Laser Treatment of Scars

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Abstract

Recent advances in optical technologies have produced laser systems capable of optimizing the appearance of scars from various etiologies. Laser treatment can commence as early as the time of the initial injury and as late as several years after the injury. Optimal results can now be attained with minimal down time. Herein, we review several available optical technologies for treatment of surgical, traumatic, and inflammatory scars, based upon our clinical experience.

Keywords

- laser
- scar
- revision
- fractional
- acne

This article will discuss use of laser technologies in acute management of soft tissue injuries in surgical incisions, trauma, and inflammatory conditions of the skin. To minimize scar formation, current standard of care in acute management of surgical incisions includes irrigation and cleansing, multilayered, tension-free closure with precise approximation and eversion of wound edges, judicious use of suture material, use of postoperative moisture barrier, or dressing and early removal of surgical sutures. Traumatic soft tissue injury involving the skin can be more challenging to manage acutely due to presence of crushed, macerated, or otherwise devitalized tissues. Additional steps are often warranted in that setting including removal of foreign bodies, copious irrigation of the wound, removal of clearly devitalized tissues, and use of antibiotics to cover polymicrobial flora. Despite these measures, poor cosmetic outcome is frequent after both traumatic skin injuries and traditional surgical procedures used to correct them.

Numerous adjunctive measures have been proposed to optimize wound healing and obviate the need for operative scar revision, many of which are discussed in this volume. These include use of steroids, posttreatment dressings, avoidance of sunlight, dermabrasion, and laser treatment. In classic dermabrasion, mechanical debridement of the superficial papillary dermis leads to reepithelialization via the adnexal structures resulting in improved texture and color of the skin. This is an excellent method for smoothing an irregular surface or correcting pigmentary discrepancy between adjacent skin edges, which alters how light creates shadows across the surface. Dermabrasion is recommended 6 to 8 weeks after injury/surgical procedure. More substantial improvements are reported during this period as the immature scar is still undergoing remodeling rather than during the mature phase.[1] Proposed mechanism of action for this modality has been described by Harmon et al[2] as reorganization of connective tissue ultrastructure and epithelial cell–cell interactions with an increase in collagen bundle density and size with a tendency toward unidirectional orientation of fibers parallel to the epidermal surface. Although excellent outcomes have been described with this technique, it does require operator expertise and a greater learning curve for the manual control of the dermabrasion depth and the feathering of edges. Additionally, this technique can be complicated by bleeding and the tearing of tissues at the treatment margin. Laser scar revision is a competing technology that has gained popularity due to the potential for excellent

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hemostasis, ease of use, and precise control over depth of penetration and extent of treatment.

Inflammatory conditions of the skin such as cystic acne and varicella can lead to depressed scarring. This class of injury behaves differently from scars produced by surgery or trauma. Attempts to disguise the appearance of these scars with makeup are often counterproductive and lead to magnification of textural variations. Adjunctive treatment strategies such as excision, punch grafting, dermabrasion, and tissue augmentation with a variety of filler substances have been used to improve atrophic scars with inconsistent success, and are highly surgeon dependent. Recontouring of these lesions with various laser modalities has therefore gained popularity in the recent years, as with traumatic injury, altering the interplay of light and shadow across the scar contributes much to the correction of the deformity.

Since the introduction of laser skin resurfacing for aesthetic surgery in the mid-1990s, the technology has evolved as a useful tool for scar revision. Laser and optical methods for the management of cutaneous injuries have a very vital role in the therapeutic outcome. With advances in this technology, clinicians are now at a crossroads with respect to making the decision to treat a scar with surgical revision, dermabrasion, or various laser technologies. We present and review our experience herein to provide some guidance with this decision making process in the acute setting. This article will discuss indications and relative merits of available optical treatment modalities. Our discussion is practically oriented and structured around the specific applications of each technology.

Scar Classification

In this section, we seek primarily to distinguish between hypertrophic and atrophic scars in terms of their variable etiology. Hypertrophic scars are erythematous and raised, occurring in areas under tensile deformation or in locations that are prone to slow wound healing. These scars result from relatively unrestrained proliferation of collagen during the wound remodeling phase. Abnormal tissue proliferation typically occurs within 1 month of injury and may regress over time. Keloids represent extension of scar formation beyond the boundaries of the original wound and they have been linked to ethnic/genetic predispositions. Pulsed dye laser (PDL) treatment of these lesions helps decrease vascularity and inhibit overactive fibroblast growth.

In contrast, atrophic scars are depressions of the dermal layer of the skin that are associated with inflammatory conditions that lead to destruction of the collagen component of the dermis. Less commonly, surgery and traumatic injuries can cause this histopathologic pattern of scarring. Although the use of dermal fillers makes intuitive sense for replacing lost volume, their operator-dependent efficacy as well as temporary clinical effects and cost limit their usefulness. In contrast, laser resurfacing allows for reproducible vaporization and contouring of the surrounding skin with improved operator control.

Considerations in the Management of Surgical Scars

Scars can be disfiguring, aesthetically unacceptable, and cause pruritus, tenderness, pain, sleep disturbance, anxiety, and depression in postsurgical patients. Regardless of the specific strategy for treatment, current optical technologies offer the reconstructive surgeon valuable tools to lessen the psychological burden of undergoing surgery by optimizing the cosmetic outcome in a noninvasive or minimally invasive form. Availability of these tools can lead to higher levels of patient satisfaction after surgery.

For purposes of this discussion, a surgical incision is defined as an incision that is closed per standard of care as discussed above with optimal postsurgical care and without perioperative wound complications. The ideal postsurgical scar is flat, flexible, and indistinguishable from surrounding skin in terms of color and texture. Despite optimal wound closure and postoperative care, aberrant fibroblast response can lead to hypertrophic or keloid scars and aberrant angiogenesis may lead to telangiectasias or a hyperemic scar. Imperfect surgical closure or poor postoperative management can lead to suboptimal outcomes with step-offs, depressions, suture marks, dyspigmentation, or broad hypertrophic scars due to wound tension or distal flap vascular compromise and tissue necrosis. Abnormal collagen deposition has been demonstrated histologically in hypertrophic scars with elevated levels of collagen III.[3] Traditionally improved via mechanical dermabrasion, the current arsenal for optimization of surgical wounds includes various optical technologies such as conventional ablative laser resurfacing and nonablative laser treatment as well as fractionated and pulsed laser technologies. Acute optimization of wound healing can start immediately after the completion of surgery as in laser-assisted scar healing,[4] after removal of sutures within 1 week postoperatively, or it may focus on treatment of maturing scars several weeks to months after surgery (see ►**Fig. 1**).

Considerations in Management of Traumatic Scars

Some injuries such as uncomplicated straight lacerations are indistinguishable from surgical incisions. The challenge with traumatic skin injuries lies in irregular borders, high tension,

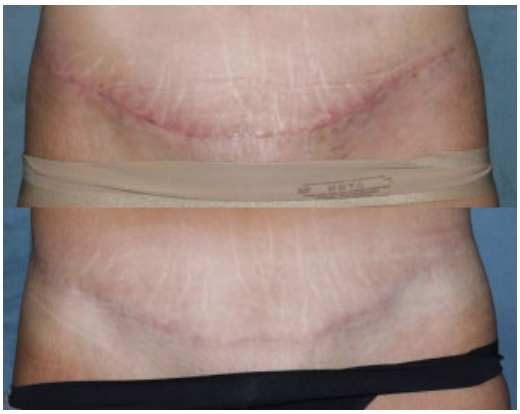

Figure 1 (Top) One month after abdominoplasty. (Bottom) Six months after four treatment sessions with Fraxel Re:Store (1550 nm) 30 mJ/32% staring 1 month after surgery.

macerated tissue, and tissue loss. More often than not, traumatic lacerations involve nonlinear or stellate disruption of the epidermis that is not orthogonal to the skin surface. Abrasions can harbor foreign bodies, which if not adequately debrided can lead to traumatic tattooing. Presence of tissue edema, hematoma, and loss of tissue can force a high-tension closure, which can lead to broad hypertrophic scarring. Risk of infection is compounded by inadequate cleansing and irrigation of tissues and lack of proper antibiotic coverage after repair. Devitalized, necrosed skin edges and infected wounds can lead to severe atrophic or hypertrophic scars and extremely poor cosmetic outcomes. Use of copious irrigation and antibiotic coverage for gram-positive skin flora with first or second generation cephalosporins or clindamycin should be considered in these patients. In the case of an animal or human bite or other gross contaminations of the wound, appropriate adjustments to the antibiotic coverage must be made.

Due to the specific patient population as well as the treatment setting, poor follow-up is often an issue with these patients leading to improper postoperative care such as suture retention or delay in diagnosis of wound infection. Use of rapidly absorbing suture material where available and appropriate is therefore advised in traumatic skin closure, particularly in those whose attention to follow-up is uncertain. Delayed presentation to the surgeon can also be an issue in this population as the patient is often acutely managed by an emergency room physician, family doctor, physician assistant, or a general surgeon as opposed to a specialist with reconstructive surgical expertise. Intervention should occur as early as possible following presentation to prevent progression in the direction of an undesirable mature scar, which may require surgical revision (see ►**Fig. 2**).

Considerations in Management of Acne Scars

Although acne remains a minor nuisance in the lives of the majority, a sizable number of patients suffer from more severe inflammatory forms of the disease that lead to social ostracism, withdrawal, and depression. Depressed acne scars can be diagrammed as variably shaped troughs in the skin that are visible as irregularities of the skin due to their differential reflection of the light. The goal of laser treatment is to ablate the surrounding skin in such a way to reduce the angularity depth of these troughs and potentially induce new dermal tissue growth and thereby improve the overall texture of the skin. As an additional benefit, thermal effects of the laser can lead to collagen remodeling and partial regeneration of the dermal layer, thus further effacing the depressed scar (see ►**Fig. 3**).

Previous history of isotretinoin (Accutane™ [Roche Pharmaceuticals, Nutley, NJ]) use, chemical peels, dermal fillers, and silicone injections in the area of interest should be considered in these patients as reasons to delay or abandon the use of laser treatment due to the possibility of excessive scarring and poor wound healing after the procedure.

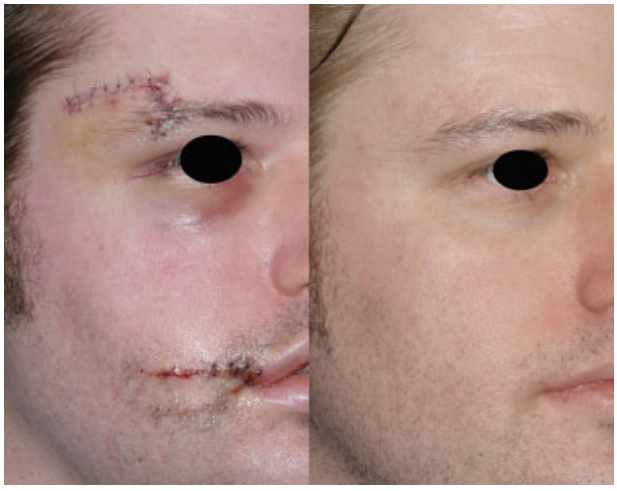

Figure 2 (Left) Three days after traumatic laceration. (Right) One month after six treatment sessions with Fraxel Re:Store (1550 nm) 20 mJ/32% performed at 2-week intervals starting 2 weeks after suture removal.

Optical Management of Scars

This discussion will encompass: (1) conventional ablative resurfacing lasers; (2) PDL; and (3) fractionated lasers.

Ablative Laser Resurfacing

Traditional laser resurfacing is a technique that is commonly accomplished via ablative devices such as conventional carbon dioxide (CO_2) or erbium:yttrium-aluminum-garnet (YAG) lasers. The mechanism of action is similar to using a mechanical dermabrader with the potential to modulate wound healing through thermal effects of laser treatment and trigger the same regenerative mechanisms as when these devices are used for classic facial resurfacing. Tissue removal by laser is a function of treatment parameters, tissue optical properties, and tissue thermal properties. Histologically, laser-treated skin shows a subepidermal dermal repair zone consisting of compact new collagen fibers overlying collagen with evidence of solar elastosis.[5] Because it is possible to achieve discrete, measurable incremental amounts of tissue removal with each pulse, the learning curve for achieving optimal results is relatively modest.

Carbon Dioxide

The CO_2 laser is the workhorse of cosmetic dermatology and the platform technology to which all optical therapies should be compared. With nearly 20 years of broad clinical adoption, CO_2 laser skin resurfacing remains very valuable, can remove bulk amounts of tissue in a bloodless fashion, and correct contour irregularities/facets at the periphery of lesions. Differences in outcomes between CO_2 and dermabrasion remain incompletely understood, and no randomized prospective study on this topic has been reported to the best of our knowledge.[6,7] However, due to decreasing technology-associated costs, ease of use, and reduced reliance upon extensive training and experience, CO_2 laser resurfacing has slowly gained popularity. CO_2 lasers emit light at 10,600 nm that is preferentially absorbed by water (its principal chromophore) leading to superficial ablation of tissue by vaporization, provided pulse energy is adequate to heat water past its

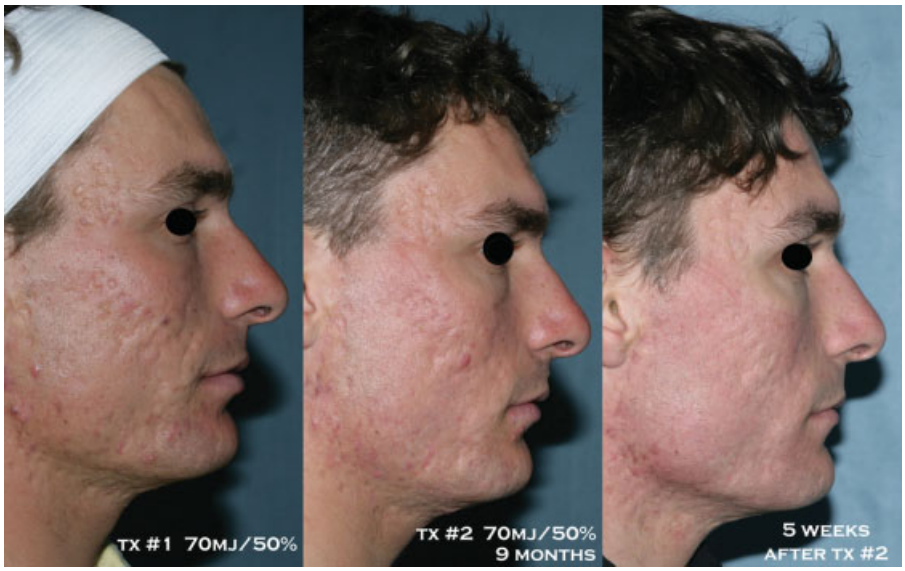

Figure 3 Acne scarring prior to treatment. No treatment (left), after first treatment (middle), and 5 weeks after two treatments (right). Treatment using Fraxel Re:Pair (10640 nm) 70 mJ, 50%.

phase transition at 100°C. Although the majority of the energy is absorbed by the first 20 to 30 µm of the skin, the zone of thermal damage can be as much as 1 mm deep, depending upon the pulse duration of the laser.[8] Residual thermal injury in the remaining tissue is in part responsible for the persistent erythema experienced by patients that can continue for 6 months or longer after CO_2 laser treatment, albeit this contributes to enhanced collagen remodeling. Timing of the treatment is typically the same as mechanical dermabrasion, optimally performed 4 to 8 weeks after the initial injury. The ideal application of this laser is for induction of contour changes and collagen remodeling in elevated scars.

Erbium:YAG Laser

Introduced to dermatology in the mid 1990s, the erbium: YAG laser also removes tissue, but the penetration depth of its wavelength (2936 nm) is shallow as is the corresponding depth of thermal injury. Light from this laser is absorbed 12 to18 times more efficiently by water compared with the CO_2 laser. However, the more superficial depth of penetration and surrounding tissue injury lead to decreased induction of collagen remodeling and contraction.[9] Due to poor coagulative properties, hemostasis can also be a problem with this modality, particularly if extensive tissue needs to be removed. Application of this laser is for generating subtle contour changes in depressed and atrophic scars. Additionally, the erbium:YAG laser may be used in cases where thermal injury is undesirable (such as a known keloid former).

Pulsed Dye Laser

The PDL relies upon the concept of selective photothermolysis.[10] The 585- to 595-nm wavelengths are preferentially absorbed by hemoglobin, although epidermal melanin absorption can be of concern in patients with darker skin phototypes. This selectivity makes this technology ideal for the treatment of vascular skin lesions such as telangiectasia, port-wine stains, and hemangiomas. During scar treatment, PDL destroys the blood supply to the wound edge at the level of dermal microvasculature, inhibiting the formation of scars. The angiolytic mechanism of action has been disputed by some authors.[11] Alternatively, changes in cell cycle distribution of fibroblasts in keloid scars has been proposed recently as a mechanism of action of PDL treatment in keloid scars.[12]

Properties of this laser make it suitable for treatment of red, hyperemic, hypertrophic scars and keloids. The PDL improves color, texture, and pliability of scars by reducing pigmentation, vascularity, and bulk of scar tissue.[13] Because it spares the epidermal and dermal tissues, treatment can be repeated at 6- to 8-week intervals with significantly reduced downtime and erythema compared with conventional CO_2 laser resurfacing. Due to competitive absorption of the emitted energy by melanin, darker-toned individuals (Fitzpatrick IV to V) may not be suitable candidates for this treatment due to risk of dyspigmentation.[14] Our parameters for PDL wound optimization are listed in ►**Table 1**.

Fractional Photothermolysis

Fractional photothermolysis, first introduced by Manstein and colleagues in 2004,[15] is the latest in the available phototherapeutics for scars. Fractionation refers to a technology in which thousands of pinpoint laser beams are directed at the skin surface simultaneously in such a way as to target a fraction of the overall surface area while sparing the intervening areas of skin. Confluent epidermal damage is thus avoided. Mechanism of action is via initial induction of proinflammatory cytokines followed by dermal remodeling and collagen induction.[16] Reepithelialization is observed after as early as 1 day leading to reduced downtime and higher patient satisfaction.

Table 1 Our Parameters for Treatment of Surgical and Traumatic Scars

Device	Parameters
PDL	Low fluence (4 to 5 J/cm^2), short pulse (0.45 ms), large spot 10 to 12 mm, 30/30 DCD, starting 2 to 4 wk after suture removal, 4- to 6-wk treatment intervals
Sciton™ ProFractional® (Sciton Inc., Palo Alto, CA)	250- to 600-μm spot size, 20–30% coverage, starting 2 to 4 wk after suture removal, 4- to 6-wk treatment intervals
Fraxel™ Re:Store® (Reliant Technologies Inc., Mountain View, CA)	20 mJ and 32% density, starting 2 wk after suture removal, 4 to 6 treatments at 2-wk intervals

PDL, pulsed dye laser; DCD, dynamic cooling device.

The first fractional lasers were nonablative using mid-infrared erbium-doped fiber lasers. However, the technology base has broaden to include several ablative and nonablative fractionated lasers such as 532-nm diode, 850- to 1350-nm infrared, 1064- to 2940-nm erbium:YAG, 2790-nm yttrium scandium gallium garnet, and 10,600-nm CO_2. The exact technique and device parameters including microablation spot size and density are highly variable and physician- and device-dependent. No ideal fractionation pattern has been established to date, as this is still an emerging technology with heterogeneous use and adoption patterns. These lasers have demonstrated efficacy in improvement of surgical and traumatic atrophic and hypertrophic scars.[17,18] The chief advantage of these lasers is their superior side-effect profile compared with conventional ablative lasers including lower risk of scarring and dyspigmentation along with proven effectiveness (see ►**Figs. 4** and **5**).

Timing of Treatment

Most reconstructive surgical interventions are focused on timing with respect to return of tissue mechanical stability. Conventional laser resurfacing and mechanical dermabrasion can potentially destabilize a healing tissue bed or disrupt the protective epidermal barrier prior to the incision seal. Therefore the optimal time for treatment was during the premature phase of scar formation at ~6 to 8 weeks postinjury. Newer nonablative, pulsed, or fractionated lasers place minimal mechanical stress on the tissues making an argument for earlier treatments. Earlier intervention can in theory alter the inflammatory phase of wound healing and change fibroblast migration leading to a reduction in the appearance of scars. Additionally, alterations in microcirculation of the wound induced by laser treatment may be responsible for prevention of excessive scar formation at the incision line.

Benefits of early treatment with PDL for prevention of traumatic and surgical scars were initially demonstrated in a study by McGraw et al in 1999.[19] Treatment within the first few weeks resulted in faster resolution of scar stiffness and erythema and less frequent development of hypertrophic scarring. Moreover, excellent color blending of the treated scars was obtained after treatment. Other studies have since confirmed the benefits of treatment as early as the time of suture removal.[20,21] Initial consensus recommendations for nonablative fractional laser Fraxel (Reliant Technologies Inc., Mountain View, CA) included treatment at 2 to 4 weeks postinjury/postoperative.[22]

Further development of the concept of early interference has led to the development of laser-assisted scar healing. This was first proposed by Capon et al in 2001 using an 815-nm diode laser.[4] In animal subjects, they demonstrated accelerated healing with an earlier continuous dermis and epidermis, resulting in a more indiscernible scar. Tensile strength was significantly greater than control at 7 and 15 days. Clinical trials have affirmed this result, and benefits of the use of this technique in a known hypertrophic scar former have also been demonstrated since the pilot study.[23–25] These preliminary results seem encouraging, but further clinical studies to confirm the effects and to elucidate the exact mechanisms of action are warranted.

Figure 4 (Left) Hypertrophic scarring that resulted from a full-face plasma resurfacing procedure 3 months previously. (Right) One year after completing treatment with intralesional 5-fluorouracil/Kenalog (45 mg/mL and 1 mg/mL), V-Beam Perfecta (595 nm, 6 J/cm^2, 6 ms, 10 mm), and Fraxel Re:Store (20 to 30 mJ/32%). Treatments were done at 2-day to 1-month intervals.

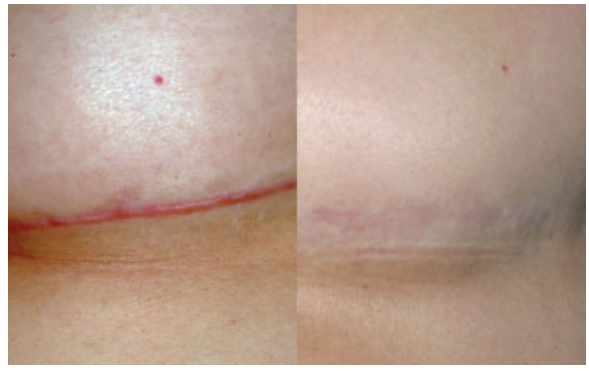

Figure 5 (Left) Hypertrophic scar 1 month after breast augmentation. (Right) One year after completing treatment with intralesional 5-fluorouracil/Kenalog (45 mg/mL and 1 mg/mL), V-Beam Perfecta (595 nm, 6 J/cm^2, 6 ms, 10 mm), and Fraxel Re:Store (20 to 30 mJ/32%).

Treatment of Traumatic Tattoos

Inadequate primary cleansing of dirt-ingrained skin abrasions can result in disfiguring traumatic tattoos. The resultant traumatic micropigmentation may be treated with excision, dermabrasion, salabrasion, overgrafting, cryotherapy, and microsurgical removal in addition to optical treatments. Laser treatment of collagen entrapped pigmented particles takes advantage of selective photothermolysis principle. As such, it is theorized that selective absorption of thermal energy by the entrapped particles leads to photodisruption of the particles into numerous smaller particles that are subsequently phagocytosed and removed by macrophages. Q-switching is a laser technology with widespread use in removal of elective tattoos that allows production of high peak powered pulses with extremely short nanosecond pulse durations. Q-switched ruby, alexandrite, and Nd:YAG lasers have all been demonstrated as effective treatment modalities for traumatic tattoos.[26–29] Repeated treatment, spaced apart by a minimum of 1 month, may be necessary.

Laser Treatment of Acne Scars

Traditional recontouring of atrophic facial scars with CO_2 and erbium:YAG lasers has become popular over the last decade. The ability of these laser systems to ablate water-containing tissue selectively led to reproducible degrees of skin vaporization and provided greater operator control than with chemical peels or dermabrasion; albeit at a higher technology cost. Use of ablative lasers was, however, associated with an extended posttreatment recovery period and the potential risks of delayed wound healing, pigmentary changes, and scarring. As with the case of other scar categories, use of nonablative lasers for initiation and enhanced dermal collagen remodeling in atrophic scars has been popularized. The newest generation of nonablative modalities, including 1320-nm Nd:YAG, 1450-nm diode, and 1540-nm erbium:glass laser systems, uses deeply penetrating mid-infrared wavelengths coupled with surface cooling technologies to protect the epidermis. As such, these treatment modalities are better tolerated by patients as they strive to match results achieved by gold-standard ablative CO_2 laser resurfacing.[30,31]

Fractional photothermolysis was first introduced for use in treatment of acne scars in 2006.[32] Since then, this technology has shown promise for treatment of inflammatory scars with limited downtime and side effects (see ►**Fig. 6**). Special note should be made of nonablative fractional lasers, which have shown clinical efficacy with minimal posttreatment erythema or pigmentary changes.[33]

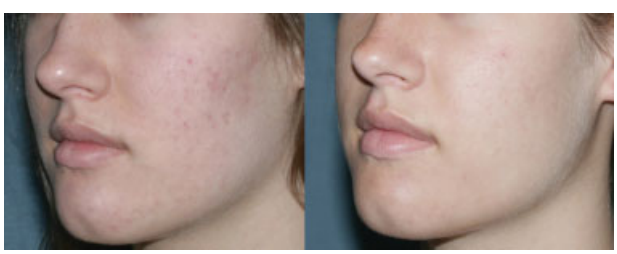

Figure 6 (Left) Acne scars prior to treatment. (Right) Six months after two treatment sessions using Fraxel Re:Store (1550 nm) 30 mJ/32% performed at 1-month interval.

Side Effects and Complications of Laser Treatment

Despite the relative safety and efficacy of laser scar revision, side effects and complications may arise that the treating clinician must be aware of and manage. As previously described, conventional CO_2 laser resurfacing can lead to significant thermal damage to tissues. Continuous wave lasers, in particular the CO_2 laser, carry the risk of scarring due to considerable collateral thermal damage and necrosis. Hypertrophic scarring is a rare complication of treatment often caused by poor intraoperative technique and is treated with topical or intralesional steroids or PDL. Intense postoperative erythema lasting up to 6 months posttreatment is an indicator of the degree of nonspecific tissue injury. Intensity and duration are most pronounced with conventional CO_2 lasers. In addition to the erythema, complete epidermal ablation produces an exposed weeping wound along with edema, pain, and pruritus during the initial week after treatment. These symptoms can be managed with cold compresses, pain control, steroids, and antihistamines. Irritation of the skin at this stage can also lead to acne eruptions and contact dermatitis. Infectious complications include reactivation of the herpes simplex virus, bacterial infections, and fungal infections. Close monitoring and appropriate antibiotic/antiviral treatment and preoperative prophylaxis for herpetic infection can minimize the incidence and adverse sequelae of these infections. Postinflammatory hyperpigmentation can complicate recovery of patients with darker skin types and is generally managed with topical bleaching agents, steroids, and retin-A. Incidence of complications can be substantially reduced with careful patient selection, preoperative planning, and meticulous treatment technique. Early detection and treatment of complications is the key to circumventing poor treatment outcomes.

Conclusion

An unsightly scar negatively affects patients as an unwelcome and often public reminder of a past injury. Conventional CO_2 is a powerful tool for nonsurgical revision of inflammatory, traumatic, and surgical scars, promising excellent results. Unfortunately, the extended recovery period and the side-effect profile of the treatments makes some patients hesitant to undergo this treatment. Newer targeted therapies such as PDL, fractional laser, and nonablative lasers have moderate side-effect profiles, and rapid recovery periods while striving to achieve cosmetic results approaching conventional CO_2 laser resurfacing. Earlier intervention, in particular for surgical wounds, can lead to optimized outcomes with respect to scarring.

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