Review

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A systematic review of treatments for acne scarring. Part 2: Energy-based techniques

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Abstract

Introduction: Acne scarring is a very common problem, which can be extensive, and may lead to significant psychosocial morbidity. Multiple types of treatments are used to ameliorate atrophic scars with varying degrees of success. This paper provides an overview of the various energy-based modalities that are commonly employed against acne scarring.

Objectives and methods: A comprehensive literature search of papers published since 2008 was performed in order to determine the efficacy and adverse reactions of commonly used energy-based treatments against post-acne scarring.

Results: A total of 59 relevant articles were identified covering a multitude of different devices.

Discussion: Ablative lasers seem to achieve the highest degree of efficacy, albeit this is associated with significant pain and downtime, and the risk for long-term pigmentary changes. Non-ablative fractional photothermolysis (FP) has a much safer profile but cannot achieve as good cosmetic results. The efficacies of fractional radiofrequency microneedling and radiofrequency are slightly inferior to that of FP but offer an even safer adverse profile. Little evidence is available on the remaining devices, with larger studies required in order to reach more solid conclusions.

Conclusion: Multiple devices have been used with varying levels of efficacy and very different safety profiles. There is an overall lack of high-quality evidence about the effects of different interventions. Furthermore, no standardised scale is available for acne scarring, leading to variability in evaluation and interpretation of data in different studies.

Keywords
Ablative, acne scarring, energy devices, lasers, non-ablative, photothermolysis, radiofrequency

Introduction

Scarring is the main complication of acne and arises from the disorganised production and deposition of collagen around inflamed follicles, resulting in visibly depressed scars.[1] Such scarring is very common and can lead to impairment in quality of life, as well as being a risk factor for depression and even suicide. Furthermore, it has been linked to poor self-esteem, anxiety and lowered academic performance.[2]

Despite the wide array of methods available to improve the appearance of acne scarring, no

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'gold standard' modality has emerged to date that will clear such scars completely and consistently. Newer treatments and the combination of multiple modalities could therefore be key in achieving consistent results in a large percentage of patients, even in those with severe scarring.

Therapeutic interventions can be generally split into energy- and non-energy-based techniques.

Commonly employed non-energy-based methods include chemical peels, subcision, microneedling, dermabrasion and tissue augmentation with a variety of fillers. These have been covered in part 1 of this literature review.[3]

Energy-based modalities can be further divided into light-based modalities, lasers and radiofrequency devices.

Lasers are the commonest employed modality and come in different types. Traditionally, ablative lasers were widely used in the past due to their ability to produce good cosmetic results after only one treatment.[4] Ablative methods work by removing the epidermis and part of the dermis on the affected areas, leading to subsequent neocollagenesis and remodelling;[5] however, the association of the ablative lasers with extended recovery periods and other untoward side effects has led to the increasing use of the safer fractional and non-ablative technologies.[4]

Unlike traditional ablative means, fractional ablative lasers utilise regularly spaced arrays over a fraction of the skin surface. These induce thermal ablation in microscopic columns of epidermal and dermal tissue while sparing the remaining skin. This approach leads to significantly faster recovery times when compared to traditional ablative resurfacing.[6]

Non-ablative lasers, on the other hand, are able to cause thermal injury in the dermis while preserving the epidermis from any ablation. This process is known as fractional photothermolysis (FP) and limits side effects and recovery time even further.[7]

With radiofrequency (RF) devices, electrical current flows through the skin between the electrode-pin rows generating deep dermal heating. This in turn induces skin injury eliciting a healing response and stimulating the remodelling of dermal collagen.[8]

The microneedling RF (MRF) method consists of multiple needles that enable the delivery of RF directly to the dermis. The needles are insulated to prevent electrothermal damage from occurring anywhere but at the very tip of the needle and never in the epidermis, which undergoes purely mechanical needling. In contrast to ablative and non-ablative lasers, treatment with MRF can be controlled by varying the depth of the needles, thus allowing for discrete electrothermal coagulation at different levels of the dermis.[9,10]

Objectives and methods

The aim of this paper is to provide with an overview of the most up-to-date energy-based treatments used in acne scarring.

A comprehensive literature search of papers published since 2008 was performed on PubMed. A search using the keywords [(scar(s), scarring) AND (acne)] was utilised. Only original articles written in English were included. Individual case reports were excluded. Following screening of abstracts, a total of 59 relevant articles were selected.

Results

A total of 59 relevant articles were included in this review. These have been categorised according to research methodology and modality.

Randomised controlled trials

Twenty-three randomised controlled trials (RCTs) were identified (Table 1).

CO_2 laser

Ten papers focused on the efficacy of the CO_2 laser. In the largest RCT in this group (42 patients), Faghihi et al. compared treatment with punch elevation alongside fractional CO_2 laser resurfacing (21.4% minimal response, 42.9% moderate, 35.7% good) against that of isolated CO_2 laser resurfacing (26.2% minimal response, 42.9% moderate, 31% good).[11]

In other large trials, Zhang et al. (33 patients) compared fractional microplasma radiofrequency (RF) (56.4% mean improvement) to the fractional ablative CO_2 laser (59.2%).[12]

Gawdat et al. (30 patients) assessed the efficacy of the fractional ablative CO_2 laser combined with either saline (excellent improvement in 26.7%), intradermal platelet rich plasma (PRP) (excellent improvement in 66.7%) or topical PRP (excellent improvement in 60%).[13]

Ahmed et al. (28 patients) found the efficacy of CO_2 laser pinpoint irradiation to be superior to that of chemical peeling (trichloroacetic acid chemical reconstruction of skin scars – TCA CROSS technique).[14]

Table 1. A synopsis of all randomised controlled trials.

Authors	Publication year	Patients (n)	Level of evidence*	Treatment method	Cosmetic outcome	Adverse effects
Ahmed et al.	2014	28	1.c	CO_2 laser pinpoint irradiation (Group 1) vs. TCA CROSS (Group 2)	CO_2 laser pinpoint irradiation is more effective than TCA CROSS	CO_2 laser group: pustules and hyperpigmentation; TCA CROSS group: itching, infection and hyperpigmentation
Alexis et al.	2016	7	1.d	Low-energy (Group 1) vs. high-energy (Group 2) non-ablative fractional Er:Glass laser	Mean improvement in scarring was measured as 'significantly improved'; no statistically significant difference was found between the two groups	Both groups: pain, erythema, oedema, bleeding, hyperpigmentation and hypopigmentation
Bjørn et al.	2013	11	1.d	Fractional CO_2 laser at 1-month intervals (Group 1) vs. at 3-month intervals (Group 2)	Scarring improved from a mean value of 5.86 $\pm$ 1.87 to: • Group 1: 1.56 ± 1.24 • Group 2: 1.33 ± 1.66 (Based on a 10-point scoring method)	Pain, oozing, bleeding, oedema, erythema, hypopigmentation and hyperpigmentation
Cachafeiro et al.	2016	42	1.c	Non-ablative fractional Er:Glass laser (Group 1) vs. microneedling (Group 2)	Group 1: mean improvement of 3.41; Group 2: mean improvement of 4.05 (based on the Quantitative Global Grading System)	Both groups: pain, erythema, hyperpigmentation, crusting, pustules and bullae
Chae et al.	2015	40	1.c	Non-ablative fractional Er:Glass laser (Group 1) vs. FRM (Group 2)	Overall scar improvement: Group 1: none - 1 patient, slight - 3 patients, average - 5 patients, good - 8 patients, and excellent - 3 patients; Group 2: none - 2 patients, slight - 5 patients, average - 5 patients, good - 7 patients, and excellent - 1 patient	Both groups: pain, erythema, oedema, acneiform eruptions, dryness and hyperpigmentation
Cho et al.	2010	8	1.c	Non-ablative fractional Er-Glass laser (Group 1) vs. ablative fractional CO_2 laser (Group 2)	Group 1: 1 patient had no improvement, 6 patients improved by 26–50%, and 1 by 51–75% Group 2: 5 patients improved by 26–50%, 2 patients by 51–75%, and 1 by $>$ 76%	Both groups: pain, crusting, erythema, oedema, hyperpigmentation, bleeding, oozing and aggravation of active acne lesions
Faghihi et al.	2015	42	1.c	Punch elevation plus fractional CO_2 laser resurfacing (Group 1) vs. isolated CO_2 laser resurfacing (Group 2)	Group 1: minimal response in 21.4%, moderate 42.9%, good 35.7%, excellent 0%; Group 2: minimal response 26.2%, moderate 42.9%, good 31%, excellent 0%	Both groups: erythema, crusting, burning, hyperpigmentation, pain, oedema, discharge and pruritus

(Continued)

Table 1. (Continued)

Authors	Publication year	Patients (n)	Level of evidence*	Treatment method	Cosmetic outcome	Adverse effects
Faghihi et al.	2016	16	1.c	Ablative fractional CO_2 laser plus intradermal PRP (Group 1) vs. ablative fractional CO_2 laser plus intradermal normal saline (Group 2)	Group 1: no or little response in 12.5%, fair or good in 87.5%, excellent in 0%; Group 2: no or little response in 31.2%, fair or good in 68.8%, excellent response in 0%	Both groups: erythema and oedema
Gawdat et al.	2013	30	1.c	Fractional ablative CO_2 laser and intradermal PRP (Group 1) vs. fractional ablative CO_2 laser and intradermal saline (Group 2) vs. fractional ablative CO_2 laser and topical PRP (Group 3)	Group 1: excellent improvement achieved in 66.7%; Group 2: excellent improvement achieved in 26.7%; Group 3: excellent improvement achieved in 60%	All groups: pain, erythema, oedema, crusting and hyperpigmentation
Hedelund et al.	2012	12	1.c	Fractional CO_2 laser vs. untreated control	Mean pre-treatment scar texture 6.15 $\pm$ 1.23 and atrophy 5.72 $\pm$ 1.45 scoring; post-treatment scar texture 3.89 $\pm$ 1.7 and atrophy 3.56 $\pm$ 1.76 scoring (based on a 10-point scoring method)	Pain and erythema
Kim et al.	2009	20	1.d	High- (Group 1) vs. low-energy ablative fractional CO_2 laser (Group 2) vs. low-energy CO_2 laser combined with non-ablative Nd:YAG laser (Group 3)	Group 1: 2 patients had 30–49% improvement and 8 had 50–69%; Group 2: 7 patients had 10–39% improvement and 3 had 40–59%; Group 3: 1 patient had 40–49% improvement, 7 had 50–59%, 9 had 50–69% and three had 60–69%	All groups: erythema, crusting and hyperpigmentation
Kim et al.	2009	18	1.c	Non-ablative fractional Er:Glass laser (Group 1) vs. TCA CROSS (Group 2)	Group 1: average scarring improvement of 2.51; Group 2: average scarring improvement of 2.44 (based on a 4-point scoring method)	Both groups: pain and erythema
Leheta et al.	2012	39	1.c	PCI combined with 20% TCA (Group 1) vs. non-ablative fractional Er:Glass laser (Group 2) vs. PCI and Er:Glass laser (Group 3)	Group 1: 59.79% improvement in scarring; Group 2: 61.83% improvement; Group 3: 78.27% improvement	All groups: pain, erythema, oedema and desquamation
Mahmoud et al.	2010	15	1.d	10mJ (Group 1) vs. 40mJ (Group 2) fractional Er:YAG laser	Average scar improvement of 1.2 (Group 1) and 1.4 (Group 2) (based on a 4-point scoring method)	Both groups: pain, erythema, hyperpigmentation and urticarial eruptions
Min et al.	2015	20	1.c	FRM (Group 1) vs. bipolar RF (Group 2)	FMR was more effective than BR, especially in ice-pick and boxcar scars; scarring decreased by 65% on the FMR-treated side	Both groups: erythema
Min et al.	2009	19	1.c	Non-ablative Nd:YAG laser (Group 1) vs. combined Nd:YAG and PDL lasers (Group 2)	Group 1: 27% improvement in scarring; Group 2: 32.3% improvement. Both modalities were effective at treating superficial rolling and boxcar scars but ineffective at treating deep and ice-pick scars	Both groups: pain, erythema and oedema

Table 1. (Continued)

Authors	Publication year	Patients (n)	Level of evidence*	Treatment method	Cosmetic outcome	Adverse effects
Min et al.	2016	24	1.c	Ablative fractional Er:YAG laser (Group 1) vs. bipolar RF combined with non-ablative infrared diode laser (Group 2)	Group 1: 50% mean improvement in scarring; Group 2: 25% mean improvement	Group 1: pain, oozing and crusting; Group 2: erythema
Phothong et al.	2016	30	1.d	High energy (Group 1) vs. moderate energy bipolar fractional RF (Group 2)	Scar appearance was significantly reduced in both groups. Group 1 demonstrated enhanced improvement in appearance	Both groups: pain, erythema and hyperpigmentation
Ronsgaard et al.	2014	20	1.c	Fractional bipolar RF (Group 1) vs. non-ablative fractional Er:Glass laser (Group 2)	Group 1: mean improvement of 2.70 $\pm$ 0.37; Group 2: mean improvement of 2.86 $\pm$ 0.42 (based on a 4-point scoring method)	Both groups: pain, erythema, dryness and crusting
Wanitphakdeedecha et al.	2009	24	1.d	300 μs (Group 1) vs. 1500 μs (Group 2) of ablative variable square pulse Er:YAG laser	Group 1: 72.7% of patients achieved $>$ 50% improvement; Group 2: 63.6% of patients achieved $>$ 50% improvement	Both groups: hyperpigmentation and acneiform eruptions
Yang et al.	2016	30	1.c	Non-ablative fractional Er:Glass laser (Group 1) vs. asiaticoside cream (Group 2)	Group 1: mean improvement of 5.65 $\pm$ 4.34 ($P < 0.0001$); Group 2: mean improvement of 1.23 $\pm$ 3.41 ($P < 0.0938$) (based on a 4-point scoring method)	Group 1: hyperpigmentation; Group 2: none
Yuan et al.	2014	20	1.d	Fractional CO2 laser 20 mJ, 10% density (Group 1) vs. 20 mJ, 20% density (Group 2) vs. 10 mJ, 10% density (Group 3)	Group 1: 35% achieved marked improvement, 45% moderate and 20% minimal; Group 2: 50% achieved marked improvement, 30% moderate and 20% minimal Group 3: 20% achieved marked improvement, 60% moderate, and 20% minimal improvement ($<$25% minimal improvement, 26-50% moderate, 51-75% marked, and $>$75% near total)	All groups: pain, bleeding, oozing, oedema, crusting, erythema, pruritus, dryness and hyperpigmentation; Groups 1 and 2: acneiform eruptions
Zhang et al.	2013	33	1.c	Fractional microplasma RF (Group 1) vs. fractional CO_2 laser (Group 2)	Group 1: scarring improved by a mean of 56.4%; Group 2: scarring improved by a mean of 59.2%	Both groups: pain, crusting, erythema and hyperpigmentation

*Joanna Briggs Institute classification.

One study (16 patients) studied the effects of the ablative fractional CO_2 laser either in isolation (31.2% little or no response, 68.8% fair or good response) or alongside with intradermal PRP (12.5% little or no response, 87.5% fair or good response).[15] Another study (12 patients) achieved good improvement in scar texture and atrophy with the ablative fractional CO_2 laser.[7] Compared to the non-ablative fractional Er-Glass laser, Cho et al. (eight patients) achieved slightly superior results with the ablative fractional CO_2 laser.[16]

Kim et al. (20 patients) assessed the response of high-energy (two patients had 30–49% improvement and eight had 50–69% improvement) and low-energy (seven patients had 10–39% improvement and three had 40–59% improvement) ablative fractional CO_2 laser resurfacing as well as that of fractional ablative CO_2 laser resurfacing combined with non-ablative Nd:YAG resurfacing (one patient had 40–49% improvement, seven had 50–59% improvement, nine had 50–69% improvement and three had 60–69%).[17]

Yuan et al. (20 patients) reviewed the effects of three different energy and density settings of the fractional CO_2 laser (20mJ, 10% vs. 20mJ, 20% vs. 10mJ, 10%). Results were comparable across all three groups, but with somewhat efficacy in the higher-energy higher-density group.[18]

Finally, Bjørn et al. (11 patients) assessed the response of acne scars to treatment with the fractional CO_2 laser at either one- or three-month intervals.[19] Results were significant in efficacy and comparable across both groups.

Er:Glass fractional photothermolysis

Seven RCTs were included in this category.

Cachafeiro et al. (42 patients) compared Er:Glass laser to microneedling (mean improvement of 3.41% and 4.05%, respectively),[2] and Ronsgaard et al. (20 patients) compared Er:Glass to bipolar RF (mean improvement of 2.86% ± 0.42 and 2.70% ± 0.37, respectively).[8]

Another study (40 patients) reported moderate but slightly superior results with the Er:Glass against those achieved with fractional radiofrequency microneedling (FRM).[1]

One study (39 patients) compared isolated Er:Glass FP (59.79% improvement) to that of FP plus percutaneous collagen induction (PCI) (61.83% improvement) and also against PCI plus 20% TCA (78.27% improvement).[20]

Kim et al. (18 patients) compared the Er:Glass laser to the TCA CROSS method (average improvement of 2.51% and 2.44%, respectively)[21] and Yang et al. (30 patients) compared it to asiaticoside cream (mean improvement of 5.65% ± 4.34 and 1.23% ± 3.41, respectively).[22]

The final study in this category (seven patients) reported significant and comparable improvement in appearance, with both high- and low-energy levels of Er:Glass photothermolysis.[23]

Er:YAG fractional photothermolysis

Three studies utilised this modality.

Min et al. (24 patients) displayed superior efficacy with the Er:YAG laser (50% mean improvement) compared to the combination of bipolar RF and the non-ablative infrared diode laser (25% mean improvement).[24]

Mahmoud et al. (15 patients) attained mild improvement with both 10-mJ and 40-mJ energy settings of the Er:YAG laser.[25] Wanitphakdeedecha et al. (24 patients), on the other hand, found that 72.7% of patients achieved > 50% improvement with the 300-ms wavelength, whereas only 63.6% achieved > 50% improvement with the 1500-ms wavelength.[26]

Other modalities

The remaining RCTs studied a mixture of energy devices.

Min et al. (20 patients) assessed the efficacy of FRM against that of bipolar RF and found FMR to be superior, especially against ice-pick and boxcar scars.[27]

In a different paper, Min et al. (19 patients) studied the effects of treatment with the long-pulse Nd:YAG laser either in isolation (27% improvement) or in combination to the PDL laser (32.3% improvement).[28] Both modalities were found to be effective at treating superficial rolling and boxcar scars but ineffective at treating deep and ice-pick scars.

Finally, one study (30 patients) compared high- to moderate-energy bipolar fractional RF.[29] Scar appearance was significantly reduced in both groups but high-energy settings demonstrated superior efficacy.

Non-randomised controlled trials

Two non-RCTs were identified (Table 2).

In a study of six patients, Cameli et al. compared treatment with fractional CO_2 laser plus

Table 2. A synopsis of all non-RCTs.

Authors	Publication year	Patients (n)	Level of evidence*	Treatment method	Cosmetic outcome	Adverse effects
Cameli et al.	2014	6	2.c	Fractional CO_2 laser plus RF (Group 1) vs. fractional CO_2 laser in isolation (Group 2)	Group 1: 50% achieved excellent, and 50%, good scar improvement; Group 2: 30% achieved excellent, 40% good, and 30% sufficient scar improvement	Both groups: burning, erythema and oedema
Uebelhoer et al.	2007	6	2.c	Single pass of stacked double pulses (Group 1) vs. double pass of single pulses (Group 2) of non-ablative diode laser	Both groups: mean improvement in scar appearance of < 1 (based on a 3-point scoring method)	Both groups: erythema, oedema, burning and hyperpigmentation

*Joanna Briggs Institute classification.

RF (50% achieved excellent and 50% good scar improvement) against that of fractional CO_2 laser in isolation (30% achieved excellent, 40% good and 30% sufficient scar improvement).[30]

Uebelhoer et al. treated six patients with the non-ablative diode laser, either with a single pass of stacked double pulses or with a double pass of single pulses.[31] In both groups, mean improvement in scar appearance was minimal.

Retrospective studies

Four papers were included in this category (Table 3).

Alajlan et al. compared the efficacy of the non-ablative Er-doped fractional laser (77% attained > 25% improvement and 35% attained > 50% improvement) against that of fractional ablative CO_2 laser (70% attained > 25% improvement and 37% attained > 50% improvement).[34]

Chan et al. assessed the effects of the non-ablative fractional Er-doped fibre laser by comparing full (mild improvement in 23.1%, moderate in 7.7%, good in 15.4%, excellent in 53.8%) against mini resurfacing (mild improvement in 0%, moderate in 13.3%, good in 40%, excellent in 46.7%).[33]

Using the fractional ablative CO_2 laser, Kim et al. achieved moderate improvement in appearance across the vast majority of patients,[34] whereas with the use of the non-ablative Nd:YAG laser Badawi et al. achieved moderate results.[35]

Observational studies

A total of 30 observational studies have been included in this review article, which are summarised in Table 4.[9,10,36–63]

Discussion

The ablative fractional CO_2 laser was identified as the modality with the most available evidence (20 studies), followed by the Er:Glass laser and RF (18 and 13 studies, respectively). Interestingly, no studies in this review were found to have used fully ablative, non-fractional CO_2 lasers.

A critical review of the existing studies shows that CO_2 ablative fractional resurfacing (AFR) achieved improvement in appearance that ranged from modest to excellent in most of the studies. Rolling and boxcar scars were found to respond the best while ice-pick scars responded the least.[48] Interestingly, combining the CO_2 laser with punch elevation was found to be beneficial against such deeper scars.[11]

The efficacy of the CO_2 laser was synergistic to treatment with the Nd:YAG laser.[17] However, complementary use of platelet rich plasma (PRP) yielded contradictory results across different studies.[13,15]

In direct comparison, CO_2 laser AFR was found to be superior to both Er:Glass FP and TCA CROSS.[14,16]

The risk of developing hyperpigmentation was heavily influenced by treatment

Table 3. A synopsis of all retrospective studies.

Authors	Publication year	Patients (n)	Level of evidence*	Treatment method	Cosmetic outcome	Adverse effects
Alajlan et al.	2011	82	2.d	Non-ablative fractional Er:Glass laser (Group 1) vs. ablative fractional CO_2 laser (Group 2)	Group 1: 77% attained > 25% improvement and 35% > 50%; Group 2: 70% attained > 25% improvement, and 37% > 50%	Groups 1 and 2: hyperpigmentation, acneiform eruptions, herpes reactivation; Group 2: hypopigmentation and erythema
Badawi et al.	2011	22	2.d	Non-ablative Nd:YAG laser	Median improvement of 2 (based on a 3-point scale)	Erythema and oedema
Chan et al.	2011	47	2.d	Full (Group 1) vs. mini (Group 2) non-ablative fractional Er:Glass laser	Group 1: mild improvement in 23.1%, moderate in 7.7%, good in 15.4%, excellent in 53.8%; Group 2: mild improvement in 0%, moderate in 13.3%, good in 40%, excellent in 46.7%	Both groups: oedema and hyperpigmentation
Kim et al.	2014	20	2.d	Ablative fractional CO_2 laser	Almost all patients achieved moderate improvement	Pain, erythema and crusting

*Joanna Briggs Institute classification.

parameters, with more aggressive regimes causing hyperpigmentation in as high as 55–100% of patients.[18] This risk can, however, be brought down further by employing a number of different interventions. These include using lower treatment densities and pulsed energies, avoiding sun exposure and using broad-spectrum sunblock, and utilising pre-treatment bleaching agents.[18] Lengthening the treatment interval was theorised to lead to fewer adverse effects; however, this was not demonstrated in practice.[19]

Er:Glass FP is commonly employed for multiple cosmetic purposes, including the treatment of rhytides, stretch marks and melasma.[36] It is also widely used against acne scarring with moderate efficacy. More specifically, much better results can be achieved against boxcar and rolling scars, than against ice-pick scars.[54] Even though comparison FP and the TCA CROSS method achieved similar outcomes, closer scrutiny reveals that FP is more effective against rolling scars, whereas the CROSS method has a better effect against ice-pick scars.[20,21] This is likely due to the fact that ice pick scars are deep and the thermal effect of FP cannot reach their base in order to induce stimulation of the dermis and lead to collagen remodelling.[21]

Overall, results were comparable to those achieved by RF. However, FP is associated with higher levels of procedural discomfort.[8] Other adverse reactions are mild and of short duration and can be further reduced by employing lower energy densities.[33]

RF energy, unlike lasers, is not absorbed by melanin, making this modality potentially safer in individuals with dark skin.[30,55]

In general, RF achieved moderate results and was found to be more effective against ice-pick than other types of scars.[53] However, treatment was particularly effective when combined with certain other modalities such as acoustic pressure ultrasound, Er:YAG, diode and CO_2 lasers.[8,24,30]

Overall, the main advantage of the RF modalities is their low profile of side effects, especially that of hyperpigmentation, and the low downtime associated with their use.[51,53]

Table 4. A synopsis of all observational studies.

Authors	Publication year	Patients (n)	Level of evidence*	Treatment method	Cosmetic outcome	Adverse effects
Bencini et al.	2012	87	2.d	Non-ablative fractional Er:Glass laser	8% showed moderate improvement and 92% marked improvement	Pain, erythema, oedema, acneiform eruption, hyperpigmentation
Brauer et al.	2016	20	2.d	Picosecond laser with diffractive lens	Mean improvement in scar appearance of 1.4 (based on a 3-point scoring method)	Pain, erythema and oedema
Chan et al.	2011	47	2.d	Full (Group 1) vs. mini (Group 2) non-ablative fractional erbium laser	Group 1: mild improvement in 23.1%, moderate in 7.7%, good in 15.4%, excellent in 53.8%; Group 2: mild improvement in 0%, moderate in 13.3%, good in 40%, excellent in 46.7%	Both groups: oedema and hyperpigmentation
Chandrashekar et al.	2014	31	2.d	FRM	Grade 3 scars: 76.47% improved by 2 grades; Grade 4 scars: 85.71% improved by 2 grades; Rolling and boxcar scars showed better response than ice-pick scars (based on the Qualitative Global Scarring Grading System)	Pain, erythema, oedema, hyperpigmentation and track marks
Chapas et al.	2008	13	2.d	Ablative fractional CO_2 laser resurfacing	Mean scar improvement of 66.8%	Erythema, oedema, petechiae, oozing, crusting and hyperpigmentation
Cho et al.	2009	12	2.d	Non-ablative fractional Er:Glass laser	Mean improvement of 2.8 (based on a 4-point scoring system)	Pain, erythema and oedema
Chrastil et al.	2008	29	2.d	Non-ablative fractional erbium laser	5 patients achieved $>$ 75% improvement, 18 achieved 50–75%, 5 achieved 25–50%, and 1 achieved $<$ 25% improvement	Discomfort, erythema and oedema
Engin et al.	2012	21	2.d	Ablative Er:YAG laser	Near total improvement in 19%, good in 57% and fair in 24%	Erythema, crusting, oozing and aggravation of active acne lesions
Gonzalez et al.	2008	9	2.d	Plasma skin regeneration system	Mean improvement of 34.4%	Pain, pruritus, erythema, hyperpigmentation and herpetic lesions
Hu et al.	2011	34	2.d	Ablative fractional Er:YAG laser	Good to excellent improvement in 63.6% and fair improvement in 36.4%	Erythema, oedema, crusting and hyperpigmentation
Hwang et al.	2012	10	2.d	Fractional CO_2 laser resurfacing	Overall scar improvement of 2.9 (based on a 4-point scoring method)	Pain, pinpoint bleeding, erythema, oozing, crusting, oedema and hyperpigmentation
Keller et al.	2007	12	2.d	Non-ablative Nd:YAG laser	Mild to moderate clinical improvement was observed in most patients	Pain, burning, scarring and hyperpigmentation

(Continued)

Table 4. (Continued)

Authors	Publication year	Patients (n)	Level of evidence*	Treatment method	Cosmetic outcome	Adverse effects
Kim et al.	2011	20	2.d	Ablative fractional YSGG laser	Fourteen patients had 60–90% improvement and six had 40–59% improvement	Erythema
Majid et al.	2014	60	2.d	Fractional CO_2 laser resurfacing	Excellent response was observed in 43.3%, good in 25% and poor in 31.7%; Rolling and superficial boxcar scars responded the best and ice-pick scars responded the least	Erythema, crusting, oedema, acneiform eruption and hyperpigmentation
Nirmal et al.	2013	25	2.d	Ablative fractional Er:YAG laser	96% of patients showed at least fair improvement; Rolling and superficial boxcar scars showed significantly higher improvement compared to ice-pick and deep boxcar scars	Crusting, hyperpigmentation, acneiform eruptions and erythema
Omi et al.	2011	7	2.d	Fractional CO_2 laser	Some improvement in scarring was observed in all patients	Erythema
Park et al.	2015	20	2.d	Fractional RF and sublative fractional RF	Mean improvement in rolling scars 3.3, boxcar scars 2.7, and ice-pick scars 1.8 (based on a 4-point scoring system)	Pain, crusting, erythema, flushing, oozing, hyperpigmentation and aggravation of acne
Peterson et al.	2011	15	2.d	Combined RF and fractionated RF	Mean scar severity decreased by 72.3%	Discomfort
Petrov et al.	2016	40	2.d	Fractional CO_2 laser	Average scores pre and post treatment: • Ice-pick: from 3.46 to 1.86 • Rolling: from 4.1 to 2.37 • Boxcar: from 3.5 to 1.9 (based on a 4-point scoring method)	Erythema, oedema, prickling sensation and hyperpigmentation
Ramesh et al.	2010	30	2.d	Matrix-tunable RF	4 patients achieved > 60% improvement; 18 patients achieved 35–60% improvement; 8 patients achieved < 35% improvement	Burning and erythema
Sardana et al.	2014	35	2.d	Non-ablative fractional Er:Glass laser	Boxcar scars: mean improvement of 52.9%; Rolling scars: mean improvement of 43.1%; Ice-pick scars: mean improvement of 25.9%	Erythema, oedema, pain, acneiform eruptions, dryness and hyperpigmentation
Taub et al.	2011	20	2.d	Sublative fractional bipolar RF combined with non-ablative diode laser	Significant improvement in scar appearance	Erythema and oedema

Table 4. (Continued)

Authors	Publication year	Patients (n)	Level of evidence*	Treatment method	Cosmetic outcome	Adverse effects
Tay et al.	2008	9	2.d	Minimally ablative Er:YAG laser	Mild to moderate improvement was noted in all patients	Pain, erythema, peeling and crusting
Trelles et al.	2014	19	2.d	Fractional ablative microplasma RF combined with acoustic pressure ultrasound (US)	Back and shoulder scars: mean score improved from 3.15 to 1.77 ($P < 0.0001$); Facial scars: mean score improved from 3.64 to 1.89 ($P < 0.0001$) (based on a 6-point scoring method)	Pain, prickling sensation, erythema, oedema and crusting
Vejjabhinanta et al.	2014	26	2.d	FRM	Excellent improvement in scar appearance in 8% of patients, good in 23%, fair in 36.5%, and slight in 32.5%	Pain, oedema, erythema, scabbing and pigmentary changes
Verner et al.	2016	12	2.d	Fractional bipolar RF	All patients achieved very good improvement in appearance	Discomfort, erythema, oedema and crusting
Walgrave et al.	2009	30	2.d	Fractional CO_2 laser	Surface texture improved by 1.63 ± 0.85; Atrophy improved by 1.09 ± 0.82; Overall scar appearance by 1.73 ± 0.84 (based on a 4-point scoring method)	Pain, oozing, punctate bleeding, erythema, oedema and hyperpigmentation
Wang et al.	2013	37	2.d	IPL followed by fractional CO_2 laser	Scar appearance improved slightly, but non-significantly ($P > 0.05$) after IPL, whereas it improved significantly after CO_2 treatment ($P < 0.05$)	Pain, comedone and pustule formation, and erythema
Yeung et al.	2012	20	2.d	Non-ablative fractional diode laser combined with bipolar RF	Mean reduction in scarring of 29%	Pain, erythema, oedema and hyperpigmentation
Yoo et al.	2009	16	2.d	Non-ablative fractional erbium laser	Overall scar improvement: > 75% in 25% of patients, 51–75% in 38%, 25–50% in 25%, 0–25% in 13%	Erythema and oedema

* Joanna Briggs Institute classification.

Even though no direct comparison with FRM is available, efficacy seems to be better against rolling and boxcar type scars.[9] Results seem to be inferior to those achieved by ablative resurfacing, and comparable but slightly inferior to those achieved by FP.[1]

Combined treatment with FRM and sublative fractional radiofrequency lead to excellent outcomes with apparent synergistic effects between the two modalities, while maintaining a safe profile.[10]

Because FRM affects a smaller fraction of the epidermis than most lasers (5% in FRM vs. 10–70% in FP), it was also associated with milder pain, lesser frequency and extent of hyperpigmentation, and shorter downtime.[1] Therefore, FRM may be a good option in patients who are sensitive to pain, those at risk of hyperpigmentation (darker skin phototypes or prior history of post-procedural hyperpigmentation) or those who prefer a shorter downtime.[1,9]

The long-pulsed Nd:YAG achieved moderate efficacy against atrophic acne scars, mainly superficial boxcar and rolling scars, with measurable and statistically significant increase in the number of collagen fibres.[28,35,46] Combination treatment with the Nd:YAG and PDL lasers leads to synergistic effects.[28]

The picosecond laser is a promising modality in this field. Unfortunately, small numbers of patients were treated with this laser as only one study utilised a 755-nm picosecond laser with a diffractive lens array. Results showed a 25–50% improvement against rolling type scars with minimal pain, little downtime and no pigmentary changes.[37]

The efficacy of the non-ablative diode in isolation has been found to be low against acne scars while also leading to significant discomfort (especially in those with darker skin).[24,31]

Even though the efficacy improved when treatment was combined with RF, it is unclear whether any synergistic effects were manifested.[24,55,62]

The ablative YSGG laser achieved excellent improvement in appearance, in the range of 40–90%. However, given the small numbers of patients treated with this device, it is hard to judge the place of this modality in the overall treatment pathway of acne scars. Further studies are required to reach more conclusive results.

The plasma skin regeneration system (PRS) has been advocated as an alternative to ablative and fractional resurfacing lasers. It utilises RF in order to convert nitrogen gas into plasma. The plasma is then directed onto the skin via a handpiece, delivering thermal energy in a precise manner.[43] Efficacy against acne scars was found to be moderate.

Benefits of this device include a lower cost, better safety and shorter downtime than ablative devices, and less training required for the operator.[43] It is also worth noting that significant discomfort and hyperpigmentation are potential drawbacks to its use.[43]

One of the main problems of reviews in this field lies in the difficulty of comparing outcomes. Although several different grading systems have been proposed to standardise acne scar classification and evaluation, there is no universal accepted scale. Similarly, there is no widely accepted device for measuring acne scar improvement in a reproducible and objective fashion. The lack of such standardisation has led to great variability in evaluation and interpretation of data across different studies.[37,54]

Another important drawback lies in failing to identify the type of atrophic scar being treated. The depth of penetration of most lasers seems appropriate to ameliorate most superficial and some deeper scars (rolling and boxcar scars); however, ice-pick scars extend vertically to the deep dermis or subcutaneous tissue and are likely deeper than the depth that can be reached with conventional lasers.[54] Because acne scars are usually a mix of ice-pick, boxcar and rolling scars, the final effect of fractional lasers would likely depend more on the predominant scars than on the fractional laser being used.[54]

Conclusions

Multiple devices have been used with varying levels of efficacy and very different safety profiles.

There is an overall lack of high-quality evidence about the effects of different interventions because of poor methodology, underpowered studies and different scarring subtypes being assessed. Furthermore, no standardised scale is available for acne scarring, leading to variability in evaluation and interpretation of data in different studies.

Ablative lasers seem to achieve the highest degree of efficacy among all devices tested, albeit this is associated with significant pain and downtime, and the risk for long-term pigmentary changes. Non-ablative FP has a much safer profile but does not achieve as good cosmetic results. The efficacy of FRM and RF is slightly inferior to that of FP but offers an even safer adverse profile. Little evidence is available on the remaining devices, with larger studies required to reach more solid conclusions.

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