Effects of Different Techniques ("Surgical Versus Laser") on Impairment of Lymphatic Drainage and Scar Formation in Humans

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Abstract

Scars are abnormal changes in skin tissue caused by injuries, infections, and various factors. They commonly result from fibroblasts in affected skin synthesizing collagen, leading to irregular growth and excessive collagen accumulation within the extracellular matrix.

This study aims to investigate the effects of surgical and laser methods on scar formation mechanisms and lymphatic drainage, as well as their outcomes. The objective is to assess skin scars created by laser and surgical incisions and their impact on pathophysiology and lymphatic flow in humans.

A total of 20 patients with skin lesions were included in this study. The migration of methylene blue dye through the lymphatic vessels of the lower limbs was evaluated, with the administered dose limited to under 2 mg/kg. Transverse incisions were then performed distally using either a surgical blade or laser. The wounds were allowed to heal by secondary intention.

The results indicated that laser-treated wounds did not heal completely, retaining a noticeable area of granulation tissue along with hair loss. In contrast, wounds created through surgical incisions healed entirely. Additionally, significantly lower dye migration levels were observed in the limbs after laser treatment compared to surgical incisions ($p = 0.007$).

The findings suggest that scar size may be influenced by the type of incision used. However, further research is required to validate these results.

Keywords: Skin scar, Pathophysiology, Surgical incision, Laser incision, Skin cancer

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Introduction

Scars indicate pathological changes in skin tissue caused by injuries, infections, and various other factors. They are generally believed to result from the increased collagen-producing capacity of fibroblasts in injured skin, leading to excessive collagen accumulation within the extracellular matrix.

In recent years, the incidence of skin cancers has risen. The most prevalent types include squamous cell carcinoma, basal cell carcinoma, and melanoma, which accounts for 4% of all malignant tumors. Particular attention should be given to malignant melanomas, as even a small primary lesion just a few millimeters in size can undergo significant metastasis, thereby reducing overall survival rates [1,2].

The rising incidence of skin cancer and increasing awareness have led more individuals to seek evaluation at outpatient clinics for skin lesion removal. Many patients request excision for aesthetic reasons, while others present with a prior diagnosis of skin malignancy. Among the samples sent from the Department of Plastic Surgery, General Surgery, and Dermatology for both inpatient and outpatient cases at our hospital, incidental melanoma and other skin cancer findings were identified in 10% of post excision specimens.

The primary technique employed for skin lesion removal is standard surgical excision, with laser treatments and cryotherapy used less frequently.

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Regardless of the method, a scar forms as a natural response to injury and healing. Achieving a cosmetically favorable scar is a key objective for practitioners, regardless of the technique utilized.

Aim

The aim of this study was to assess skin scars resulting from surgical incisions and laser procedures, as well as their impact on pathophysiology and lymphatic drainage in patients.

Material and Methods

The study was conducted only after obtaining approval from our hospital's ethics committee, covering the period from March 2023 to November 2023. All members of the research team who engaged with patients had received the necessary training.

The study involved 20 male participants. Each patient received subcutaneous xylocaine injections for anesthesia, administered at a maximum dosage of 7 mg/kg of body weight. Following anesthesia administration, the inner sides of their thighs were shaved. Subsequently, methylene blue dye was injected subcutaneously using a 2 ml syringe, targeting an area of 0.02 cm^2 to create 5 mm vesicles (Fig. 1). These injections were specifically directed to the inner thighs. After 30 minutes, dye migration was assessed by measuring the length of the discolored skin (in mm) from the edge of the vesicle toward the inguinal region (Table 1).

After a 7-day period during which the dye was eliminated, transverse incisions were made using a surgical blade on the inner surface of the right thigh, approximately at the midsection of its length. In half of the patients, comparable incisions were made using a KaVo Master-laser diode (wavelength: 890 nm, power range: 0.2–8 W, peak power: 10 W). The wounds were allowed to heal by secondary intention.

Four weeks later, the wound healing process was evaluated. Patients were re-administered xylocaine anesthesia, and injections of 0.02 cm^3 methylene blue dye were introduced distally from the skin incisions. After 30 minutes, the dye spread was reassessed, and tissue samples were collected for microscopic analysis.

Statistical analysis

The χ^2 test used for statistical analysis.

Results

The surgical incision wounds have fully healed, leaving behind a thin, almost invisible scar. Patient number 3 had a scar that was noticeably wider. The wounds resulting from the laser treatment are still in the healing process. In patients 2, 3, 4, and 5, areas of granulation tissue measuring 1–1.5 mm were observed around the laser incision, without the presence of epidermis. In one individual, 80% of the wound length had healed with visible epidermis, although hair loss was noted at both ends of the scar. A comparison of the results indicated no significant difference in dye penetration between healthy skin and surgical scars (p

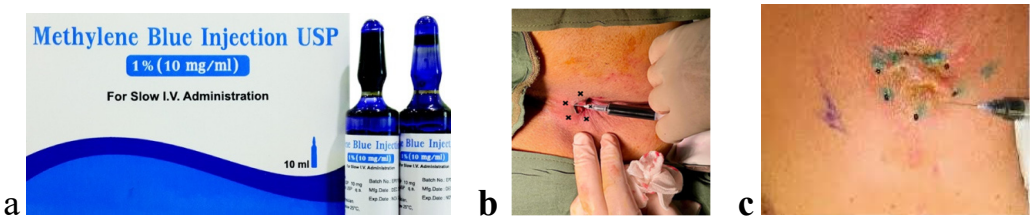

Fig. 1: Methylene blue a. injection b. injection sites around melanoma c. injection around laser scar

Table 1: Penetration of dye in healthy skin and skin scars after 30 min

No of patients.	In healthy skin, penetration of dye [mm]	Penetration of dye through surgical incision scar [mm]	Penetration of dye through a laser scar [mm]
3	15	9	3
4	11	13	2
3	13	4	0
4	12	27	17
6	30	14	0

Table 2: Microscopic assessment of an excised scar tissue sample

No of patients.	Surgical epidermis incision	Laser epidermis incision	Surgical dermis incision	Laser dermis incision
3	No change	Ulceration	No fibrosis	Fibrosis ++,
4	No change	Ulceration	No fibrosis	Fibrosis +++ subcutaneous tissue coagulated
3	Ulceration	Ulceration	Fibrosis +++	Fibrosis +++
4	No change	Ulceration	Fibrosis +	Fibrosis +++ subcutaneous tissue coagulated
6	No change	Ulceration	No fibrosis	Fibrosis +++ subcutaneous tissue coagulated

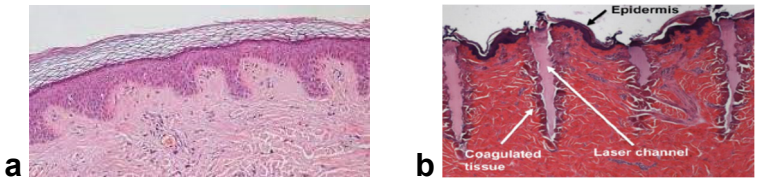

Fig. 2: Scar histopathology after (a) surgical excision and (b) laser excision

= 0.6); however, a statistically significant difference in penetration was observed between healthy skin and laser scars (p = 0.038). Furthermore, the migration of the dye was significantly poorer after laser therapy compared to surgical incisions (p = 0.007) when assessed on a patient-by-patient basis (Table 2).

Discussion

The formation of scar tissue involves a range of pathophysiological processes that facilitate local tissue repair through regeneration, repair, and remodeling. These mechanisms serve as the body's inherent adaptive defense response to cellular damage. Typically, these processes are divided into three stages: the inflammatory response stage, the granulation tissue formation stage, and the tissue remodeling stage.

The core concept of laser therapy is to eliminate skin tissue using thermal energy and ablation. The author has observed that skin damage can extend beyond the area directly affected by the laser, with the extent influenced by several factors, including exposure time, power, and wavelength. Omi et al. noted differences in the depth of skin damage between fractional ablative and non-ablative lasers, with the damage zone reaching approximately 300 µm [4]. Baleg et al. found in their study that the amount of tissue affected by a CO_2 laser at a wavelength of 600 nm increased as the epithelium was removed [3]. Walsh et al. also concluded that laser tissue removal generates a zone of damage [5].

All researchers agree that appropriate laser parameters are crucial for minimizing undesirable tissue damage. Nevertheless, the increasing popularity of laser therapy does not always align with the level of expertise among clinicians. Observations suggest that surgical techniques have a steeper learning curve, while mastering laser treatment requires more time and practice.

In this study, the author observed that the damage inflicted on the skin and subcutaneous tissue from a surgical incision is less severe compared to that caused by laser treatment. Most patients experienced a healing period exceeding four weeks following laser treatment. Upon microscopic examination of scars, the author found that the zones of fibrosis and coagulation were more extensive after laser treatment than after a surgical incision [Table 2]. This is also depicted in the histopathology images [Fig. 2].

It is widely understood that prolonged healing and the resulting inflammation can lead to larger scars [Fig. 3]. Clinical evaluations of patients indicate that the time required for healing post-laser therapy surpasses that of surgical methods. The size of a scar resulting from a surgical procedure can significantly impact clinical outcomes, particularly in the context of postoperative melanoma diagnosis and the need for sentinel lymph node mapping. Haedersdal et al. have investigated the ablation zone following laser treatment; however, the impact of scars on lymphatic flow within the skin has not been previously examined [6].

Another question arises regarding whether insufficient cutaneous lymphatic flow could affect sentinel lymph node mapping [7]. Lopez-Prior's

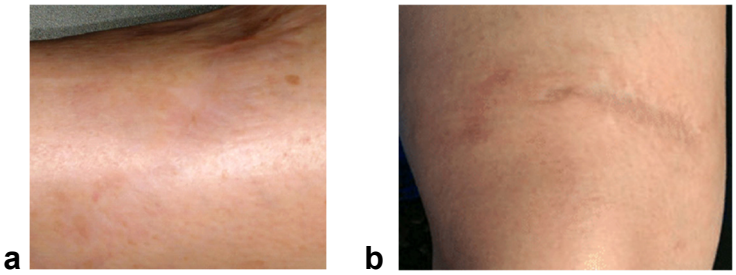

Fig. 3: Visible scar (a) after surgical excision (b) after laser excision

clinical trial indicated that prior breast surgeries (including aesthetic procedures) did not significantly impact sentinel lymph node mapping [7]. Several studies have confirmed that immunological mechanisms play a crucial role in the initiation and modulation of scar formation and growth [8]. The immune response serves a dual purpose in scar tissue formation, both fostering regenerative repair and prolonging wound healing. For instance, during the inflammatory stages of scar formation, a considerable accumulation of macrophages, neutrophils, and T lymphocytes occurs, contributing to and initiating the body's local and systemic immune defenses [8].

A few studies have indicated that the proliferation of fibroblasts and growth factors is responsible for scar development [11, 12, 13]. This was evident in our patient, where an extended wound healing time triggered the production of these factors, as observed in wounds treated with laser. Some researchers highlight the importance of collagen characteristics in the formation of scars [14]. We did not identify any studies correlating postoperative or post-traumatic scars with limb sentinel lymph node mapping.

It seems that in clinical situations where a scar on the upper or lower extremity obstructs lymphatic drainage, such occurrences are rare. However, there is no evidence suggesting that, in these instances, the accuracy of lymph node mapping would be compromised, potentially leading to false-negative findings. Research conducted on patients demonstrated that deep scars resulting from laser therapy can hinder lymphatic flow in the skin. It should be noted that the outcomes of laser therapy can be influenced not only by the device's specifications but also by the operator's level of experience.

Consequently, it is advisable for clinicians to utilize the technique they are most skilled at when excising potentially malignant skin lesions [5]. Clinicians should make every effort to minimize scar formation by implementing preventive strategies to prolong wound healing and applying pressure modalities to expedite scar remodeling [9, 10].

Conclusions

The findings from this study suggest that the method chosen for making incisions may influence the extent of scarring. Following laser treatment, alterations in the pathophysiology and lymphatic flow of the skin can lead to larger scars, potentially affecting the evaluation of sentinel lymph nodes. However, further investigation is necessary to establish connections between this theory and other factors, including immune response, as well as the roles of growth factors and collagen characteristics in scar formation relative to the treatment method.

Regardless of whether the approach is surgical or laser-based, efforts should be made to minimize scar size by preventing infections and implementing pressure therapies such as silicone wraps or sheets to reduce their visibility.

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Conflict of interest

The author declares no conflict of interest.

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