10-31-2021

Energy-based devices for the treatment of Acne Scars: 2022 International consensus recommendations

Fares Salameh

Peter R. Shumaker

Greg J. Goodman

Leah K. Spring

Meghan Seago

See next page for additional authors

Recommended Citation

Salameh F, Shumaker PR, Goodman GJ, Spring LK, Seago M, Alam M, Al-Niaimi F, Cassuto D, Chan HH, Dierickx C, Donelan M, Gauglitz GG, Haedersdal M, Krakowski AC, Manuskiatti W, Norbury WB, Ogawa R, Ozog DM, Paasch U, Victor Ross E, Clementoni MT, Waibel J, Bayat A, Goo BL, and Artzi O. Energy-based devices for the treatment of acne scars: 2021 international consensus recommendations. Lasers Surg Med 2021.

Authors

Fares Salameh, Peter R. Shumaker, Greg J. Goodman, Leah K. Spring, Meghan Seago, Murad Alam, Firas Al-Niaimi, Daniel Cassuto, Henry H.I. Chan, Christine Dierickx, Matthias Donelan, Gerd G. Gauglitz, Merete Haedersdal, Andrew C. Krakowski, Woraphong Manuskiatti, William B. Norbury, Rei Ogawa, David M Ozog, Uwe Paasch, E. Victor Ross, Matteo Tretti Clementoni, Jill Waibel, Ardeshir Bayat, Boncheol Leo Goo, and Ofir Artzi

Accepted: 3 October 2021

DOI: 10.1002/lsm.23484

REVIEW ARTICLE

Energy-based devices for the treatment of Acne Scars: 2022 International consensus recommendations

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

[1]Department of Dermatology, Tel Aviv Sourasky Medical Center, Tel Aviv, Israel

[2]VA San Diego Healthcare System and University of California, San Diego, California, USA

[3]Department of General Practice, Monash University, Clayton, Victoria, Australia

[4]Micrographic Surgery and Surgical Oncology, SkinCare Physicians, Chestnut Hill, Massachusetts, USA

[5]Micrographic Surgery and Surgical Oncology, Scripps Clinic, La Jolla, California, USA

[6]Department of Dermatology, Northwestern University Feinberg School of Medicine, Chicago, Illinois, USA

[7]Aalborg University, Aalborg, Denmark

[8]Private Practice, Milan, Italy

[9]Private Practice and Department of Medicine (Dermatology), University of Hong Kong, People's Republic of China

[10]Skinperium Clinic, Luxembourg, Luxembourg

[11]Department of Surgery, Massachusetts General Hospital, Shriners Hospitals for Children—Boston, Harvard Medical School, Boston, Massachusetts, USA

[12]Department of Dermatology and Allergy, Ludwig Maximillian University, Munich, Germany

[13]Department of Dermatology, Bispebjerg Hospital, University of Copenhagen, Copenhagen, Denmark

[14]Department of Dermatology, St. Luke's University Health Network, Easton, Pennsylvania, USA

[15]Department of Dermatology, Faculty of Medicine Siriraj Hospital, Bangkok, Thailand

[16]Department of Surgery, University of Texas Medical Branch, Shriners Hospital for Children—Galveston, Galveston, Texas, USA

[17]Department of Plastic, Reconstructive and Aesthetic Surgery, Nippon Medical School, Tokyo, Japan

[18]Department of Dermatology, Henry Ford Hospital, Detroit, Michigan, USA

[19]Department of Dermatology, Venereology, and Allergy, University of Leipzig, Leipzig, Germany

[20]Scripps Clinic, San Diego, California, USA

[21]Laserplast, Milan, Italy

[22]Miami Dermatology and Laser Institute, Miami, Florida, USA

[23]Plastic & Reconstructive Surgery Research, Centre for Dermatology Research, NIHR Manchester Biomedical Research Centre, University of Manchester, England, UK

[24]MRC-SA Wound Healing Unit, Hair & Skin Research Laboratory, Division of Dermatology, University of Cape Town, Cape Town, South Africa

[25]Naeum Dermatology and Aesthetic Clinic/Skin Rehabilitation Center, Seoul, Korea

Correspondence
Ofir Artzi, Department of Dermatology,
Tel Aviv Sourasky Medical Center, Lilinblum St.
Tel Aviv, Gush Dan, Tel Aviv 6513212, Israel.
Email: Benofir@gmail.come

Abstract

Background and Objectives: Acne scars are one of the most distressing and long-term consequences of acne vulgaris, with damaging effect on a person's physical, mental, and social well-being. Numerous treatment options are available including surgical and nonsurgical techniques, depending on the clinical presentation. Although considerable advances in the development of new treatment technologies and applications have been made in the last decade, 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 potential utility of energy-based devices (EBDs) for acne scarring, offer recommendations for safe and efficacious treatment, and provide consensus-based EBD treatment options based on varying presentations demonstrated in a series of real-life clinical photographs.

Study Design/Materials and Methods: An international panel of 24 dermatologists and plastic surgeons from 12 different countries and a variety of practice backgrounds was self-assembled to develop updated consensus recommendations for the treatment of acne scars. A two-step modified Delphi method took place between March 2020 and February 2021 consisting of two rounds of emailed questionnaires. The panel members approved the final manuscript via email correspondence.

Results: The manuscript includes a comprehensive discussion and panel recommendations regarding the following topics: 1. the role of EBD in mitigating and treating acne scars in a patient with active acne, 2. the use of various EBDs for the treatment of different acne scar types with special focus on commonly used laser platform such as vascular lasers, ablative fractional lasers (AFLs) and non-AFLs (NAFLs), 3. treatment combinations, and 4. acne scar treatments in skin of color. The last part comprised of 10 photos of real-life clinical cases with the panel recommendation treatment plan to achieve best aesthetic outcome.

Conclusion: Panel members were unanimous in their view that EBDs have a role in the management of acne scars, with AFLs, NAFLs, vascular lasers, and RF devices preferentially selected by most of the panel experts. EBDs are considered a first-line treatment for a variety of acne scar types and patients without access to these treatments may not be receiving the best available care for optimal cosmetic results. Future high-quality research and updated international treatment guidelines and reimbursement schemes should reflect this status.

KEYWORDS
acne scars, energy based devices, lasers

INTRODUCTION

Acne is one of the most common and troublesome inflammatory skin diseases encountered by dermatologists. The disorder typically begins at puberty, affecting 95%–100% of adolescent boys and 83%–85% of adolescent girls, and persists into adulthood in approximately 12%–14% of cases.[1,2] One of the most distressing and long-term consequences of acne is scarring, affecting up to 95% of patients, with 30% categorized as severe.[3,4] Acne scars are not only aesthetically displeasing but can also result in a significant social and societal burden. They have been described as a risk factor for a variety of psychological sequelae including suicide, depression, anxiety, poor self-esteem, as well as social impairment, low academic performance, and unemployment.[5,6] The pathophysiology driving acne scar development is attributed to an altered wound healing response initiated by cutaneous inflammation, leading to an imbalance in matrix degradation and collagen biosynthesis.[7] The ultimate severity is correlated with acne grade and delay in treatment of active disease.[8] The end result is either an excess of collagen that manifests as hypertrophic/keloid scars or, more commonly, decreased collagen deposition that manifests as atrophic acne scars in 80 to 90 percent of cases.[3]

Jacob and colleagues have described a classification system to categorize atrophic acne scars into three basic types: *icepick*, *rolling*, and *boxcar*. Among atrophic scars, the ice pick type represents 60%–70%; the boxcar type 20%–30%; and the rolling type 15%–25%.[9] According to the qualitative scarring grading system proposed by Goodman and Baron, a macular acne scar type also exists, which clinically shows erythematous, hyperpigmented, or hypopigmented flat marks.[10] These three scar types are usually seen in the same person, often making it difficult to differentiate between them.[11] On one hand, this classification system has allowed a consistent and standardized definition of acne scars that has been adopted into clinical research and has aided in treatment regimens.[12] On the other hand, clinical assessment of scars demonstrates significant variation between assessors,[13] and the lack of a universally accepted quantitative or qualitative scoring system makes it difficult to compare treatments for scarring.

Treatment options for acne scars depend on the clinical presentation and include surgical (e.g., excision, subcision, punch techniques) and nonsurgical approaches (e.g., dermabrasion, needling, chemical peels, injectable fillers, and energy-based devices).[14] Various factors, including color, depth, and morphology, can affect the treatment choice for each individual scar,[15] and a combined modality approach may produce more benefit compared with a single modality. Although considerable advances in the development of new treatment technologies and applications have been made in the last decade, there is a paucity of high-quality clinical studies supporting many of these therapies and combinations. The results of a 2016 Cochrane review failed to provide sufficient evidence to support the first-line use of any intervention in the treatment of acne scars. Moreover, the relative safety of the different interventions as monotherapies or in combination had not been adequately determined, and there were no randomized controlled trials (RCTs) to define the gold standard treatment against which other approaches should be measured.[16]

In light of these challenges, a multidisciplinary panel of international experts in scar management was assembled to generate treatment recommendations based upon available literature and expert opinion. A similar effort by the same group was undertaken for traumatic scars in 2020.[17] Our goals are to highlight the potential utility of energy-based devices (EBDs, e.g., lasers and radiofrequency [RF]) for acne scarring, offer recommendations for safe and efficacious treatment, and provide consensus-based EBD treatment options based on varying presentations demonstrated in a series of real-life clinical photographs. Due to a greater footprint in the literature, the focus of this manuscript will be on laser devices, with RF forming a minor part of the discussion. Other devices, while promising, are not yet well-represented in the literature.

METHODS

An international panel of 24 dermatologists and plastic surgeons was self-assembled to develop updated consensus recommendations for the treatment of acne scars. The panel members represented a broad range of experience in academic, private practice, and hospital-based settings from 12 different countries. Four authors (F.S., O.A., P.S., and G.G.) curated the initial clinical questions based on panel input and literature review. A two-step modified Delphi method was implemented between March 2020 and February 2021. The Delphi method is an iterative process used to achieve consensus for a defined clinical problem where there is little or conflicting published evidence and where expert opinion is decisive.[18] Our modified Delphi method consisted of two rounds of email questionnaires in which the following topics were highlighted:

1. The role of EBD in mitigating and treating acne scars in a patient with active acne.
2. The use of various EBDs for the treatment of different acne scar types.
3. Treatment combinations including EBDs.
4. Considerations in skin of color.

The last part of the questionnaire was comprised of 10 photos of real-life clinical cases in which each panelist offered his/her recommended treatment plan to achieve best aesthetic outcome.

The role of EBD in mitigating and treating acne scars in a patient with active acne

The coexistence of active inflammatory acne lesions and acne scars poses both a challenge, and an opportunity, in timely management of acne scarring. Time between acne onset and first effective treatment was found to be a risk factor for developing acne scars.[19] While most patients are treated solely with topical and/or systemic antiacne medication, prior studies have shown that a range of EBD including intense pulsed light (IPL), diode, 585/595 nm pulsed dye laser (PDL), 532 nm potassium titanyl phosphate (KTP) lasers, several infrared lasers, including the 1550 nm erbium glass, 1064 nm and 1320 nm Nd:YAG lasers, and fluorescent light treatment may also be effective in treating moderate-to-severe acne.[20–25] The proposed mechanism of action is through reduction of *Propionibacterium acnes* (*P. acnes*) levels, disruption of sebum production, and reducing inflammation.[25–27] Laser therapies are likely to offer the greatest benefit to acne vulgaris patients when used in conjunction with medical therapy,[28] and literature on their efficacy is growing rapidly. There is increasing evidence for the effectiveness of fractional radiofrequency (FRF) microneedling in the treatment of active acne, either as sole treatment[29,30] or

in combination with other EBDs, such as carbon dioxide (CO_2) lasers.[31] FRF was found to be effective in decreasing the number of acne lesions (inflammatory and noninflammatory) and sebum excretion.

EBDs and isotretinoin

Patients with nodulocystic and severe acne who are on, or have recently completed, isotretinoin are also highly likely to be among those who would benefit from intervention with EBD to mitigate scarring. Isotretinoin (13-cis-retinoic acid) is a metabolite of vitamin A that is approved by the FDA for treating severe acne, acne unresponsive to other treatments, and cases in which other treatments would be likely to leave scars and have negative emotional effects.[32] It has demonstrated benefit in patients with severe acne resulting in numerous effects including involution of the pilosebaceous unit, decreased acne lesions and related scarring, and a decrease in associated symptoms of anxiety and depression.[33–36]

For decades dogma has held that patients who are on, or are within 6 to 12 months of completing, a course of isotretinoin should avoid most cutaneous procedures due to a concern for heightened risk of delayed wound healing and raised dermal (hypertrophic/keloid) scarring in the context of decreased healing potential from diminution of the pilosebaceous apparatus. Interestingly, this expansive and durable recommendation was based largely on a relatively small number of case reports from the 1980s, primarily involving mechanical dermabrasion.[37] This topic received a re-examination in 2017 with the publication of two seminal consensus documents, including one published under the auspices of the American Society for Dermatologic Surgery (ASDS).[38,39] Only three prior reports of abnormal scarring after laser procedures within 6 months of isotretinoin were found on literature review, including one argon laser, one fully ablative Er:YAG, and one pulsed dye laser treatment. The ASDS task force concluded that there was insufficient evidence in the literature to justify delaying treatment with hair removal devices, vascular lasers, nonablative fractional lasers (non-AFL), and AFL in patients receiving, or who have received, isotretinoin within the last 6 months. They also recommended that fully ablative (i.e., non-fractionated) treatments should generally be avoided until 6 months after the completion of isotretinoin in accordance with traditional practice.

The consensus panel that authored the JAMA Dermatology article came to similar conclusions and indicated that avoiding procedural intervention for 6–12 months after completing isotretinoin conflicts with current trends toward early intervention for scarring, and effectively delays treatment for a condition with significant physical and mental sequelae.[39] Results of a provider survey on procedures in the context of isotretinoin indicated that while a small majority of respondents recommended patients wait at least 6 months or longer after completing isotretinoin therapy before receiving laser and light-based treatment, 70% reported that primarily medicolegal concerns guided their treatment decisions.[40] Since 2017 multiple studies have found various EBD including vascular lasers, non-AFL, and 1064-nm lasers safe and effective for acne and acne scarring either in combination with isotretinoin or starting within 1 month of completing isotretinoin.[41–44]

Panel recommendations: EBD for mitigating and treating acne scars in a patient with active acne

- Seventy-four percent of panel members indicated that patients with active acne and acne scars should be treated with EBD and topical or systemic medications in parallel. The proposed rationale for using EBD was reducing the severity and/or duration of inflammation and scarring potential (98% of the panelists) and enhancing the effectiveness of topical or oral medication (54% of the panelists).
- The most prominent considerations for the use of EBD in the treatment of active acne were:
  - Poor candidates for oral medication (e.g., pregnancy, mental health issues, etc.) (94% of panelists).
  - Presence of existing scars (75%).
  - Elevated risk of scarring in the context of active inflammatory lesions (69%).
- Vascular lasers were the preferred EBD in the management of inflammatory acne (80%) of panelists.
  - Seventy-five percent of panelists use 595-nm PDL. Three to ten milliseconds was the preferred pulse width for the majority of panelists (67%). The preferred settings for 595-nm PDL ranged between 7 and 10 mm, 3–10 milliseconds, 6.5–10 J/cm^2, with the minority of responders choosing settings for shorter pulse durations of 5–10 mm, 0.45–1.5 milliseconds, 5–9 J/cm^2.
  - Fifty percent of panelists use the 1064-nm Nd:YAG. This wavelength may be preferable for patients with darker skin types due to decreased melanin absorption, or for hypertrophic scars due to greater depth of penetration.
  - Other devices used by panel members for inflammatory acne management were AFL and NAFL (25% of panelists) and FRF (20%).
  - Most panel experts (82%) indicated that parallel treatment with vascular, AFL, or NAFL and oral antibiotics can have a positive synergistic effect on inflammatory acne.
  - The majority of panelists (82%) indicate that EBDs may be safely used concurrently with isotretinoin in the appropriate setting.

- Thirty-three percent of panelists indicated there may be a synergistic anti-inflammatory and anti-scarring effect with combined treatment.
- Most panelists (80%) selected vascular lasers as their preferred EBD for patients who were being treated with isotretinoin. Approximately three-fourths reported the need for adjusting vascular laser settings including decreasing the pulse energy and number of passes in the setting of isotretinoin use.
- Sixty percent and forty five percent of the panelists supported the use of NAFL and AFL, respectively, during isotretinoin treatment. For those who would not use AFL while on isotretinoin, there was an even split between those advocating waiting 1–5 months and 6 months or more after cessation.

Conclusions and areas of future study

- It is clear that EBDs are regularly utilized by experts for treating active inflammatory acne, with vascular lasers the clear choice among panel members. Additional studies are required to confirm individual platforms and comparative efficacy with potential mechanisms of action and safety issues, including the potential of acne flares in active acne patients treated with AFL and NAFL. Combining EBD and medical therapy (topical and systemic) for active acne is fertile ground for new research.
- There is consensus among the panel members that selected EBDs, particularly vascular lasers, may be used safely in combination with isotretinoin treatment. It is important to consider that there is a continuum in cumulative thermal injury, and likely relative associated risks, among devices progressing from vascular lasers, to NAFL, AFL, and finally fully ablative "full-field" lasers. Given the impact of acne scarring on the overall psychosocial as well as quality of life, a new more inclusive treatment paradigm is required. Indeed, early intervention with EBDs should be adopted and informed consent should include a discussion of these options. To this end, additional research confirming safety and efficacy for each platform in the setting of isotretinoin is required, in addition to determining the presence or absence of a synergistic response.

The use of various EBDs for the treatment of different acne scar types

EBDs, primarily lasers and FRF, have emerged as a noninvasive option for the treatment of acne scars in the last decade.[45] Controlled thermal and non-thermal (e.g., Picosecond lasers) injury to the epidermis/dermis stimulates extracellular matrix remodeling, production of collagen and elastin, and, depending upon the selected laser wavelength, reduction of dyspigmentation and erythema.[46–48]

Panel members are unanimous in their view that EBDs have a role in the management of acne scars, with AFLs, NAFLs, vascular lasers, and RF devices preferentially selected by 70%–90% of the panel experts due to their perceived efficacy, familiarity, and footprint in the literature. Selection of the most appropriate device and setting are highly nuanced decisions influenced by a variety of factors including the clinical presentation (e.g., skin type, scar location, and morphology, etc.), characteristics of the device (e.g., wavelength and targeted chromophore, depth of penetration, etc.), and patient factors such as goals, tolerance for discomfort and downtime, and financial considerations. Previous comparative studies have shown that severe atrophic scars respond better to ablative lasers, such as CO_2 and Er:YAG, whereas mild-to-moderate atrophic scars can be treated with less invasive modalities, such as NAFL and RF devices.[49] The variability in response to treatment between different scar types derives from the pathological structure of each scar, including collagen loss and the degree of fibrosis and anchoring fibrous bands.

Panel recommendations: Device and settings selection

- The most important factors that influenced EBD selection were the type (e.g., boxcar, ice pick, rolling) and site (i.e., face, off-face) of acne scarring (77% of panelists). Interestingly Fitzpatrick skin type and severity of scarring were less influential among panelists (56% and 43%, respectively). One factor may be the relative tolerability of fractional devices for the entire range of skin types given the water chromophore (AFL, NAFL) and degree of epidermal sparing (FRF).
- EBDs were considered a first-line treatment of acne scars for the following scar types: macular dyscoloration (95%); mild atrophic scarring (i.e., rolling scars, 73%); and moderate atrophic scarring (i.e., superficial boxcar scars, 78%).
- For atrophic acne scars, panelists selected superficial boxcar scars (91%) as the most likely to respond to EBD treatment. AFL was the most common EBD of choice for boxcar scars (62%). Table 1 highlights the selected platforms for each acne scar subtype.
- In consideration of the anticipated degree of maximal improvement after the completion of a typical treatment course with EBD devices:
  - AFL 51%–70% improvement.
  - NAFL and RF devices 31%–70% improvement.
  - Vascular devices 31%–>70% improvement (in erythema).
- Six months after the final treatment was selected by most panelists as the appropriate interval for evaluating the efficacy of a course of EBD therapy for acne

TABLE 1 Platforms used according to scar type and color

To note: Each panelist could choose multiple devices for each scar type

1. Deep atrophic scars: AFL (85%), FRF (25%), subcision (25%), and NAFL (18%).
2. Shallow atrophic scars: AFL (72%), NAFL (68%), and RF (12%).
3. Hypertrophic scars: AFL (56%), pulsed dye laser (PDL, 47%), laser-assisted delivery (LAD, 31%), and intralesional injection of TAC/5-FU (22%).
4. Flat erythematous scars: PDL (85%), 532 nm laser (25%), NAFL (18%), and ms-pulsed 1064 nm laser (12%).
5. Patients with dark skin: NAFL (66%), PDL (18%), FRF devices (18%), Nd:YAG (12%).
6. Hyperpigmented scars or post-inflammatory hyperpigmentation: picosecond Nd:YAG lasers (57%) Q-switched laser mostly Nd:YAG (33%) and NAFL (20%) and AFL (13%)

scars. Almost all (95%) would continue laser therapy according to patient preference if there were no contraindications and if the condition continued to improve, rather than adhere to a predetermined number of treatments.

- The most common selected setting combinations for a typical atrophic acne scars were high energy and low-moderate density for AFL (Table 2), NAFL, and FRF. For deeper scars, the vast majority (87%) of panelists would increase the energy setting of their devices.
- The most common method for evaluating efficacy after a treatment course with EBD was photographic evaluation (48%). Only 21% routinely employed scales (e.g., Vancouver Scar Scale [VSS], Patient and Observer Scar Assessment Scale [POSAS], Manchester Scar Scale [MSS], Global Aesthetic Improvement Scale [GAIS], Goodman Baron qualitative).

AFL in the treatment of acne scars

Ablative fractional lasers take advantage of high absorption of associated wavelengths (i.e., 2940 nm Er:YAG and 10,600 nm CO_2) by ubiquitous tissue water to generate an array of narrow columns of vaporization and varying degrees of surrounding coagulation. This controlled thermal injury induces a vigorous wound healing and remodeling response in the area of treatment. By targeting tissue water rather than melanin, AFL may be employed in a wide range of skin types. Since absorption by water at the 2940 nm wavelength is approximately 10 times the absorption at 10,600 nm, there is less heat diffusion and consequently a narrower rim of surrounding coagulation. This characteristic can be associated with more treatment-related bleeding and possibly more moderate remodeling results compared to CO_2.[47,50–52]

TABLE 2 Relative density and pulse energy settings for a common ablative fractional laser platform in treating acne scars (Lumenis UltraPulse™, Deep FX™, Yokneam, Israel)

(1) Pulse energy
- **I.** High: >30 mJ (>0.9 mm ablation depth, use only with low density).
- **II.** Moderate: 15–30 mJ (0.45–0.9 mm ablation depth, use only with low or moderate density).
- **III.** Low: <15 mJ (<0.45 mm ablation depth, software only supports use with moderate density).

(2) Density
- **I.** High: ≥15% (use with caution, and only with low pulse energy).
- **II.** Moderate: 10%.
- **III.** Low: ≤5%.

Panel recommendations: Ablative fractional laser in the treatment of acne scars

- Forty-seven percent of panelists indicated that the fractionated CO_2 laser is more effective than the fractionated Er:YAG for acne scarring, while 8% thought the opposite. The remainder indicated that additional research is required.
- A majority of panelists (65%) indicated that AFL is a more effective platform for treating rolling and superficial boxcar acne scars than NAFL, while 8% had the opposite view.
- Most panelists (73%) agreed that a series of AFL treatments are more effective in treating rolling and superficial boxcar acne scars than a single phenol peel or fully ablative CO_2 laser treatment.
- A large majority of panelists (95%) expected to perform a series of 2–4 AFL treatments to achieve a satisfactory clinical response.
  - The preferred interval between AFL treatments for 43% of the respondents was 2–3 months, 26% and 21% preferred 1 month and 4–6 months, respectively.
  - A variety of commercially available fractional ablative CO_2 lasers are available, but panelists agreed that in order contextualize settings it was important to establish a known platform as a reference. The parameters offered in Table 2 pertain to the Lumenis UltraPulse™ (Yokneam, Israel) Deep FX/SCAAR FX™. Settings for other devices can be extrapolated based on individual characteristics and manufacturer recommendations. Of course, individual patient considerations (e.g., skin type, pain tolerance, etc.) will dictate setting selections in any given treatment session.
- The majority of panelists favored moderate-to-high pulse energy and low-to-moderate density in the acne-scared area with some feathering for the remainder of the cosmetic unit.
- Some panelists endorsed judicious application of a second superficial pass of macro-fractional treatment (Active Fx™) at a pulse energy of 90–125 mJ and density 3–4, 1.3 mm spot size over the entire cosmetic unit.

NAFL for the treatment of acne scars

Non-ablative fractional skin remodeling systems, such as the 1550-nm Er:glass and 1565-nm fiber lasers, have become increasingly popular for the treatment of atrophic acne scars due to a perception of increased tolerability (i.e., darker skin types) and decreased associated downtime of 1–2 days compared to 1–2 weeks for ablative systems.[53] Since water is the target chromophore without absorption by epidermal melanin, NAFLs may be considered in the full range of skin types. NAFLs were the first variety of fractional lasers and were designed to create narrow (submillimeter) and widely spaced columnar thermal wounds at a depth and density selected by the operator. This pattern allows treatment at sufficient depths for robust remodeling while minimizing damage to the epidermis and diffuse dermal injury.[50,54] This combination theoretically offers a decreased risk of side effects such as erythema, edema, crusting, infection, and worsening scarring compared to AFL.[55,56] However, this greater margin of safety for NAFL is also likely associated with a need for more treatments and a lower ceiling for overall efficacy compared to AFL.[57]

Panel recommendations: NAFL in the treatment of acne scars

- The preferred interval between NAFL treatments was 1 month by 60% of the respondents.
- Most panelists (90%) expect to perform 4–8 NAFL treatments to achieve a satisfactory clinical response.
- The preferred standard settings for NAFL in the treatment of atrophic acne scars were moderate to high pulse energy and low to moderate density.
- NAFL may be the preferred choice for patients with more moderate acne scarring, a lower tolerance for downtime, darker skin types, and mature non-erythematous scars since efficacy is not dependent on hemoglobin.

Vascular lasers for the treatment of erythematous acne scars

Vascular devices emit wavelengths that are absorbed by hemoglobin which demonstrates peaks at 542 and 577 nm for oxyhemoglobin. These devices, such as the 595 nm PDL, selectively heat vascular components of the dermis. In addition to treating scar-associated erythema, vascular lasers also induce a wound-healing and collagen remodeling response via key mediators involved in scar formation such as the transforming growth factor-β isoforms.[57,58] Successful treatment usually requires 3 or more treatments given at approximately 1-month intervals. Since shorter vascular wavelengths are also absorbed to a significant extent by epidermal melanin, patients with darker skin types may not be suitable candidates for these devices.

Panel recommendations: Vascular lasers in the treatment of acne scars

- Erythema is often the most pronounced finding in patients with acne scarring so vascular lasers can play an important role in their overall management.
- Importantly, erythema is a characteristic of early acne scars including future atrophic and hypertrophic acne scars. As such, early intervention with vascular devices may help to minimize incipient pathological scars.
- Sixty-five percent of panelists selected erythematous flat acne scars as the scars most likely to respond to EBD treatment alone, and 95% indicated that EBDs are a first-line treatment for these scars.
- The 595 nm PDL was the most frequently selected vascular device among panelists due to its familiarity and footprint in the literature. However, other vascular devices such as the 532 nm KTP and intense pulsed light may also be employed.
- Panelists were divided into two major groups with regard to PDL settings. One group advocated medium-length pulse durations and somewhat higher fluences (7–10 mm; 6–10 J/cm^2; 6–10 milliseconds) and the other shorter pulse durations and somewhat lower fluences (5–12 mm; 4.5–6 J/cm^2; 0.45– 1.5 milliseconds).
- Vascular lasers were the EBD of choice among panelists for hypertrophic acne scars. PDL was the preferred vascular-specific laser for 77% of panelists, who also tended to use shorter pulse durations in this setting.
- More than 95% of the respondents indicated the need for at least 3–6 vascular laser sessions for typical erythematous hypertrophic acne scars.

Short-pulsed (nanosecond and picosecond) lasers for the treatment of acne scars

The Q-switched (nanosecond) Nd:YAG 1064 nm laser is a mature technology that is associated with relatively deeper dermal penetration than other platforms and photomechanical as well as photothermal effects.[59] Published reports indicate that the Nd:YAG provides a safe and effective noninvasive treatment for mild-to-moderate facial acne scarring,[60,61] though less effective than the fractional CO_2 for atrophic acne scarring.[62] These devices may also have a role for post-inflammatory hyperpigmentation.

Introduced in 2012, picosecond lasers were originally designed to remove tattoos and other pigments with small particle sizes. The ultra-short pulse durations create significant photoacoustic as well as photothermal effects. Later iterations incorporated a diffractive lens array which redistributes the laser beam into peaks of high fluence surrounded by a low fluence background, thus creating optical breakdown of dermal tissue and the induction of a wound healing and remodeling response with neocollagen formation. Several published reports have demonstrated mild to moderate clinical effectiveness for atrophic acne

scarring with a very low side effect profile and corresponding histologic changes.[63–70] Two prospective, split-face, randomized controlled trials compared the 1064 nm Nd:YAG picosecond laser to the non-ablative 1550 nm erbium-glass laser. One found the picosecond laser to be superior in terms of both efficacy and safety,[69] while the other was inconclusive.[70] Of note differences in the reported outcomes might be partly explained by the different laser settings used in the two studies. Picosecond lasers may also have a prominent role in the treatment of post-inflammatory hyperpigmentation.

Panel recommendations: Short-pulsed lasers for the treatment of acne scars

- As may be expected, short-pulsed lasers were the EBD of choice among panelists for macular hyperpigmentation associated with acne, both in fractional and non-fractional modes.
- The novel effects produced by picosecond lasers are promising for improvement in both the atrophy and hyperpigmentation that follow acne, but additional research is required to elucidate any additional benefits over nanosecond devices as well as the impact of fractionation.
- Eighty-six percent of respondents indicated the need for 3–6 laser treatments with short-pulsed devices to achieve a satisfactory result.

FRF

RF is an electromagnetic radiation with a frequency range between 3 Hz and 300 GHz. In fractional bipolar RF device, the RF current flows through the skin between the electrode-pins or microneedles. It generates fractional deep dermal heating in the region of the electrode matrix to induce skin injury and then elicits a wound healing response, stimulating the remodeling of dermal collagen. New developments have allowed for more precision in the delivery of RF energy to different desired depths within the dermis.[71,72]

Panel recommendations: FRF devices for the treatment of acne scars

- Though there was generally less experience among panelists with FRF than other laser devices, most respondents (69%) indicated that FRF has a promising role in the management of atrophic acne scars.
- Most panelists (60%) indicated that microneedling alone (with no RF) yields inferior results compared to FRF in the management of atrophic acne scars.
- A small majority of panelists (52%) indicated that the insulated FRF devices are associated with better results compared to non-insulated FRF devices, probably due to higher thermal effect along the different dermal layers. Several treatment passes were considered to have better results than a single pass.
- Additional research is required to show the effects of multiple-depth passes and high-energy FRF for treating acne scars.
- Further clinical research is required to establish the comparative effectiveness between FRF, NAFL, and AFL.
- The preferred interval between FRF treatments was 1 month for 60% of respondents, and the average number of FRF treatments to achieve satisfactory results for atrophic acne scars was 4–8.

Selected non-laser, non-RF EBDs in the treatment of acne scars

A range of other energy-based devices demonstrate potential utility for the treatment of acne scars. Since there is a relative paucity of experience with non-laser, non-RF devices, only two of the most commonly mentioned devices will be discussed here. Moreover, additional research will be required to elaborate their potential respective roles in the management of acne scarring. The Tixel™ (Novoxel LTD.) is a non-laser, fractional, non-ablative, thermo-mechanical system based on thermal conduction which combines thermal energy with motion. The thermal energy is delivered to the tissue via a tip with tiny titanium pyramids heated to 400°C. The amount of thermal energy delivered to the skin is determined by the pulse duration and the protrusion. The pulse duration is the period of time that the tip is in contact with the skin, varying between 5 and 18 milliseconds. The protrusion is defined as the distance over which the heated tip moves as measured from the edge of the handpiece distance gauge. The device was found to be effective in skin rejuvenation,[73] hypertrophic scars,[74] and drug delivery.[75] Only a minority of panelists (34%) indicated having experience with this device in the treatment of acne scars. Among those, most estimated the expected maximal improvement after a standard course of treatment to be mild (<20%).

The Enerjet™ (PerfAction Technologies UK Ltd.) employs pneumatic acceleration of drugs or fillers. It is a needle-free jet injector implementing the kinetic energy of a liquid jet for transcutaneous delivery of drugs or fillers into soft tissues. It was shown to be effective in treating keloids and hypertrophic scars via intralesional jet injection of bleomycin, 5-fluorouracil (5-FU), and triamcinolone.[76,77] Several case reports of this device or similar technologies also demonstrated efficacy in the treatment of acne scars.[78,79] Among panelists, 39% indicated having experience with this device in the treatment of acne scars. The estimated expected maximal improvement after a standard course of treatment was also expected to be mild (<20%).

Combination modalities in the management of acne scars

Since there are such a wide variety of patients presenting with acne scarring of mixed types, a combined approach to EBD treatment is often considered. This may include combinations of different EBD platforms, as well as EBDs combined with other treatment approaches such as subcision, excision, and fillers that may achieve better outcomes than any single modality alone.[45,80] Injectable fillers can be used to mitigate atrophic acne scars in two ways: direct filling under individual scars with products such as hyaluronic acid (HA), and biostimulatory fillers such as poly-L-lactic acid (PLLA) or calcium hydroxylapatite (CaHA) in an area where volume loss and tissue redistribution has accentuated existing scars.[80,81] Laser-assisted PLLA delivery[82] and FRF-assisted PLLA delivery[52] have also been described in the treatment of atrophic acne scars.

Panel recommendations: Combination of modalities in the treatment of acne scars

- The vast majority of panelists (95%) combine multiple EBD platforms, and other treatment modalities, in the same treatment session. There is no "cookbook" or "gold standard" approach here as a treatment plan is based on multiple factors unique to an individual patient on a particular day which includes scar types, co-existing conditions, prior treatments and response, skin type, degree of melanization, tolerance for pain, patient compliance and downtime.
- When EBDs and other modalities are performed in the same session, frequently the other modalities are employed first due to associated skin changes that may affect landmarks such as post-EBD erythema and edema.
- The EBD-second approach may be particularly beneficial when surgical approaches (e.g., excision) are considered as EBDs may mitigate the surgical scars as well as the surrounding acne scars. There was not significant agreement on the timing of surgical approaches and subsequent EBD treatment, ranging from same session (39%) to 4–6 weeks after the surgical procedure.
- A caveat to the EBD-second approach may apply to fillers. A course of EBD (perhaps including subcision) before filler placement may better prepare the skin to accept the filler and help mitigate the tendency for filler to "donut" around a tethered scar. In terms of cost-effectiveness for the patient, less filler may ultimately be required. If one is considering EBD-assisted delivery of a filler such as PLLA, the fractional device will naturally be applied first to access the dermis.
- When performing subcision, 65% of panelists will prefer to subscise the tethering fibers before EBD treatment at the same session.
- Ice pick scars were considered the type least likely to respond to EBD. Most experts endorsed surgical approaches (e.g., punch techniques) or chemical reconstruction of skin scars (CROSS) using trichloroacetic acid (TCA) first followed by EBD, often in the same session.
- When combining EBDs, most panelists recommended the combination of PDL and fractional lasers. When this combination is used, the vascular laser should generally be applied first since fractional lasers are associated with immediate tissue reactions that could impact vascular laser treatment. Three-quarters of panelists do not adjust EBD settings when using multiple platforms in the same session, though it is important to consider tissue response and visual endpoints when choosing EBD settings to minimize the risk of excessive thermal injury.
- More than 69% of panelists reported using tissue fillers or biostimulators with EBDs as part of acne scar treatment. Of these approximately 70% reported a preference for using HA-based fillers.
- There was nearly complete consensus (95%) for combining EBD (mainly PDL) with intralesional and/or LAD of 5-FU and/or triamcinolone acetonide suspension (TAC) for treating hypertrophic acne scars.
- For the treatment of patients with dark skin and/or hyperpigmented flat macules post-acne, most of respondents (56%) combine EBD treatment and topical formulations or peels. The three most selected formulations were hydroquinone 2%–5% (47%), retinoic acid (35%), and glycolic or salicylic acid (17%). The in-office formulations are used immediately post-EBD treatment.
- Seventy-three percent of panelists indicated that LAD has a significant potential role in acne scar treatment. The medications that are most commonly used by the panelists in combination with ablative fractional lasers for LAD were corticosteroids (82%) and 5-FU (56%) for hypertrophic acne scars and PLLA (43%) for atrophic acne scars.
- Almost 94% of respondents prescribe different formulations between or before EBD treatments for all acne scar patients, with 0.01%–0.05% retinoic acid being the most common formulation (56%).
- Future comparative studies are required to guide the optimal combinations of EBD and other modalities as well as timing and settings.

Considerations in skin of color

Hyperpigmentation is a potential complication of any EBD intervention, especially for patients with darker

skin phototypes (i.e., IV–VI). The concept of fractional lasers was introduced by Manstein et al.[83] Fractionation has revolutionized the field of dermatologic surgery, allowing operators for the first time to choose the depth and density of treatment. By sparing large areas of adjacent dermis and epidermis, fractional lasers allow access to deeper dermal levels with a high degree of safety and efficacy. With water as the target chromophore, fractional lasers can also be applied in the full range of skin types.

While these lasers offer a greater theoretical margin of safety compared to prior platforms, they are not without side effects. Transient erythema, edema, dermatitis, acneiform eruptions, outbreaks of herpes simplex virus and varicella reactivation, and dyspigmentation have all been documented in existing studies. Post-inflammatory hyperpigmentation (PIH) is more commonly observed in patients with darker skin types.[84] Similarly, FRF offers the benefits of fractionation, but may also have an additional theoretical margin of safety due to greater sparing of the epidermis with insulated needles. As noted vascular devices may not be appropriate in all skin types due to significant melanin absorption at associated wavelengths.

Both pulse energy and density are key parameters that determine the safety and efficacy of fractional resurfacing in patients with darker skin types, but it appears that density may play a more important role in determining the risk of PIH. Regardless of the platform, patients with darker skin types may require treatment modifications including: a reduction in fluence/pulse energy; decreased microcolumn density; greater intervals between treatments; longer pulse durations; epidermal cooling with fastidious technique to ensure appropriate cooling, additional cooling in between passes to decrease bulk heating; and pretreatment and posttreatment topical regimens (e.g., retinoids, bleaching creams, etc.) and strict sun precautions.[54] Furthermore, the application of a short course of topical corticosteroid was found effective in reducing the risk PIH.[85]

Panel recommendations: Consideration in skin of color

- In patients with darker skin types (Fitzpatrick phototype III–VI) presenting with atrophic boxcar acne scars, the majority of panel members (77%) selected NAFL as their preferred EBD. FRF devices were the next highest choice (39%– some panelists selected both).
- Regarding NAFL parameter modifications in patients with darker skin types, almost 70% of panelists reported decreasing density; 47% reported increasing the interval between treatments; 40% reported decreasing the pulse energy.
- Almost 60% of panelists reported using adjunctive medical therapy for patients with darker skin types to help prevent PIH (e.g., bleaching creams, steroids, etc.) when treating with NAFLs for patients with darker skin types.
- Regarding AFL parameter modifications in patients with darker skin types (IV–VI), most panelists (56%) reported that they will increase the interval between treatments; almost 50% indicated that they will decrease density; a majority (65%) favored using adjunctive medical therapy in addition to laser treatment.
- NAFL, AFL, and FRF devices are regularly employed by experts for the treatment of acne scars in patients with darker skin types. Comparative studies are lacking, and future research should help match an optimal platform with the clinical presentation.
- For hyperpigmented macules, a large portion of experts favor picosecond lasers. They are a promising but relatively new technology and future prospective comparative studies are required to evaluate their efficacy and safety.
- The combination of laser and medical therapy (e.g., topical agents, chemical peels, etc.) is fertile ground for new research.

Clinical case examples

The literature is replete with studies evaluating EBD for acne scarring. However, given the numerous unexplored treatment options including device and procedure combinations, timing, parameters, and adjunctive therapies, comprehensive guidelines are currently lacking. To begin to offer some guidance, panelists were presented a series of photos representing varying clinical scenarios and asked to offer their proposed treatment plans incorporating EBD.

Patient 1: Female, Fitzpatrick skin type 2, erythematous and mildly atrophic dish-like scars.

Agreed upon intervention

Almost 94% of panelists favored a vascular laser, largely PDL, as the initial treatment (Settings mentioned were 7 mm, 1.5–3 milliseconds or 7–10 mm, 6–10 milliseconds 7–10 J/cm^2).

Additional possible measures suggested by some panelists:

- Combination of PDL with NAFL in the same or alternating treatment sessions.
- FRF
- IPL
- PDL with topical salicylic acid 30%, oral antibiotics, or low (i.e., 20 mg per week) or high (i.e., 40 mg per day) dose isotretinoin. Of note rules regulating the use of isotretinoin vary from country to country.
- NAFL and HA filler once erythema is improved.

Patient 2: Female, Fitzpatrick skin type 3, deep and broad atrophic areas.

Agreed upon intervention:

Seventy-eight percent of panelists preferred using AFL, Suggested CO_2 laser settings (Lumenis UltraPulse Deep FX™, Yokneam, Israel) included 40–50 mJ, 5% density, 0.12 mm spot size, focal scar treatment, 15–17.5 mJ, 10%–15% density single pass over the scarred cosmetic area; followed by Active FX 80–125 mJ, density 3–4.

Most panelists favored combining AFL with other interventions including:

- Subscision (43%).
- Filler with HA, CaHA, or PLLA (43%).
- Excisions (17%).

Most experts recommended that subscision should precede AFL treatment, and that filler treatments be administered 2–4 weeks after AFL treatment.

Patient 3: Male, Fitzpatrick skin type 3, punched out deep atrophic scars.

Agreed upon intervention:

Most panelists (77%) selected AFL as the appropriate EBD.

Additional possible measures suggested by some panelists:

- Combining AFL with a surgical technique (punch techniques/subcision/excision).
- CROSS TCA combined with AFL.
- NAFL combined with surgical technique.
- FRF devices combined with surgical technique.
- Fillers (including PLLA).
- Enerjet.

Patient 4: Male, Fitzpatrick skin type IV, hyperpigmented and mildly atrophic scars.

Agreed upon intervention:

Due to PIH tendency, most panelists (74%) agreed on using a non-AFL devises, there choices were divided evenly between NAFL (35%) and AFL (35%).

Additional possible measures suggested by some panelists:

- Several panelists suggested using a test area before using AFL.
- Thirty percent favored the combination of a surgical technique (punch biopsy/subcision/excision) with EBDs.
- Twenty-one percent panelists favored using topical bleaching medications, including tretinoin, azelaic acid, hydroquinone, and Tri-luma (brand info) cream.

Patient 5: Female, Fitzpatrick skin type II, hypopigmented and mildly erythematous scars.

Agreed upon intervention:

Most panelists (55%) selected hyperpigmentation targeted lasers for treating this patient: NAFL being the most frequently selected device (30%) and fractional picosecond laser came in second place (21%).

Additional possible measures suggested by some panelists:

- Thirty percent would combine topical medication for improving color complexity including tretinoin, glycolic acid 30%, hydroquinone, or bimatoprost.
- IPL, AFL, and PDL were selected each by 13% of panelists.

Patient 6: Female, Fitzpatrick skin type 3, moderately atrophic dish-like erythematous scars.

Agreed upon intervention:

Almost 44% of panelists selected AFL as the appropriate EBD for this case.

Additional possible measures suggested by some panelists:

- NAFL and vascular lasers (mainly PDL) were each selected by 26% of the panelists.
- EBD combinations (usually vascular laser and AFL) were also suggested.
- A surgical technique (punch biopsy/subcision/excision) and fillers (including PLLA) were advised by 17% and 21% of the panelists, respectively.

Patient 7: Female, Fitzpatrick skin type 2, erythematous and mildly atrophic linear and dish-like scars.

Agreed upon intervention:

Almost 60% of panelists favored using a vascular laser (mostly PDL).

Additional possible measures suggested by some panelists:

- Most of the panelists will combine the vascular laser with other EBD to address atrophic scars: 39% selected NAFL and 34% selected AFL.
- A surgical technique (punch biopsy/subcision/excision) and fillers (including PLLA) were also suggested in combination with EBD (each by 13% of panelists).

Patient 8: Male, Fitzpatrick skin type 3, extra-facial broad atrophic scars on the upper back.

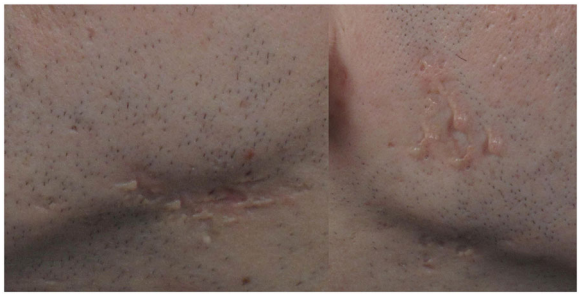
Agreed upon intervention:

Suggestions for treating this extra-facial area were divided almost equally between AFL (47%) and NAFL (39%) by panelists.

Additional possible measures suggested by some panelists:

- Twenty-six percent suggested combining a filler (mostly PLLA or Profillo) as LAD or using Enerjet.
- Glycolic acid peel 30% or 70% was suggested by two experts.

Patient 9: Male, Fitzpatrick skin type 2, hyperplastic papular scars.



Agreed upon intervention:

Most responders (69%) selected AFL as their EBD of choice for this scar type, usually combined with LAD of corticosteroids or 5-FU in 60% of those choosing AFL. Seventy-three percent of the panelists favored using intralesional/LAD corticosteroids or 5-FU as part of the treatment plan for this patient.

Additional possible measures suggested by some panelists:

- Three suggested using the non-fractional fully ablative mode of CO_2 laser to address the persistent elevated parts.
- PDL combined with AFL or IL corticosteroids/5-FU injections was selected by 17% of the panelists.

Patient 10: Male, Fitzpatrick skin type 2, punched-out deep atrophic scars.

Agreed upon intervention:

- The large majority of the panelists (77%) selected AFL.
- Surgical procedures were suggested to performed immediately before AFL at the same session or before AFL session.
- Fifty-two percent and 43% of experts favored using a surgical technique (punch biopsy/subcision/excision) or a filler injection (including PLLA), respectively, for mitigating these scars as sole procedure or in combination with AFL.

Additional possible measures suggested by some panelists:

- Some (17%) favored using NAFL with the above combination.
- Cross TCA.
- RF devices.

Patient 11: Male, Fitzpatrick skin type 3, extra-facial broad keloidal scars on the upper chest.

Agreed upon intervention:

- Most responders (69%) favored using intralesional corticosteroids alone or in combination with 5-FU for treating these acne keloid scars.

Additional possible measures suggested by some panelists:

- AFL was the most selected device for this patient (43%) mostly used as for LAD of TAC/5-FU.
- PDL was the next most suggested device in combination of AFL, intralesional TAC/5-FU, or both.
- Some experts (13%) suggested using surgical techniques (specifically Z-plasty).
- Fifty-two percent and 43% of experts favored using a surgical technique (punch biopsy/subcision/excision) or filler injection (including PLLA), respectively, for mitigating these scars as sole procedure or in combination with AFL.
- Some experts (17%) favored using NAFL with the above combination.

CONSENSUS RECOMMENDATIONS SUMMARY

The current published data in the field of acne scar treatment is vastly limited, including the lack of large, well-controlled multicenter comparative trials of various laser and energy treatments for acne scars. Such trials would be helpful in establishing the relative utility and persistence of benefit of various laser treatments and also in comparing their effectiveness versus that of nonenergy treatments. Randomized studies comparing bundles of modalities, sets of so-called combination treatments, would also be helpful, as these are most common in actual clinical practice. These limitations, notwithstanding, the current recommendations are based on a large volume of observational data and high level of expert consensus. The following consensus statements are most useful in guiding clinical care when the high-level evidence is lacking, as in this current case.

1. Seventy percent of panel members indicated that patients with active acne and acne scars should be treated with EBD and topical or systemic medications in parallel. The rational is to reduce the severity and/or duration of inflammation and scarring potential and enhance the effectiveness of topical or oral medication.
2. Vascular lasers were the preferred EBD in the management of inflammatory acne (84% of panelists) with 595-nm PDL being the most selected platform (79% of panelists).
3. Panel members are unanimous in their view that EBDs have a role in the management of acne scars, with AFLs, NAFLs, vascular lasers, and RF devices preferentially selected by 70%–90% of the panel experts.
4. Most panel experts (86%) indicated that parallel treatment with vascular, AFL, or NAFL and oral antibiotics can have a positive synergistic effect on inflammatory acne.
5. The majority of panelists (86%) indicate that EBDs may be safely used concurrently with isotretinoin in the appropriate setting. Most panelists (84%) selected vascular lasers as their preferred EBD for patients who were being treated with isotretinoin. Approximately three-fourths of these reported adjusting vascular laser settings including decreasing the pulse energy and number of passes in the setting of isotretinoin use. Sixty percent and 45% of the panelists supported the use of NAFL and AFL, respectively, during isotretinoin treatment.
6. EBDs were considered a first-line treatment of acne scars for the following scar types: macular discoloration (95%); mild atrophic scarring (i.e., rolling scarring, 73%); and moderate atrophic scarring (i.e., superficial box car scarring, 78%).
7. For atrophic acne scars, panelists selected superficial boxcar scars (91%) as the most likely to respond to EBD treatment.
8. The platforms used for each acne scar subtype are highlighted in Table 1.
9. In the absence of contraindications, 95% of panelists will continue laser treatment until the desired effect is achieved, or improvement plateaus, rather than adhere to a predetermined number of treatments.
10. Considering AFL, 47% of panelists indicated that the fractionated CO_2 laser is more effective than the fractionated Er:YAG for acne scarring, (91%) expected to perform a series of 2–4 AFL treatments to achieve a satisfactory clinical response and preferred interval between treatment ranged from 2 to 6 months.
11. The majority of panelists favored moderate-to-high pulse energy and low-to-moderate density in treating acne scars with AFL. See Table 2 for relative density and pulse settings for a common AFL.
12. Most panelists (90%) expect to perform 4–8 NAFL treatments to achieve a satisfactory clinical response.
13. The preferred standard settings for NAFL in the treatment of atrophic acne scars were moderate to high pulse energy and low to moderate density.

14. Considering vascular lasers, 95% indicated that EBDs are a first-line treatment for erythematous flat acne scars.
15. Vascular lasers were the EBD of choice among most panelists (52%) for hypertrophic acne scars. PDL was the preferred vascular-specific laser for 73% of panelists, who also tended to use shorter pulse durations in this setting.
16. More than 91% of the respondents indicated the need for at least 3–6 vascular laser sessions for typical erythematous hypertrophic acne scars.
17. The vast majority of panelists (91%) combine multiple EBD platforms, and other treatment modalities, in the same treatment session. There is no "cookbook" approach as a treatment plan is based on multiple factors unique to a particular patient on a particular day such as scar types, co-existing conditions, prior treatments and response, skin type and degree of melanization, and tolerance for pain and downtime.
18. When combining EBDs, most panelists (84%) recommended the combination of PDL and fractional lasers. When this combination is used the vascular laser should generally be applied first since fractional lasers are associated with immediate tissue reactions that could impact vascular laser treatment. Three-quarters of panelists do not adjust EBD settings when using multiple platforms in the same session.
19. More than 73% of panelists reported using tissue fillers or biostimulators with EBDs as part of acne scar treatment. Of these approximately 70% reported a preference for using HA-based fillers.
20. There was nearly complete consensus (95%) for combining EBD (mainly PDL) with intralesional and/or LAD of 5-FU and/or TAC for treating hypertrophic acne scars.
21. In patients with darker skin types (Fitzpatrick phototype III–VI) presenting with atrophic boxcar acne scars, the majority of panel members (73%) selected NAFL as their preferred EBD. FRF devices were the next highest choice (39%—some panelists selected both).
22. Regarding NAFL parameter modifications in patients with darker skin types, almost 70% of panelists reported decreasing density.

CONFLICT OF INTEREST DISCLOSURES

All authors have completed and submitted the ICMJE Form for Disclosure of Potential Conflicts of Interest and no relevant disclosures 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.

ORCID

Peter R. Shumaker http://orcid.org/0000-0002-8828-2203
Leah K. Spring https://orcid.org/0000-0002-4971-8115
Meghan Seago https://orcid.org/0000-0002-0075-1723
Henry HL Chan http://orcid.org/0000-0002-9657-1435
Woraphong Manuskiatti http://orcid.org/0000-0001-8393-7963
Jill Waibel http://orcid.org/0000-0003-4876-5857

REFERENCES

1. Goodman GJ. Post acne scarring: a review of its pathophysiology and treatment. Dermatol Surg. 2000;26(9):857–71.
2. Fabbrocini G, Annunziata MC, D'arco V, De Vita V, Lodi G, Mauriello MC, et al. Acne scars: pathogenesis, classification and treatment. Dermatol Res Pract. 2010;2010:893080.
3. Layton AM, Henderson CA, Cunliffe WJ. A clinical evaluation of acne scarring and its incidence. Clin Exp Dermatol. 1994;19:303–8.
4. Holland DB, Jeremy AHT, Roberts SG, Seukeran DC, Layton AM, Cunliffe WJ. Inflammation in acne scarring: a comparison of the responses in lesions from patients prone and not prone to scar. Br J Dermatol. 2004;150:72–81.
5. Fife D. Practical evaluation and management of atrophic acne scars: tips for the general dermatologist. J Clin Aesthet Dermatol. 2011;4(8):50–7.
6. Tasoula E. The impact of acne vulgaris on quality of life and psychic health in young adolescents in Greece. Results of a population survey. An Bras Dermatol. 2012;87(6):862–9.
7. Lee WJ, Jung HJ, Lim HJ, Jang YH, Lee SJ, Kim DW. Serial sections of atrophic acne scars help in the interpretation of microscopic findings and the selection of good therapeutic modalities. J Eur Acad Dermatol Venereol. 2013;27:643–6.
8. Layton AM, Henderson CA, Cunliffe WJ. A clinical evaluation of acne scarring and its incidence. Clin Exp Dermatol. 1994;19:303–8.
9. Jacob CI, Dover JS, Kaminer MS. Acne scarring: a classification system and review of treatment options. J Am Acad Dermatol. 2001;45:109–17.
10. Goodman GJ, Baron JA. Postacne scarring: a qualitative global scarring grading system. Dermatol Surg. 2006;32(no. 12):1458–66.
11. Levy LL, Zeichner JA. Management of acne scarring, part II: a comparative review of non-laser-based, minimally invasive approaches. Am J Clin Dermatol. 2012;13(5):331–40.
12. Monica B, Carolyn J. A review and update of treatment options using the acne scar classification system. Dermatol Surg. 2019;45(3):411–22.
13. Finlay AY, Torres V, Kang S, Bettoli V, Dreno B, Goh CL, et al. Classification of acne scars is difficult even for acne experts. J Eur Acad Dermatol Venereol. 2013;27(3):391–3.
14. Shashank Bhargava PR, Cunha J, Lee GK. Acne scarring management: systematic review and evaluation of the evidence. Am J Clin Dermatol. 2018;19(4):459–47.
15. Basta-Juzbasic A. Current therapeutic approach to acne scars. Acta Dermatovenerol Croat. 2010;18(3):171–5.
16. Abdel Hay R, Shalaby K, Zaher H, Hafez V, Chi CC, Dimitri S, et al. Interventions for acne scars. Cochrane Database Syst Rev. 2016;4:CD011946.
17. Seago M, Shumaker PR, Spring LK, Alam M, Al-Niaimi F, Rox Anderson R, et al. Laser treatment of traumatic scars and contractures: 2020 international consensus recommendations. Lasers Surg Med. 2020;52:96–116.
18. Dalkey N. The Delphi method: an experimental study of group opinion. Futures. 1969;1:408–26.
19. Tan J, Kang S, James L. Prevalence and risk factors of acne scarring among patients consulting dermatologists in the USA. J Drugs Dermatol. 2017;16(2):97–102.

20. Mohamed EE, Tawfik K, Mohamed E. Intense pulsed light versus 1,064 long-pulsed neodymium: yttrium–aluminum–garnet laser in the treatment of facial acne vulgaris. J Clin Diagn Res. 2016;10(7): WC01–03.
21. Wat H, Wu DC, Rao J, Goldman MP. Application of intense pulsed light in the treatment of dermatologic disease: a systematic review. Dermatol Surg. 2014;40(4):359–77.
22. Wiznia LE, Stevenson ML, Nagler AR. Laser treatments of active acne. Lasers Med Sci. 2017;32(7):1647–58.
23. Koceva I, Rümmelein B, Gerber PA, Edge D, Nielsen MCE. Fluorescent light energy: a new therapeutic approach to effectively treating acne conglobata and hidradenitis suppurativa. Clin Case Rep. 2019;7(9):1769–72. doi:10.1002/ccr3.2334
24. Edge D, Mellergaard M, Dam-Hansen C, Corell DD, Jaworska J, Scapagnini G, et al. Fluorescent light energy: the future for treating inflammatory skin conditions? J Clin Aesthet Dermatol. 2019;12(5):E61–8.
25. Moneib H, Tawfik AA, Youssef SS, Fawzy MM. Randomized split-face controlled study to evaluate 1550-nm fractionated erbium glass laser for treatment of acne vulgaris—an image analysis evaluation. Dermatol Surg. 2014;40(11):1191–200.
26. Seaton ED, Mouser PE, Charakida A, Alam S, Seldon PE, Chu AC. Investigation of the mechanism of action of nonablative pulsed-dye laser therapy in photorejuvenation and inflammatory acne vulgaris. Br J Dermatol. 2006;155(4):748–55.
27. Jasim ZF, Al-Qarqaz F, Handley JM. To the editor: effect of single pulsed dye laser treatment on acne vulgaris. Dermatol Surg. 2005;31(11 Pt 1):1483.
28. Thiboutot D, Gollnick H, Bettoli V, Dréno B, Kang S, Leyden JJ, et al. New insights into the management of acne: an update from the global alliance to improve outcomes in acne group. J Am Acad Dermatol. 2009;60(5 suppl):S1–50.
29. Kim ST, Lee KH, Sim HJ, Suh KS, Jang MS. Treatment of acne vulgaris with fractional radiofrequency microneedling. J Dermatol. 2014;41(7):586–91.
30. Zeng R, Liu Y, Zhao W, Yang Y, Wu Q, Li M, et al. A split-face comparison of a fractional microneedle radiofrequency device and fractional radiofrequency therapy for moderate-to-severe acne vulgaris. J Cosmet Dermatol. 2020;19(10):2566–71.
31. Kim J, Lee YI, Kim J, Jung JY, Lee WJ, Lee JH. Safety of combined fractional microneedle radiofrequency and CO2 as an early intervention for inflammatory acne and scarring treated with concomitant isotretinoin. Dermatol Surg. 2020;46(10):e71–7.
32. Strauss JS, Krowchuk DP, Leyden JJ. Guidelines of care for acne vulgaris management. J Am Acad Dermatol. 2007;56:651–63.
33. Amichai B, Shemer A, Grunwald MH. Low-dose isotretinoin in the treatment of acne vulgaris. J Am Acad Dermatol. 2006;54: 644–6.
34. Goldstein JA, Socha-Szott A, Thomsen RJ, Pochi PE, Shalita AR, Strauss JS. Comparative effect of isotretinoin and etretinate on acne and sebaceous gland secretion. J Am Acad Dermatol. 1982;6:760–5.
35. Jones DH, King K, Miller AJ, Cunliffe WJ. A dose-response study of I3-cis-retinoic acid in acne vulgaris. Br J Dermatol. 1983; 108:333–43.
36. Layton AM, Knaggs H, Taylor J, Cunliffe WJ. Isotretinoin for acne vulgarise10 years later: a safe and successful treatment. Br J Dermatol. 1993;129:292–6.
37. Spring LK, Krakowski AC, Alam M, Bhatia A, Brauer J, Cohen J, et al. Isotretinoin and timing of procedural interventions. A systematic review with consensus recommendations. JAMA Dermatol. 2017;153:802–9.
38. Waldman A, Bolotin D, Arndt KA, Dover JS, Geronemus RG, Chapas A, et al. ASDS guidelines task force: Consensus recommendations regarding the safety of lasers, dermabrasion, chemical peels, energy devices, and skin surgery during and after isotretinoin use. Dermatol Surg. 2017;43:1249–62.
39. Spring LK, Krakowski AC, Alam M, Bhatia A, Brauer J, Cohen JL, et al. Isotretinoin and timing of procedural interventions: a systematic review with consensus recommendations. JAMA Dermatol. 2017;153(8):802–9.
40. Prather HB, Alam M, Poon E, Arndt KA, Dover JS. Laser safety in isotretinoin use: a survey of expert opinion and practice. Dermatol Surg. 2017;43:357–63.
41. Gold MH, Manturova NE, Kruglova LS, Ikonnikova EV. Treatment of moderate to severe acne and scars with a 650-microsecond 1064-nm38 laser and isotretinoin. J Drugs Dermatol. 2020;19:646–51.
42. Gao L, Wang L, Li K, Tan Q, Lu M, Li Y, et al. Treatment of acne vulgaris using 1,565 nm non-ablative fractional laser in combination with isotretinoin and pricking blood therapy. J Dermatol Treat. 2020;19:1–7.
43. Xia J, Hu G, Hu D, Geng S, Zeng W. Concomitant use of the 1,550-nm nonablative fractional laser with low-dose isotretinoin for the treatment of acne vulgaris in Asian patients: a randomized split-face controlled study. Dermatol Surg. 2018;44:1201–8.
44. Ibrahim SM, Farang A, Hegazy R, Mongy M, Shalaby S, Kamel MM. Combined low-dose isotretinoin and pulsed dye laser versus standard-dose isotretinoin in the treatment of inflammatory acne. Lasers Surg Med. 2020;53(5):603–9.
45. Kroepfl L, Emer JJ. Combination therapy for acne scarring: personal experience and clinical suggestions. J Drugs Dermatol. 2016;15(11):1413–9.
46. Cohen BE, Brauer JA, Geronemus RG. Acne scarring: a review of available therapeutic lasers. Lasers Surg Med. 2016;48(2):95–115.
47. Rivera AE. Acne scarring: a review and current treatment modalities. J Am Acad Dermatol. 2008;59(4):659–76.
48. Kirsanova L, Araviiskaia E, Rybakova M, Sokolovsky E, Bogantenkov A, Al-Niaimi F. Histological characterization of age-related skin changes following the use of picosecond laser: low vs high energy. Dermatol Ther. 2020;33(4):e13635.
49. Sadick NS, Cardona A. Laser treatment for facial acne scars: a review. J Cosmet Laser Ther. 2018;20(7–8):424–35.
50. Goerge T, Peukert N, Bayer H, Rutter A. Ablative fractional photothermolysis—a novel in skin resurfacing. Med Laser Appl. 2008;23:93–8.
51. Alexiades-Armenakas MR, Dover JS, Arndt KA. The spectrum of laser skin resurfacing: nonablative, fractional, and ablative laser resurfacing. J Am Acad Dermatol. 2008;58:719–37.
52. Juhasz MLW, Cohen JL. Microneedling for the treatment of scars: an update for clinicians. Clin Cosmet Investig Dermatol. 2020;13:997–1003.
53. Kang WH, Kim YJ, Pyo WS, Park SJ, Kim JH. Atrophic acne scar treatment using triple combination therapy: dot peeling, subcision and fractional laser. J Cosmet Laser Ther. 2009;11: 212–5.
54. Goldberg DJ. Laser therapy. In: Krieg T, Bickers DR, Miyachi Y, editors. Therapy of skin disease. Berlin Heidelberg: Springer; 2010. p. 93–104.
55. Sardana K, Manjhi M, Garg VK, Sagar V. Which type of atrophic acne scar (ice-pick, boxcar, or rolling) responds to nonablative fractional laser therapy? Dermatol Surg. 2014;40(3): 288–300.
56. Cho SB, Lee SJ, Cho S, Oh SH, Chung WS, Kang JM, et al. Nonablative 1550-nm erbium-glass and ablative 10600-nm carbon dioxide fractional lasers for acne scars: a randomized split-face study with blinded response evaluation. J Eur Acad Dermatol Venereol. 2010;24(8):921–5.
57. Lee DH, Choi YS, Min SU, Min SU, Yoon MY, Suh DH. comparison of a 585-nm pulsed dye laser and a 1064-nm Nd:YAG laser for the treatment of acne scars: a randomized split-face clinical study. J Am Acad Dermatol. 2009;60:801–7.
58. Seaton ED, Mouser PE, Charakida A, Alam S, Seldon PM, Chu AC. Investigation of the mechanism of action of nonablative

pulsed-dye laser therapy in photorejuvenation and inflammatory acne vulgaris. Br J Dermatol. 2006;155:748–55.
59. Goldberg DJ, Silapunt S. Histologic evaluation of a Q-switched Nd: YAG laser in the non ablative treatment of wrinkles. Dermatol Surg. 2001;27:744–6.
60. Maluki AH, Mohammad FH. Treatment of atrophic facial scars of acne vulgaris by Q-Switched Nd:YAG (Neodymium: Yttrium-Aluminum-Garnet) laser 1064 nm wavelength. J Cosmet Laser Ther. 2012;14(5):224–33.
61. Friedman PM, Jih MH, Skover GR, et al. Treatment of atrophic facial acne scars with the 1064-nm Q-switched Nd:YAG laser: six-month follow-up study. Arch Dermatol. 2004;140(11):1337–41.
62. Asilian A, Salimi E, Faghihi G, Dehghani F, Tajmirriahi N, Comparison SMH. of Q-Switched 1064-nm Nd: YAG laser and fractional CO2 laser efficacies on improvement of atrophic facial acne scar. J Res Med Sci. 2011;16(9):1189–95.
63. Brauer JA, Kazlouskaya V, Alabdulrazzaq H, Bae YS, Bernstein LJ, Anolik R, et al. Use of a picosecond pulse duration laser with specialized optic for treatment of facial acne scarring. JAMA Dermatol. 2015;151(3):278–84.
64. Bernstein EF, Schomacker KT, Basilavecchio LD, Plugis JM, Bhawalkar JD. Treatment of acne scarring with a novel fractionated, dual-wavelength, picosecond-domain laser incorporating a novel holographic beam-splitter. Lasers Surg Med. 2017;49(9):796–802.
65. Dierickx C. Using normal and high pulse coverage with picosecond laser treatment of wrinkles and acne scarring: Long term clinical observations. Lasers Surg Med. 2018;50(1):51–5.
66. Huang CH, Chern E, Peng JH, Hsien-Li Peng P. Noninvasive atrophic acne scar treatment in asians with a 755-nm picosecond laser using a diffractive optic lens—A retrospective photographic review. Dermatol Surg. 2019;45(2):195–202.
67. Huang CH, Hsieh FS, Chang HC, Peng JH, Peng HP. 755 nm picosecond laser for facial atrophic scar—case reports of long-term clinical efficacy following up. J Cosmet Dermatol. 2019;18:778–82.
68. Yang C-S, Huang Y-L, Cheng C-Y, Hu S, Chang S-L, Lee M-C. A Prospective study of fractionated dual-wavelength picosecond laser in treating acne scar. Lasers Surg Med. 2020;52(8):735–42.
69. Kwon HH, Yang SH, Cho YJ, Shin E, Choi M, Bae Y, et al. Comparison of a 1064-nm neodymium-doped yttrium aluminum garnet picosecond laser using a diffractive optical element vs. a nonablative 1550-nm erbium-glass laser for the treatment of facial acne scarring in Asian patients: a 17-week prospective, randomized, split-face, controlled trial. J Eur Acad Dermatol Venereol. 2020;34:2907–13.
70. Chayavichitsilp P, Limtong P, Triyangkulsri K, Pratumchart N. Comparison of fractional neodymium-doped yttrium aluminum garnet (Nd:YAG) 1064-nm picosecond laser and fractional 1550-nm erbium fiber laser in facial acne scar treatment. Lasers Med Sci. 2020;35:695–700.
71. Lolis MS, Goldberg DJ. radiofrequency in cosmetic dermatology: a review. Dermatol Surg. 2012;38:1765–76.
72. Min S, Park SY, Yoon JY, Suh DH. comparison of fractional microneedling radiofrequency and bipolar radiofrequency on acne and acne scar and investigation of mechanism: comparative randomized controlled clinical trial. Arch Dermatol Res. 2015;307:897–904.
73. Elman M, Fournier N, Barnéon G, Bernstein EF, Lask G. Fractional treatment of aging skin with Tixel, a clinical and histological evaluation. J Cosmet Laser Ther. 2016;18(1):31–7.
74. Artzi O, Koren A, Niv R, Mehrabi JN, Mashiah J, Friedman O. A new approach in the treatment of pediatric hypertrophic burn scars: tixel-associated topical triamcinolone acetonide and 5-fluorouracil delivery. J Cosmet Dermatol. 2020;19(1):131–4.
75. Shavit R, Dierickx C. A new method for percutaneous drug delivery by thermo-mechanical fractional injury. Lasers Surg Med. 2020;52(1):61–9.
76. Saray Y, Güleç AT. Treatment of keloids and hypertrophic scars with dermojet injections of bleomycin: a preliminary study. Int J Dermatol. 2005;44(9):777–84.
77. Levenberg A, Vinshtok Y, Artzi O. Potentials for implementing pressure-controlled jet injection in management of keloids with intralesional 5FU and corticosteroids. J Cosmet Dermatol. 2020;19(8):1966–72.
78. Patel T, Tevet O. Effective treatment of acne scars using pneumatic injection of hyaluronic acid. J Drugs Dermatol. 2015;14(1):74–6.
79. Kim BY, Chun SH, Park JH, Ryu S, Kim Il-H. Prospective evaluation of atrophic acne scars on the face with needle-free high-pressure pneumatic injection: quantitative volumetric scar improvement. Dermatol Surg. 2019;45(6):829–35.
80. Fife D, Zachary CB. Combining techniques for treating acne scars. Curr Dermatol Rep. 2012;1:82–8.
81. Sadove R. Injectable poly-L lactic acid: a novel sculpting agent for the treatment of dermal fat atrophy after severe acne. Aesthetic Plast Surg. 2009;33:113–6.
82. Rkein A, Ozog D, Waibel JS. Treatment of atrophic scars with fractionated CO2 laser facilitating delivery of topically applied poly-L-lactic acid. Dermatol Surg. 2014;40(6):624–31.
83. 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):426–38.
84. Graber EM, Tanzi EL, Alster TS. Side effects and complications of fractional laser photothermolysis: experience with 961 treatments. Dermatol Surg. 2008;34(3):301–5.
85. Cheyasak N, Manuskiatti W, Maneeprasopchoke P, Wanitphakdeedecha R. Topical corticosteroids minimise the risk of postinflammatory hyper-pigmentation after ablative fractional CO2 laser resurfacing in Asians. Acta Derm Venereol. 2015;95(2):201–5.

How to cite this article: Salameh F, Shumaker PR, Goodman GJ, Spring LK, Seago M, Alam M, et al. Energy-based devices for the treatment of Acne Scars: 2022 International consensus recommendations. Lasers Surg Med. 2021;1–17. doi:10.1002/lsm.23484