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Laser treatment for facial acne scars: A review

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ABSTRACT

Background and Objectives: Acne scarring is a widely prevalent condition that can have a negative impact on a patient's quality of life and is often worsened by aging. A number of options are available for the treatment of acne scarring, including retinoids, microdermabrasion, dermal fillers, and surgical techniques such as subcision. The aim of this review is to evaluate the different laser modalities that have been used in peer-reviewed clinical studies for treatment of atrophic acne scars, and summarize current clinical approaches.

Materials and Methods: A Medline search spanning from 1990 to 2016 was performed on acne scarring. Search terms included "atrophic acne scars," "ablative", "nonablative," "fractional," "nonfractional," "neodymium," "alexandrite," "pulsed dye" lasers, and results are summarized.

Results: Various types of lasers have been evaluated for the treatment of atrophic acne scars. While they are efficacious overall, they differ in terms of side effects and clinical outcomes, depending on patients skin and acne scar type. A new emerging trend is to combine lasers with other energy-based devices and/or topicals.

Conclusion: Evaluation of the literature examining acne scar treatment with lasers, revealed that clinical outcomes are dependent on various patient factors, including atrophic acne scar subtype, patient skin type, treatment modality, and side-effect profile.

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Ablative; acne; scars; laser; inflammation

Introduction

Acne is a chronic inflammatory disease of the pilosebaceous unit that results in scarring in approximately 1% of acne sufferers (1,2). The presence of scars has a profoundly negative impact on an individual's quality of life, as they experience loss of confidence in their physical appearance, feelings of exclusion by others, and depression, which affects their professional and personal lives (3).

The pathophysiology driving acne scarring development is attributed to an altered wound healing response initiated by cutaneous inflammation, leading to an imbalance in matrix degradation and collagen biosynthesis. The end result is either excess or decreased collagen deposition, that corresponds to the presence of hypertrophic/keloid or atrophic acne scars respectively (4–6). The majority of acne scars (80–90%) are atrophic, while a minority is keloid or hypertrophic scars (Table 1) (7,8). Atrophic scars are further subclassified into ice-pick, rolling, and boxcar scars (9). Ice-pick scars are usually narrow (<2 mm), deep, sharply demarcated tracts that can extend into the deep dermis or subcutaneous tissue. Rolling scars are wider (4–5 mm) and shallower than ice-pick scars, producing an undulating appearance. Boxcar scars are wider at the base than ice-pick scars, do not taper, and can be shallow (<0.5 mm) or deep (>0.5 mm). Hypertrophic acne scars and keloids are characterized by excess collagen deposition, resulting in a raised papule or plaque. The difference between hypertrophic and keloid scars is that the former extend beyond the margin of the original wound, while the latter do not (10). Aside from matrix deposition, erythema and melanogenesis may be stimulated after an acne lesion resolves, thus atrophic, keloid, or hypertrophic scars can be erythematous, hyperpigmented/hypopigmented. The manifestations present within a scar ultimately dictate the therapeutic approach that would be most successful to its resolution.

A variety of treatment strategies exist to treat acne scars, and energy-based devices, primarily light/lasers and radiofrequency have emerged as an appealing noninvasive option for this indication. Thermal energy absorption by chromophores present in the epidermis/dermis stimulates extracellular matrix remodeling, production of collagen and elastin, and depending on the selected wavelength, reduction of pigment and erythema (11,12). Patient skin type and their unique acne scar profile (depth, inflammation) often dictates a multistep staged approach using different laser or other therapeutic modalities (13–15). Despite the therapeutic potential of lasers, securing optimal clinical outcomes has been challenging as efficacy is often compounded with side effects, particularly in the case of the earlier ablative lasers. Conversely nonablative lasers have milder adverse effects, but require multiple treatment sessions and produce more modest clinical outcomes (Table 2).

The aim of this review is to evaluate the therapeutic potential of lasers for acne scarring, with a focus on atrophic acne scars. Current guidelines and the author's experience using

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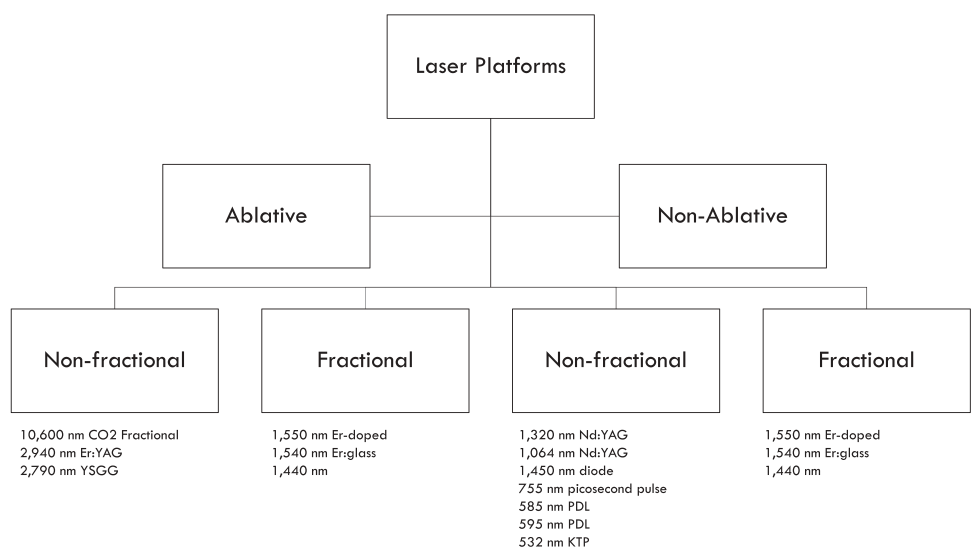
Color versions of one or more of the figures in the article can be found online at www.tandfonline.com/ijcl.

Table 1. Types of scars.

Acne scar	Description
Superficial macular scars	Commitment of the epidermis and superficial dermis clinically shows macula pigment and erythema.
Ice-pick scars	This type of scar has cone shaped. The surface is generally wider than its infundibulum, which is aimed at deeper layers of skin .It goes deeper until the reticular dermis and sometimes until the subcutaneous tissue. These scars are difficult to treat because they are very deep, this is the reason why these types of scars do not respond to many treatments.
Rolling scars	The shape of this type of scars is corrugated (wavy): There is a junction fibrous dermo-hypodermic defective, due to damaged subcutaneous fat.
Boxcar scars	These have an oval shape. The diameter of the surface is greater than its depth. It varies in depth within 0.1–0.5 mm and more variable length up to 4 mm diameter.
Hypertrophic scars	Characterized by Increase tissue in the scar periphery, these scars can also have a spontaneous remission
Keloids	Disproportionate excess tissue outside the boundaries of the initial injury. They are not commonly caused by acne.

Table 2. Overview of lasers available for acne scarring.



lasers and energy-based devices to treat atrophic acne scars are also discussed.

Ablative nonfractional lasers

Ablative lasers can stimulate profound dermal remodeling, but require significant downtime and the associated side-effects include persistent erythema, edema, oozing, and crusting after treatment (16). Ablative laser treatments work by delivering an intense wavelength of light to the skin, superheating water molecules in the epidermal skin cell layer, which is then vaporized in a skin-peeling effect. Depending on the depth of the laser, thermal injury below the vaporization zone leads to stimulation of the dermal cells to produce excess collagen resulting in significant improvement of photodamaged skin, rhytides, dyschromias, and scars (17–19).

CO_2 lasers emit a light at a wavelength of 10,600 nm and target tissue water without regard to melanin and hemoglobin. Pulse duration is less than 1 ms and fluences of 5 J/cm^2 lead to optical penetration of 20–30 mm. Erbium-doped yttrium aluminum garnet lasers (Er:YAG) emit a wavelength of 2940 nm and have a penetration depth of only 1–3 mm, thus leading to more moderate resurfacing results compared to CO_2 laser treatment.

The expected convalescent period after traditional CO_2 laser resurfacing is around 2 weeks, followed by several weeks to months of persistent facial erythema. Shorter recovery periods are associated with resurfacing with traditional Er:YAG lasers as reepithelialization is usually complete after 3–8 days and postoperative erythema resolves more quickly. Although ablative laser treatment was the gold standard for atrophic acne scars, its use has been limited in patients with high Fitzpatrick skin type due the adverse effects (20). One of the most common and distressing side effects caused by ablative nonfractional lasers is postinflammatory hyperpigmentation (PIH), a reactive hypermelanosis of the skin that appears as asymptomatic macules or patches. Patients with dark skin types are mostly at risk from PIH and a patch skin test is recommended before any laser treatment (21). Strategies used to mitigate these effects include treating lesions with only a single pass, applying lower fluences and using pulsed instead of scanning lasers (22,23). A summary of clinical studies that have used ablative non-fractional lasers for acne scars is presented in Table 3 (24–30).

Ablative fractional lasers

The relatively long recovery period and associated adverse effects of ablative lasers led to the development of ablative

Table 3. Clinical studies using ablative nonfractional lasers.

Reference	Laser	Patient number	Skin type	Scar type	Methods	Findings
(Walia and Alster 1999)	CO_2	60	I–V	Moderate to severe atrophic scars (subtype not specified)	• 41 patients: 300 mJ, 5–7 W, 8 mm • 19 patients: 500 mJ, 3 mm • Two passes	73% improvement at 1 year, 75% at 18 months. Erythema and PIH resolved within 6 months
(Lee, Kang et al. 2014)	2940 nm	22	III–V	Moderate to severe atrophic facial acne scars (ice-pick, rolling, and box scar)	• Single session • 70 µm of ablation 17.5 J/cm^2 with spot size of 4 mm (short pulse) • 25 µm of ablation mode at 6.25 J/cm^2, 10 µm of ablation 6.25 J/cm^2 (dual)	Statistically significant mean improvement of 3.41 in scarring ($p < 0.001$) at 6-months. Adverse effects included PIH and erythema.
(Hu and Gold 2010)	2940 nm	180	III–IV	Atrophic rolling scars	• 2 mm single spot ablation in a circular motion followed by a full-face epidermal peel set at a 10–30 micron (levels I–III)	21% of patients rated results excellent, 69% rated good, 10% rates fair. The procedure was well tolerated, even at level III.
(Wanitphakdeedecha, Manuskiatti et al. 2009)	2940 nm	24	III–V	Atrophic, rolling	• Two monthly treatments • Four passes: 7-mm spot size, fluence of 0.4 J/cm^2 • Two pulse widths: 300 micros (short pulse,) and 1500 micros (extra-long pulse)	In the long pulse group skin smoothness improved significantly, in the short pulse group, skin smoothness, and scar volume improved significantly from baseline. Adverse effects included transient PIH (18%) and acneiform eruption (9%).
(Jeong and Kye 2001)	2940 nm	35	III–V	Atrophic ice pick	Pulsed Er:YAG laser with a 5 mm handpiece at a setting of 7.0–7.5 J/cm^2 with a 10 ms pulse Four to five passes	Excellent results in 10 patients (36%), good in 16 patients (57%), and fair in 2 patients (7%). Erythema lasted around 3 months and PIH occurred in 8 patients (29%).
(Tanzi and Alster 2002)	2940 nm	25	I–V	Severe atrophic scars (subtypes not specified)	• Single treatment • 90 micros ablation 22.5 J/cm2 with 50% spot overlap and 50 micron coagulation • Three passes	Average 2.16 clinical improvement (range 1–3) at the 12 month follow up. Erythema and PIH self resolved within a month
(Woo, Park et al. 2004)	2940 nm	150	III–V	Ice pick, boxcar, rolling	• 83 patients received 350-micros short-pulsed Er:YAG laser at 12 to 15%/cm^2 • 35 patients received variable-pulsed Er:YAG laser at the setting of 7.0–7.5%/cm^2 and 7-ms pulse duration • 40 patients received dual-mode Er:YAG laser with 350-micro ablation mode at 17.5%/cm^2 and 8-ms coagulation mode at 3.15%/cm^2	Short-pulsed Er:YAG laser: good to excellent results for ice pick, boxcar scars, fair to good for deep boxcar scars, and poor to fair for rolling scars. Variable-pulsed laser: good to excellent results for ice pick and shallow boxcar scars, fair to good for deep boxcar scars, and good for rolling scars. Dual-mode laser: good to excellent results for ice pick, shallow, and rolling scars and produced good results on deep boxcar scars.

Table 4. Ablative fractional lasers for acne scars.

Reference	Laser	Patient number	Skin type	Scar type	Methods	Findings
(Huang 2013)	Fractional CO_2	44	IV	Atrophic scar (subtype not specified)	● Two full face treatments ● Superficial mode to scar areas; two to three passes (100–150 mJ, density 5–7 (30–40% overlap) ● Deep mode to scar areas; 1 pass (10–15 mJ), density 10–15%	64% had 51–75% improvement; mean overall improvement of 53%. Erythema, PIH resolved within 3 months.
(Hedelund, Haak et al. 2012)	Fractional CO_2	13	I–III	Atrophic scar (subtype not specified)	● Three monthly treatments ● Single pass with spot diameter of 0.5 mm, pulse duration of 4 ms, laser power of 12–14 W, microbeam energy of 48–56 mJ per pulse, 100 MTZ/cm^2 and density of 13%	Independent evaluation demonstrated scar improvement at 1 and 3 months. Patients were satisfied with treatments and evaluated scar texture to be mild or moderately improved. Adverse effects were minor.
(Majid and Imran 2014)	Fractional CO_2	60	II–IV	Icepick and rolling	● Three to four sessions every 6 weeks ● One to two passes (15–25 J/cm^2, 100–150 MTZ/cm^2)	68.3% improvement at the 6-month follow up. Rolling scars had the best response. Three cases of PIH were reported.
(Chapas, Brightman et al. 2008)	Fractional CO_2	13	I–IV	Atrophic (type not specified)	● 2–3 Tx at 1–2 month intervals ● Fixed spot size was 120 mm, pulse energies of 20–100 mJ per pulse, densities of 100–400 MTZ/cm^2 per pass and total treatment densities of 200–1200 MTZ/cm^2.	26–50% improvement in all cases. Mean improvement in depth of scars ~66%. All side effects were transient.
(Walgrave, Ortiz et al. 2009)	Fractional CO_2	30	I–V	Moderate/severe atrophic (type not specified)	● Three sessions ● 20–100 mJ with total densities of 600–1600 MTZ/cm^2.	92% had improvement at 3-month follow up. Side effects were transient.
(Kim 2011)	Fractional 2,790 nm	20	IV	Atrophic (type not specified)	● Two sessions at 3-month intervals ● Treatment energies varied from 80 to 120 mJ per microspot. The 300-mm-diameter microspots were applied with a medium density pulse pattern in all patients.	At the 3-month follow-up, 70% of the participants were rated as having at least 50–89% improvement of scars.
(Firooz, Rajabi-Estarabadi et al. 2016)	Fractional 2940 nm	9	III–IV	Atrophic (type not specified)	● Two to Five sessions 4–6 weeks apart. ● Spot size 5 mm, energy 1000–1500 mJ, 1–3 passes on individual atrophic scars.	Majority of patients satisfied, high level of improvement and reduced downtime
(Nirmal, Pai et al. 2013)	Fractional 2,940 nm	25	III–IV	Rolling and boxcar	● Four session with one month interval ● 9 × 9 tips with fluence of 1200 and 1400 mJ for treatment 1 and 2 ● 7 × 7 tips with fluence of 1200 and 1400 mJ for treatment 3 and 4. ● Long pulse mode (2 Hz) was used for all four sessions.	Marked improvement in 96% of the patients. Downtime was minimal and 2% of patients experienced PIH.

Figure 1. (a) 30-year-old female (skin type II) with erythematous boxcar scars before and (b) 6 months after three treatments with PDL (585 nm, 12 J/cm^2, 10–30 mm spot size, 5 ms).

fractional lasers, based on the evolution of fractional photothermolysis. This refers to the creation of pixilated columnar zones of thermal injury (microthermal treatment zones, MTZ), which are delivered to the dermis thereby stimulation collagen production (31). One of the main fractional ablative laser devices currently used for acne scars is the CO_2 laser, but the Er:YAG laser platform has also been also toggled to integrate fractionated technology. Although this generation of fractional laser is superior to their nonfractional counterparts, patients still develop side effects such as erythema, edema, scarring, and pigment changes. Many authors postulate however that side effects can be minimized by selecting appropriate settings depending on patient skin type and following the manufacturer's protocol (32). In general however, nonablative fractional laser resurfacing is favored when available, as it is associated with fewer side effects and little difference in benefit to treatment compared to ablative fractional lasers (33,34). A summary of clinical studies using ablative fractional lasers for atrophic acne scars is presented in Table 4 (15,16,35–40).

Nonablative lasers

Nonablative laser systems are also frequently used to treat atrophic acne scars. They emit wavelengths in the visible or in the infrared (IR) range, resulting in stimulation of type I and III collagen and elastic fibers (41). One benefit of nonablative lasers is that they deliver energy into the dermis without destroying the overlying epidermis resulting in less side effects and shorter recovery times. However, clinical improvement may be moderate, especially for deeper icepick and boxcar scars, and patients may require multiple treatment sessions (14). Cooling devices are often incorporated in these lasers to reduce patient discomfort and ensure that the epidermis is protected while the upper papillary dermis is stimulated for collagen production. Aside from matrix remodeling, some nonablative lasers are utilized to clear pigment and erythema in atrophic scars. The treatment of erythema and pigment in acne scars is an important and often the first component of treatment to be addressed, as coloration accentuates acne scars and makes them more noticeable to the observer. Reducing coloration can improve the appearance of acne scars even without improvement in the more difficult to correct textural abnormalities.

Nonablative laser rejuvenation systems used for treating acne scars include the 1540 nm Er:Glass laser, 1320 nm neodymium-doped yttrium aluminum garnet (Nd:YAG) prototype that weakly absorbs superficial water-containing epidermis, but penetrates in to deeper structures and the 1064 nm Nd:YAG laser that penetrates more deeply into the dermis and exhibits a greater extent of absorption by oxyhemoglobin and melanin (42). Other nonablative lasers used for acne scars include the 1450 nm diode laser, the 755 nm alexandrite picosecond laser, the 58 and 595 nm pulsed-dye laser (PDL). Both the 755 nm and PDL lasers are typically used to treat pigment and erythema respectively. PDL therapy improves erythema in scars by targeting oxyhemoglobin within vascular structures in the skin, and successful treatment usually requires three to four or more treatments given at approximately 1-month intervals (Figure 1) (43). A summary of clinical studies using nonablative lasers for atrophic acne scars is presented in Table 5 (43–50).

Nonablative fractional lasers

Nonablative fractional lasers entered the market in 2003 with the aim to increase efficacy in scar treatment while reducing downtime and side effects. The 1550 nm Er:Doped laser that still dominates the market today, targets and gently heats water in the dermis, leading to controlled thermal damage. The fractionated component of the laser allows for a spatially precise pattern of tissue injury across the treated area, while retaining the healing function of the epidermis. Other lasers in this range are the 1540 nm and the combination 1550 nm Er:glass/1927 Thulium Fiber laser which has both ablative and nonablative capabilities. The 1440 nm fractionated laser that delivers energy through a microarray of lenses known as the combined apex pulse technology, evenly distributing across a 300 mm depth, has also been used for acne scars. Since

Table 5. Non-ablative lasers for acne scars.

Reference	Laser	Patient number	Skin type	Scar type	Methods	Findings
(Alster and West 1996)	585 nm	22	II–IV	Erythematous atrophic scars	• One to two treatments with a 6-week interval • 0.45 ms pulse, average fluence 6.5 J/cm2, 7 mm spot size	68% reduction in clinical erythema/scarring. No side effects.
(Patel and Clement 2002)	585 nm	10	I–IV	Boxcar scars	• Single treatment • Settings: 0.350 ms, 1.9–2.4 J/cm^2, 5 mm spot size	All patients reported visible cosmetic improvement. The depth of the acne scars was reduced by 47.8%. No adverse effects of this treatment were reported.
(Yoon, Lee et al. 2008)	595 nm	12	III–IV	Erythema/early scarring (mixed inflammatory/ noninflammatory)	• Two treatments every 4 weeks • Spot size 7 mm, 10 ms, 9.5–11 J/cm^2	90% of patients experienced clinical improvement. Significant improvements were noted in erythema indexes, and skin elasticities after each treatment.
(Brauer, Kazlouskaya et al. 2015)	755 nm	20	I–V	Rolling scars	• Six treatments every 4–8 weeks • Spot size of 6 mm, fluence of 0.71 J/cm2, repetition rate of 5 Hz, and pulse width of 750 ps)	Mean 24.3% improvement in scar volume, maintained at 1 (24.0%) and 3 (27.2%) months post treatment. High patient satisfaction. Pain score was low.
(Bellew, Lee et al. 2005)	1320 nm	29	I–IV	Atrophic	• Mean number of treatments 5.5 (range 2–17) every 6 weeks • Fluences of 15 to 20 J/cm^2, 6 mm fixed spot, 50 ms.	Mean improvement by physician assessment score was 2.8 ($p < .05$) (0–4 scale). Mean improvement by patient assessment score was 5.4 ($p < .05$) on a (0–10 scale). Treatments were well tolerated, with side effects limited to mild, transient erythema, and edema.
(Bhatia, Dover et al. 2006)	1320 nm	16	II–IV	Atrophic	• Six monthly treatments • Spot size 10 mm, fluences 18–20 J/cm^2	62% of patients were satisfied. Degree of improvement on a 1–10 scale was 5.4.
(Chua, Ang et al. 2004)	1450 nm	57	IV–V	Atrophic	• Four to six treatments • 6-mm spot size; fluence, 11–12 J/cm2; pulse duration, 250 ms	Clinical improvement ranged from 15–20% and side effects were mild. Main side effects were mild to moderate pain during the procedure, transient erythema, and hyperpigmentation.
(Politi, Levi et al. 2016)	1540 nm	25	II–IV	Atrophic	• Three to six treatments with 2–3 weeks intervals • Spot size 4 mm, fluence of 400–600 mJ/pulse, three stacked pulses emitted at a rate of 3 Hz	Average improvement was 3.9 and 4.1 points on the quartile scale used for outcome assessment 1 and 3 months following the last session, respectively. Patient satisfaction rate was 4.2. Side effects were minimal and transient.
(Badawi, Tome et al. 2011)	1064 nm	19	III–VI	Atrophic	• Six treatments 3 weeks apart. • 14–16 J/cm^2, pulse duration of 300–500 µs	Clinically and statistically significant results with reduced risk of pigment complications and patient discomfort

Table 6. Non-ablative fractional lasers for acne scars.

Reference	Laser	Patient number	Skin type	Scar type	Methods	Findings
(Alster, Tanzi et al. 2007)	1550 nm	53	I–V	Mild/moderate atrophic	• One to five monthly treatments • Fluence 8–16 J/cm^2, 125–250 MTZ/cm^2, 8–10 passes, 15 mm spot size	Clinical improvement (51% –75%) in 90% of patients after three monthly laser treatments.
(Chrastil, Glaich et al. 2008)	1550 nm	29	I–V	Atrophic (icepick, boxcar, rolling)	• Two to six treatments at one month interval • Energy settings ranged from 35 to 40 mJ/MTZ, 15 mm spot size	50–75% improvement in 62% of patients. No adverse effects were noted
(Mahmoud, Srivastava et al. 2010)	1550 nm	15	IV–VI	Atrophic	• Five monthly treatments (10 or 40 mJ)	There was a significant improvement in the acne scarring with no difference between 10 and 40 mJ. Significant PIH occurred.
(Bencini, Tourlaki et al. 2012)	1540 nm	87	II–V	Atrophic (icepick, boxcar, rolling)	• Six treatments every 3 weeks • 10-mm handpiece, four passes with a 50% overlap at 15-ms pulse duration, energy from 50–60 mJ/microbeam	At the 6-month follow up 92% of patients had marked improvement
(Lee, Lee et al. 2008)	1550 nm	27	IV–V	Moderate to severe atrophic acne scars	• Three to five treatments at intervals of 3–4 weeks • Fluence of 12–20mJ/MTZ, a total density of 750–1500 MTZ/cm^2	Marked improvement in the appearance of acne scars at 3 months posttreatment. Adverse events were limited to transient pain, erythema and edema.
(Hedelund, Moreau et al. 2010)	1540 nm	10	I–IV	Atrophic acne scars	• Three monthly treatments • 10-mm handpiece, 15-ms pulse duration, energy in the range 70–100 mJ per microbeam in three or four passes	Scars appeared more even and smooth than untreated control areas (4.5, 2–6.5), at 4 weeks. Patients were satisfied with the treatment (5.5, 1–7, after 12 weeks). Patients experienced moderate pain, erythema, and crusts.

nonablative fractional lasers leave the epidermis intact there are fewer adverse effects such as erythema, edema, bleeding, crusting, infection, and scarring compared to ablative fractional lasers (51). Moreover, although these lasers are effective in patients of all skin types, patients with darker skin are more at risk for posttreatment hyperpigmentation. A typical nonablative fractional laser resurfacing treatment regimen consists of four to six treatments given at 1-month intervals. A summary of clinical studies using nonablative lasers for atrophic acne scars is presented in Table 6 (20,31,52–55).

Combination treatments

Eradication of acne scars presents a challenge, and despite the plethora of available lasers to accommodate all skin and acne lesion types there is still a need for improved therapeutic strategies, especially in patients that present mixed types of acne lesions. Combination approaches such as using energy-based technologies with other strategies such as chemical peels, subcision, fillers, microneedling, and/or punch excision have been shown to result in better outcomes, than any single therapeutic modality. The ultimate goal is to exploit the therapeutic benefits of each approach, in terms of tissue remodeling/pigment/erythema reduction, and maximize positive clinical outcomes (56). The author has found that combining fractional resurfacing with injectable permanent fillers such as polymethyl methacrylate (PMMA) results in almost complete eradication of acne scars (Figure 2). Combining fractional laser treatments with peels and subcision have also yielded positive results. Although combination studies for acne are still in the empirical stage, a few peer-reviewed clinical studies exploring the combination-modality approach have been published (Table 7) (57–60).

Conclusion

There is a large variety of laser modalities to treat acne scars, and peer-reviewed clinical studies demonstrate that all technologies can be more-or-less effective depending on the parameters and techniques used. Comparative studies have also been completed to assess the relative efficacy or different lasers for the atrophic acne scar treatment (Table 8) (8,61–64). Summarizing, ablative lasers such as the CO_2 and Er:YAG lasers are most efficacious for severe atrophic scars whereas nonablative lasers, such as the 1550 and 1540 nm fractional laser or the 755 nm picosecond pulse duration laser, may be considered in patients with mild/moderate scars. The 585 nm PDL and 755 nm Alexandrite and 1064 Nd:YAG lasers can be utilized for scars with erythema/pigment, since they can target the hemoblogin and melanin. For patients with darker skin types, since Er:YAG lasers produce less thermal injury than CO_2 lasers, they are safer and less likely to put the patients at risk of hyperpigmentation and hypopigmentation while not compromising results. Nonablative fractional lasers like the 1540 nm are also suitable for treating scars in dark skinned patients. Using lower power settings and multiple three to four treatments can minimize the risk of any side effect. Patient goals and expectations can aid in customizing the selection of laser modalities, since lifestyle and pain thresholds can alter the clinical decision when taking into account recovery times and adverse effects. Combination therapies with fillers, peels, or topical medications should be considered for patients with mixed types of scars, and these ancillary modalities that can be used to treat acne scars merit the composition of another review article. Continuous rigorous clinical studies for the new laser modalities entering the market is critical to ensure their safety and efficacy for acne treatment and the development of appropriate therapeutic protocols.

(a) (b)

Figure 2. (a) 27-year-old male (skin type III) with rolling scars before and (b) 12 months after 3 monthly treatments with fractional 1550 nm (35 mJ) followed by permanent filler injection (2 cc).

Table 7. Combination treatments for acne scarring.

Reference	Treatment	Patient number	Skin type	Scar type	Methods	Findings
(Kang, Kim et al. 2009)	1550 nm TCA Subcision	10	IV–V	Atrophic (icepick, rolling, boxcar)	• Three to four treatments with laser • Four passes, 350–800 spots/cm^2 • 2 weeks after laser: peel (100% TCA) with subcision, repeated twice at 2 month intervals	The mean scar severity scores decreased to 34.8 as compared to 80.0 before the treatment Patients reported significant improvement and no complications were noted.
(Taylor, Zaleski-Larsen et al. 2017)	CO_2 TCA Subcision	114	I–V	Atrophic rolling scars	• 20% TCA peels • Subcision • Laser Treatment 30–50 mJ/mb, density of 40–50% coverage with four passes on the face and two on the neck	A mean improvement of 2.9 on a scale of 1–4 was achieved following a single treatment.
(Carniol, Vynatheya et al. 2005)	1450 nm 30% TCA	9	II–III	Atrophic (rolling, boxcar)	• Four monthly laser treatments • 12–13 J/cm^2. The dynamic cooling spray varied from 30 to 40 ms • Two bimonthly 30% TCA peels	Mean improvement self-assessment score was 6.4 (0–10). Independent evaluator assessment 6.8 (0–10). Mean improvement of rolling scars was 5.3 while the mean improvement of boxcar scars was 1.5.
(Zhou, Zhang et al. 2016)	Split face: CO_2 or CO_2+ADSC-CM	13	II–IV	Atrophic scars (subtypes not specified)	• Three treatments • 8 W, spot density 25% two passes • Topical application of ADSC-CM	Combination treatment increased subject satisfaction, skin hydration, and skin elasticity and decreased roughness.

Table 8. Comparative studies.

Reference	Laser	Patient number	Skin type	Scar type	Methods	Findings
(Min, Choi et al. 2009)	Split face 1064 nm and 585/1064 nm	19	II–IV	Mild moderate atrophic (rolling, boxcar, ice pick)	• Four treatments every 2 weeks • Nd:YAG: fluence 50–70 J/cm^2, 50- to 100-ms pulse duration, 7-mm spot size • Combined treatment PDL: fluence 10–11 J/cm^2, 40-ms pulse duration, 7-mm handpiece. Nd:YAG: fluence 50–70 J/cm^2, 50- to 100-ms pulse duration, 7-mm spot size.	Improvement after long-pulse Nd:YAG was 27%, and 32.3% after combined 585/1064-nm laser. Both modalities were particularly effective at treating superficial rolling and boxcar scars (440% improvements at 8 weeks posttreatment completion). Deep scars and icepick scars were relatively resistant to both treatments. Compared to icepick, deep boxcar scars tended to improve more after combined 585/1064-nm laser treatment (26.7% vs. 37.5%).
(Asilian, Salimi et al. 2011)	1064 vs. fractional CO_2	64	II–IV	Severe atrophic (rolling, boxcar, ice pick)	• Four treatments every 4 weeks. • 32 patients: 1064-nm Q-switched Nd:YAG laser (2.5 J/cm^2, spot size: 7 mm) • 32 patients: fractional CO_2 laser with pulse duration of 350 µs (three passes)	Mean percent of scar improvement at 6-month follow up was 46.6% in the CO_2 and 31.9% in the 1064-nm Nd: YAG laser.
(Lee, Choi et al. 2009)	585 nm vs. 1064 nm	18	IV–V	Atrophic superficial (rolling, boxcar, ice pick)	• Four treatments every 2 weeks • 585-nm PDL: fluence 10–11 J/cm^2, 40-ms pulse duration, 7-mm hand piece. • 1064-nm long-pulsed Nd:YAG laser fluence 50–70 J/cm^2, 50–100-ms pulse duration, 7-mm spot size.	At 8 weeks posttreatment, acne improvement with PDL was 18.3% vs. 18.7% with the Nd:YAG. Both modalities were effective at treating rolling/boxcar scars. Ice-pick and deep scars were resistant to both treatments. Ice-pick scars tended to improve more so after PDL treatment (11.7% vs. 9.4%, respectively), and deep boxcar scars tended to improve more so after Nd:YAG treatment (15% vs. 9.4%, respectively) at 8 weeks after treatment completion.
(Tanzi and Alster 2004)	Split face 1320 nm and 1450 nm	20	I–V	Mild/moderate atrophic	• Three monthly treatments • 1450-nm diode laser was used at fluences ranging 9–14 J/cm^2 (average of 11.8 J/cm^2, 6-mm spot). • 1320-nm Nd:YAG laser applied fluences ranging 12–17 J/cm^2 (average of 14.8 J/cm^2) through a 10-mm spot size.	Maximum clinical improvement was evident at 6 months for both lasers. At each postoperative visit, higher average clinical scores were seen on the 1450-nm diode laser-treated facial half. Patient satisfaction revealed a mean satisfaction score of 4.6 on the 1320-nm Nd:YAG-treated facial half and 5.7 on the 1450-nm diode laser-treated facial half.
(Alajlan and Alsuwaidan 2011)	1550 nm vs. CO_2	82	III–V	Atrophic (subtype not specified)	• Five treatments for 1550 nm and 2.5 treatments for CO_2 • 45 patients treated with 1550 nm: 2.87 kJ (95%CI: 0.29, 2.58–3.16) • 37 patients treated with CO_2 system: fluence was 125 mJ/cm2 (95%CI: 8.06, 116.9–133.06) with total coverage of 30%.	Objective clinical assessment: 77% of patients treated with the 1550 nm laser attained more than 25% improvement and 35% attained more than 50% improvement. In the CO_2 laser, 70% reached more than 25% improvement and 37% attained more than 50%. Downtime with the 1550 nm was less than that with the CO_2 laser.

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