Scar Therapy of Skin

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KEYWORDS

• Scars • Scar therapy • Acne scars • Surgical scars • Burn and trauma scars
• Early intervention scars • Laser-assisted drug delivery scars

KEY POINTS

- Contemporary scar therapy has evolved rapidly with multiple treatment modalities including topical, intralesional, surgical, and energy-based therapies developed to restore damage to more normal skin.
- Early intervention in wounds can mitigate and even prevent scar formation.
- Current technologies permit successful treatment of various types of scars.

Video content accompanies this article at http://www.facialplastic.theclinics.com.

INTRODUCTION: SCARS AND SCAR THERAPIES

Scars are the result of wounds that affect millions of people in the world and are prevalent in both civilians and wounded warriors injured in military combat. Scar treatment is important in medicine and belongs to all medical professionals (Videos 1 and 2). The goal of treating scars includes maximizing the functional independence of patients, improving the patient's quality of life, and enabling patients to get back as close as possible to their preinjury state. The initial injury may be caused by trauma, surgery, burns, or inflammatory skin disease (acne, lupus, and so on). Treatment of acute wounds includes systemic stabilization and surgical intervention. Despite excellent trauma and surgical care, patients continue to have functional impairments and difficult symptoms from scars. Severe cutaneous scars are disfiguring and have many associated symptomatology including pruritus, pain, decreased function, and restricted range of motion. The new goal for scar treatment is that definitive reconstruction ends with recovery of optimal appearance and function.

Multiple therapeutic options have been used to improve scars.[1] Contemporary scar therapy has evolved rapidly with a focus on tissue rehabilitation. There are multiple treatment modalities including topical, intralesional, surgical, and energy-based therapies developed to restore damaged to more normal skin. Multiple scar treatment options are listed in **Table 1** (**Fig. 1**).

Treatment of scars necessitates a multiprocedural and multispecialty approach by a team of scar-experienced medical professionals. There are many ideas and innovations showing great promise in scar therapy, but laser-based therapy has undoubtedly been the most rapid and impactful advance in scar treatment in modern days. Lasers have given scar patients the option for further scar improvements in function, symptoms, and cosmesis. Lasers are a scientifically precise and effective treatment modality to rehabilitate and improve scars.[2] In recent consensus guidelines lasers are considered first-line therapy in the management of scars.[3] Laser has added a powerful tool to improve scar deformities and symptoms.[4]

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Table 1
Scar treatment options

Current Scar Therapies	Adjunctive Scar Therapies
Topical silicone materials—gels, gel sheeting, sprays	Physical therapy
Novel wound dressings and supports	Psychological and psychiatric therapy
Topical balms—vitamin E, corticosteroids, paper tape	Emerging regenerative medicine—not FDA approved yet
Intralesional injections—triamcinolone acetonide, 5-fluoruracil, bleomycin, retinoic acid, botulinum toxin A	
Surgical revision	
Laser therapy	
Laser-assisted drug delivery	
Autologous fat grafting	
Hyperbaric oxygen therapy	

Scarring is a tissue response, acquired during the second trimester of fetal development at the same time of cellular immunity.[5] Scar tissue has increased vascular and lymphatic channels as well as changes in collagen structure compared with normal skin. However, in scars the blood vessels, lymphatics, and collagen often are in a chaotic array with resultant decreased physiologic function.

It took a Nobel prize winner, Albert Einstein, to form the concept of stimulated emission of radiation in 1917. Einstein postulated the creation of a stream of uniform photons could create a laser beam. The first carbon dioxide (CO_2) laser was invented by Patel of Bell Labs in 1964.[6]

We continue to gain understanding of the biological basis by which scars improve after laser therapy. The scar improvements occur in the epidermis, dermis, and in the adnexal skin structures. Many patients report immediate improvement in pruritus, pain, and increased range of motion within hours to weeks after even one treatment session. After laser therapy typically the skin heals first with improvement of dyschromias followed in time with improvements in texture and topography.

SURGERY AND LASER SYNERGY FOR TREATMENT OF SCARS

The treatment of scars is a multispecialty endeavor. A combination approach with medical experts yields optimal scar improvements. If an injury heals in the presence of tension, hypertrophy often ensues. Understanding the role of tension in the development of a scar is essential to design a successful treatment strategy. If there is significant hypertrophy or contracture present in a scar, surgical intervention is necessary to relieve the tension or there is a high likelihood the scar with reform. Z-plasties remain an important partner with laser in the treatment of contracture scars (**Fig. 2**). After tension relief, hypertrophic and contracture scars are more elastic with new remodeling of collagen and are more amenable to treatment with laser. However, if a scar has had initial fractional laser therapy this often makes surgical intervention easier to perform due to thinner and more pliable collagen bundles.

Fig. 1. Before and after 4 combination laser treatments of pulsed dye laser, 1927 nm thulium laser fractional ablative laser followed by 2 months of hyperbaric oxygen to heal ulcer on elbow.

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Fig. 2. Before and after a series of punch biopsies and 3 fractional ablative CO2 laser treatments on acne scars.

APPROACH TO TREATMENT OF CUTANEOUS SCARS

In the initial evaluation of the scar the physician should determine what characteristics the scar possesses and then choose therapies to address these issues. Some factors to consider when treating scars include the thickness of the scar, age of scar, body location of the scar and tension forces, skin type of the patient, and comorbid medical conditions. Next determine if a scar is hypertrophic, keloid, contracture, atrophic, or a combination. Then dyschromia of a scar should be evaluated for erythema, hyperpigmentation, and hypopigmentation. Often severe scars have multiple of these characteristics within the same scar. Our approach is to first use nonablative laser to treat vascular and pigmented components of the scar and then to use fractional ablative devices for ablation of scar tissue, coagulation of microvasculature, and stimulation of subsequent neocollagenesis, followed by a beneficial laser-assisted delivery drug. The fractional ablative devices are the mainstay of therapy due to their ability to improve all scar types. Repeated laser sessions can occur until the patient and/or physician is satisfied. After, healing silicone gel sheeting or compression therapy is reinitiated and used until scar reaches optimal improvement.

CLINICAL INDICATIONS AND TREATMENT RECOMMENDATIONS

Treating cutaneous scars requires proper diagnosis of scars as well as an understanding of their histology and biology. Most scars result from acne, surgery, trauma, or burns. Techniques and settings for each of these scars is reviewed in this chapter based on cause of scar.

Acne Scars

Acne vulgaris is the most common inflammatory dermatosis in the world. Although it presents in 95% to 100% of men and 83% to 85% of women during puberty,[7] acne commonly extends into adulthood.[8] Acne can result in scarring, postinflammatory erythema (PIE), and postinflammatory hyperpigmentation (PIH). Postinflammatory dyschromia poses a significant psychological burden on acne patients, often accounting for greater concern than the original acne lesions. For this reason, the management and treatment of postinflammatory dyschromia represents a substantial proportion of the clinical, emotional, and economic burden associated with acne vulgaris.[9] Importantly, this burden most commonly and disproportionately affects skin-of-color patients[10] and can be the most distressing aspect of acne in skin-of-color patients with Fitzpatrick skin phototypes III to VI. Laser therapy with nonablative lasers can help significantly with PIE and PIH (**Fig. 3**). Acneiform scars are the result of compromised collagen production during the natural wound healing process, resulting in cutaneous depressions. Topographic features of acne scarring include perpendicular bundles of collagen that anchor the skin of the scars down. Most of the patients have facial atrophic scars including boxcar, ice pick, and rolling types. These scars result from loss of collagen from inflammation during the wound healing process of acneiform lesions.

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Fig. 3. Before and after 2 treatments of pulsed dye laser and nonablative 1550 nm fractional laser for postinflammatory erythema, resulting in improvement of color and texture of skin.

The goal of laser resurfacing is to create neocollagenesis in the areas of collagen loss (**Fig. 4**). Given the dermal pathology present with acne scarring, particularly with atrophic scars, treatment modalities should optimally be capable of affecting dermal remodeling at least 1 mm below the skin. Patients with acne scars on their chest and back are often hypertrophic or keloidal.

Fig. 4. Combined PDL and fractional ablative CO2 laser. Before and after rolling acne scars status postablative fractional laser treatment with subcision and laser-assisted delivery of poly-L-lactic acid.

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Treatment options for acne scars include those listed in **Box 1**.

Treatment of acne scars has traditionally been challenging; however, with the advent of deep-reaching fractional lasers greater success has been achieved. Superficial approaches include glycolic acid chemical peels and topical tretinoin and topical hydroquinone for skin surface improvement and pigmentary variation. Moderate approaches to address deeper scars include punch biopsy and closure, z-plasty transposition flap, fat polysaccharide matrix or collagen, scar subcision, dermabrasion, CO_2 laser resurfacing, and most recently, fractional photothermolysis.[11] An international consensus recommendation for the energy-based devices for the treatment of acne scars was published in 2022 with multiple algorithms and recommendations.[7] In these recommendations, ablative fractional lasers played a prominent role. Ablative fractional CO_2 laser has been well studied for acne scarring. In a case series of 2 to 3 treatment sessions for moderate-to-severe acne scarring, clinical improvements of 26% to 50% were achieved in texture, atrophy, and overall improvements and on topographic analysis. Improvements in scar depths of 43% to 79.9% were achieved, with a mean depth improvement of 66.8%. Greater degree of improvement seen with ablative fractional laser technology as opposed to previous studies with nonablative fractional laser technology resulted from deeper dermal penetration of the fractionated CO_2 and Erbium:YAG devices. Particularly, they noted that patients treated for deeper scars on the cheeks with higher energy levels on the second and third treatments received the highest improvement scores.[12] Side effects with the ablative fractional device were mild to moderate, including posttreatment erythema, edema, and petechiae, all of which resolved within 7 days after each treatment. Correlating with these clinical data, in vivo studies by Hantash and colleagues with this device have shown tissue ablation and thermal effects as deep as 1 mm into this skin, likely accounting for the effect on moderate-to-severe acne scarring observed.[13]

Another study with the fractionated CO_2 laser for the treatment of acne scarring 15 subjects underwent up to 3 treatments. Patients with a diversity of skin types (I–V) were treated with no complications of short- or long-term hyperpigmentation reported. Eighty-seven percent of subjects sustained significant improvement in the appearance of acne scarring at 3-month follow-up visits. All subjects reported transient erythema, which resolved in the first 2 weeks after treatment.[14] Ablative fractional devices work for all skin types. In a prospective study in 5 Asian patients of skin phototype IV, with moderate to severe atrophic acne scarring, 2 sessions of an ablative fractional CO_2 laser treatment were performed 6 to 8 weeks apart.[15]

Box 1
Acne scar treatments

- Punch biopsies—rolling and boxcar
- Z-plasty
- Microcoring
- Subcision
- Fractional laser resurfacing
- Microneedling radiofrequency
- Fillers and biostimulators
- Injectable antimetabolites
- Retinoids
- Dermabrasion

Surgical Scars

All surgical scars improve with fractional ablative laser. First one must evaluate if the surgical scar is elevated (hypertrophic) or depressed (atrophic). The thicker hypertrophic scars need deeper treatment depths, whereas more atrophic scars can be treated more superficially. Early surgical scars with significant erythema respond to vascular lasers with or without same day treatment of fractional lasers (**Fig. 5**). In a study of 23 Korean women with thyroidectomy scars single session of 2 passes with a fractional CO_2 laser with a pulse energy of 50 mJ and density of 100 spots/cm^2 was performed. Treatments were performed 2 to 3 weeks after surgery.[16]

Burn and Traumatic Scars

Burn and traumatic scars are typically first treated by the burn and reconstructive surgeons to stabilize the injuries. The surgical tools are listed in **Box 2**. After surgical intervention laser therapy should be used. Erythematous, hypertrophic scars are seen frequently in the first year after injury. Vascular-specific lasers and light devices, especially the 595-nm pulsed dye laser (PDL), are already well established for such applications, and its use has been highlighted in 2 recent reviews.[17,18] PDL may be applied alone for small hypertrophic scars but is often combined with fractional laser therapy in either concurrent or alternating treatment sessions. Hypertrophic scars develop as a result of increased proliferation of dermal fibroblasts, resulting in excess of collagen in the wound, which results in an elevated cutaneous surface. Hypertrophic burn

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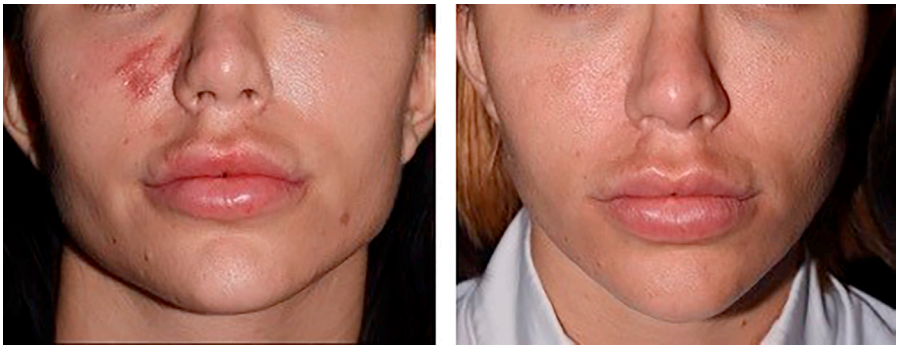

Fig. 5. Before and after early intervention 1 month postsurgical revision from traumatic injury 2 treatment sessions of pulsed dye laser, 1927, AFL.

and traumatic scars are best improved by either ablative or nonablative fractional lasers (Fig. 6). Ablative fractional lasers have the capacity to induce a more robust remodeling response than nonablative fractional lasers.[16,17] Ablative lasers have a significantly greater potential depth of thermal injury compared with nonablative lasers, 1.8 mm compared with 4.0 mm, respectively (LumenisSCAAR FX software). Furthermore, tissue ablation seems to induce a modest immediate photomechanical release of tension in some restrictive scars. An appropriate degree of surrounding thermal coagulation facilitates the subsequent remodeling response. An estimation of scar pliability and thickness through palpation is central to determining appropriate laser pulse energy settings (treatment depth). Treatment depth should not exceed the thickness of the scar. Pigmentary abnormalities (hypopigmentation, hyperpigmentation, depigmentation) of scars also improve with fractional therapy.

Flat or atrophic scars from burns and trauma also respond to fractional laser therapy (Fig. 7). Atrophic scars are dermal depression that occur due to collagen destruction during an injury. The goal of laser treatment of atrophic scars is to stimulate collagen production within the atrophic areas. Neocollagenesis is stimulated the most from fractional laser therapy and thus makes it the best choice for flat or thin scars.

Box 2
Surgical correction of hypertrophic scars and contracture scars

Scar release with local tissue—Z-plasty, W-plasty
Scar release with skin graft
Flaps
Composite tissue allotransplantation
Autologous fat grafting
Laser therapy

PREOPERATIVE AND TREATMENT SCAR THERAPY CONSIDERATIONS

With any scar therapeutic procedure, informed consent should include a realistic discussion of therapeutic goals, limitations, and potential complications. A team approach is vital, as professional wound care, physical and occupational therapy, and surgical consultation should be available, if possible, throughout the treatment course to optimize outcomes. Pertinent historical information during the initial evaluation includes the time and mechanism of injury, surgical history and schedule of upcoming procedures, previous complications, current limitations and treatment goals, pain and sensory issues, presence of posttraumatic stress, and response to current therapy. Physical examination should elicit scar characteristics such as the presence of residual erosions and ulcers, erythema, pliability, textural irregularity, dyspigmentation, and scar thickness and degree of restriction. Associated features that may relate to adjunctive treatments include the presence or absence of residual hair, hyperhidrosis, traumatic tattoos, and related dermatologic conditions such as folliculitis.

Lastly, many patients with severe burn or traumatic scars may have developed posttraumatic stress (PTSD) and/or traumatic brain injury (TBI). If patients have either PTSD or TBI other medical paraprofessionals including psychiatrists are recommended to be part of the treatment team.

Laser-Assisted Delivery of Scars

Laser-assisted delivery uses fractional ablative columns to deliver molecules to maximize each scar treatment. These fractional ablative zones created by either CO_2 or erbium:YAG fractional lasers may be used immediately postoperatively to deliver drugs and other substances to synergistically create an enhanced therapeutic response. Ablative channels are tunable and can be

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Fig. 6. Before and after hypertrophic burn scar after 5 sessions 1927 nm and 2940 AFL TAC/5FU LAD and sustained compression.

delivered in depths of 100 to 4000 μm for targeted cutaneous drug delivery. **Table 2** shows types of scars and published types of laser-assisted drug delivery. Waibel and colleagues authored a head-to-head trial looking at ways to repigment hypopigmentation, and the statistical winner for best repigmentation was laser-assisted delivery with bimatoprost, a prostaglandin analogue.[18] The study showed the use of the nonablative fractional laser, ablative fractional laser, ablative fractional laser with laser-assisted delivered bimatoprost, and an epidermal harvesting system. Using a fractional nonablative laser or ablative laser alone can cause repigmentation by stimulating stem cells that exist deep along the hair follicle. Another laser often used for hypopigmentation is the 308-nm Excimer laser that will stimulate melanocytes as well in many hypopigmented scars. Initially older patients with glaucoma used drops of bimatoprost in their eyes to lower intraocular pressure and notice their eyelashes growing longer and darker. It turns out bimatoprost and other prostaglandin analogues in this drug class stimulate melanocytes to create pigmentation. The melanocytes are located in the basal laser of the epidermis and are about 90 to 100 μm in depth. In 2011 Edwards and colleagues studied the effects head-to-head on pigmentation of 3 prostaglandin

Fig. 7. Before and after dog bite atrophic trauma scar status after 6 treatment sessions of pulsed dye laser, 1550 nm nonablative fractional laser, 1927 nm nonablative thulium laser, ablative fractional laser, and poly-L-lactic acid.

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Table 2
Types of scars and published types of laser-assisted drug delivery

Type of Scar	Laser-Assisted Drug	Comments
Hypertrophic scar	Corticosteroid Triamcinolone acetonide 10–40 mg/mL	Typically recommend starting with 10 mg/mL for most scars, caution in skin of color; higher doses may lead to transient or permanent damage to melanocyte/hypopigmentation
Hypertrophic scar	5-Fluoruracil	—
Atrophic scar	Poly-L-lactic acid	—
Hypopigmented scar	Poly-L-lactic acid Bimatoprost, latanoprost, and travoprost	Use twice a day after laser for 7 d

analogues including latanoprost versus bimatoprost versus travoprost on periocular skin pigmentation. The conclusions revealed that all 3 prostaglandin analogues induce darkening of the eyelid skin that is objectively detected as a decrease in the L* value. Although not reaching levels of statistical significance, this change was more dramatic for bimatoprost, more common in Caucasians and in women. The greatest degree of change occurred at 6 and 9 months after initiating treatment.[19] Lastly, a recent evidence-based practice guideline for laser-assisted drug delivery was published with pearls and pitfalls for clinicians.[20]

WHEN TO TREAT A SCAR: EARLY INTERVENTION MAKES A DIFFERENCE

Scar tissue forms slowly, and depending on which type of scar and tissue, it may take months to years. Thus, intervening early on the provider may not only mitigate but actually prevent scar formation. **Table 3** reviews early interventions that have the potential to reduce scar formation. Traditionally reconstructive efforts have been delayed until 1 year after injury. At this time many patients have formed hypertrophic scars and have a significant decrease in range of motion. We now have clinical evidence that minimally invasive devices applied early after injury may prevent scars. After significant trauma injury fibroblasts eventually will close the wound by causing it to contract and by laying down collagen in excess. It is important to remember that hypertrophic scarring typically increases over the first 3 to 5 months after acute burn injury and can increase for over 2 years. In 2018 Karmisholt and colleagues published a systemic review on early laser intervention in different wound healing phases and potential clinical outcome on scar formation.[21] According to the results of this review, treating scars in the healing and proliferative phases decreased scar formation significantly more than the mature phase. Waibel and colleagues then performed a randomized control trial on the early intervention of fractional ablative lasers versus control for acute severe burn injuries of those hospitalized in the burn unit. This is the first randomized control study on severe trauma patients to show early intervention with the ablative fractional CO_2 laser prevents scarring when used within the first 3 months after burn injury. This information could potentially help patients live a better quality of life.[22,23] The optimal time to begin fractional laser treatment is early. As a rule, there should be a healed and intact epidermis before laser treatment. Younger, less mature scars are less tolerant of aggressive treatment and should be treated more cautiously. Mature scars, whether 1 year old or 60 years old, all respond well to laser therapy. A minimum treatment interval of 1 to 3 months between fractional laser treatments is recommended to give scar tissue, which is the compromised time to heal. Even after just one treatment session a patient may continue to have improvement for many months up to 1 year.

Table 3
Early interventions that have the potential to reduce scar formation

Passive General Preventative Measures	Active Preventative Scar Mitigation
Moisturization Silicone products Sun avoidance	Contracture—stretch Raise up—compression/pressure garments Firm—soften—massage, silicone Color/texture—laser

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SUMMARY

Scar treatments have been around as long as life. The Egyptians, Romans, and Chinese all developed remedies to promote the healing of wounds to prevent scars. In these times cocoa, aloe, honey, and oak bark were used. Military medicine has challenged medicine, as our trauma surgeons can save any life and often with catastrophic injuries. We must continue to be committed through scientific inquiry to helping both wounded warriors and civilians. It is a new era in the treatment of scars. Current technologies permit successful treatment of various types of scars. The research is in an exciting state of intensive investigation, with many promising therapies being studied to evaluate their role in scar therapy. Many pharmacologic therapies may help prevent scars although more research is needed. Other scientists are studying mechanical ways to facilitate healing and prevent scarring by using methods to modulate tension vectors on skin that contribute to hypertrophic scarring. The next major breakthrough will most likely be regenerative medicine. Regenerative medicine, whether using stem cells, messenger RNA, or gene modification, may prevent scarring altogether. Current day patients receive new elegant devices such as lasers to let human body regenerate itself. Early preventative measures are emerging as an important role in scar mitigation. Laser therapy is at the forefront of treatment. Continued advances in science, medicine, and regeneration will serve to further shape the management of scars in the future.

CLINICS CARE POINTS

- Early intervention is beneficial to lessen possible complications of scarring.
- Start by evaluating the scar, noting the thickness, location, and tension forces surrounding it.
- Then, determine its phenotype for better treatment approach.
- Fractional ablative devices benefit all scar types.
- The most common corticosteroid to combine with ablative fractional lasers is triamcinolone acetonide suspension.
- When treating acne scars, treatment modalities should penetrate at least 1 mm below the skin.
- For contracture scars, z-plasties are often paired with laser treatment for best results.

SUPPLEMENTARY DATA

Supplementary data related to this article can be found online at https://doi.org/10.1016/j.fsc.2023.06.005.

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