and functional. Scar is one of the main tasks for researchers that work in this area.

The classical inflammatory process of wound healing consists of four phases: hemostasis, inflammation, proliferation, and remodeling. These phases are initiated when tissue injury occurs and can last from a few hours to a few years.4,5 Studies in tissue cultures and animal experiments with LLLT in the near-infrared spectra have demonstrated an increase in the proliferation of fibroblasts, endothelial cells, and keratinocytes, increases in collagen deposition, and stimulation of angiogenesis after application laser radiation in optimal doses. All of these effects seem to be related to the acceleration of the wound-healing process, ulcers, and skin flaps.6–9

LLLT in human postoperative wounds has shown beneficial effects, especially visible spectra.10–13 The only use of an 830-nm diode laser found in the literature was the study carried out by Lagan et al.14 on small scars. However, in larger postsurgical cuts, no data were found in the literature.
The interaction of laser light with biological tissue shows different effects depending on the dosages used. Additional studies are needed on the range of these dosage parameters to evaluate their use in the healing processes in humans. The purpose of our study was to evaluate the effect of the infrared GaAlAs (830 nm) laser on postsurgical scars in human beings.

Materials and Methods

Study population

Thirty patients who underwent surgery for an inguinal hernia were recruited by the Clinical Service of General Surgery at the University Hospital of the University of São Paulo. The exclusion criteria were: (a) a history or suspicion of malignant neoplasia; (b) diabetes; (c) skin color - black; (d) ethnicity - Asiatic patients.

This study was carried out at the University Hospital of the University of São Paulo, Center for Study and Research, Faculty of Physical Therapy at the Medical School. The subjects were randomized by receiving stamped envelopes containing the numbers 1 or 2, indicating which group they would be placed in.

This work was approved by the Ethical Committee for Research with Human Beings of the University Hospital, University of São Paulo (USP), under register CEP: no. 505/04.

Procedures

All patients signed the free and informed consent forms and completed the evaluation protocol, which included personal data, anthropometric data, body mass index (BMI), associated pathology, and Visual Analogue Scale (VAS) and Vancouver Scar Scale (VSS) data.

The VAS is a classical tool used to help a person to grade the intensity of certain sensations and feelings, such as pain. The VAS for pain is a straight line, with one end meaning no pain and the other end meaning the worst pain imaginable. The patients were instructed to mark a point on the line that matched the amount of pain they felt. The range of the VAS varied from 0 to 10.

The VSS has four parameters: vascularity, height, pigmentation, and malleability. The total scores ranged from 0 to 15. At the end of the evaluation, the values were summed. The lower the score, the better the appearance, and consequently the healing, of the cut. The VSS was performed by a trained and blinded plastic surgeon.

The patients were subjected to inguinal-hernia surgery (length ± 10 cm) and the closing of the incision was always the same, with separate and simple stitches, using 4.0 mononylon surgical sutures (Ethicon, Johnson & Johnson, São Paulo, SP, Brazil).

Experimental group (G1)

The patients in the experimental group were exposed to irradiation using a GaAlAs diode laser with a continuous power output of 40 mW and a wavelength of 830 nm. The spot size was 0.08 cm², with an irradiation time of 26 s, and 1.04 J of energy per point.

The application was done along the entire length of the scar (±10 cm), with a distance of 1 cm between each point. Ten points per scar were irradiated giving a total of 10.4 J per treatment. The laser beam was covered with a PVC film, avoiding direct contact with the patient. The PVC film does not provoke important losses in the transmission of the laser light. Irradiation was performed in contact mode, with the laser probe held stationary with slight pressure at a 90-degree angle to each point.

Irradiation was initiated on the first postoperative day and then on days 3, 5, and 7 to give a total of four applications. The power output was verified by a laser power meter (Ophir 30A-P-Dif).

The area of the scar was photographed with a Sony DSC-F828 camera adjusted to a distance of 15 cm, in the same location and with the same light intensity. The VSS was performed after a period of 6 mo by a trained and blinded plastic surgeon. The measurements of the scar thickness were performed from the photographs by using computer software (AUTOCAD 2005). The thickness was measured at three points: one in the center of the scar and two 1 cm from each end. The average of the three points was then calculated to determine the thickness of the scar.

Control group (G2)

The control group did not receive any treatment. They were photographed and evaluated at the same time as the experimental group.

Statistical analysis

The Kolmogorov–Smirnov test was used to determine the normality of the total score and the specific scores for the VSS, VAS, age, Body Mass Index (BMI), and scar thickness between the two groups. The normality of the data was verified only for the total VSS score.

The comparisons of the total scores in VSS variable between the groups were performed by means of an independent Student’s t-test. Since normality was not found in the specific scores for the components of VSS, VAS, age, BMI, and scar thickness, the comparisons between G1 and G2 for those variables were done by means of the nonparametric Mann–Whitney test.

Results

Twenty-eight out of thirty patients who underwent inguinal-hernia surgery completed the study. Two patients did not return to the follow-up (one from each group), due to address changes. The average age of the patients in G2 was 47.14 (±9.56) and 47.07 (±7.51) in G1, and the average BMI was 26.35 (±2.46) and 25.67 (±1.74), respectively, thus showing two homogeneous groups (Table 1).

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean</th>
<th>Std. dev.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>47.14 (G2)</td>
<td>16.57 (G2)</td>
</tr>
<tr>
<td>BMI</td>
<td>26.35 (G2)</td>
<td>4.26 (G2)</td>
</tr>
<tr>
<td></td>
<td>25.67 (G1)</td>
<td>3.02 (G1)</td>
</tr>
</tbody>
</table>

Mann–Whitney test.

Table 1. Comparison of Mean and Standard Deviation in Age and BMI between G1 and G2
As we have observed, the irradiated group presented the best results when compared with the control group, with the exception of the vascularity parameter, where the values were approximately equal.

**Pain measurements (VAS)**

The VAS did not demonstrate statistically significant differences. However, the control group presented, on average, around a 50% higher pain than the experimental group (Table 2).

**Vancouver Scar Scale (VSS)**

In the VSS totals, the irradiated group had a significantly smaller score of 2.14 (±1.51), while the control group presented 4.85 (±1.87), with a $p$ value of 0.0002, clearly demonstrating the increased quality of the scar (Table 3). The results showed statistically significant differences between the experimental group and the control in the malleability parameter (0.049) and the thickness parameter (0.01), both of which had a $p < 0.05$ (Table 2).

**Discussion**

Controversy about the results of LLLT studies still exist, perhaps because of the different parameters, dosages, and types of lasers used. Nevertheless, some studies with lasers in the near-infrared spectra have shown encouraging results in healing wounds such as skin flaps, pressure ulcers, and burns, showing an increase in the proliferation of fibroblasts, acceleration of collagen synthesis, angiogenesis, and reduced healing time for the wound.

Our study showed that G1 showed a significant improvement in some of the parameters studied when compared with G2. These improvements can be seen in the lower total VSS scores, better malleability, and reduction in scar thickness in the treated group. Interestingly, as we can see in Tables 1–3, the control group presented higher standard deviations, which means that the laser group showed more homogeneous healing. The effect of LLLT on fibroblast activity in other studies may offer an explanation for the positive results observed in this study, such as the influence on the mobility and proliferation of fibroblasts, which quickens fibroplasias, accelerating the synthesis and the maintenance of the collagen morphology, angiogenesis, and increase in the number of endothelial cells.

Thus, our results are similar to Conologue and Norwood who used a 595-nm laser. They also found a significant difference in the total VSS values and the malleability and vascularity parameters when compared to the control group. This significant difference in the vascularization could be explained by the fact that the final process of tissue repair lasts from 6 mo to a few years, and these authors evaluated the

### Table 2. Mean and Standard Deviation for Variables between G1 and G2

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean (G2)</th>
<th>Std. dev. (G2)</th>
<th>$p$ value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pigmentation</td>
<td>1.85</td>
<td>1.29</td>
<td>0.107</td>
</tr>
<tr>
<td></td>
<td>0.92</td>
<td>1.32</td>
<td></td>
</tr>
<tr>
<td>Vascularization</td>
<td>1.0</td>
<td>0.67</td>
<td>0.462</td>
</tr>
<tr>
<td></td>
<td>1.28</td>
<td>0.99</td>
<td></td>
</tr>
<tr>
<td>Height</td>
<td>0.50</td>
<td>0.85</td>
<td>0.301</td>
</tr>
<tr>
<td></td>
<td>0.007</td>
<td>0.26</td>
<td></td>
</tr>
<tr>
<td>VAS</td>
<td>0.92</td>
<td>1.32</td>
<td>0.241</td>
</tr>
<tr>
<td></td>
<td>0.35</td>
<td>1.33</td>
<td></td>
</tr>
</tbody>
</table>

Mann–Whitney test *for $p < 0.05$.

### Table 3. Mean and Standard Deviation Total VSS Scores between G1 and G2

<table>
<thead>
<tr>
<th>Group</th>
<th>Mean</th>
<th>Std. dev.</th>
<th>$p$ value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>4.85</td>
<td>2.05</td>
<td>0.0002*</td>
</tr>
<tr>
<td>Experimental</td>
<td>2.14</td>
<td>1.51</td>
<td></td>
</tr>
</tbody>
</table>

Independent Student’s t-test by group *for $p < 0.05$.

**FIG. 1.** Comparison of scar thickness (mm) between G1 and G2.

**FIG. 2.** Comparison of total VSS scores between G1 and G2.
scar at a 3-month follow-up. The laser may have acted to accelerate angiogenesis, and consequently the increase in vascularization of the scar. On the other hand, in our study this difference could be decreased due to the time period, i.e., 6 mo after surgery, the wound possibly reached a more advanced stage in the vascularization process than after 3 months, and both groups seem to converge to the same stage at this time.

The results also corroborate the work carried out by Viegas et al.\textsuperscript{25} who compared 685 and 830-nm lasers and meloxicam (NSAIDs) in the inflammatory reactions during the scarring process. Their study also showed that the group treated with a 830-nm laser presented better organization and greater maturation of collagen fibers when compared to the other groups. The groups irradiated with both lasers showed greater vascular activation in first 36 h of tissue repair, and the irradiated groups presented an increase in the quality of the repair from a cellular point of view.

In the case of pain, our study showed the average of the VAS in G2 to be around 50% higher when compared with G1, corroborating some works\textsuperscript{23,26–29} where the relief of pain was described as one of the main characteristics of LLLT.

Dosage is an important parameter in the development of laser treatment.\textsuperscript{30,31} In our study, we observed that, at least for human healing and near-infrared laser, lower doses were more effective than higher doses in promoting high-quality healing and avoiding the formation of keloids.\textsuperscript{22,31}

Rezende et al.,\textsuperscript{30} using a 830-nm laser, concluded that a single application of 1.3 J produced better results in the bio-metric evaluation in the semi-quantitative histologic study when compared to the group irradiated with 3 J and to the control group.

Al-Watban and Delgado\textsuperscript{32} used several different fluencies (1, 5, 9, and 19 J/cm\textsuperscript{2}) to treat scarring in experimental rats, and concluded that a fluency of 1 J/cm\textsuperscript{2} enhanced the healing process. Our study corroborates these results, showing that low doses are efficient from the point of view of the scarring processes.

In our clinical protocol, laser applications started within the first 24 h following surgery. Perhaps the importance of starting with the treatment as early as possible can be explained by the findings of some authors such as Gal et al.\textsuperscript{33} who showed that in the first 24 h the laser-treated group presented significant polymorphonuclear formation, diminishing 48 h after the irradiation. In the control group, these cells appeared at 48 h and only diminished 96 h after. The proliferation of fibroblasts could be seen to be significantly greater in the first 24 h and 72 and 96 h in the treated group, with the same number of fibroblasts in the other two groups being seen only after 120 h of the injury.
Viegas et al. showed that the use of the laser results in a shorter acute inflammatory phase and an earlier onset of the proliferative phase, thus speeding up the healing process. The authors reported substantial vascular activation in the first 36 h in the irradiated group, favoring the arrival of some chemical mediators of the inflammatory phase of the injury.

The main growth factors involved in cell migration, proliferation, and tissue repair are Platelet Derived Growth Factor (PDGF), Transforming Growth Factor (TGF-β), Epidermal Growth Factor (EGF), and Fibroblast Growth Factor (FGF).

Some works have shown an increase in the expression of basic Fibroblast Growth Factor (bFGF) after irradiation using lasers with wavelengths of 632.8 nm and 830 nm in epithelial fibroblast culture. In animal experiments with rats, an increase in the gene expression of PDGF and TGF-β was found by Safavi et al.

Lasers with wavelengths of 632.8 nm and 830 nm stimulated a larger cellular migration and an increase in the production of interleukin-6 (IL-6), which promotes cellular proliferation and migration, as well as assisting in the immune response of the lymphocytes, preventing infection and the spread of pathogens. This favors the acceleration of the inflammatory phase and the complete healing process, suggesting its synergistic performance with bFGF. The production of these cytokines is dependent not only on the physiological status of the cells but also on the dose and wavelength. Regarding the frequency of the applications, Al-Watban and Delgado have undertaken some studies where applications were made three times per week and compared to protocols of five applications per week. They concluded that there was no difference between the frequencies in terms of improvement to the wound healing. Our study corroborates these data, showing that an application the every other day for a week promotes good therapeutic results.

The properties of LLLT, such as improving the healing process, closing surgical incisions more quickly while increasing the tensile strength of the scar, as demonstrated in this and other works, can help many patients to experience a faster recovery and improve the quality of their surgical scars.

**Conclusion**

According to the results obtained in this work, treatment with LLLT with an 830-nm wavelength and the parameters discussed to treat inguinal-hernia incisions resulted in improved aspects and quality of the scars 6 mo postsurgery.

**Author Disclosure Statement**

No competing financial interests exist.

**References**


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