Lasers in Surgery and Medicine 52:96–116 (2020)

Laser Treatment of Traumatic Scars and Contractures: 2020 International Consensus Recommendations

Meghan Seago, MD[1,2] **Peter R. Shumaker**, MD,[1*] **Leah K. Spring**, DO,[3] **Murad Alam**, MD,[4] **Firas Al-Niaimi**, MSc, MRCP, EBDV,[5] **R. Rox Anderson**, MD,[6] **Ofir Artzi**, MD,[7] **Ardeshir Bayat**, BSc (Hons), MBBS, PhD,[8] **Daniel Cassuto**, MD,[9] **Henry HL Chan**, MD, PhD,[10] **Christine Dierickx**, MD,[11] **Matthias Donelan**, MD,[12] **Gerd G. Gauglitz**, MD,[13] **Boncheol Leo Goo**, MD,[14] **Greg J. Goodman**, MD,[15] **Geoffrey Gurtner**, MD,[16] **Merete Haedersdal**, MD, PhD,[17] **Andrew C. Krakowski**, MD,[18] **Woraphong Manuskiatti**, MD,[19] **William B. Norbury**, MD,[20] **Rei Ogawa**, MD, PhD,[21] **David M. Ozog**, MD,[22] **Uwe Paasch**, MD,[23] **E. Victor Ross**, MD,[24] **Matteo Tretti Clementoni**, MD,[25] and **Jill Waibel**, MD[26]

[1]*Department of Dermatology, Naval Medical Center, San Diego, California, 92134*
[2]*Fellow, Micrographic Surgery and Surgical Oncology, Scripps Clinic, La Jolla, California, 92037*
[3]*Fellow, Micrographic Surgery and Surgical Oncology, SkinCare Physicians, Chestnut Hill, Massachusetts, 02467*
[4]*Department of Dermatology, Northwestern University Feinberg School of Medicine, Chicago, Illinois, 60611*
[5]*Private Practice, London, United Kingdom*
[6]*Department of Dermatology, Harvard Medical School, and Wellman Center for Photomedicine, Massachusetts General Hospital, Boston, Massachusetts, 02114*
[7]*Department of Dermatology, Tel Aviv Sourasky Medical Center, Tel Aviv, Israel*
[8]*Division of Dermatology, Groote Schuur Hospital, University of Cape Town, Cape Town, South Africa*
[9]*Private Practice, Milan, Italy*
[10]*Private Practice and Department of Medicine (Dermatology), University of Hong Kong, People's Republic of China*
[11]*Skinperium Clinic, Luxembourg, Luxembourg*
[12]*Department of Surgery, Massachusetts General Hospital, Shriners Hospitals for Children—Boston, Harvard Medical School, Boston, Massachusetts, 02114*
[13]*Department of Dermatology and Allergy, Ludwig Maximillian University, Munich, Germany*
[14]*Naeum Dermatology and Aesthetic Clinic/Skin Rehabilitation Center, Seoul, Korea*
[15]*Department of General Practice, Monash University, Clayton, Victoria, Australia*
[16]*Department of Surgery, Stanford University School of Medicine, Stanford, California, 94305*
[17]*Department of Dermatology, Bispebjerg Hospital, University of Copenhagen, Copenhagen, Denmark*
[18]*Division of Dermatology, St. Luke's University Health Network, Bethlehem, Pennsylvania, 18015*
[19]*Department of Dermatology, Siriraj Hospital, Bangkok, Thailand*
[20]*Department of Surgery, University of Texas Medical Branch, Shriners Hospital for Children—Galveston, Galveston, Texas, 77550*
[21]*Department of Plastic, Reconstructive and Aesthetic Surgery, Nippon Medical School, Tokyo, Japan*
[22]*Department of Dermatology, Henry Ford Hospital, Detroit, Michigan, 48202*
[23]*Department of Dermatology, Venereology, and Allergy, University of Leipzig, Leipzig, Germany*
[24]*Scripps Clinic, San Diego, California, 92130*
[25]*Laserplast, Milan, Italy*
[26]*Miami Dermatology and Laser Institute, Miami, Florida, 33173*

Background and Objectives: There is currently intense multidisciplinary interest and a maturing body of literature regarding laser treatments for traumatic scars, but international treatment guidelines and reimbursement schemes have not yet caught up with current knowledge and practice in many centers. The authors intend to highlight the tremendous potential of laser techniques, offer recommendations for safe and efficacious treatment, and promote wider patient access guided by future high-quality research.

Study Design/Materials and Methods: An international panel of 26 dermatologists and plastic and reconstructive surgeons from 13 different countries and a

Meghan Seago, Peter R. Shumaker, and Leah K. Spring contributed equally as first author.

Conflict of Interest Disclosures: All authors have completed and submitted the ICMJE Form for Disclosure of Potential Conflicts of Interest and none were reported.

Disclaimer: The views expressed in this article are those of the authors and do not necessarily reflect the official policy or position of the Department of the Navy, Department of Defense, Department of Veterans Affairs, or the United States Government.

*Correspondence to: Peter R. Shumaker, MD, Department of Dermatology, Naval Medical Center, San Diego, CA. E-mail: peter_shumaker@yahoo.com

Accepted 27 November 2019
Published online 9 December 2019 in Wiley Online Library (wileyonlinelibrary.com).
DOI 10.1002/lsm.23201

Published 2019. This article is a U.S. Government work and is in the public domain in the USA.

variety of practice backgrounds was self-assembled to develop updated consensus recommendations for the laser treatment of traumatic scars. A three-step modified Delphi method took place between March 2018 and March 2019 consisting of two rounds of emailed questionnaires and supplementary face-to-face meetings. The panel members approved the final manuscript via email correspondence, and the threshold for consensus was at least 80% concurrence among the panel members.

Results: The manuscript includes extensive detailed discussion regarding a variety of laser platforms commonly used for traumatic scar management such as vascular lasers and ablative and non-ablative fractional lasers, special considerations such as coding and laser treatments in skin of color, and 25 summary consensus recommendations.

Conclusions: Lasers are a first-line therapy in the management of traumatic scars and contractures, and patients without access to these treatments may not be receiving the best available care after injury. Updated international treatment guidelines and reimbursement schemes, additional high-quality research, and patient access should reflect this status. Lasers Surg. Med. © 2019 Wiley Periodicals, Inc.

Key words: laser; scar; traumatic scar; burn scar; fractional; vascular

INTRODUCTION

Paradigms for the treatment of traumatic scars have shifted significantly over the last decade, driven largely by the integration of laser technology. An accumulating number of publications from multiple disciplines highlight the enormous potential for minimally invasive laser techniques to offer new hope for the millions of patients worldwide who suffer from disfiguring and debilitating scars. Lasers fill the void between conservative management (i.e., compression, silicone, massage, and injectables) and surgical revision, both as a stand-alone treatment and especially as a complement to existing treatments. Laser devices and expertise are widely available, repurposed from cosmetic applications to help restore function and cosmesis, and improve symptoms such as pain and pruritus. We are currently in a period characterized by intense interest and a maturing body of supporting literature, but also uneven patient access and variable treatment regimens. International treatment guidelines and reimbursement schemes have not yet caught up with current knowledge and practice in many centers.

Traumatic scars are inherently heterogenous, with as many presentations as there are patients. Conducting randomized controlled trials in this setting is very challenging. No two injuries are alike, and split-scar studies make little sense when function is limited by the entire contracture. The existing scar assessment tools also fail to adequately address the entire range of scar impact, particularly functional compromise and the subjective experience of the patient [1]. Promising prospective studies therefore abound, but large randomized controlled trials confirming efficacy and illuminating proper settings and device combinations are in shorter supply. To establish a greater sense of order during this period of transition, a multidisciplinary panel of international experts in scar management was assembled to generate treatment recommendations based on available literature and expert opinion. Our goals are to highlight the potential of these techniques, offer recommendations for safe and efficacious treatment, and promote wider access guided by future high-quality research. While other energy-based technologies such as radiofrequency also show promise, they have a relatively low profile in the literature at present and the focus of this article will be on laser treatment.

METHODS

An international panel of 26 dermatologists and plastic and reconstructive surgeons was self-assembled to develop updated consensus recommendations for the laser treatment of traumatic scars. The panel members were recruited by targeted invitation to include a broad range of experience including academic, private practice, hospital-based, and military practice settings from 13 different countries. The members have been recognized for their clinical expertise and/or research contributions to the field of scar management, with a particular emphasis on laser treatment.

Three authors (P.S., M.S., and L.S.) curated the initial clinical questions based on the panel input and literature review. A three-step modified Delphi method took place between March 2018 and March 2019. The Delphi method is an iterative process used to achieve consensus for a defined clinical problem where there is little or conflicting evidence and where expert opinion is important [2]. Our modified Delphi method consisted of two rounds of email questionnaires (P.S., M.S.) and supplementary face-to-face meetings held at the second annual Scar Treatment Conference in Tel Aviv, Israel, in March, 2018 and the 38th annual meeting of the American Society for Lasers in Medicine and Surgery in April 2018 directed by one of the authors (P.S.). Face-to-face meetings were not a component of the original Delphi method developed in 1963 but allow for expert interaction, lively discussion surrounding differing viewpoints, context and clarification of recommendations, and goal setting [3]. The panel members approved the final manuscript via email correspondence. The threshold for consensus recommendations was at least 80% concurrence among the panel members.

WOUND HEALING AND SCAR FORMATION

The interval between injury and the formation of a mature normotrophic scar has been described extensively in a variety of settings and will not be recapitulated in detail here. In brief, it was characterized by three overlapping phases termed *inflammatory* (up to approximately 1 week after injury), *proliferative* (approximately 1–3 weeks), and *remodeling* (3 weeks to approximately 1 year). The *inflammatory phase* after injury is characterized by hemostasis, platelet activation, and the attraction of modulating leukocytes that drive subsequent events through a network of cytokine pathways. The *proliferative phase* is characterized by angiogenesis, fibroplasia, the synthesis of the nascent extracellular matrix, and re-epithelialization. In the final phase of *remodeling*, the extracellular matrix undergoes an orchestrated balance of synthesis, degradation, and remodeling of collagen and other components with a gradual decrease in cellularity and vascularity that concludes with the formation of a mature scar [4,5]. Multiple factors can influence the maturation process with sustained inflammation and proliferation, potentially leading to pathological scarring (i.e., hypertrophic scars and keloids). These include individual predisposing factors such as young age and darker constitutive skin pigmentation; characteristics of the scar such as body location (i.e., jawline, chest, shoulders), degree of tension, and prolonged healing time; and external factors such as infection. Erythema is a surrogate for inflammation/proliferation. While erythema is a normal finding in the early phases of wound healing and scar formation, prolonged erythema can be a sign of an incipient pathological scar. "Mature" and "immature" scars are often defined by arbitrary periods of time (i.e., <1 year after injury). However, they may be better defined by the clinical presentation, which includes signs and symptoms of activity such as erythema, elevation, and symptoms of pain and pruritus.

The basic science of pathologic scarring is complex, often involving persistent dysregulation of the normal healing process or irreversible damage to the structures involved in regeneration and homeostasis. A determination of scar subtype and origin can help predict the outcomes of various interventions and informs patient counseling. For example, a sclerotic radiation-induced scar with focal DNA damage may not respond to treatment in the same manner as a sclerotic scar with differing etiology. An atrophic acne scar responds differently than an atrophic surgical scar, possibly due to a varied inflammatory infiltrate during wounding [6]. The three-phase wound healing process described above gives us a starting point, but normotrophic scars are the least important from a clinical perspective. However, this pathway may closely reflect the beneficial tissue response to controlled laser injury. Most peer-reviewed articles on the basic science of scarring focus on hypertrophic scars, and minimal basic science work has been conducted in atrophic scarring [7–9]. Radiation scars have proved challenging to rehabilitate with laser therapy, barring adjuvant treatment.

Fractional ablative and non-ablative thermal injuries from laser devices induce controlled micro-wounds in hypertrophic scars, which drive the treated scar tissue toward a more normotrophic state via a wound healing and remodeling response. The area of improvement is typically greater than directly treated tissue, possibly from sub-ablative thermal damage or biochemical "spillover" during the remodeling process. The biochemistry is mediated primarily by an increase in TGFβ_3/type III collagen seen in early wound healing and scarless fetal healing, although there is a complex cascade of collagenases/degradative enzymes and modulation of fibrotic pathways. The histological architecture manifests as more normal-appearing finer/fibrillar multi-directional collagen, a greater number of blood vessels with improved function, and an epidermis that appears papillary rather than effaced. There remains, however, a near total loss of adnexal structures, including eccrine/apocrine glands, follicular units, and sebaceous structures [10–12].

INDICATIONS FOR LASER TREATMENT

The panel members are unanimous in their view that lasers are a first-line therapy in the management of traumatic scars and contractures. The potential indications for laser treatment are determined based on clinical findings (i.e., erythema, hypopigmentation, hyperpigmentation, atrophy, hypertrophy, degree of epithelialization, pliability, and restriction) as well as subjective symptoms including pain and pruritus. A trauma patient may manifest scars with all of these characteristics. Though most laser platforms were designed with cosmetic indications in mind, they can be routinely applied to help restore form, function, and comfort after trauma. The lasers that target all major chromophores in the skin have demonstrated utility in the management of traumatic scars including hemoglobin (e.g., 595-nm pulsed dye laser [PDL]), pigment (e.g., 532-, 694-, 755-, and 1064-nm lasers), and tissue water (e.g., 1,540- and 1,565-nm non-ablative fractional lasers [NAFL]), 2940- and 10,600-nm ablative fractional lasers (AFL), and full-field ablative lasers. The fractional lasers, especially AFL, have the most potential to treat the entire range of clinical issues as a single modality. The optimal treatment routinely includes multiple laser types in concurrent or alternating treatment sessions to suit varying clinical presentations and treatment goals in a particular location at a particular time. Effective comprehensive traumatic scar management frequently incorporates surgical evaluation, ongoing conservative measures (i.e., compression, massage, and silicone gels and sheets); physical and occupational therapy; medical management such as corticosteroids and antimetabolites; and mental health evaluation where appropriate (Table 1). In addition, lasers may be successfully employed to treat trauma-related sequelae such as traumatic tattoos and to reduce hair transferred during reconstruction procedures or to improve the fit and comfort of prosthetic devices on residual limbs.

Hyperpigmentation and Hypopigmentation

Dyspigmentation is exceedingly common after trauma, and may be the most obvious presenting feature of mature scars in darker skin types [13]. Improvement in dyspigmentation has been noted with various light-based platforms [14–17]. Short-pulsed lasers with pulse durations in

TABLE 1. Considerations for Multidisciplinary and Multimodal Scar Management

(1)	Surgical evaluation for significant functional and cosmetic deficits. Laser treatment may precede surgery, be performed concurrently, and/or be implemented after surgical management to optimize results
(2)	Continue conservative measures such as silicone gels/sheets, massage, compression
(3)	Engage (or re-engage) physical and occupational therapy for functional issues
(4)	Consider mental health evaluation if there are signs of post-traumatic stress or depression

the nano- and picosecond range have been employed as monotherapy to treat hyperpigmentation, particularly resulting from traumatic tattoos. Fractional lasers offer a promising additional option for the management of hypopigmented scars. Laser-assisted delivery of medications such as bimatoprost (a prostaglandin analog) may augment repigmentation but additional studies are warranted [18].

Panel recommendations: Hyperpigmentation and hypopigmentation

- For hyperpigmented scars, 64% of panelists would initiate treatment with a nano- or picosecond range laser, while 30% would start with NAFL or AFL. Among panelists who favored short-pulsed lasers, picosecond was selected over nanosecond pulse durations in a 2:1 ratio.
- When asked to select the single most effective platform for scar-related dyspigmentation, panelists were evenly split between short-pulsed lasers and fractional lasers. Approximately one-third of respondents overall selected NAFL (including the 1,927-nm thulium laser).

TABLE 2. Technique for Laser-Assisted Delivery of Corticosteroids and Antimetabolites

(1)	Triamcinolone acetonide suspension (TAC) is the most common corticosteroid used in combination with ablative fractional lasers. It can be applied in concentrations of 40 mg/ml or less depending on the degree of hypertrophy.
(2)	5-flurouracil (5-FU) solution is most commonly applied in a concentration of 50 mg/ml alone, or mixed with TAC in ratios of 9:1 or 3:1 (5-FU:TAC).
(3)	Hypertrophic portions of the scar are treated with AFL, and within a few minutes of laser treatment the solution/suspension is squirted and applied onto the treatment area. The excess may be wiped off with gauze and wound care can proceed in the standard fashion.
(4)	Be aware of the body surface area of treatment to avoid excessive absorption.
(5)	Delivery of medications in this manner represents "off-label" use.

- For hypopigmented scars, 95% of respondents indicated that they would initiate treatment with a fractional laser. Of these, 56% indicated preference for AFL. The most common adjunct noted by respondents is topical bimatoprost after fractional laser treatment, though this is not yet an FDA-approved use of the medication.

Conclusions and areas of future study

- It is clear that both fractional lasers and short-pulsed lasers are employed regularly by experts for scar-related hyperpigmentation. Comparative studies are lacking, and future research should help match that optimal platform with the clinical presentation.
- Picosecond lasers are a relatively new technology but offer promise for management of scars with hyperpigmentation and associated traumatic tattoos. Comparative studies are required to evaluate their efficacy and safety relative to nanosecond lasers.
- AFLs and NAFLs are promising treatment options for scar-related hypopigmentation and hyperpigmentation. In particular, hypopigmentation has historically been very difficult to treat.
- Combining laser and medical therapy (e.g., prostaglandin analogs and autologous cell transplantation [19]) provides fertile ground for new research.

Erythema

Erythema is a normal finding in the first weeks after injury, but prolonged erythema can be a harbinger of pathological scarring. As such, erythema is an indicator of scar activity and is an attractive target for laser therapy in the early days and weeks after injury for scar mitigation, or months and years after injury to manage scar hypertrophy and symptoms such as pain and pruritus. The literature on the topic is dominated by the 585- and 595-nm PDL, but intense pulsed light (IPL), the 532-nm potassium-titanyl-phosphate (KTP) laser, and the 1,064-nm neodymium-doped yttrium–aluminum garnet (Nd:YAG) laser all owe their efficacy (at least in part) to hemoglobin absorption.

Panel recommendations: Erythema

- Vascular-specific lasers and light devices form a core part of the surgeon's armamentarium against traumatic scars and are the single most common type of device applied by panel members.
- For patients presenting with flat red scars, vascular devices are the first choice among all panel members.
- When multiple laser devices are used in a single session in the same area, vascular devices should generally be applied first since other interventions will frequently result in reactive erythema, edema, and discharge in the treatment area.

Conclusions and areas of future study

- Relatively few comparative studies exist to help differentiate the various vascular-specific devices and a variety of devices may be effective [20–22]. The PDL is the

TABLE 3. Relative density and pulse energy settings for a common ablative fractional laser platform (Lumenis UltraPulse™, Deep FX™, SCAAR FX™, Yokneam, Israel)

(1) Pulse energy
- (i) High: > 80 mJ (>~ 1.8 mm ablation depth; use only with low density)
- (ii) Moderate:30-80 mJ (~ 0.9-1.8 mm ablation depth; use only with low or moderate density)
- (iii) Low: < 30 mJ (<~ 0.9 mm ablation; software only supports use with moderate density)

(2) Density
- (i) High: ≥ 10% (use with caution, and only with low pulse energy)
- (ii) Moderate: 5%
- (iii) Low: 1-3%

The device has a microcolumn diameter of approximately 120 μm; a pulse width of approximately 250 microseconds; a maximum ablation depth of approximately 3.5 mm; and a rim of coagulation of approximately 80 μm at a pulse energy setting of 50 mJ. The settings for other similar platforms may be inferred based on individual characteristics. Conservative density settings are the safest option for traumatic scars.

most common device in this setting due to factors such as footprint in the literature, availability, and familiarity with settings.
- The mechanism of action of vascular devices for scar remodeling is not fully understood, but appears to result from cytokine-mediated scar remodeling rather than simply decreasing bulk through vascular destruction [23]. As such, energy density (fluence) settings should likely be reduced in scar management relative to settings used for the elimination of blood vessels (e.g., port wine stains) with a clinical endpoint of mild purpura.
- Optimal combinations and treatment order remain to be determined through additional study. The most common combination used by panel members is a vascular device followed by AFL, but not all panel members apply multiple devices in the same area in the same treatment session. When devices are combined, settings must be chosen judiciously to avoid excessive thermal injury in a particular area.

Texture, Pliability, Thickness, and Contractures

Changes in scar thickness and pliability/stiffness are nearly universal after traumatic injury, and evaluation of these characteristics are components of both the patient and observer portions of the commonly utilized Patient and Observer Scar Assessment Scale (POSAS) [24]. These elements have shown significant improvement with treatment across all mentioned laser platforms. Notably, laser therapy has proven beneficial in scars that span from atrophic [25,26] to hypertrophic [21,27]. Contractures are a common complication of burn scars and form due to scar shortening (contraction) across a joint, often profoundly decreasing mobility and function. Significant improvements in function were not generally discussed in the literature on laser scar treatment until the advent of AFL [28]. Penetration depths up to approximately 4 mm with current technology and an appropriate degree of surrounding thermal coagulation help to create a robust remodeling response at levels unattainable by previous laser technology. At the same time, the fractionated nature of the controlled thermal injury increases tolerability and safety in the compromised environment of scar tissue. Though AFLs have been successfully applied as monotherapy for scar contractures, optimal results are likely achieved in combination with physical therapy and surgical referral as necessary for severe contractures [28,29].

Panel recommendations: Texture, pliability, thickness, and contractures

- According to panel members, the single most effective laser type for managing thick scars and contractures is AFL.
- Approximately 75% of respondents indicated that vascular lasers and AFL were the best initial treatments for a thick red scar.
- All panel members frequently combine laser and medical therapy (e.g., injectables such as corticosteroids and antimetabolites) in the same session for hypertrophic scars (HTS).
- More than 80% of respondents use intralesional triamcinolone acetonide suspension (TAC), and more than two-thirds laser-assisted delivery (LAD) of TAC through the freshly ablated channels (Table 2).
- Approximately 38% of panelists use intralesional 5-fluorouracil (5-FU), and 28% LAD of 5-FU.
- Approximately 38% of panelists use a combination of TAC and 5-FU. Among those, approximately 39% use a ratio of 9:1 (5-FU:TAC) and 23% a ratio of 3:1.
- For atrophic post-traumatic scars, half of respondents selected AFL and half NAFL as their initial treatment of choice.
- For atrophic post-traumatic scars, more than 80% of respondents combine laser treatment with cutaneous fillers. Approximately 36% frequently combine injectable fillers and LAD.
- Fat grafting was advised for consideration of restoration of contour in patients with traumatic scars by 62% of respondents.
- Eighty-six percent of respondents treat split thickness skin graft donor sites with lasers. 56% of respondents treat with PDL; 41% treat with AFL; 36% treat with NAFL (sum is great than 100% because panelists may use multiple laser types).
- Ninety-six percent of respondents treat split- and full-thickness skin grafts with lasers after the initial healing phase. 32% of respondents lower the pulse energy and the density; 9% lower the density; and 9% lower the pulse energy. 36% of respondents do not make any adjustments in the settings when treating grafted sites.

Conclusions and areas of future study

- AFL is a groundbreaking treatment for thick scars and scar contractures, and one of the most important developments in scar treatment in decades.
- Additional research is required to determine the optimal beam profile, but favorable characteristics of the AFL columns to promote efficacy and safety include a narrow beam diameter (<300 μm), a short pulse width (<1 ms), and a relatively low density (10% or less, decreasing with greater pulse energy to avoid excessive thermal injury).
- AFLs and NAFLs are the initial treatment of choice for atrophic traumatic scars, but additional studies are required to elaborate on comparative efficacy. The majority of panel members combine laser and cutaneous fillers.
- AFL is frequently combined with corticosteroids and antimetabolites delivered intralesionally and through LAD for HTS and contractures. 5-FU offers the potential advantage of decreased incidence of atrophy [14], but additional studies confirming efficacy, dosing, and appropriate combinations are required.
- In addition to offering treatment for traumatic scars, lasers should be considered for the proactive management of graft donor sites. Laser choice depends on the presence of erythema (e.g., PDL) and textural change (e.g., AFL, NAFL).
- Traumatic injuries often include a combination of primary scarring and reconstruction through techniques such as skin grafts. Both are treated regularly by the panel, though approximately half of respondents make setting adjustments (lower pulse energy and density) when treating skin grafts.
- The role of injectables such as hyaluronidase and botulinum toxin in the treatment of texture, pliability, thickness, and contractures merits further study.

Pain and Pruritus

Lasers have been noted to improve pain and pruritus since PDL was first reported to treat erythematous post-burn scars in the last millenium [30]. The incorporation of these elements into the patient arm of the POSAS created a method for standardizing the patient's subjective experience of pain and itch, and is an acknowledgment of the importance and potentially debilitating nature of these symptoms. Both have been shown to improve significantly with treatment across vascular and AFL platforms [31–34].

Panel recommendations: Pain and pruritus

- More than 80% of respondents indicated that lasers have a significant role in the treatment of post-burn pain and pruritus.
- Approximately 48% respondents indicated that lasers were a first-line treatment; 38% indicated that lasers were a second-line treatment.
- Vascular lasers were the first choice among 60% of respondents for post-burn pain and pruritus. AFL and LAD of corticosteroid was the first choice among 25% of respondents. AFL or AFL and LAD of corticosteroid was the second choice among approximately 75% of respondents.
- When applied for post-burn pain and pruritus, 1 month was the preferred treatment interval among 73% of respondents.

Conclusions and areas of future study

- Lasers offer an important and under-utilized therapeutic option for post-burn pain and pruritus and were considered a first- or second-line treatment by the large majority of panelists. Intralesional corticosteroids and 5-FU were the most common first-or second-line choices. Many panelists use lasers and injectables in combination. Other therapies include systemic medications such as GABA-ergic drugs, antihistamines, and non-steroidal anti-inflammatory drugs (NSAIDS).
- Vascular lasers and AFL, with and without LAD of corticosteroids and antimetabolites, were the clear choice among panel members.
- In addition to improvements in appearance, pliability, and range of motion, laser therapy should be considered a primary therapeutic option for anticipatory scar mitigation as well as scar-related pain and pruritus, guided by further research.

DEVICE APPLICATION AND SETTINGS

A discussion of device settings is informed by a variety of qualifiers and caveats. Each operator must select settings appropriate for a particular device, on an individual patient, on a particular scar, at a given moment, and guided by feedback from the desired cutaneous endpoints. Optimal wavelengths and settings for traumatic scar management have not yet been fully elaborated in the literature and settings will vary depending on the characteristics of the particular device chosen by the operator, the clinical findings on the day of the visit (e.g., degree of erythema, presence of a tan, etc.), and issues specific to the patient (e.g., pain tolerance, approximate downtime, etc.). For example, the depth of penetration for given pulse energy, microbeam diameter, and zone of coagulation must be considered with AFL devices when selecting corresponding density settings. Likewise, the skin phototype and degree of hyperpigmentation must be considered when using vascular devices given the overlap with melanin absorption. A large majority of the panel of experts (86%) combine multiple laser platforms in the same area in the same treatment session; the most common combination is vascular lasers followed by AFL. However, less experienced operators should approach each situation with humility and use the lowest effective settings and consider performing treatments on alternate treatment sessions.

Vascular Devices

Vascular devices emit wavelengths that are absorbed by hemoglobin, which demonstrates peaks at 542 and 577 nm for oxyhemoglobin. These were among the first utilized to treat traumatic (including burn) scars, and can help reduce erythema, and improve scar pliability and hypertrophy [29–31,35,36]. Although more efficacious if utilized earlier in the healing process [37], they have shown efficacy in scars of varying duration contingent in the presence of erythema [38]. A consensus algorithm for the treatment of burn scars included the use of vascular lasers early in the treatment course [39]. Vascular lasers have also demonstrated safety and efficacy when utilized in combination with ablative lasers [34,40]. A combination of vascular and AFLs is commonly employed by about half of the panelists, and is suggested to have a synergistic effect.

Additional devices emitting wavelengths adjacent to hemoglobin's peak absorption, including the 532-nm KTP and IPL, can also be employed. The 1,064-nm Nd:YAG in the millisecond range may also be appropriate for the treatment of erythema, especially if the scar has more significant depth or for patients with darker skin types, though no significant difference was observed between 595 and 1,064 nm in one comparative study [21].

Panel recommendations: Vascular lasers

- Among vascular devices, the PDL is the first choice of more than 80% of panel members. Reasons cited include ample supporting literature, broad availability, familiarity with device use and settings, and perceived advantage in efficacy [29,31,38].
- Regarding fluence settings for the 595-nm PDL with a 10-mm spot and 1.5-ms pulse width, 41% selected a fluence of 5–6 J/cm^2; 27% selected a fluence of 4–5 J/cm^2; 27% selected a fluence of 6–7 J/cm^2.
- Regarding pulse width setting with a 595-nm PDL and a 10-mm spot, 50% of respondents use 1.5 ms; 18% use 0.45 ms; 18% use 3 ms.

Conclusions and areas of future study

- While the PDL was favored by most panelists for reasons noted above, other vascular-selective devices such as the 532-nm KTP, IPL, and 1064-nm Nd:YAG also appear efficacious and are even preferred by some respondents [41–43]. Future comparative studies are required to help confirm any differential efficacy for selected applications. It should also be noted that shorter-wavelength devices such as the 532-nm KTP and 595-nm PDL may not be appropriate for darker skin types and devices such as the 1064-nm Nd:YAG may be a better choice due to competing epidermal melanin.
- There is a trend toward treating traumatic scars with the PDL with lower fluence settings than when applied for vascular destruction (e.g., port wine stain). Sixty-eight percent of respondents treat erythematous traumatic scars with fluence settings of 6 J/cm^2 or less.
- There is a trend toward treating traumatic scars with shorter pulse widths with the PDL. Sixty-eight percent of respondents treat with a pulse width of 1.5 ms or less. When coupled with relatively lower fluences, the clinical endpoint of mild purpura is likely appropriate.
- Despite trends toward lower fluences and shorter pulse widths with the PDL, additional studies are required to help elaborate the appropriate settings.

AFL

Building on NAFL technology introduced in 2004 [44], AFLs were introduced in 2007 and have become established as a first-line treatment for traumatic scars in many centers [45]. Far-infrared wavelengths (i.e., 2,940-nm Er:YAG and 10,600-nm CO_2) are absorbed avidly by tissue water resulting in vaporization of cylindrical vertical microcolumns of tissue with a variable surrounding rim of coagulation. Fractional CO_2 lasers create a somewhat larger zone of coagulation surrounding the ablated microcolumn than Er:YAG owing to less specific absorption and greater heat diffusion [10,45]. The depth and density of the ablated microcolumns are determined by the operator, offering a unique level of control to accommodate the variable and compromised environment of scar tissue. An accumulating number of studies document consistent and significant subjective and objective improvements in scar restriction, texture, color, pliability, pain, itch, and quality of life, as well as a histopathological basis for these improvements with a relative normalization of architecture and composition [27,33,39,46–49]. Creating a new and important niche in traumatic scar management, they offer faster and more profound improvements than existing conservative treatments such as injectables, pressure and massage, with more diffuse impact and less morbidity than invasive treatments such as surgical revision. However, effective comprehensive management of severe restrictive scarring frequently includes all of these components. Despite the heterogeneous nature of scars, consistently cited features that improve with AFL include thickness, height, pliability, range of motion, erythema, pain, and pruritus [11,12,14,27,33,34,50–52]. Histologic studies have elucidated the relative normalization of collagen that occurs after a course of AFL [10,52].

Panel recommendations: AFL

- Sixty-four percent of respondents selected AFL as the most effective overall laser platform for traumatic scars.
- Sixty-eight percent of respondents report that the fractionated CO_2 laser is more effective than fractionated Er:YAG for traumatic scars. 5% selected the Er:YAG, and 27% noted that more research is required before a determination can be made.
- The comparative efficacy between fractionated Er:YAG and CO_2 has been minimally addressed in the literature, with two small studies that suggested superior efficacy with the 10,600-nm CO_2[53,54]. Despite the limited literature, the panel clearly leans more heavily in favor of the fractional CO_2 laser. A noted exception was in treating patients with Fitzpatrick phototypes IV–VI, where Er:YAG was cited as having a lower risk of post-inflammatory hyperpigmentation (PIH), possibly due to decreased thermal effects.

- Setting selection is based on clinical assessment (e.g., scar thickness). For HTS, 95% of respondents prefer low-density treatments; of these, 59% pair low density with high pulse energy (i.e., depth), and 36% with moderate pulse energy.
- For atrophic scars, 36% of respondents selected moderate pulse energy and moderate density; 24% each selected low energy, low density, and low energy, high density; 9% selected moderate energy, low density (Table 3).
- When treating early (<1 year after injury, greater erythema) versus longer duration scars, 62% of respondents do not adjust density settings and 59% do not adjust pulse energy settings. Thirty-two percent will increase the pulse energy settings for mature scars.
- More than two-thirds of respondents believe that the ideal depth of treatment should be "greater than half" to "full" scar thickness [55].
- Moderate to high energy and low-density settings were preferred by 95% of our panel when treating hypertrophic scars.

Conclusions and areas of future study

- The majority of respondents selected fractionated CO_2 over fractionated Er:YAG in the management of traumatic scars. The most common cited reasons include wider availability and footprint in the literature, greater available penetration depth, and enhanced thermal response. However, additional research is required to confirm any discrepancy in efficacy, as well as the factors that might determine any differences in histopathological response (i.e., microcolumn characteristics such as diameter, depth, and rim of coagulation). Some respondents noted potential advantages for the Er:YAG in certain situations, such as less pain and potential for post-treatment pigmentation in darker skin types due to decreased thermal response.
- Low-density treatments are the accepted standard among panelists to minimize excessive thermal injury when applying AFL for hypertrophic traumatic scars and contractures, particularly when high pulse energies are used (Table 3).
- There is more of a tendency toward moderate density treatments when treating atrophic scars, but only in the context of moderate and low pulse energy, respectively. Additional research is required to determine the best combination for atrophic scars as there is not a consensus among the panel.
- High pulse energy and high density is a recipe for worsening scarring.
- Eighty-two percent of respondents selected an interval of 8 weeks or less between fractional CO_2 laser treatments. Clinical judgment should be applied to avoid excessive treatments and treatment combinations, and individual patient factors.
- The optimal microbeam profile and ablative fractional pattern has yet to be identified in the literature, though panelists have found existing devices both safe and effective. The most important beam characteristics identified by panelists include tunable depth of penetration and density with the option to penetrate several mm into thick scars; narrow beam diameter; appropriate but not excessive surrounding coagulation; and short pulse duration to minimize the thermal injury. Specific microbeam characteristics noted included a cylindrical form; beam diameter approximately 300 μm or less; available penetration depth 3 mm or more; pulse width 1 ms or less.
- The most important determinant for treatment settings is scar thickness. The maximum depth of ablation available with current laser technology is approximately 3.5–4 mm. The literature on this topic is limited, but the panel (and recent literature) supports depth of treatment proportional to, but not exceeding the depth of the scar [56]. Panelists would favor increased available depth of penetration for appropriate scars; a relatively narrow column diameter and pulse width would likely be prerequisites for safe treatment. Scar assessment with ultrasound and other noninvasive techniques is prudent to consider with high depths of penetration but is not generally necessary for routine use outside of research settings.

NAFL

NAFL lasers function at mid-infrared wavelengths associated with moderate absorption by tissue water, creating vertical microcolumns of coagulation up to approximately 1.5 mm in depth with current technology [57]. The resulting wound healing response is evidenced by induction of heat shock proteins, increased collagen III production, and other mediators [58]. These devices may provide the benefit of reduced downtime, less post-inflammatory hyperpigmentation (PIH), and lower overall risk profile compared with AFL, particularly in skin of color. They have shown significant efficacy in the treatment of hypertrophic and atrophic scars associated with burns. In a pilot study of 10 patients with burn scars, Waibel et al. showed that dyschromia, hypertrophy or atrophy, overall scar quality, and patient self-esteem all improved significantly after 5 monthly treatments with a 1550-nm Er:glass NAFL [15]. Haedersdal et al. utilized NAFL in burn scars of greater than 2 years duration. Both patient and blinded observer responses showed that NAFL had a significant effect on texture, with minimal effect on erythema and pigment. There was a trend toward greater improvement in more superficial scars, likely linked to the more superficial depth of penetration associated with this platform [59]. Additionally, Taudorf et al. assessed NAFL in burn scars over 4 years old with 3 monthly treatments, using superficial and deep handpieces and assessing clinical and histologic response. Improvements were noted using the modified POSAS, with 82% of patients reporting an improvement in scar-related texture. There was a trend toward histologic normalization, with collagen taking on a more interwoven architecture and increased vascularization [60].

Panel recommendations: NAFL

- Forty percent of respondents would treat with moderate pulse energy and moderate density; 20% of respondents would treat with a high pulse energy and low-density setting; 15% with a low pulse energy and low-density setting; 10% would treat with a high pulse energy and high-density setting; 10% would treat with a high pulse energy and moderate density setting.
- NAFL platforms were consistently cited by panelists as an alternative to AFL in patients with skin phototypes IV–VI, but with a lower ceiling for results and generally more required treatments.
- For patients unwilling to tolerate the PIH associated with AFL, NAFL offers potential benefits for superficial textural abnormalities and dyspigmentation.
- Panelists were unanimous that NAFL for skin phototypes IV–VI is safe, though with some modifications to parameters or additional adjuncts (bleaching creams, corticosteroids, etc.).

Conclusions and areas of future study

- With lower depths of penetration and less associated thermal injury, NAFL treatments are applied by some panelists with relatively higher density settings than AFL. However, the wide range of different combinations described by panelists indicates that additional studies are required to elaborate the optimal setting combinations.
- For traumatic scars associated with mild-to-moderate texture irregularity, NAFL may provide an effective alternative to AFL. However, for thicker hypertrophic scars associated with contractures and chronic wounds, AFL is generally a superior choice.

Other Energy-Based Devices to Consider

The most common laser platforms used for traumatic scar management include AFL, NAFL, and vascular devices such as the PDL. This reflects their familiarity and footprint in the literature. A range of energy-based devices demonstrate potential and are worthy of additional study include, but are not limited to, those listed in Table 4.

TABLE 4. Non-Laser Energy-Based Techniques Noted by Panelists for Additional Study in Traumatic Scar Management

(1)	Radiofrequency microneedling
(2)	Thermal conduction (e.g., Tixel™, Novoxel LTD, Netanya, Israel)
(3)	Pneumatic acceleration and drug delivery (e.g., Enerjet™, PerfAction Technologies UK Limited, London, England)

TIMING

Accumulating evidence suggests that lasers can treat the sequelae of existing traumatic scars, and importantly they may also have the potential to proactively modulate the early wound healing process to mitigate traumatic scars and contractures as they form. A systematic review of 25 articles by Karmisholt et al. in 2018 detailed the clinical outcomes of laser intervention within 3 months of wounding (primarily post-surgical scars) [37]. There was an overall trend toward improvement with early laser treatment, and statistically significant scar improvement was found in 3 of 4 studies when laser was initiated in the inflammatory phase of wound healing, in 6 of 16 studies when initiated in the proliferative phase, and in 2 of 5 studies when performed in the remodeling phase. A recent randomized, split-scar study investigated treatment with a 1,540-nm NAFL versus no laser treatment at three time points: immediately before surgery; at suture removal; and 6 weeks after surgery, revealing modest but consistent and statistically significant improvement of VSS scores in the NAFL-treated sides [61]. Statistically significant improvement of VSS was also noted in a study examining the use of AFL in 27 Egyptian patients (skin type III–V) at 4 weeks post-operative, with notable improvement of pigmentation, height, and pliability [62].

Panel recommendations: Timing of laser procedures for traumatic scars

- Sixty-eight percent of respondents believe laser intervention can help prevent the development of pathological scars (i.e., HTS and keloids). Twenty-seven indicated that additional study is required.
- Regarding smaller traumatic injuries such as lacerations and surgery: 9% of respondents would typically initiate laser treatment immediately upon closure; 59% would initiate treatment at suture removal; 23% would initiate treatment at 1 month after injury. Cumulatively, nearly 70% of respondents would begin laser treatment at approximately 1 week or less, and more than 90% at 1 month or less after injury.
- Seventy-seven percent of respondents believe there is a role for laser therapy (specifically AFL and PDL) before complete closure of burn wounds.
- Regarding larger traumatic injuries such as burns: 33% of respondents would typically initiate laser treatment 1–3 weeks after injury and related reconstruction; 43% would begin at 1–2 months after injury; 24% would begin at 3–4 months after injury; 10% would begin at 6–12 months after injury. Cumulatively, 76% of respondents would initiate treatment at 2 months or less after injury, and 90% within 4 months or less.
- Regarding the appropriate interval between fractional CO_2 laser treatments, 46% selected 6–8 weeks; 36% selected 4 weeks; 14% selected 8–12 weeks; 9% selected 12–16 weeks. 77% of respondents do not change the treatment interval when treating an early scar. 14% increase the interval.
- The impetus for early laser intervention represents a shift in treatment priorities and practice patterns of laser experts—earlier clinical guidelines of scar

TABLE 5. Sample treatment and post-treatment protocol for AFL

(1) Infections are uncommon after AFL, but antimicrobials can be considered at the surgeon's discretion based on clinical judgement. Antibiotics are infrequently used by most panelists, particularly when the treatment area is small.
  (i) Consider antivirals when treating in facial locations to provide prophylaxis against HSV reactivation
  (ii) Consider appropriate antibiotic coverage in certain clinic situations as indicated by treatment area (e.g. axilla, groin), large body surface area, or practice environment associated with higher rates of infection and colonization (e.g. burn center)

(2) Vigorous antiseptic skin preparation is not routinely used by most panelists in most situations
  (i) Ensure general skin cleansing to remove make-up and topical anesthetic residue
  (ii) Can consider alcohol skin preparation
  (iii) Consider more aggressive skin preparation (such as with chlorhexidine-based cleansers) in certain clinical situations when risk of bacterial load or colonization is high (e.g. axilla, groin, burn centers), or in association with surgery.

(3) Pain control methods for outpatient treatment based on patient tolerance and related to surface area, location, and age of patient. Methods may be combined while adhering to institutional guidelines.
  (i) Cold packs and forced chilled air
  (ii) Commercially available and compounded topical anesthetics
  (iii) Injectable anesthetics for blocks and local infiltration
  (iv) Oral pain medication and anxiolytics
  (v) Nitrous oxide
  (vi) Intravenous sedation
  (vii) General anesthesia

(4) For hypertrophic scars, consider laser-assisted delivery of triamcinolone acetonide immediately after AFL, and continuing application of corticosteroid ointment for 1 to 3 days at the discretion of the surgeon.

(5) Petrolatum applied after treatment until re-epithelialization (recommended range by panelists 2 days to 2 weeks). Non-stick dressings for convenience.

(6) Topical fusidic acid is used by some panelists.

(7) Ongoing systemic pain medication is rarely required after AFL treatment.

(8) Avoid untreated water (ocean, lakes, etc.), hot tubs, and submersion for approximately 2 to 3 days or until re-epithelialized (or longer at the discretion of the surgeon). Municipal water supplies may demonstrate mycobacteria but infections appear to be very infrequent.

(9) Showering with soap and water may usually begin within 1 to 2 days.

(*Continued*)

(10) Patients may usually resume normal activities such as work, school, and physical therapy the following day.

(11) Resume pressure garments approximately 2 to 5 days after treatment when oozing ceases.

management focused on efficacy, not when lasers could work best [63].

- Over 80% of respondents treat at intervals of 4 weeks (36.4%) to 6–8 weeks (45.5%). Over 95% of respondents believe that in the absence of contraindications, treatment may be continued until the desired effect is achieved or improvement plateaus.
- About half of respondents routinely combine different laser platforms in the same session. For those that do, the most common combination is a vascular laser and either a NAFL or AFL.

Conclusions and areas of future study

- There is strong and consistent sentiment among panel members that lasers have a prominent role in the mitigation of pathological scars through early intervention after injury, though additional research is required to elaborate efficacy, timing, and treatment combinations. This represents a critical paradigm shift in the procedural management of large traumatic scars, where surgical intervention (flaps, grafts, etc.) has traditionally been delayed a year or more after injury to allow for scar maturation.
- It is never too late to initiate laser treatment for traumatic scars.
- Early intervention is advocated by the panel to help minimize complications such as contractures and improve ultimate cosmetic and functional results. It should be noted that “early” is relative to the injury type. Traumatic lacerations, similar to surgical scars, appear amenable to treatment in the first days and weeks after injury. However, more extensive injuries such as burns may tolerate laser treatment after epithelialization is mostly completed beginning within approximately 1–2 months of injury.
- Complete epithelialization is not necessarily a prerequisite to initiate treatment, and treatment of scars with associated chronic wounds may actually facilitate healing [64].
- The panel did not consider specific laser combinations in any detail. Safe treatment for inexperienced laser physicians should likely include a single platform in a particular area on a single day with additional interventions after several weeks to observe the tissue response.

SCAR ASSESSMENT

A variety of subjective and objective clinical scar assessment methods have been developed to facilitate scar research and evaluate progress during a course of treatment. Early scar assessment scales such as the Vancouver

TABLE 6. Sample protocol for NAFL and AFL treatment in skin of color (Fitzpatrick skin types III-VI)

(1) Strict sun precautions for at least 6 weeks before and 6 weeks after treatment
(2) Pre-treatment regimens may include retinoic acid and/or hydroquinone for 2 to 6 weeks prior to treatment.
(3) Consider altering treatment parameters for skin of color. Some panelists do not modify treatment parameters
  (i) Consider decreasing density and pulse energy by approximately 20 to 33% (some panelists feel density is more important)
  (ii) Extend treatment interval from approximately 6 to 8 weeks to 12 weeks
(4) Consider laser-assisted delivery of corticosteroids at the time of treatment, and several days of moderate potency corticosteroids after treatment.
(5) Post-treatment regimens include prophylactic or as-needed topical azelaic acid 15%, hydroquinone 4% for 2-6 weeks after treatment
(6) Wait until post-inflammatory pigment alteration has resolved prior to next treatment, at least 4 weeks or more

Scar Scale (VSS) focused largely on visual appearance, while more recent contributions have attempted to integrate additional subjective patient factors such as symptoms (i.e., pain, pruritus) and overall quality of life. The advent of laser scar management, particularly AFL, has significantly increased the expectations for minimally invasive scar treatment. For the first time, large interval improvements in function and symptoms have to be accounted for, but at present no single scale adequately addresses the full range of impact [1,65]. A variety of devices used for the non-invasive quantitative evaluation scar color, pliability, relief, and structure are also available.

Scar Evaluation Scales

The VSS was developed in 1990 as the first objective, validated scar scale, and remains the most commonly used method to rate scars [66]. Four parameters—vascularization, height/thickness, pliability, and pigmentation—are scored by the clinician, creating a total score between 0 and 13 (a higher score indicating a higher degree of scar severity). The simplicity of the VSS has allowed for widespread use, but with accompanying limitations including indeterminate evidence for its validity and reliability (particularly with large or irregular scars) and omission of associated symptoms (pain and itch), function, and psychological sequelae [67].

The POSAS was devised in 2004, and consists of two six-criteria assessments (scored 1–10), with an overall opinion (also scored from 1–10) as determined by both the patient and physician [24]. Appearance (color, stiffness, thickness, and irregularity) and symptoms (pain and pruritus) are rated by the patient; the observer analyzes the appearance only (vascularity, pigmentation, thickness, relief, pliability, and surface area; or VSS plus relief and surface area). The POSAS is one of the most comprehensive scar scales currently available. The Modified POSAS was proposed by Fearmonti et al. in 2011. In addition to the criteria in the original scale, the modified scale integrates an evaluation of symptoms (frequency of pain and pruritus) and impact on activities of daily living (a basic functional assessment) [68].

The Visual Analog Scale (VAS) and Dermatology Life Quality Index (DLQI) are used routinely, respectively, by 33% and 22% of our panel. The VAS is a simple and quick subjective assessment originally designed to assess pain. The patient is asked to rate the overall appearance of their scar on a 10-cm scale, where the 0-cm mark represents normal skin and the 10-cm mark represents the worst scar imaginable. Whereas the VAS is a very simple tool that assesses only the physical appearance of the scar, the DLQI is a more comprehensive tool that assesses the quality of life and psychosocial aspects of the scarred patient. Six sections (symptoms and feelings, daily activities, leisure, work and school, personal relationships, and treatment) are scored, resulting in an overall score between 0 and 30 (a higher score indicating a more severe impairment of quality of life) [67].

Objective scar assessment

Color. Erythema and pigmentation are characteristics assessed by the VSS and POSAS that can also be quantitatively measured. The Chroma Meter (Konica Minolta, Osaka, Japan) analyzes scar color with tristimulus reflectance colorimetry (a measure of color and intensity of reflected light). Data are reported as three color parameters (L^*, a^*, and b^*). L^* is a measurement of clarity, lightness, or brightness; a^* is the amount of red-green (erythema); and b^* is a measurement of the amount of blue-yellow (pigmentation). Chroma Meter readings correspond well with VSS vascularity scores, though tristimulus colorimetry poorly correlates with patient scar scales when measuring pigmented or hypopigmented scars. The DSM II Colormeter (Cortex Technology, Hadsund, Denmark) is a small hand-held device that uses both tristimulus colorimetry and narrow-band spectrophotometry, a technique that measures vascularization and pigmentation of the scar based on differences in red and green light absorption by hemoglobin and melanin, respectively. The Mexameter (Courage + Khazaka electronic GmbH, Köln, Germany) also employs narrow-band spectrophotometry. Both the Mexameter and DSM II Colormeter have demonstrated good reliability in scar assessments and show a slightly better correlation with clinical evaluation compared with the Chroma Meter [69].

Thickness. Subjective estimation of scar thickness has been shown to be relatively unreliable—67% when measured against ultrasound-measured thickness. Objective thickness can be obtained using a high-frequency ultrasound such as the DermaScan-C (Cortex Technology), which has been shown to have high reliability and correlation with VSS. Ultrasound measures the response when an acoustic pulse is directed into the skin. Areas with a small contrast in density between structures (i.e., scar tissue and fat) will produce a low reflection, and thus will be visualized as a dark color. Areas with significant contrast in density between structures (i.e., healthy dermis) will be visualized as a bright color. The ideal frequency for cutaneous imaging is between 18 MHz and 50 MHz, as lower frequencies (7.5 MHz) allow deeper penetration (50–70 mm), but will produce lower resolution images. Very high frequencies (>50 MHz) will not penetrate to the average depth of hypertrophic scars (4–5 mm) [69].

Pliability. The pliability of a scar relates to its movement (i.e., "suppleness") when exposed to outside forces; during examination this is often assessed subjectively by pinching the tissue. The Cutometer (Courage + Khazaka, Köln, Germany) and the DermaLab elasticity probe (Cortex Technology) are both suction methods by which the stiffness of a scar can be measured. Although these devices have been shown to provide reliable measurements of elastic and mechanical properties, they have only a weak to moderate correlation with pliability scores of both the VSS and POSAS. These devices are also unreliable when measuring severe scars [69]. The Dermal Torque Meter (DTM310-Dia-Stron Ltd, Broomall, PA) applies rotary torque forces to evaluate angular strain and strain rates, and has been successfully employed to assess changes in the mechanical properties of scar tissue during a course of laser treatment [47].

Non-invasive structural assessment. Optical coherence tomography (OCT) produces ultrahigh resolution 2D and 3D images of tissue microarchitecture (collagen density, vessels, scar depth, and volume), providing information previously only available with histopathologic analysis of tissue biopsies. Images are generated by light, and thus are only capable of imaging to a depth of approximately 1–2 mm due to scattering and absorption in the skin. This technology is currently in its infancy with limited availability, but has potential for future study and applications [69].

Panel recommendations: Scar assessment

- Fifty-nine percent of respondents routinely use scar assessment scales in clinical practice. 64% of these use the VSS; 50% use the POSAS; 43% use a VAS; 29% use the DLQI. These are also the most common choices for panel members conducting scar-related research.
- Sixty-five percent of respondents routinely incorporate objective scar assessment into clinical practice. 62% utilize three-dimensional imaging (e.g., Vectra^{TM}); 54% evaluate degrees of motion; 31% assess pliability (e.g., Cutometer) and color (Chroma Meter). Twenty-three percent use ultrasound; 8% use OCT. These also reflect the most common choices for scar-related research.
- VSS and POSAS represented the preferred scar assessment scales for 61% of panelists when conducting research, with 50% of respondents also utilizing the VAS and the DLQI.

Conclusions and areas of future study

- Continuing research is vital to determining the optimal laser devices, timing, combinations, and settings in the management of traumatic scars.
- Experienced laser surgeons routinely use both subjective and objective scar assessment in both clinical practice and ongoing scar research.
- Patient access and reimbursement for laser scar revision have not kept pace with current research and practice. Future high-quality research will bolster further dissemination and patient access to these promising procedures.
- Given the greater range of scar response to current laser techniques such as AFL, future scar assessment should incorporate evaluation of function, symptom relief, and overall quality of life to a greater extent.
- A systematic review by Lee et al. [69] recommended a panel of devices for objective scar assessment including 3D imaging for surface area and volume, DSM II Colormeter for color, Dermascan high-frequency ultrasound for thickness, and Cutometer for skin elasticity and pliability.
- In addition to pre-treatment scar assessment, it is also important for the laser surgeon to consider visual tissue endpoints during treatment to provide real-time feedback on tissue response and tolerance [70].

COMPLICATIONS AND PRE-, INTRA-, AND POST-TREATMENT PROTOCOLS

Standardized pre-, intra-, and post-treatment protocols for laser scar revision currently do not exist. Aside from excessive thermal injury associated with ill-considered laser treatment parameters and combinations, infectious complications associated with laser scar therapy have the potential to cause prolonged wound healing, post-inflammatory pigment alteration, and worsened scarring. However, there appears to be a low risk of serious complications and a very favorable profile for AFL based on existing reports [27,39,71]. Comprehensive evaluation of these rates is hindered by a wide range of practice situations, including both burn centers and smaller office-based cosmetic practices, as well as variations in treatment parameters and technique. There is relatively little safety data in the traumatic scar literature, but available data and extrapolation from existing reports drawn from the cosmetic and full-field resurfacing literature also supports favorable complication rates [72–76]. Transient erythema and hyperpigmentation are common, but frequently short-lived [77]. In an age of antibiotic stewardship and with the very low rate of bacterial infections after ablative and non-ablative fractional treatments, the standard approach of using oral antibiotics in the pre- and post-treatment period has diminished significantly from the time where two-thirds of laser physicians were using oral antibiotics as a standard approach for full-field resurfacing [78].

Complication rates for less invasive laser platforms such as NAFL and vascular devices appear to be even lower than AFL. Impetigo is a rare complication, occurring in 0.2% of cases in one retrospective analysis of 961 cases treated with NAFL [73]. Reactivation of HSV in patients undergoing facial procedures is a known risk, often addressed with antiviral prophylaxis for facial procedures (especially perioral). In a retrospective review of 500 cases, Nanni et al. reported reactivation in 7.4% of patients undergoing full-field ablative laser of the face [79]. Graber et al. evaluated 961 patients treated with NAFL on the face and reported HSV reactivation in 1.8% of patients with a history of HSV who received antiviral prophylaxis prior to treatment [73]. One study indicated that the rate dropped from 0.3% to 0% over a series of 1,000 treatments after the addition of 5 days of prophylactic antivirals in patients with a history of facial HSV [80]. Some degree of surgeon discretion on pre- and post-treatment protocols is anticipated, as details surrounding the treatment will likely be tailored to a particular patient at a particular time. Factors to consider include the patient's constitutive skin type, medical history (including associated injuries), proximity to injury, self-care capabilities, body location, anticipated treatment, treatment combinations and adjuncts, etc.

Panel recommendations: complications and pre- and post-treatment protocols (Table 5)

Complications

- Seventy-three percent of respondents indicate a rate of significant complications (infections, worsening scarring, significant pain) associated with AFL of <1% (the lowest category offered on the survey). The remainder indicate a rate of 1–5%.
- All respondents indicate a rate of serious complications associated with vascular lasers and NAFL of <1%.
- The incidence of serious complications associated with AFL, such as infection and worsening scarring, is estimated to be less than 1 in 1,000 by most respondents.

Skin preparation and antimicrobials associated with AFL

- Regarding skin preparation prior to AFL: 36% prepare the treatment area with alcohol; 32% use no skin preparation; 32% use chlorhexidine-based cleansers in locations off the face.
- The majority of respondents treating small sites (<10% body surface area) do not use antibiotic prophylaxis as a standard approach.
- Two primary indications for antibiotic prophylaxis were noted by respondents: size and location of the treatment site. Treating >10% body surface area would significantly increase the likelihood of antibiotic use, as would treatment in the groin, axilla, perioral, perinasal, or perianal regions. Other risk factors included a history of infections (including MRSA), heavy tobacco use, and recent hospitalization in a burn unit. Travel within 3 days of treatment would also lower the threshold for antibiotic and antiviral use for some surgeons due to limited ability to monitor the patient.
- Medications specifically cited by the group included topical mupirocin or fusidic acid, and oral cephalexin, sulfamethoxazole-trimethoprim, and doxycycline.
- Antiviral prophylaxis was advocated by the large majority of respondents, particularly for treatments around the mouth.
- Dilute vinegar compresses were advocated by some respondents in the first 1 to 3 days after AFL.

Adjuncts

Surgery, compression, silicone sheeting, injectables, and massage have long been standard in the treatment of burn and other traumatic scars. Compression and silicone have been shown to improve scar thickness, erythema, and texture in controlled trials [81]. Other standard interventions include intralesional corticosteroids [82] and 5-FU [83].

- Eighty-two percent of respondents endorse surgical revision (e.g., Z-plasty) and laser treatment in the same session, as indicated, for extensive and/or severe scar contractures. 75% of these perform laser after surgery during the session.
- The large majority of respondents combine corticosteroids and antimetabolites with laser treatment for hypertrophic scars. It should be noted that laser-assisted delivery of medications represents "off-label" use and, in general, medications have not been formulated for this mode of delivery.

- Seventy percent of respondents employ silicone sheeting and compression garments between laser treatments for traumatic scars. There was variation on the timing to restart compression, ranging from immediately to 2 weeks after treatment.
- 40% advocate massage at the treatment site between treatments.

Pain control

Topical anesthetics, non-pharmacologic methods such as forced air cooling and cold rollers, and even no anesthesia are often sufficient for treating scars with vascular devices and NAFL. Indeed, the vascular blanching that occurs with these methods may even interfere in treatment with vascular-specific devices. Smaller areas of treatment with AFL may require topical anesthetics, including compounded products, and the use of injectable local or regional anesthesia [84]. Larger cases, tender areas such as the face, hands, and feet, patients with an attenuated pain threshold, and children may require sedation or general anesthesia. One study from an outpatient surgical center affiliated with a major burn center found that the use of a 15% lidocaine 5% prilocaine compounded ointment applied to sites for 60 minutes, preoperatively, significantly reduced the requirement for post-treatment opioid therapy and reduced procedure times by an average of 30 minutes [85].

- The vast majority of patients treated by the panel are in outpatient centers. Forced air cooling, cold rollers, or ice packs are commonly employed. Pre-treatment with oral NSAIDs, acetaminophen, midazolam, or narcotics were options commonly utilized by respondents.
- Among respondents, topical and injectable anesthetics (especially lidocaine) are the most common forms of anesthesia provided to patients. For smaller areas such as on the face, concentrations of compounded topical lidocaine up to 30% were reported.
- Sedation and general anesthesia are less common and generally utilized for pediatric cases and larger adult cases.
- Two authors utilize tumescent anesthesia in larger cases where restriction and the risk of compartment syndrome are not of concern.

Post-treatment protocol

- Following AFL treatment, 73% of respondents use petrolatum or petrolatum-based dressings alone. Eighteen percent apply an occlusive dressing. Some respondents supplement with an antibiotic ointment, such as mupirocin or fusidic acid.
- Between treatments, 68% of respondents advocate treatment with silicone gels, sheets, and garments; 42% advocate scar massage; 37% advocate treatment with topical corticosteroids.
- For patients that are prescribed pressure garments who receive AFL, 35% of respondents advocate restarting the garments within 2–3 days; 30% after 1 week; 15% after 2 weeks; 10% restart pressure garments immediately.
- In the presence of significant functional impairment, 82% of respondents routinely advocate physical and occupational therapy in concert with laser sessions.
- Hydroquinone and 15% azelaic acid were cited by over half of respondents to reduce the risk of PIH.
- Other reported adjuncts applied post-treatment include class II or III topical corticosteroids, tranilast 8% gel, and a variety of commercial wound-healing topical products.
- All respondents indicated that patients can generally resume normal physical activity immediately after treatment, with the caution that submersion in standing water (pools, hot tubs, ocean, lakes) is contraindicated until the skin has fully re-epithelialized. About half of respondents recommend showering after 48 hours, and the other half cite that showering the same day of the procedure is safe. Larger cases or the use of occlusive dressings would favor bathing after the 48-hour mark.
- Post-treatment sun precautions were advocated by most respondents.
- Post-operative pain medication is not frequently required after AFL and other laser procedures.

Conclusions and areas of future study

- Despite a wide range in treatment protocol and patient populations served, serious complications associated with laser treatment of traumatic scars such as infection and worsening scarring are estimated to be less than 1 in 1,000 by most respondents. While additional study is certainly warranted, AFL and other laser procedures appear to compare very favorably to scalpel surgery in terms of complications.
- More frequent but less severe complications such as prolonged erythema and post-operative discomfort are estimated at 1–5% by most panelists.
- The use of topical and systemic antibiotics in association with AFL treatments is highly variable and are routinely used by approximately half of respondents in certain situations. In part, this may reflect differences in practice population (i.e., burn center vs. outpatient clinic). Additional research is required, but the infection rate appears to be relatively low regardless.
- Antiviral prophylaxis can be considered for AFL treatments on the face, particularly in the perioral region.
- Systemic antibiotics are considered by some panelists when treating in specific areas such (e.g., perinasal, axilla, and groin), large body surface areas, or by protocol in the operating room. Clinical judgment is required based on the situation, such as doxycycline or trimethoprim/sulfamethoxazole when MRSA is a consideration in burn centers. This area requires additional study.
- Pain control for AFL is variable depending on factors such as the location, area of involvement, and age of the patient. The majority of treatments are performed by panelists in the outpatient setting using a ramp of increasing intervention including cold packs and chilled air, compounded or commercially available topical anesthetics, injectable anesthetics, systemic medications including acetaminophen, opioids, and benzodiazepines, intravenous sedation, and general anesthesia.
- Topical anesthetics may be very useful for pain management but must be utilized judiciously (i.e., over limited body surface area) to avoid excessive absorption and potential toxicity. This is particularly applicable to higher-concentration compounded anesthetics.
- Pain medication is not frequently required in the post-operative period after AFL and other laser procedures. The presence of significant pain within the first few days of treatment should initiate a search for potential causes such as infection or excessive thermal injury.

CONSIDERATIONS IN SKIN OF COLOR

Dyspigmentation is both an undesirable consequence of cutaneous injury, and also a potential complication of any scar-related procedural intervention. This is especially pertinent for patients with darker phototypes (i.e., IV–VI). Beam fractionation of ablative and non-ablative devices has enhanced the safety and efficacy profile of laser treatment by reducing bulk heating and confluent epithelial damage while increasing the available depth of penetration [62]. With water as the target chromophore, fractional lasers have utility for the full range of skin types. One retrospective study of 961 successive 1,550-nm NAFL treatments revealed an overall post-inflammatory hyperpigmentation (PIH) rate of 0.73%. However, the incidence of PIH varied by skin phototype (SPT); SPT II had a 0.26% incidence of PIH, whereas SPT III, IV, and V had incidences of 2.6, 11.6, and 33%, respectively [73]. This increased incidence of PIH in patients with SPT III–V has been associated with intrinsic factors (i.e., increased epidermal melanin, labile melanocytes, larger melanosomes, reactive fibroblasts) [86]. These can be exacerbated by extrinsic factors such as UV light exposure, and the contrast of darker constitutive pigmentation with depigmented and hypopigmented scars. As a practical matter, traumatic scars are frequently associated with dyspigmentation and devices such as fractional lasers offer excellent treatment options for both hyperpigmentation and hypopigmentation. Generally speaking, PIH is frequently more of a concern when lasers (i.e., NAFL, AFL) are applied for other indications such as rejuvenation and acne scars where baseline dyspigmentation is not significant.

The impact of PIH on daily practice varies according to factors such as the patient population served and the intensity of sun exposure (i.e., latitude). Optimal management of PIH therefore varies but includes an algorithmic approach to prophylaxis [87], prompt recognition of complications, and expedient intervention. Photoprotection should likely include the pre-treatment period, and may extend months after treatment as UV exposure has been shown to impair epithelization [88] and increase associated hyperpigmentation [89]. When started the first day after AFL, sunscreen has been shown to result in a statistically significant reduction of melanin index and decreased incidence of PIH [90]. Both application of a broad-spectrum daily sunscreen (SPF > 30) and avoidance of sun exposure (protective clothing) may be of benefit. Hydroquinone 4% cream 2 weeks prior to treatment and a topical corticosteroid applied 1–2 weeks after the procedure (particularly if post-procedural erythema or edema is appreciated) may also reduce the rate of PIH. In addition to modifying sun exposure and pharmacologic therapies, more conservative laser treatment parameters may also help reduce the incidence of PIH in darker skin types. This may include lower treatment densities, lower pulse energies, and longer intervals between treatments; this likely translates into a greater number of sessions required to achieve treatment goals. If dyspigmentation occurs, prompt recognition and treatment will improve outcomes. Hyperpigmentation can be treated with topicals such as hydroquinone and kojic or glycolic acid creams in conjunction with a broad-spectrum sunscreen. Conversely, topical tacrolimus may be considered for iatrogenic hypopigmentation as it enhances both tyrosinase activity and melanocyte migration [91].

Panel recommendations: Traumatic scar management in skin of color

- One hundred percent of respondents believe NAFL is safe for traumatic scar management in skin of color; 86% of respondents believe AFL is safe for traumatic scar management in skin of color.
- Proactive management of post-inflammatory pigment alteration was advocated, particularly after AFL. Eighty-two percent of panelists use medical management to reduce the risk of hyperpigmentation; 55% use a combination of bleaching agents and corticosteroids; 23% corticosteroids; 9% bleaching creams.
- Seventy-three percent of respondents modify treatment parameters when treating skin of color, with approximately an even distribution decreasing pulse energy, density, or both.
- Greater spacing between treatments is often utilized to ensure resolution of PIH before re-treating.
- Greater attention to cooling, including contact cooling, was also advocated.
- Protocols for pre- and post-treatment vary by region, but include strict sun avoidance, bleaching creams, topical corticosteroids, and oral tranexamic acid.

Conclusions and areas of future study (Table 6)

- With water as the target chromophore, fractional lasers are appropriate to treat traumatic scars in the entire range of skin types. Given the high degree of trauma-related dyspigmentation in darker skin types, the additional impact of laser treatment is often low and dyspigmentation is often improved.
- Pre- and post-treatment regimens are variable among panelists depending on individual practice preferences and the underlying populations they serve. These range from no variation to sun precautions and aggressive use of topicals such as bleaching creams and corticosteroids.
- It is common, though not universal, for panelists to increase the treatment interval and decrease the density and pulse energy of fractional treatment in skin of color. Multiple panelists feel density is the more impactful for pigment alteration than pulse energy. Additional study is required to elucidate the optimal regimen, including parameters and medication use, when treating traumatic scars in skin of color.

INTEGRATING TRAUMATIC SCAR TREATMENT INTO PRACTICE

Laser treatment for traumatic scars is an extremely promising therapy with an established and rapidly-accumulating supporting literature. In some centers, procedures such as AFL have served as a first-line treatment for over a decade with life-changing results for thousands of patients. However, millions of patients still lack consistent access to the procedure for a variety of reasons. Despite a broad multidisciplinary base of supporting literature, AFL and other laser procedures have not yet been consistently established as a universal standard of care for traumatic scar management. The volume and reach of related research are expanding rapidly as burn centers and surgical disciplines increase their involvement. One of the primary motivations for publishing this multidisciplinary international expert consensus is to continue to help establish AFL and other laser procedures as a worldwide standard of care, and bring practice more in line with current knowledge. A manifestation of these issues and a primary driver of uneven access is the lack of consistent reimbursement for laser treatment. The panel is composed of members from 13 different countries so it is difficult to generalize. In Denmark, it was noted that laser treatments are offered as a benefit of the national health system. However, in most locations insurance coverage is very limited or non-existent, and most panelists indicated that patients pay out of pocket or treatments are provided pro-bono by the surgeons. Clearly, this has a deleterious effect on access. There is some momentum, as indicated by recent coding developments in the United States (see below). However, it must be stated that without access to laser treatments millions of patients are likely not receiving the best available care for their traumatic scars.

CODING FOR TRAUMATIC SCAR TREATMENT IN THE UNITED STATES

There is good evidence that fractional ablative lasers can be used to provide functional improvement (i.e., improved range of motion) to children with burns, wounded warriors with traumatic scars, and the like. For instance, the restrictiveness of a traumatic or burn scar on the hand may be reduced so that a patient is now able to hold a fork or pen. From an intuitive standpoint, low density, high energy ablative lasers drill small diameter but deep holes in a grid pattern into the scar. This renders the previously solid, hard scar into a mesh-like structure with more give and mobility. Until recently, there was no CPT code for this service, which *prima facia* clearly appears to be medically indicated and is also important to provide on compassionate grounds. However, since 2018 there has been a Category III CPT code to represent this service, as seen below:

0479T Fractional ablative laser fenestration of burn and traumatic scars for functional improvement; first 100 cm^2 or part thereof, or 1% of body surface area of infants and children

+**0480T** each additional 100 cm^2, or each additional 1% of body surface area of infants and children, or part thereof (List separately in addition to code for primary procedure)

- *Use 0480T in conjunction with 0479T*
- *Report 0479T, 0480T only once per day*
- *Do not report 0479T, 0480 T in conjunction with 0492T; For excision of cicatricial lesion[s] [e.g., full thickness excision, through the dermis], see 11400-11446*

While this code is specified for laser, other fractional ablative modalities may also qualify if they are used in substantially the same manner. For instance, ablative radiofrequency, ultrasound, and plasma do not have separate codes and so this would be the closest, and hence most appropriate, code. On the other hand, full-field ablative treatments or non-ablative "resurfacing" is not included in this code. Similarly, non-invasive skin tightening devices (e.g., infrared light, radiofrequency, ultrasound), vascular lasers, and other device-based scar treatment modalities are also not described by this code.

Importantly, 0479T and +0480T are Category III codes. Category III codes are emerging technology codes that *may* be paid by Medicare and private insurers. If payers do decide to reimburse these codes, they pay what they each deem appropriate, and hence the codes are said to be "carrier-priced." If Category III codes are not upgraded to Category I or actively approved to be kept on as Category III codes, then they sunset in 5 years. Ideally, the codes would be reclassified as Category I codes. Upgrading to Category I requires three conditions to be met: (i) level I evidence showing effectiveness of the treatment (i.e., a randomized clinical trial, preferably multicenter, conducted in the United States); (ii) clinical guidelines for the use of the treatment; and (iii) widespread usage of the Category III codes by many providers at many centers across the country (since, AMA-CPT is reluctant to create codes used by a handful of providers, it is preferable that several hundred or thousand providers use the code a few times each rather than a few providers use the code hundreds or thousands of times). If a Category I code is achieved, then this would be valued by the RUC in relative value units and priced by CMS in dollars. Category I codes are generally paid by CMS and most private insurers.

While 0479T and +0480T currently remain as Category III codes, it is important for those of us who deliver these services to use the codes, even if they are not paid by a third-party insurers. This is to help accumulate data indicating the frequency with which they are used, thereby helping with the transition to Category I.

When using 0479T and +0480T, it is important to convey to the patient that these may not be paid by their insurer. Prior to delivering treatment, submit a request for approval to the insurer, with the expected fee and appropriate documentation. If the request is approved, have the patient sign a waiver, such that if the payer reneges, the patient knows what they are responsible for paying. If the request is denied, let the patient know they will be responsible for payment, and apprise them of the fee per treatment, and the approximate number of treatments. If you find that you are using these codes repeatedly, and you commonly provide this service to patients insured by the same carrier consider meeting with the carrier's medical director to plead your case, and to set a carrier-based price per service going forward. The creation of such a negotiated rate may mitigate the risk of not being paid, or having to submit supplemental documentation or appeals in each case. Keep in mind that any preset rate may apply only to your patients and only to a particular carrier.

Just as are there are now new codes for functional improvement of scars, there are also new codes for laser treatment of wounds. These codes, which are also Category III, are designed to expedite re-epithelialization of ulcers and open wounds:

0491T Ablative laser treatment, non-contact, full field and fractional ablation, open wound, per day, total treatment surface area; first 20 sq cm or less

+**0492T** Each additional 20 sq cm, or part thereof (List separately in addition to code for primary procedure)

- Use 0492T in conjunction with 0491T
- Do not report 0492T in conjunction with 0479T, 0480T

Note that these codes are also for laser, and while Er:YAG laser is listed in the formal code proposal, the CPT code is not so specific. As with the functional scar codes, these codes could potentially be used with other laser-like energy devices. Unlike the functional scar codes, the open wound laser codes are appropriately coded when *either* fractional ablative or full-field devices are used. The purpose of such treatments must be to stimulate the healing of open wounds, particularly pressure, venous, or diabetic foot ulcers, as well as chronic wounds.

Neither set of Category III codes described above is intended for treatment of hypertrophic scars or keloids that do not pose a functional restriction. For instance, there is no specific laser code for treatment of painful, itchy, or erythematous scars and keloids. Injection of antimetabolites and intralesional corticosteroids into such symptomatic but not functionally restrictive lesions, may, of course, be a covered service. Laser-assisted drug delivery is a rapidly advancing modality, but as of yet there are also no specific laser codes for this procedure.

CASE EXAMPLE

A man in his 50s presented to the dermatology clinic approximately 25 years after suffering aviation fuel burns over his right face and neck. He had received inpatient treatment at the regional local burn center at the time of the injury, and his reconstruction included split-thickness skin grafting. He noted persistent redness, tightness, and pulling of the right side of the face and corner of the mouth exacerbated with leftward gaze that had not improved significantly over the decades. On examination he demonstrated mildly hypertrophic confluent scarring of the right lower cheek, chin, and neck with extension to the right oral commissure and lateral upper and lower cutaneous lip. Mottled hyperpigmentation was present, and pliability in the area was reduced on palpation (Fig. 1A). Of note, the presence of moderate erythema was indicative of ongoing inflammation and activity even

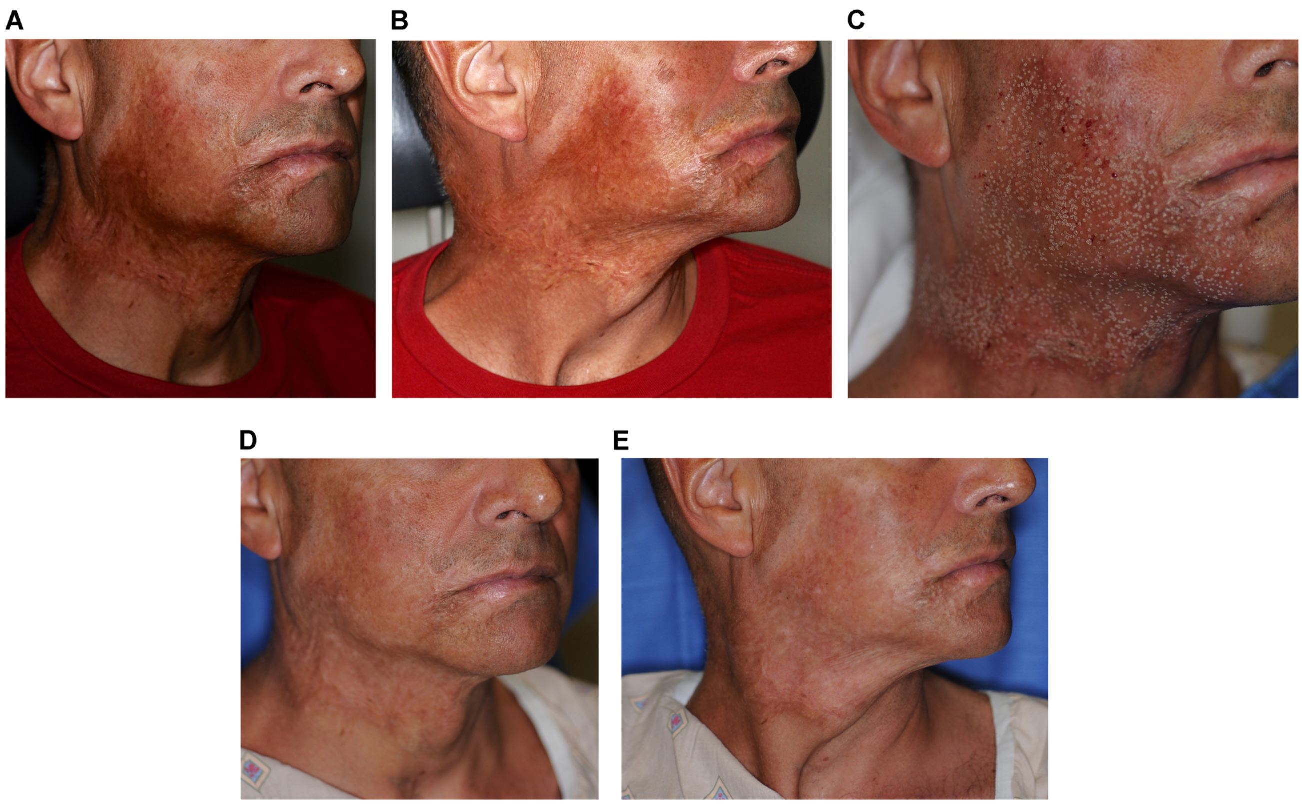

Fig. 1. (**A** and **B**) Patient at presentation approximately 25 years after burn injury with persistent hypertrophy, dyspigmentation, erythema, textural irregularity, and decreased pliability, and range of motion. (**C**) Intraoperatively demonstrating the macro-fractional pattern of injury layered on top of a micro-fractional pattern. (**D** and **E**) Patient after a series of 5 micro- and macro-fractional CO_2 laser treatments and laser-assisted delivery of corticosteroid in the outpatient setting at 2- to 3-month intervals. Significant improvements in erythema, hyperpigmentation, texture, pliability, and range of motion are noted.

decades after injury. On leftward gaze tension and downward displacement of the right oral commissure was noted (Fig. 1B).

Given the combination of esthetic and functional compromise, a series of ablative fractional and nonfractionated CO_2 laser treatments was initiated. Anesthesia was provided with topical compounded benzocaine, tetracaine, lidocaine (20%, 8%, 4%, respectively) cream applied for approximately 1 hour prior to the procedure. The tender area around the lips and oral commissure also received 2 ml of injectable 1% lidocaine with epinephrine solution. Additionally, after written consent the patient took an oral acetaminophen 325 mg/hydrocodone 2.5 mg combination (1–2 tabs Percocet) approximately 1 hour prior to treatment. Micro-fractional laser treatment was initiated over the entire scar sheet (Lumenis UltraPulse Deep FX^{TM}, Yokneam, Israel) at settings of 30–40 mJ and 5% density. Then, he received focal contouring of ridges and small elevations using a single spot at a high repetition rate (Lumenis UltraPulse Active FX^{TM}) at a pulse energy of 225 mJ. Finally, the entire area overlapping with several mm of normal skin received macro-fractional laser treatment for blending (Lumenis UltraPulse Active FX^{TM}) at a pulse energy of 100–125 mJ. To decrease the density of columns below the lowest setting of 55% surface area coverage and to increase randomization, a "painting" technique was used wherein a large pattern and high repetition rate was used while the handpiece was applied over the treatment area in a waving motion (Fig. 1C). Triamcinolone acetonide suspension at a concentration of 10 mg/ml was applied over the treatment area, followed by petrolatum ointment without a dressing. He was instructed to shower the following day and avoid water submersion for 2–3 days (especially hot tubs, lakes, ocean). He continued petrolatum for 2–3 days until re-epithelialized. Additionally, he was instructed on sun precautions. Pain medications were not required after the procedure.

Ultimately the patient received a total of five treatments at 2- to 3-month intervals in a fashion similar to that described above. Cumulative improvements in color, pliability, texture, and range of motion were noted, with minimal residual pulling on movement of the head (Fig. 1D and E). Of note the erythema and hyperpigmentation improved substantially with CO_2 laser treatment alone, and additional laser platforms were not used in this case. The rapidity and degree of improvement in such a long-standing scar is a testament to the efficacy of the technique. Erythema reduction (manifesting a corresponding reduction in inflammation) in the face of multiple episodes of controlled "reburning" of a scar is a clue to the mechanism of action via a cytokine-mediated wound healing and remodeling response.

CONSENSUS RECOMMENDATIONS SUMMARY

(1) Lasers are a first-line therapy in the management of traumatic scars and contractures, and patients without access to these treatments may not be receiving the best available care after injury. This position is supported by a consistent and expanding foundation of literature describing the safety and efficacy of laser treatment, especially AFL. Updated international treatment guidelines and reimbursement schemes, additional high-quality research, and patient access should reflect this status.

(2) Laser therapy has been noted as a primary therapeutic option for existing scars. However, it should also be integrated (guided by further research) for anticipatory scar management early in the post-injury course. For smaller traumatic injuries such as lacerations, over 90% of panelists would optimally begin laser treatment within 1 month of injury, and over 70% within 1 week or less.

(3) For larger traumatic injuries such as burns, over 90% of panelists would begin laser treatment within 4 months or less, and 76% within 2 months or less. Early intervention to minimize pathological scar formation and related disability is an important paradigm shift in traumatic scar treatment, and an essential potential benefit of minimally invasive laser procedures.

(4) It is never too late to initiate laser treatment for traumatic scars.

(5) Optimal treatment routinely includes multiple laser types in concurrent or alternating treatment sessions to suit varying clinical presentations and treatment goals in a particular location at a particular time.

(6) Effective comprehensive traumatic scar management frequently incorporates surgical evaluation; laser treatment; ongoing conservative measures (i.e., compression, massage, and silicone gels and sheets); physical and occupational therapy; medical management such as corticosteroids and antimetabolites; and mental health and other multidisciplinary evaluation where appropriate.

(7) Lasers may be successfully employed to treat trauma-related sequelae such as traumatic tattoos, to reduce hair transferred during reconstruction procedures, and to improve the fit and comfort of prosthetic devices on residual limbs.

(8) See Table 5 for a sample AFL treatment and post-treatment protocol and Table 6 for potential modifications in skin of color.

(9) Fractional lasers are a first-line treatment for hypopigmented scars.

(10) For patients presenting with flat red scars, vascular devices are the first choice among all panel members.

(11) When multiple laser devices are used in a single session in the same area, vascular devices should generally be applied first since other interventions will frequently result in reactive erythema, edema, and discharge in the treatment area.

(12) AFL is one of the most important developments in traumatic scar management in decades, and the single most effective laser type for managing hypertrophic scars and contractures.

(13) All panel members frequently combine laser and medical therapy (i.e., corticosteroids and antimetabolites) in the same session for hypertrophic scars. Delivery methods may include laser-assisted through newly ablated fractional channels and intralesional injections.
(14) Split- and full-thickness skin graft sites may be fully integrated into the area of treatment after the initial healing phase.
(15) AFLs and NAFLs are an initial treatment consideration for atrophic traumatic scars. Laser treatment may be combined with other procedures such as cutaneous fillers, subcision, and surgical revision in the presence of significant volume deficits.
(16) Lasers offer an important and under-utilized therapeutic option for post-burn pain and pruritus, and were considered a first- or second-line treatment by the large majority of panelists.
(17) Ablative fractional laser depth settings (pulse energy) should be proportional to, but not exceed, the thickness of the scar.
(18) Ablative fractional laser treatments should be performed at a low-density setting (often the lowest) to avoid excessive thermal injury in traumatic scars. High pulse energy settings (depth) when treating hypertrophic scars and contractures require a concomitant decrease in density (high energy, low-density technique) (see Table 3).
(19) The optimal microbeam profile and ablative fractional pattern has yet to be identified in the literature, though panelists have found the existing devices both safe and effective. The most important beam characteristics identified by panelists include tunable depth of penetration and density with the option to penetrate several mm into thick scars; narrow beam diameter; appropriate but not excessive surrounding coagulation; and short pulse duration to minimize thermal injury.
(20) In the absence of contraindications, laser treatment may be continued until the desired effect is achieved, or improvement plateaus.
(21) The panel did not consider specific laser combinations in detail. Safe treatment for inexperienced laser physicians should likely include a single platform in a particular area on a single day, with additional interventions after several weeks to observe the tissue response.
(22) Current scar assessment scales do not adequately address the full range of improvements achieved with laser therapy, including improvements in range of motion, symptoms, and overall quality of life.
(23) Complication rates associated with the laser treatment of traumatic scars appear to be extremely low and compare favorably with scalpel surgery.
(24) Medications are rarely required after laser scar treatment; the presence of severe post-procedure pain should stimulate a search for possible causes such as infection and excessive thermal injury.
(25) Fractional lasers may be applied in all skin types, though changes in medication regimen and procedure parameters may be considered for darker skin types.

REFERENCES

1. Nguyen TA, Feldstein SI, Shumaker PR, Krakowski AC. A review of scar assessment scales. Semin Cutan Med Surg 2015;34(1):28–36.
2. Dalkey N. The Delphi Method: An experimental study of group opinion. Futures 1969;1:408–426.
3. Gustafson D, Shukla R, Delbecq A, Walster G. A comparative study of differences in subjective likelihood estimates made by individuals, interacting groups, Delphi groups, and nominal groups. Organ Behav Hum Perf 1973;9:280–291.
4. Wood F. An approach to scar mitigation. In: Krakowski A, Shumaker P, editors. The Scar Book. Philadelphia, PA: Wolters Kluwer; 2017.
5. Tredget E, Ding J. The cellular and molecular basis of scarring: The paradigm of hypertrophic scarring after thermal injury. In: Krakowski A, Shumaker P, editors. The Scar Book. Philadelphia, PA: Wolters Kluwer; 2017.
6. Carlavan I, Bertino B, Rivier M, et al. Atrophic scar formation in patients with acne involves long-acting immune responses with plasma cells and alteration of sebaceous glands. Br J Dermatol 2018;179(4):906–917.
7. Ansari F, Sadeghi-Ghyassi F, Yaaghoobian B. The clinical effectiveness and cost-effectiveness of fractional CO_2 laser in acne scars and skin rejuvenation: A meta-analysis and economic evaluation. J Cosmet Laser Ther 2018;20(4):248–251.
8. Xu Y, Deng Y. Ablative fractional CO2 laser for facial atrophic acne scars. Facial Plast Surg 2018;34(2):205–219.
9. Dai R, Xie H, Hua W, Li XH, Li L. The efficacy and safety of the fractional radiofrequency technique for the treatment of atrophic acne scar in Asians: A meta-analysis. J Cosmet Laser Ther 2017;19(6):337–344.
10. Ozog DM, Liu A, Chaffins ML, et al. Evaluation of clinical results, histological architecture, and collagen expression following treatment of mature burn scars with a fractional carbon dioxide laser. JAMA Dermatol 2013;149(1):50–57.
11. Connolly KL, Chaffins M, Ozog D. Vascular patterns in mature hypertrophic burn scars treated with fractional CO2 laser. Lasers Surg Med 2014;46(8):597–600.
12. 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(7):517–524.
13. Onur Erol O, Atabay K. The treatment of burn scar hypopigmentation and surface irregularity by dermabrasion and thin skin grafting. Plast Reconstr Surg 1990;85(5):754–758.
14. Waibel JS, Wulkan AJ, Shumaker PR. Treatment of hypertrophic scars using laser and laser assisted corticosteroid delivery. Lasers Surg Med 2013;45(3):135–140.
15. Waibel J, Wulkan AJ, Lupo M, Beer K, Anderson RR. Treatment of burn scars with the 1,550 nm nonablative fractional Erbium Laser. Lasers Surg Med 2012;44(6):441–446.
16. Bowes LE, Nouri K, Berman B, et al. Treatment of pigmented hypertrophic scars with the 585 nm pulsed dye laser and the 532 nm frequency-doubled Nd:YAG laser in the Q-switched and variable pulse modes: a comparative study. Dermatol Surg 2002;28(8):714–719.
17. Hultman CS, Friedstat JS, Edkins RE. Efficacy of intense pulsed light for the treatment of burn scar dyschromias: a pilot study to assess patient satisfaction, safety, and willingness to pay. Ann Plast Surg 2015;74(Suppl 4):S204–S208.
18. Massaki AB, Fabi SG, Fitzpatrick R. Repigmentation of hypopigmented scars using an erbium-doped 1,550-nm fractionated laser and topical bimatoprost. Dermatol Surg 2012;38(7 Pt 1):995–1001.
19. Goodman GJ. An automated autologous cell transplantation method for the treatment of hypopigmented scarring. Dermatol Surg 2008;34(4):578–581.
20. Jin R, Huang X, Li H, et al. Laser therapy for prevention and treatment of pathologic excessive scars. Plast Reconstr Surg 2013;132(6):1747–1758.
21. Al-Mohamady Al-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.
22. Keaney TC, Tanzi E, Alster T. Comparison of 532 nm potassium titanyl phosphate laser and 595 nm pulsed dye laser

in the treatment of erythematous surgical scars: A randomized, controlled, open-label study. Dermatol Surg 2016;42(1):70–76.
23. Kuo YR, Jeng SF, Wang FS, et al. Flashlamp pulsed dye laser (PDL) suppression of keloid proliferation through downregulation of TGF-beta1 expression and extracellular matrix expression. Lasers Surg Med 2004;34(2):104–108.
24. Draaijers LJ, Tempelman FRH, Botman YAM, et al. The patient and observer scar assessment scale: a reliable and feasible tool for scar evaluation. Plast Reconstr Surg 2004;113(7):1960–1965. discussion 1966–1967.
25. Guertler A, Reinholz M, Poetschke J, Steckmeier S, Schwaiger H, Gauglitz GG. Objective evaluation of the efficacy of a non-ablative fractional 1565 nm laser for the treatment of deliberate self-harm scars. Lasers Med Sci 2017.
26. Lee Y. Combination treatment of surgical, post-traumatic and post-herpetic scars with ablative lasers followed by fractional laser and non-ablative laser in Asians. Lasers Surg Med 2009;41(2):131–140.
27. Blome-Eberwein S, Gogal C, Weiss MJ, Boorse D, Pagella P. Prospective evaluation of fractional CO2 laser treatment of mature burn scars. J Burn Care Res 2016;37(6):379–387.
28. Shumaker PR, Kwan JM, Landers JT, Uebelhoer NS. Functional improvements in traumatic scars and scar contractures using an ablative fractional laser protocol. J Trauma Acute Care Surg 2012;73(2 Suppl 1):S116–S121.
29. 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(5):480–486.
30. Alster TS, Nanni CA. Pulsed dye laser treatment of hypertrophic burn scars. Plast Reconstr Surg 1998;102(6):2190–2195.
31. Bailey JK, Burkes SA, Visscher MO, et al. Multimodal quantitative analysis of early pulsed-dye laser treatment of scars at a pediatric burn hospital. Dermatol Surg 2012;38(9):1490–1496.
32. Levi B, Ibrahim A, Mathews K, et al. The use of CO2 fractional photothermolysis for the treatment of burn scars. J Burn Care Res 2016;37(2):106–114.
33. Issler-Fisher AC, Fisher OM, Smialkowski AO, et al. Ablative fractional CO2 laser for burn scar reconstruction: An extensive subjective and objective short-term outcome analysis of a prospective treatment cohort. Burns 2017;43(3):573–582.
34. Hultman CS, Edkins RE, Wu C, Calvert CT, Cairns BA. Prospective, before-after cohort study to assess the efficacy of laser therapy on hypertrophic burn scars. Ann Plast Surg 2013;70(5):521–526.
35. Alster TS. Improvement of erythematous and hypertrophic scars by the 585-nm flashlamp-pumped pulsed dye laser. Ann Plast Surg 1994;32(2):186–190.
36. Manuskiatti W, Fitzpatrick RE. Treatment response of keloidal and hypertrophic sternotomy scars: comparison among intralesional corticosteroid, 5-fluorouracil, and 585-nm flashlamp-pumped pulsed-dye laser treatments. Arch Dermatol 2002;138(9):1149–1155.
37. Karmisholt KE, Haerskjold A, Karlsmark T, Waibel J, Paasch U, Haedersdal M. Early laser intervention to reduce scar formation—A systematic review. J Eur Acad Dermatol Venereol 2018;32(7):1099–1110.
38. de las Alas JM, Siripunvarapon AH, Dofitas BL. Pulsed dye laser for the treatment of keloid and hypertrophic scars: A systematic review. Expert Rev Med Devices 2012;9(6):641–650.
39. Anderson RR, Donelan MB, Hivnor C, et al. Laser treatment of traumatic scars with an emphasis on ablative fractional laser resurfacing: consensus report. JAMA Dermatol 2014;150(2):187–193.
40. Admani S, Gertner JW, Grosman A, Shumaker PR, Uebelhoer NS, Krakowski AC. Multidisciplinary, multimodal approach for a child with a traumatic facial scar. Semin Cutan Med Surg 2015;34(1):24–27.
41. Cassuto D, Emanuelli G. Non-ablative scar revision using a long pulsed frequency doubled Nd:YAG laser. J Cosmet Laser Ther 2003;5(3-4):135–139.
42. Cassuto DA, Scrimali L, Siragò P. Treatment of hypertrophic scars and keloids with an LBO laser (532 nm) and silicone gel sheeting. J Cosmet Laser Ther 2010;12(1):32–37.
43. Koike S, Akaishi S, Nagashima Y, Dohi T, Hyakusoku H, Ogawa R. Nd:YAG laser treatment for keloids and hypertrophic scars: An analysis of 102 cases. Plast Reconstr Surg Glob Open 2014;2(12):e272.
44. Manstein D, Herron GS, Sink RK, Tanner H, Anderson RR. Fractional photothermolysis: A new concept for cutaneous remodeling using microscopic patterns of thermal injury. Lasers Surg Med 2004;34(5):426–438.
45. Hantash BM, Bedi VP, Chan KF, Zachary CB. Ex vivo histological characterization of a novel ablative fractional resurfacing device. Lasers Surg Med 2007;39(2):87–95.
46. Douglas H, Lynch J, Harms KA, et al. Carbon dioxide laser treatment in burn-related scarring: A prospective randomised controlled trial. J Plast Reconstr Aesthet Surg 2019;72(6):863–870.
47. Miletta N, Siwy K, Hivnor C, et al. Fractional ablative laser therapy is an effective treatment for hypertrophic burn scars: A prospective study of objective and subjective outcomes. Ann Surg 2019. [published online ahead of print August 28, 2019].
48. Patel SP, Nguyen HV, Mannschreck D, Redett RJ, Puttgen KB, Stewart FD. Fractional CO2 laser treatment outcomes for pediatric hypertrophic burn scars. Ann Surg 2019;40(4):386–391.
49. Hultman CS, Friedstat JS, Edkins RE, Cairns BA, Meyer AA. Laser resurfacing and remodeling of hypertrophic burn scars: The results of a large, prospective, before-after cohort study, with long-term follow-up. Ann Surg 2014;260(3):519–529. discussion 529–532.
50. Żądkowski T, Nachulewicz P, Mazgaj M, et al. A new CO2 laser technique for the treatment of pediatric hypertrophic burn scars: An observational study. Medicine (Baltimore) 2016;95(42):e5168.
51. Poetschke J, Dornseifer U, Clementoni MT, et al. Ultrapulsed fractional ablative carbon dioxide laser treatment of hypertrophic burn scars: Evaluation of an in-patient controlled, standardized treatment approach. Lasers Med Sci 2017;32(5):1031–1040.
52. El-Zawahry BM, Sobhi RM, Bassiouny DA, Tabak SA. Ablative CO2 fractional resurfacing in treatment of thermal burn scars: An open-label controlled clinical and histopathological study. J Cosmet Dermatol 2015;14(4):324–331.
53. Choi JE, Oh GN, Kim JY, Seo SH, Ahn HH, Kye YC. Ablative fractional laser treatment for hypertrophic scars: Comparison between Er:YAG and CO2 fractional lasers. J Dermatolog Treat 2014;25(4):299–303.
54. Khatri KA, Ross V, Grevelink JM, Magro CM, Anderson RR. Comparison of erbium:YAG and carbon dioxide lasers in resurfacing of facial rhytides. Arch Dermatol 1999;135(4):391–397.
55. Bowen RE. A novel approach to ablative fractional treatment of mature thermal burn scars. J Drugs Dermatol 2010;9(4):389–392.
56. Issler-Fisher AC, Fisher OM, Haertsch P, Li Z, Maitz PKM. Ablative fractional resurfacing with laser-facilitated steroid delivery for burn scar management: Does the depth of laser penetration matter? Lasers Surg Med 2019. [published online ahead of print September 30, 2019].
57. Bedi VP, Chan KF, Sink RK, et al. The effects of pulse energy variations on the dimensions of microscopic thermal treatment zones in nonablative fractional resurfacing. Lasers Surg Med 2007;39(2):145–155.
58. Laubach HJ, Tannous Z, Anderson RR, Manstein D. Skin responses to fractional photothermolysis. Lasers Surg Med 2006;38(2):142–149.
59. Haedersdal M, Moreau KE, Beyer DM, Nymann P, Alsbjørn B. Fractional nonablative 1540 nm laser resurfacing for thermal burn scars: A randomized controlled trial. Lasers Surg Med 2009;41(3):189–195.
60. Taudorf EH, Danielsen PL, Paulsen IF, et al. Non-ablative fractional laser provides long-term improvement of mature burn scars—A randomized controlled trial with histological assessment. Lasers Surg Med 2015;47(2):141–147.
61. Karmisholt KE, Banzhaf CA, Glud M, et al. Laser treatments in early wound healing improve scar appearance: A randomized split-wound trial with nonablative fractional laser exposures vs. untreated controls. Br J Dermatol 2018;179(6):1307–1314.

62. Ibrahim SM, Saudi WM, Abozeid MF, Elsaie ML. Early fractional carbon dioxide laser intervention for postsurgical scars in skin of color. Clin Cosmet Investig Dermatol 2019;12:29–34.
63. Gold MH, McGuire M, Mustoe TA, et al. Updated international clinical recommendations on scar management: Part 2—Algorithms for scar prevention and treatment. Dermatol Surg 2014;40(8):825–831.
64. Shumaker PR, Kwan JM, Badiavas EV, Waibel J, Davis S, Uebelhoer NS. Rapid healing of scar-associated chronic wounds after ablative fractional resurfacing. Arch Dermatol 2012;148(11):1289–1293.
65. Diegidio P, Hultman CS. Clinical Scar Research: Quantitative and Qualitative Assessment of Hypertrophic Burn Scars. In: Krakowski AC, Shumaker PR, editors. The Scar Book. Philadelphia, PA: Wolters Kluwer; 2017. pp 369–381.
66. Sullivan T, Smith J, Kermode J, McIver E, Courtemanche DJ. Rating the burn scar. J Burn Care Rehabil 1990;11(3):256–260.
67. Poetschke J, Schwaiger H, Gauglitz GG. Current and emerging options for documenting scars and evaluating therapeutic progress. Dermatol Surg 2017;43(Suppl 1):S25–S36.
68. Fearmonti RM, Bond JE, Erdmann D, Levin LS, Pizzo SV, Levinson H. The modified Patient and Observer Scar Assessment Scale: a novel approach to defining pathologic and nonpathologic scarring. Plast Reconstr Surg 2011;127(1):242–247.
69. Lee KC, Dretzke J, Grover L, Logan A, Moiemen N. A systematic review of objective burn scar measurements. Burns Trauma 2016;4:14.
70. Wanner M, Sakamoto FH, Avram MM, et al. Immediate skin responses to laser and light treatments: Therapeutic endpoints: How to obtain efficacy. J Am Acad Dermatol 2016;74(5):821–833. quiz 834, 833.
71. Zuccaro J, Ziolkowski N, Fish J. A systematic review of the effectiveness of laser therapy for hypertrophic burn scars. Clin Plast Surg 2017;44(4):767–779.
72. Bernstein LJ, Kauvar AN, Grossman MC, Geronemus RG. The short- and long-term side effects of carbon dioxide laser resurfacing. Dermatol Surg 1997;23(7):519–525.
73. Graber EM, Tanzi EL, Alster TS. Side effects and complications of fractional laser photothermolysis: Experience with 961 treatments. Dermatol Surg 2008;34(3):301–305. discussion 305–307.
74. Metelitsa AI, Alster TS. Fractionated laser skin resurfacing treatment complications: A review. Dermatol Surg 2010;36(3): 299–306.
75. Xu LY, Kilmer SL, Ross EV, Avram MM. Bacterial infections following non-ablative fractional laser treatment: A case series and discussion. Lasers Surg Med 2015;47(2):128–132.
76. Sarnoff GH, Doerfler B, Hanke GJ. The safety of laser skin resurfacing with the microablative carbon dioxide laser and review of the literature. J Drugs Dermatol 2018;17(11):1157–1162.
77. Fisher GH, Geronemus RG. Short-term side effects of fractional photothermolysis. Dermatol Surg 2005;31(9 Pt 2):1245–1249. discussion 1249.
78. Duke D, Grevelink JM. Care before and after laser skin resurfacing. A survey and review of the literature. Dermatol Surg 1998;24(2):201–206.
79. Nanni CA, Alster TS. Complications of carbon dioxide laser resurfacing. An evaluation of 500 patients. Dermatol Surg 1998;24(3):315–320.
80. Setyadi HG, Jacobs AA, Markus RF. Infectious complications after nonablative fractional resurfacing treatment. Dermatol Surg 2008;34(11):1595–1598.
81. Anthonissen M, Daly D, Janssens T, Van den Kerckhove E. The effects of conservative treatments on burn scars: A systematic review. Burns 2016;42(3):508–518.
82. Mustoe TA, Cooter RD, Gold MH, et al. International clinical recommendations on scar management. Plast Reconstr Surg 2002;110(2):560–571.
83. Nanda S, Reddy BS. Intralesional 5-fluorouracil as a treatment modality of keloids. Dermatol Surg 2004;30(1):54–56. discussion 56–57.
84. Kouba DJ, LoPiccolo MC, Alam M, et al. Guidelines for the use of local anesthesia in office-based dermatologic surgery. J Am Acad Dermatol 2016;74(6):1201–1219.
85. Edkins RE, Hultman CS, Collins P, Cairns B, Hanson M, Carman M. Improving comfort and throughput for patients undergoing fractionated laser ablation of symptomatic burn scars. Ann Plast Surg 2015;74(3):293–299.
86. Alexis AF. Lasers and light-based therapies in ethnic skin: treatment options and recommendations for Fitzpatrick skin types V and VI. Br J Dermatol 2013;169(Suppl 3):91–97.
87. Lv K, Xia Z. Chinese expert consensus on clinical prevention and treatment of scar. Burns Trauma 2018;6:27.
88. Danielsen PL, Lerche CM, Wulf HC, et al. Acute ultraviolet radiation perturbs epithelialization but not the biomechanical strength of full-thickness cutaneous wounds. Photochem Photobiol 2016;92(1):187–192.
89. Due E, Rossen K, Sorensen LT, Kliem A, Karlsmark T, Haedersdal M. Effect of UV irradiation on cutaneous cicatrices: A randomized, controlled trial with clinical, skin reflectance, histological, immunohistochemical and biochemical evaluations. Acta Derm Venereol 2007;87(1): 27–32.
90. Wanitphakdeedecha R, Phuardchantuk R, Manuskiatti W. The use of sunscreen starting on the first day after ablative fractional skin resurfacing. J Eur Acad Dermatol Venereol 2014;28(11):1522–1528.
91. Chandrashekar BS, Shenoy C, Madura C. Complications of laser and light-based devices therapy in patients with skin of color. Indian J Dermatol Venereol Leprol 2019;85(1):24–31.