Received: 25 January 2021 | Revised: 19 May 2021 | Accepted: 29 June 2021

DOI: 10.1111/jocd.14325

JCD Journal of Cosmetic Dermatology WILEY

REVIEW ARTICLE

Laser in surgical scar clearance: An update review

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Funding information
WOA Institution: Johannes Gutenberg Universitat Universitatsmedizin; Blended DEAL: Projekt DEAL

Abstract

Scar formation is a consequence of wound healing that developed from damaged tissue either from physical injury or surgical incision. A hypertrophic scar develops due to an abnormal healing response to trauma. It might lead to serious functional and cosmetic disability. There are numerous methods mentioned in the literature to treat such scars but to date, no single method has been known to cure them. In this review, we focused on differences between various types of nonsurgical management of hypertrophic scar focusing on the indication, mechanism of action, and efficacy of the pulsed dye laser (PDL), fractional carbon dioxide laser (fCO2), Er-YAG laser, and intense pulse light (IPL). The literature research included peer-reviewed articles (clinical trials or scientific reviews) which were identified by searching electronic databases like PubMed till January 2021 and reference lists of respective articles. Only articles published in the English language were included.

KEYWORDS
clearance, laser, surgical scar

1 | INTRODUCTION

Formation of scar is a complex process of wound healing, which involves four phases in an overlapping pattern. These four phases include hemostasis, inflammation, granulation, and remodeling of the damaged tissue.[1] Scar may appear as hypertrophic scars and atrophic depending on the amount of collagen formation during the wound healing process. It affects about 5 to 15% of the general population with a profound psychological and social impact depending on the amount of distortion.[2] With the availability of newer and advanced technique like lasers, the requirement of surgery has been almost abandoned.

2 | MANAGEMENT

Two types of lasers are available with a different mechanism of action. One is ablative, and another is non-ablative type.[3] Ablative type is associated with more complications like dyspigmentation and scarring and prolonged recovery period due to ablation of the epidermis before reaching the dermis. Fractional and non-ablative lasers are the comparatively newer ones with fewer side-effect profiles.[4] Both these lasers can reach the dermis without creating significant damage to the epidermis, thereby reducing the risk of complications and shortening the time of recovery.[5] Coagulation of tissue by targeting the chromophore of the dermis and sparing the epidermis is the main mechanism of action. In contrast to ablative laser, non-ablative one produces coagulation of tissue rather the vaporization.

2.1 | Lasers used for hypertrophic scar

Different types of lasers commonly used for hypertrophic scars have documented efficacy in treating various components of these abnormal scars Table 1. Platforms include pulsed dye laser (PDL), fractional carbon dioxide (fCO_2) laser, erbium:yttrium aluminum garnet (Er-YAG) laser, and intense pulse light. Often, two or more of these modalities are combined to improve the outcome. Besides, alexandrite laser and diode laser are used to destroy problematic hair follicles in the scar tissue that can potentially lead to skin irritation and infection. Traditional or nonfractional ablative lasers, including CO_2 and argon lasers, which induce nonspecific thermal damage with significant postoperative pain, prolonged erythema, and high recurrence and infection rates, are no longer used.[6]

2.1.1 | Pulsed dye laser

The PDL of 585-nm and 595-nm wavelength are the two most widely used PDL types in scar remodeling. PDL reduces the scar volume and height and improved texture and pliability.[7] Coagulation of the microvasculature up to the depth of 1.2 mm in the dermis by the laser energy is the main mechanism of action.[8] Photothermolysis of the neovascularized tissue in the hypertrophic scar leading to a reduction in inflammation and formation of tissue hypoxia and neocollagenesis is the mechanism of the PDL.[8] Efficacy of the PDL has been assessed in different randomized and non-randomized trials with the use of different settings in the different studies.[9,10]A systematic review of 10 studies from the Netherlands by Virjman C. et. al. including 248 patients demonstrated low efficacy of PDL 585 nm, whereas moderate efficacy was stated with the application of PDL 595 nm regarding the treatment of hypertrophic scar.[9] A randomized comparative study from Egypt did not show a significant difference between the PDL 595 nm and ND: YAG laser regarding improvement in hypertrophic scar management.[10]

2.1.2 | Fractional laser

The fractional laser mainly consists of two types: (1) ablative laser and (2) non-ablative laser. The working principle of these lasers is mainly fractional photothermolysis. They create microscopic areas known as microscopic thermal zone (MTZ) in the wound sparing a certain amount of dermal and epidermal tissue. These spared normal tissues lead to rapid repair of laser-induced thermal injury.[11] Both ablative and non-ablative lasers can be used in this technique. Fractional carbon dioxide (fCO_2) 10 600 nm and erbium: yttrium aluminum garnet (Er: YAG) 2940 nm ablative lasers are the primary lasers used for hypertrophic scars.[12] Depth of the MTZs is 250 to 800 microns with a diameter of 70 to 100 microns. When the fCO_2 is used for fractional laser, intracellular water is targeted and vaporized leading

TABLE 1 Laser options for surgical scar clearance

Devices	Mechanism	Outcome
Pulsed dye laser	Target hemoglobin and decrease blood supply	Improve scar color, texture and pliability
Fractional laser	Fractional photothermolysis and collagen remodeling	Improve in appearance and contracture, improve pain, and pruritus
Intense pulse light	Decrease blood supply and increase expression of CTGF	Improve scar color, texture, and pliability
Ultrasound	Acoustic pressure and hammering effect	Adjuvant therapy for traumatic scars
Er-YAG laser	Internal wound vertical migration of epithelium	Rapid healing without scaring
Low-level laser therapy	Stimulate cytochrome oxidase and mitochondrial oxidative metabolism	Wound healing, pain control, and reduction in edema

to coagulation of surrounding extracellular protein.[13] Increase in the ratio of type III collagen compared to type I collagen was noted in histology when mature burn scar treated with fractional CO2 laser.[14] Collagen remodeling in the treated scar closely resembles normal skin. The depth and density of the laser need to be adjusted according to the thickness of the scar.[12] The results are mostly positive with both ablative and non-ablative fractional laser. Better results are noted in low to medium fluency in early phases of wound healing.[13] In a single-blinded randomized controlled trial, single use of low to medium fluence non-ablative fractional laser treatment in the early phase of wound healing showed mild but clinically detectable improvement. This study indicates treatment with the fractional laser has the potential to optimize scar formation in a full-thickness wound.[15]

2.1.3 | Intense pulse light

In this technique, noncoherent light energy is delivered through a focused and controlled manner across the 515 to 1200 nm spectrum at a fluency of up to 40 J/cm^2.[16] Previously, it was used for cosmetic indications like treatment of hyperpigmentation and hair removal. Different wavelength of IPL is used for different purposes like 755 nm for collagen stimulation, 695 nm for superficial leg vein removal, and 515 nm for rosacea treatment.[16] A specific filter present in the handpiece allows the user to select a specific wavelength for the treatment. The exact mechanism of action is unknown. It can be used as an alternative option to more expensive therapy like PDL and fCO_2 laser. In a study from Turkey, 109 patients with hypertrophic scar originating from the different source were treated with an average of eight IPL, and significant improvement in the height, erythema, and hardness was observed in more than 90% of patients.[17]

2.1.4 | Ultrasound

Ultrasound is a great method of delivery of drugs at the trans-epidermal area to reduce scar formation and provide another possibility over conventional injection. The combination therapy of radiofrequency and ultrasound has proven to be effective for both hypertrophic and atrophic scar with a satisfactory result.[18] It works either by mechanical (acoustic) pressure or hammering effect: created by torques due to extension of the ultrasound wave through the sonotrode to the distal end. Satisfactory results are obtained for both hypertrophic and atrophic scars when ultrasound is combined with micro-plasma radiofrequency without the complications seen in other methods.[19]

2.1.5 | Low-level laser therapy

Nowadays, low-level laser therapy (aluminum-gallium-arsenide diode (AlGaAs) 980 nm, red light (Mustang, KLO4), Helium-Neon 630 nm) and blue light LED lasers are used for the treatment of wounds with a satisfactory result.[20] The near-infrared enhanced light (NIR-LED) acts by stimulating two pathways in the cell cycle. It stimulates the photo acceptor cytochrome oxidase, resulting in increased energy metabolism and production. Another mechanism of action includes stimulation of mitochondrial oxidative metabolism leading to enhanced cell and tissue repair. The NIR-LED light which is a newer non-invasive advanced technique is used widely for wound healing and various other condition like hair regeneration. Another important action of the low-level laser therapy is pain control and reduction in edema directly by enhancing blood circulation to remove lymphatic fluid and proteins by allowing proper lymphatic draining.[20] It also induces neo-collagens by stimulating macrophages and lymphocytes. In a randomized controlled trial involving seventeen volunteers, fifteen sessions of LLLT appeared to have a positive effect on the macroscopic scar's appearance and old scar thickness.[21]

2.1.6 | Er-YAG laser

The variable pulsed Er:YAG laser has been proved to be a useful and safe measure to treat both atrophic and hypertrophic scar. It uses both shorter and longer pulse duration ranging from 500 micro sec to 10 milliseconds. Tissue ablation is affected by shorter pulses, whereas longer pulses are used to affect coagulation and thermal injury zones.[22] Different types of handpieces are used depending on the length of pulses used. In comparison with the CO_2 laser, Er:YAG laser is a more accurate ablative tool. It emits 2940-nm wavelength light that corresponds to the 3000-nm absorption peak of water. The higher absorption coefficient and shorter pulse duration of the Er:YAG laser resulted in more efficient absorption by water-containing tissue and decreased thermal diffusion. Less effective hemostasis and increased intraoperative bleeding are also noted in this laser which hinders deep dermal treatment. The amount of collagen retraction is also less with Er:YAG treatment (1–4%) compared to carbon dioxide laser. The pulsed Er:YAG laser with a 2-mm handpiece at the setting of 500–1200 mJ/pulse at 3.5–9 W was used in one study for resurfacing of various types of scar induced by trauma, burns, or surgery with optimal outcome.[23] In another study, it was used with 2-mm handpiece at the setting of 500 mJ/pulse, and 3.5–4.5 W was used for resurfacing of pitted facial scars.[24] About 50% improvement in the scars noted after three months of treatment without any significant side effects. Similar results were seen when 5 Hz pulsed Er:YAG laser with 5-mm handpiece at a setting of 7.0–7.5 J/cm^2 with a 10-ms pulse duration for resurfacing of pitted facial acne scars.[25] Mild erythema and post-inflammatory hyperpigmentation were observed in few cases which resolved spontaneously. Hence, Er:YAG laser is one of the effective and safe modalities to treat hypertrophic scars.

3 | CONCLUSION

The PDL, radiofrequency, and ultrasound-assisted therapy can improve the texture, thickness, and appearance of the surgical scar to reduce the need for surgical excision and alleviate the contracture. PDL and IPL, both the vascular targeted devices, can be used alone or in combination with fractional laser, whereas fractional laser and radiofrequency devices can be used solely for the treatment of hypertrophic surgical scar. Er-YAG is also an effective modality to treat the hypertrophic scar. In most of the studies, short-term outcomes and improvement in the appearance of the scar have been studied without considering the long-term effect. Therefore, further studies like randomized controlled studies are needed to confirm their efficacy in the long term and optimal treatment protocol specifically when used in combination. A better understanding will promote the optimal implementation of these therapies in clinical practice for the treatment of hypertrophic scars.

ACKNOWLEDGMENTS

Open Access funding enabled and organized by Projekt DEAL.

AUTHOR CONTRIBUTION

"We confirm that the manuscript has been read and approved by all the authors, that the requirements for authorship as stated earlier in this document have been met, and that each author believes that the manuscript represents honest work."

DATA AVAILABILITY STATEMENT

Data sharing not applicable to this article as no datasets were generated or analysed during the current study.

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REFERENCES

1. Sorg H, Tilkorn DJ, Hager S, Hauser J, Mirastschijski U. Skin wound healing: An update on the current knowledge and concepts. *Eur Surg Res*. 2017;58:81-94.
2. Aarabi S, Longaker MT, Gurtner GC. Hypertrophic scar formation following burns and trauma: new approaches to treatment. *PLoS Med*. 2007;4(9):e234.
3. Alexiades-Armenakas MR, Dover JS, Arndt KA. The spectrum of laser skin resurfacing: Nonablative, fractional, and ablative laser resurfacing. *J Am Acad Dermatol*. 2008;58:719.
4. Shin JU, Gantsetseg D, Jung JY, et al. Comparison of non-ablative and ablative fractional laser treatments in a postoperative scar study. *Lasers Surg Med*. 2014;46:741-749.
5. Yang YJ, Lee GY. Treatment of striae distensae with nonablative fractional laser versus ablative CO2 fractional laser: a randomized controlled trial. *Ann Dermatol*. 2011;23:481-489.
6. Laubach HJ, Tannous Z, Anderson RR, Manstein D. Skin responses to fractional photothermolysis. *Lasers Surg Med*. 2006;38:142-149.
7. Alster TS. Improvement of erythematous and hypertrophic scars by the 585-nm flashlamp-pumped pulsed dye laser. *Ann Plast Surg*. 1994;32:186.
8. Donelan MB, Parrett BM, Sheridan RL. Pulsed dye laser therapy and z-plasty for facial burn scars: the alternative to excision. *Ann Plast Surg*. 2008;60:480.
9. Vrijman C, van Drooge AM, Limpens J, et al. Laser and intense pulsed light therapy for the treatment of hypertrophic scars: a systematic review. *Br J Dermatol*. 2011;165:934.
10. Al-Mohamady A-S, Ibrahim SM, Muhammad MM. Pulsed dye laser versus long-pulsed Nd:YAG laser in the treatment of hypertrophic scars and keloid: A comparative randomized split-scar trial. *J Cosmet Laser Ther*. 2016;18(4):208-212.
11. Khandelwal A, Yelvington M, Tang X, Brown S. Ablative fractional photothermolysis for the treatment of hypertrophic burn scars in adult and pediatric patients: a single surgeon's experience. *J Burn Care Res*. 2014;35:455.
12. Tredget EE, Levi B, Donelan MB. Biology and principles of scar management and burn reconstruction. *Surg Clin North Am*. 2014;94:793.
13. Fu X, Dong J, Wang S, Yan M, Yao M. Advances in the treatment of traumatic scars with laser, intense pulsed light, radiofrequency, and ultrasound. *Burns Trauma*. 2019;7:1.
14. Qu L, Liu A, Zhou L, et al. Clinical and molecular effects on mature burn scars after treatment with a fractional CO(2) laser. *Lasers Surg Med*. 2012;44:517.
15. Karmisholt KE, Wenande E, Thaysen-Petersen D, Philipsen PA, Paasch U, Haedersdal M. Early intervention with non-ablative fractional laser to improve cutaneous scarring—A randomized controlled trial on the impact of intervention time and fluence levels. *Lasers Surg Med*. 2018;50:28-36.
16. Hultman CS, Edkins RE, Lee CN, et al. Shine on: Review of laser- and light-based therapies for the treatment of burn scars. *Dermatol Res Pract*. 2012;2012:243651.
17. Erol OO, Gurlek A, Agaoglu G, et al. Treatment of hypertrophic scars and keloids using intense pulsed light (IPL). *Aesthetic Plast Surg*. 2008;32:902.
18. Trelles MA, Martinez-Carpio PA. Clinical and histological results in the treatment of atrophic and hypertrophic scars using a combined method of radiofrequency, ultrasound, and transepidermal drug delivery. *Int J Dermatol*. 2016;55(8):926-933.
19. Trelles MA, Martinez-Carpio PA. Attenuation of acne scars using high power fractional ablative unipolar radiofrequency and ultrasound for transepidermal delivery of bioactive compounds through microchannels. *Lasers Surg Med*. 2014;46(2):152-159.
20. Avci P, Gupta A, Sadasivam M, et al. Low-level laser (light) therapy (LLLT) in skin: stimulating, healing, restoring. *Semin Cutan Med Surg*. 2013;32(1):41-52.
21. Freitas CP, Melo C, Alexandrino AM, Noites A. Efficacy of low-level laser therapy on scar tissue. *J Cosmet Laser Ther*. 2013;15(3):171-176.
22. Issa MC, Kassuga LE, Chevrand NS, Pires MT. Topical delivery of triamcinolone via skin pretreated with ablative radiofrequency: a new method in hypertrophic scar treatment. *Int J Dermatol*. 2013;52(3):367-370.
23. Kwon SD, Kye YC. Treatment of scars with a pulsed Er:YAG laser. *J Cutan Laser Ther*. 2000;2(1):27-31.
24. Kye YC. Resurfacing of pitted facial scars with a pulsed Er:YAG laser. *Dermatol Surg*. 1997;23(10):880-883.
25. Jeong JT, Kye YC. Resurfacing of pitted facial acne scars with a long-pulsed Er:YAG laser. *Dermatol Surg*. 2001;27(2):107-110.

How to cite this article: Chowdhury B, Kassir M, Salas-Alanis J, et al. Laser in surgical scar clearance: An update review. *J Cosmet Dermatol*. 2021;00:1–4. https://doi.org/10.1111/jocd.14325