Fractional Carbon Dioxide Laser: Optimizing Treatment Outcomes for Pigmented Atrophic Acne Scars in Skin of Color

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Abstract

Dark skin type has high propensity to acne scarring and is often complicated by persistent erythema or pigmentation at the base. Fractional lasers are available for the longest period and are able to improve most atrophic acne scars. Often pigmented scar bases and dark skin types limit the use of aggressive laser parameters. Long pulse mode is preferred over short pulse to prevent epidermal damage; low fluence is chosen versus high fluence and low density versus high density. Repeated treatments are needed to minimize complications and optimize results; all these must be achieved through a controlled stage of inflammation. Interventional priming with chemical peels and laser toning before ablative fractional carbon dioxide laser helps to reduce photodamage, recent tan, and pigment at scar base, thus minimizing the risk of post-inflammatory hyperpigmentation. Multiple recent literature evidence validates the combinations to optimize outcomes in atrophic acne scars as discussed in this review article.

Keywords: Combination therapies, fractional ablative lasers, pigmented atrophic acne scars, skin of color

Introduction

Acne scars are a sequela of deep, persistent, and inflammatory acne. Individuals who scar after acne have specific biochemical characteristics in their skin, which predispose them. Managing acne scars is a challenge, and treating pigmented acne scars in skin of color multiplies this challenge.

Multiple treatment modalities for surgical to nonsurgical, peels to lasers and energy-based devices, and ablative to nonablative fractional and nonfractional are available in our armamentarium to improve acne scars [Table 1]. Of all the various modalities available, fractional lasers are available for the longest period and are able to improve most atrophic acne scars. Combination of technologies when used sequentially or rotationally improves outcome, thus minimizes side effects. The results are better lasting. Multiple recent literature evidence validates combinations to optimize outcomes in atrophic acne scars as discussed in this review article.

Acne scars morphology

Progressive scarring with acne clearance is a known phenomenon. Scars have various morphological characteristics and vary in size, shape, and depth, and are thus graded in various types as rolling, boxcar, and ice pick types. Goodman and Baron classification for acne scars is a standard tool for assessing atrophic scars and are graded from types 1–4.[1] Clinically, in addition to grades of atrophic scars, one needs to assess their stage of development, early scars may be erythematous, as they progress they may get purplish or pigmented. Pigmented scars are a prominent feature in Indian skin, which belongs to Fitzpatrick types 3–5[2,3] [Figures 1 and 2]. Acne scars in an individual maybe of mixed types and may be distributed pan-facially with variable appearance in different face zones. Dark skin type has high propensity to acne scarring and is often complicated by persistent erythema or pigmentation at the base.[4] Initial erythema may be replaced by purplish base, which may later pigment. Coexisting active acne may be superimposed[3] [Figure 3].

Access this article online

Quick Response Code:

Website: www.jcasonline.com

DOI: 10.4103/JCAS.JCAS_171_18

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How to cite this article: Arsiwala SZ, Desai SR. Fractional carbon dioxide laser: Optimizing treatment outcomes for pigmented atrophic acne scars in skin of color. J Cutan Aesthet Surg 2019;12:85-94.

Pathogenesis for acne scars

Scientific studies highlight that prolonged inflammation leads to scarring and if the inflammation is persistent then scarring may be progressive.[5] High-grade acne leads to high degree of inflammation as seen with papulonodular and cystic acne; dermal insult to tissue metalloproteinases is more long lasting and results in a decrease of tissue leading to atrophic scars. If the inflammation is nonspecific but robust and generates early angiogenesis with a quick resolution, there will be minimal scars. In all those cases, where more specific, ineffectual, but prolonged inflammatory response and angiogenesis are seen are the scarrers. Involvement of epidermis, upper, or deep reticular dermis defines the depth of acne scars and also the treatment choice.[5] Mild-to-moderate scars involving epidermis and papillary dermis respond to resurfacing laser or other technologies [Table 1], whereas the deep scars involving reticular dermis require more aggressive or combination modalities.[6]

Clinical characteristics and assessment of pigmented acne scars

Fitzpatrick skin types 3–6 are predisposed to more inflamed acne and hence more pigmentation (post-inflammatory hyperpigmentation [PIH])[3,4,7] than erythema. This results in pigmented acne and acne scars and has been proven histologically.[2,7-9] Histological studies in post-acne pigmented macules revealed epidermal melanin granules and dermal melanophages infiltration up to the reticular dermis, along with foreign body granulomas and giant cells.[9,10] Callender and Davis[4] have postulated that this heightened inflammatory response may be a major reason that African Americans with even mild-to-moderate acne still develop hyperpigmented macules, which were studied by histopathology, showing dilated, distorted, keratin-filled follicles consistent with comedones and patchy chronic inflammation.[1,8] Kligman and Mills[11] described comedogenicity of cosmetic products applied on face because of the presence of certain ingredients in their formulas also called as acne cosmetica. In skin of color with acne lesions, increased use of cosmetic products may inadvertently be a causative factor for acne and PIH.[11]

A thick stratum corneum, large melanosomes, and a thick dermis with abundant fibroblasts constitute morphological features in a dark skin prototype 4–6.[9] According to the author, interventional therapies for skin of color revolve around achieving optimum outcome, creating no pigmentary sequelae. Aggressive modalities are hence replaced by less aggressive, safer options. Repeated treatments are needed to minimize complications and optimize results; all these must be achieved through a controlled stage of inflammation as inflammatory mediators play a large role in progressive scars. Features that influence choice of therapy and predictability of outcomes include the presence of active acne, degree of erythema or pigmentation at base, scar type and grading, skin stretch test where stretchable scars have better improvement than adherent ones, which need subcision.

Table 1: Interventional modalities for atrophic acne scars

Grade 1 atrophic acne scars—macular	Peels, microdermabrasion, dermaroller, nonablative lasers
Grade 1 atrophic pigmented scars	Peels, dermaroller, nonablative lasers, QS laser toning with DRT, fractional erbium/CO_2 lasers. Transepidermal delivery of growth factors, vitamin C
Grade 2 atrophic scars	Peels and DRT, QSLT and DRT, peels and fractional erbium/CO_2 lasers, QSLT and fractional lasers, all of the above with PRP
Grade 3 atrophic scars	Laser combinations ablative and nonablative, erbium and CO_2 fractional, with peels/PRP, microneedle RF with PRP, with HA
Grade 4 atrophic scars	Subcision with fractional CO_2, with peels/PRP, microneedle RF with PRP, combination with transepidermal drug deliveries, with HA

DRT = Dermaroller therapy, RF = Radio Frequency, HA = Hyaluronic Acid, QSLT = Q- Switched laser toning

Principle of fractional photothermolysis

Laser resurfacing delivers monochromatic light into the scars and subsequent heat initiates collagen injury and neocollagenesis.[12]

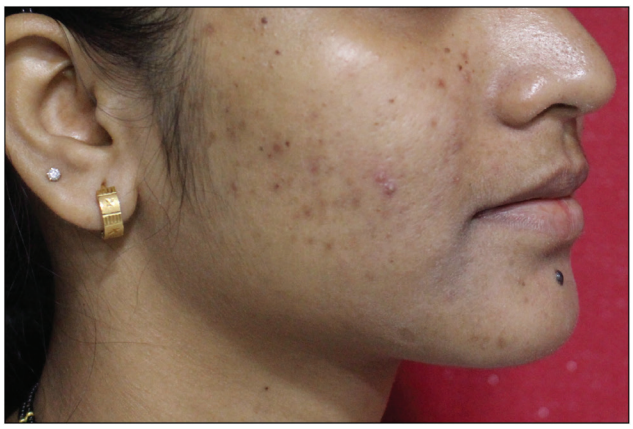

Figure 1: Pigmented macular atrophic acne scars

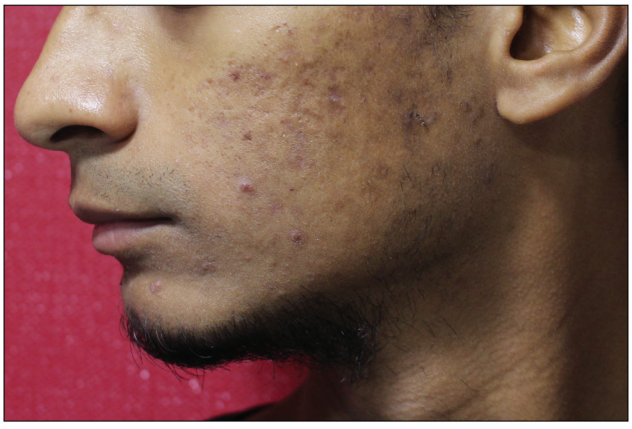

Figure 2: Pigmented atrophic acne scars (grade 2)

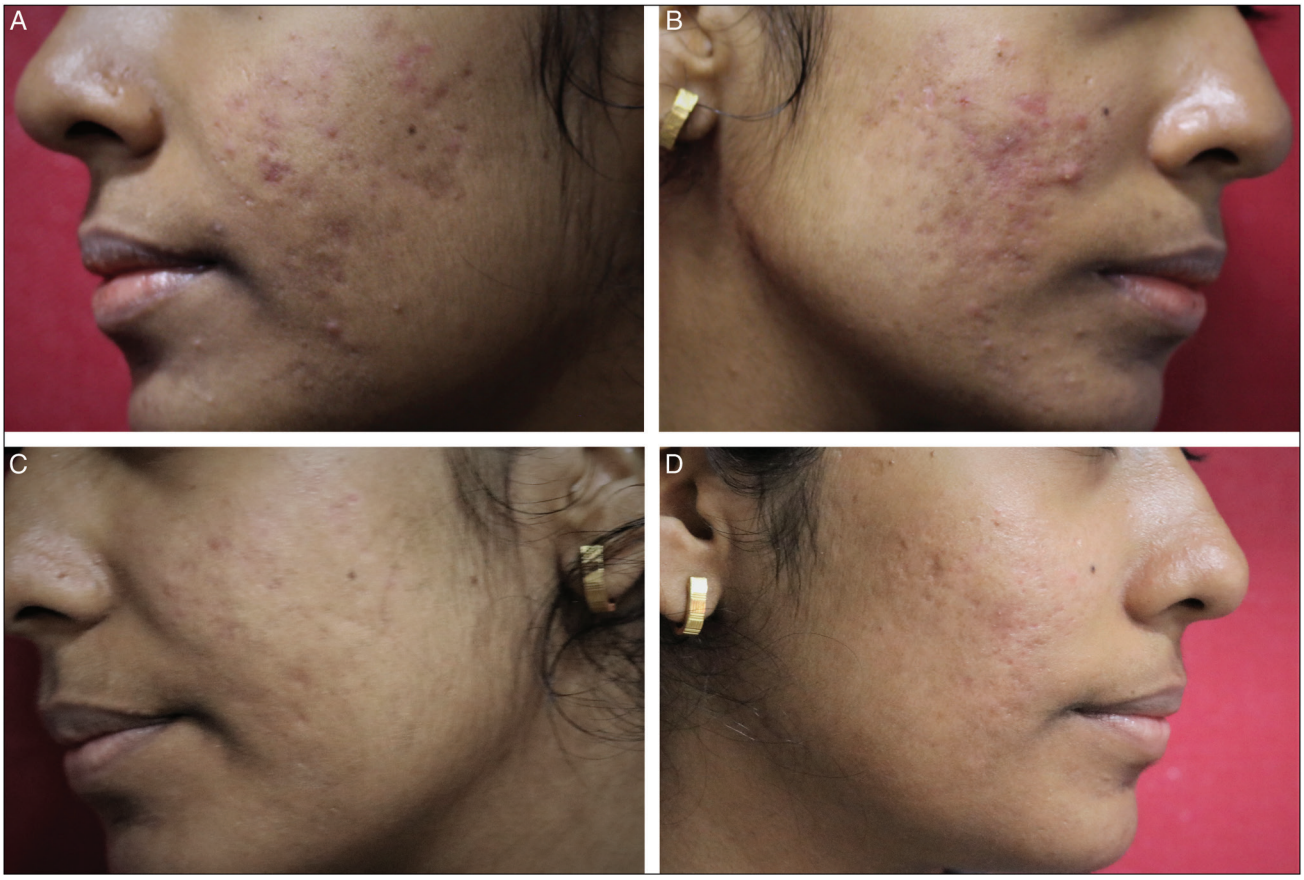

Figure 3: Erythematous acne scars (grade 3) with few active acne lesions. (A and B) before, (C and D) after peels and AFRCL

Manstein *et al.*[13] introduced the concept of fractional photothermolysis (FP). Their FP device tends to emit laser beam into pixilated manner, producing array of microthermal zones (MTZ) and creating microscopic channels by thermal injury to the skin.[13]

In contrast to ablative devices, which produce uniform and confluent patch by ablative epidermal and dermal injury, fractional resurfacing (FR) produces MTZ by ablating epidermal and dermal tissue in regularly spaced channels on the skin surface leaving intervened skin untouched, which leads to faster healing of ablated columns of tissue.[14,15]

The depth, density, and size of microthermal columns depend on the type of device and parameters used, that is, fluence, wavelength, density, and stacking of the pulse. A study reported that in atrophic acne scars with a density of 100 spots/cm^2, an energy of 100 mJ would reach a depth of 1236 μm with a coverage of around 8.6%.[14] Microthermal channels have epidermal and dermal debris, which get eliminated by transepidermal elimination.[14-16] It is followed by stimulation of reepithelialization and repair mediated through adjacent intact tissue, and thermally ablated channels get repopulated by fibroblast-derived neocollagenesis. Healing is faster as the large percentage of intervening area is not affected. Four to six treatments are performed, each treatment at the interval of 30–45 days. Neocollagenesis is significant after 3 months and continue for 6 months.[17]

Advantages of FP include the following:

1. Reduced postprocedural erythema and edema
2. Less chances of PIH as water in collagen is the chromophore
3. Less downtime
4. Better patient compliance and acceptance photothermolysis

Ablative fractional resurfacing with CO_2 laser

The wavelength of CO_2 lasers is 10,600 nm. It has high affinity for water, which is the chromophore and targets 20–60 μm depth of epidermal and papillary dermal layers, the surrounding zone of thermal damage extends up to 20–50 μm.[13] MTZ are formed and are variable according to the fluence used and the depth of penetration achieved. Thermal injury generates coagulation and denaturation of collagen and reepithelialization ensues. Fractional ablation of epidermis and dermis is enabled thus reepithelisation is facilitated from the surrounding non ablated skin and appendages.

Ablative fractional resurfacing with CO_2 laser (AFRCL) is evidenced based for resurfacing atrophic acne scars of moderate-to-severe variety [Table 2]. Multiple studies

Table 2: Studies for AFRCL on atrophic acne scars

Fractional laser/ carbon dioxide laser	Type of scar	Parameters	Outcome
Majid and Imran[19] (60 Indian patients)	Atrophic acne scars	Fractional carbon dioxide Laser as monotherapy	Excellent response was observed in 26 patients (43.3%), whereas 15 (25%) and 19 patients (31.7%) showed a good and poor response, respectively. Rolling and superficial boxcar scars responded the best, whereas pitted scars responded the least to fractional laser monotherapy.
Chapa *et al*.[20] (13 patients types 1–4)	Moderate-to-severe atrophic acne scars	Higher pulse and larger microscopic treatment zones	Significant improvements of 26%–50% on a quartile scale and improved scar depths of 66.6%. Drawback: erythema, which resolved within 1 month in most patients
Jung *et al*.[18] (10 Korean patients)	Atrophic acne scars	Split face, Evaluator blinded, lower fluence, high density vs. higher fluence, low density	A high-fluence, low-density setting has been shown to be more efficacious than a low-fluence, high-density setting
Manuskiatti *et al*.[21] (13 Asian patients) with Fitzpatrick skin type 4	Atrophic scars in Asian patients	Four treatment sessions over a 7-week duration	Scar smoothness and volume improved, 25% and 50% improvement 6 months after treatment
Cho *et al*.[22] (20 Korean patients)	Atrophic acne scars	Selected deep scars, small spot size, coagulation, and larger spot size for rest of face for rejuvenation, 3 months	Moderate-to-good improvement in deep scars and improved rejuvenation
Hedelund *et al*.[23] (13 patients)	Atrophic acne scars	Low-pulse energies of 48–56 mJ accounted for the modest results	Modest improvement in scar texture and scar atrophy
Trelles *et al*.[16] (40 patients types 2–4)	Atrophic acne scars	Single session, medium settings (2 Hz, 30 W, 60 mJ) were used, and two passes were made for dark skins and degree 1 wrinkles. High settings (2 Hz, 60 W, 120 mJ) were used, and three passes were made	Treatment improved, wrinkle aspect and scar condition, and no patient reported adverse effects or complications, irrespective of skin type

support the efficacy of AFRCL for atrophic acne scars. Various parameters, densities and fluence levels, modes, and the respective outcomes were studied by multiple authors and are enumerated in Table 2.

Often pigmented scar bases and dark skin types limit the use of aggressive laser parameters. Long pulse mode is preferred over short pulse to prevent epidermal damage, low fluence is chosen versus high fluence and low density versus high density.[18] Though this becomes safer to prevent PIH in dark skin, it results in less depth of penetration and less deeper thermal effects on acne scars.[3] Topical priming agents are often insufficient to prevent PIH when optimum parameters need to be used. Fractional lasers do not correct pigmentation at the base of scars.[3]

According to the author's experience, while conducting AFRCL for moderate-to-severe atrophic scars, dual modes of operation in the same system enable better treatment outcome where the stack mode enables high-fluence laser ablation of individual scars, and the dynamic mode with mosaic pattern of beam delivery enables textural improvement of the unscarred surrounding skin. At higher fluence and low average density with a moderate peak power, one can safely treat deep scars focally in static mode. With a low fluence and high average density and larger scan size, one can treat surrounding skin and rest of the face for textural improvement.

The conclusions drawn on the basis of the various studies [Table 2] were that ablative fractional resurfacing (AFR) improved the depth and appearance of acne scars by as much as 50% after a series of four to five treatments performed on a monthly basis. All studies reported textural improvement. A high-fluence, low-density setting has been shown to be more efficacious than a low-fluence, high-density setting. For deep scars one can selectively treat with small spot size and rest of face can be treated with large spot size and low fluence for textural improvement thus enabling dual mode treatment pattern to improve overall outcome for atrophic acne scars.[16,18,22]

Furthermore, FP significantly improved acne scars with PIH as well as scar volume. Improvement was better appreciated after 6 months of sessions as neocollagenesis sets in. As with all laser treatments in skin of color, treatment levels should be increased with caution.[16,18,22]

Special considerations for pigmented acne scars in skin of color

Priming: Before embarking on laser therapy for atrophic pigmented acne scars, one must ensure resolution of active acne and adequate priming [Figures 3–6]. As pigmented acne scars limit the use of high-fluence parameters, priming is mandatory, especially in dark-skin prototypes. Priming reduces wound healing time and decreases the risk of PIH, it determines patient tolerance and establishes patient compliance. Added antioxidants/anti-inflammatory cosmeceuticals are the new focus in priming as are oral sunscreens, antioxidants as systemic priming agents. All

these enable ultraviolet damage protection and prevent pigment darkening and hence prepare the skin.

In cases of pigmented acne scars, as pigment at base of scar is a limitation for high-fluence laser therapy and often only topical priming agents are insufficient to alleviate pigmentation adjuvant therapies (such as chemical peeling) [Figure 3A–D, Figure 5A–D], low-fluence QS laser toning acts as interventional priming, the concept being to make the scars as skin colored as possible.[2,7,24]

Optimizing outcomes, advantages of peels/laser toning as priming agents:

1. Adjunctive therapy
2. Pigment elimination, textural improvements, and photodamage correction
3. Improve compliance and tolerance
4. Adherence to therapy and enables acne and squeal monitoring
5. Synergistic to fractional ablative lasers in treating atrophic scars
6. Enhances outcome to laser resurfacing
7. Used for acne and scars in males as skin is more seborrheic and thicker

Combinations rationale for combination therapies

Achieving synergism with multiple adjunctive therapies when combined shortens time interval to achieve results with albeit safer parameters [Figures 3–6]. Combination of technologies when used sequentially or rotationally improves outcome, thus minimizes side effects. The results are better lasting. The evidence from multiple recent literature validates combinations to optimize outcomes in atrophic acne scars. Table 3 shows the possible combinations.

Subcision

Adherence of rolling acne scars can be addressed with subcision before laser resurfacing sequentially or rotationally. It is less suited for ice pick and deep boxcar scars.[26] An 18- or 20-gauge needle breaks fibrous strands, holding the scar down, and elevates the scar and subcision also stimulates and produces neocollagen formation.[26,28] Multiple treatments may be required to achieve an optimal outcome.[25-30] Combination of ablative fractional and nonablative lasers is another rationale for reducing complications and optimizing outcomes in skin of color as studied by Kim and Cho[31] who combined it in a series of 20 Asian patients (skin prototypes 4–6) with atrophic facial acne scars. Good outcome was reported in scars and texture and pigment compared to stand-alone AFR.[31]

Combination with Quality-Switched (QS) neodymium-doped yttrium aluminum garnet (Nd:YAG) quasi-pulse nonablative and/or QS Nd:YAG low-fluence laser toning[24] is another combination with good synergism with AFRCL and is widely used for pigmented atrophic acne scars [Figure 4A–D].The

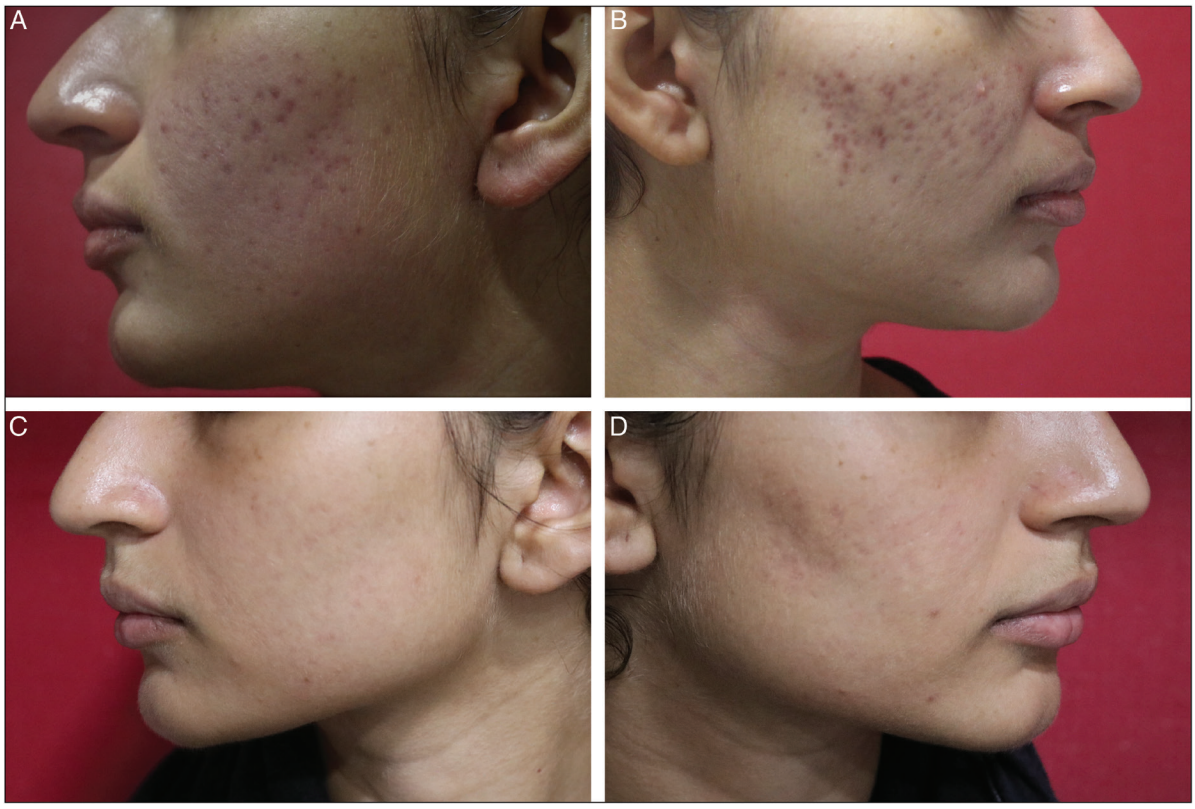

Figure 4: (A, B) Pigmented erythematous acne scars before. (C, D) Pigmented erythematous acne scars after nonablative quasi pulse Nd:YAG laser with AFRCL

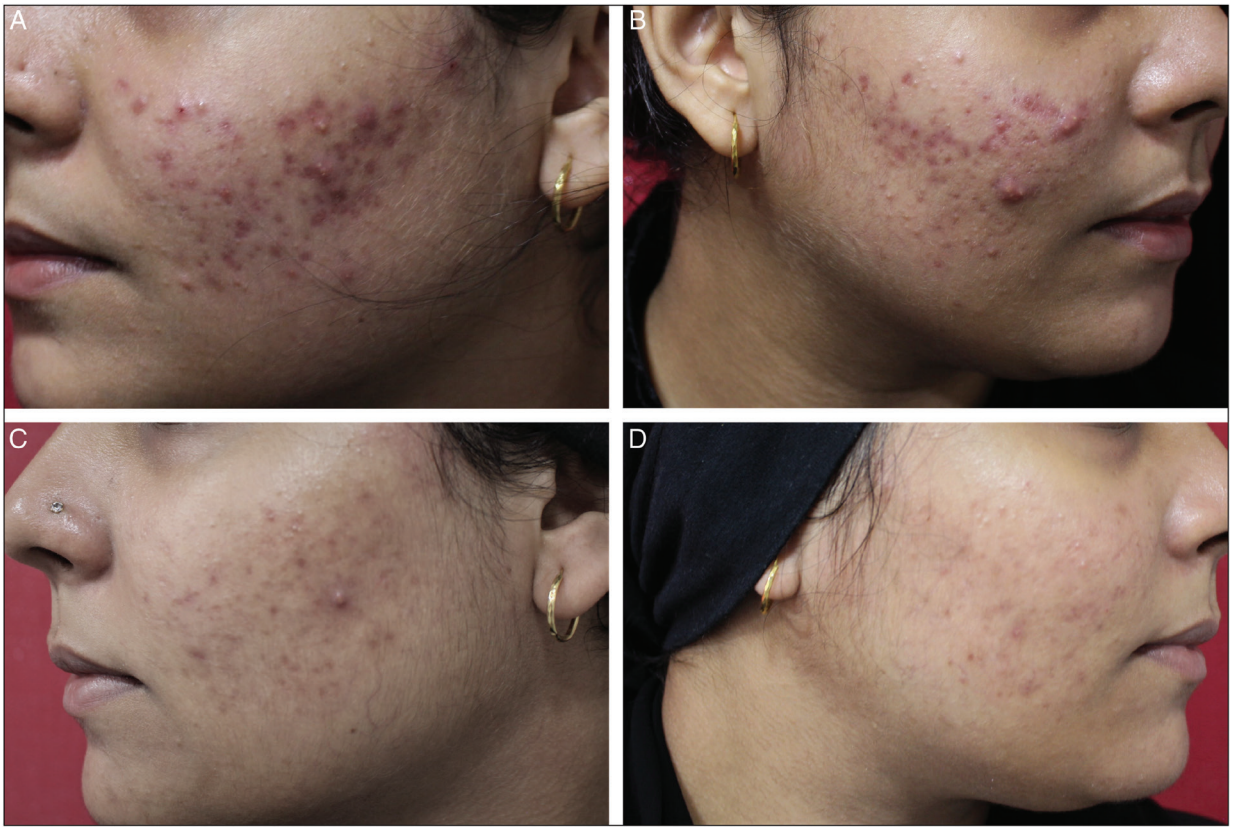

Figure 5: (A, B) Erythematous acne scars grade 3, with few active acne lesions. (C, D) Erythematous acne scars grade 3 after peels and AFRCL

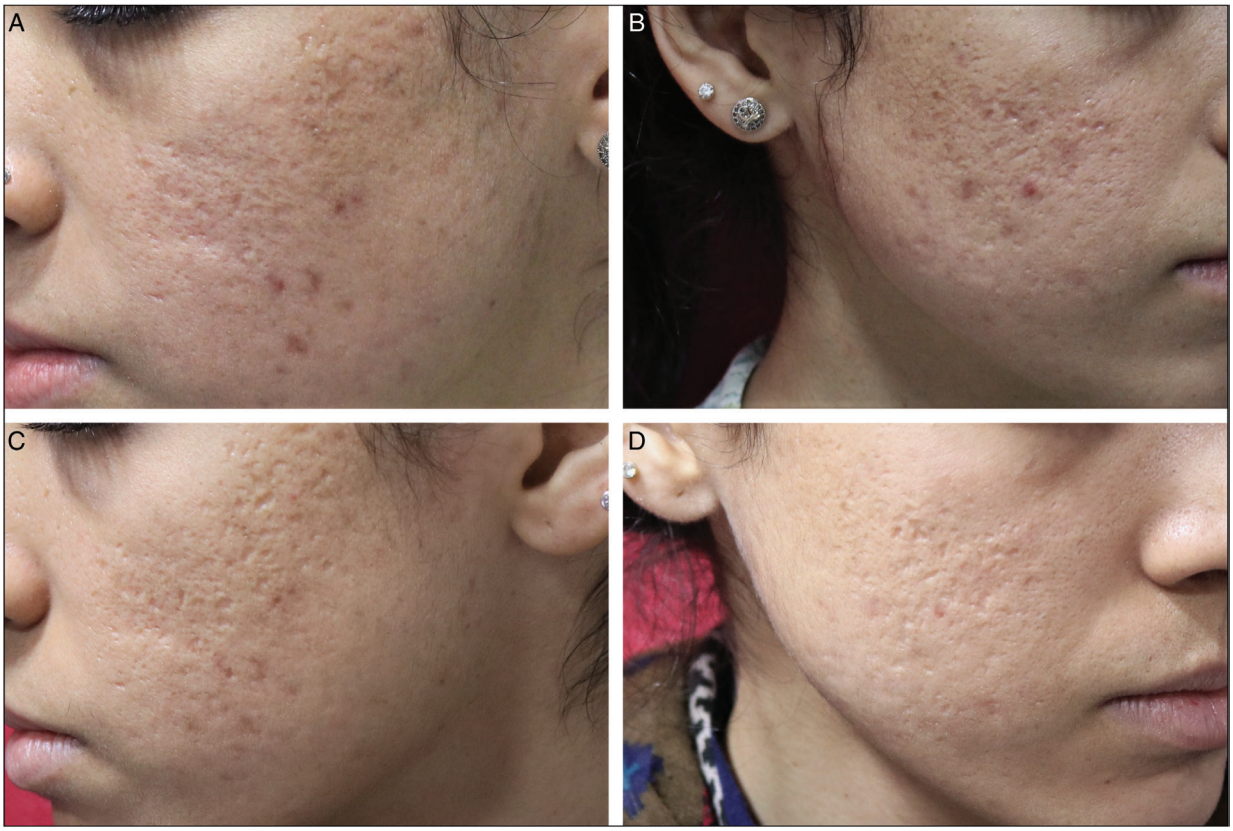

Figure 6: (A, B) Pigmented acne scars grade 3. (C, D) Pigmented acne scars after AFRCL with PRP

author uses the low-fluence laser toning before AFRCL as an interventional priming method.

Safety and efficacy of AFR with CO_2 laser are well documented, a few studies also elaborate longevity of the results from 1–2 years. Ortiz *et al.* reported clinical maintenance of the improvement in up to 74% among 10 patients.[32] The presence of inflammatory mediators and heat shock protein 47 in first 3 months after FR may attribute better appearance of improvement initially compared to that in long term, according to this study as shown by certain histologic studies.

Table 3: Synergistic possibilities in combination therapies for pigmented acne scars

Study	Method	Outcome
Split-face trail of 16 patients by Faghihi *et al.*[37], two sessions	One side treated with fractional CO_2 laser alone and the other side treated with a combination of fractional CO_2 laser with intradermal PRP	Better results and lesser side effects with combination
Gawdat *et al.*,[41] 30 patients, split face, 3 sessions, 6 months	PRP injected and applied after AFRCL vs. AFRCL alone	Combination better score with less pain after therapy
Abdel Aal *et al.*,[39] 20 patients	AFRCL vs. AFRCL with topical PRP	Better results with combination

Table 4: Studies of AFRCL combined with PRP

Interventional modality	Atrophic scar response
Peels	Improves acne, seborrhea, pigmentation, texture, and grade 1–2 acne scars
Microdermabrasion	Improves texture, grade 1 scars
Subcision	Adherent scars—boxcar scars
Microneedling	Types 1 and 2 scars
Lasers—nonablative	Types 1–3 rolling scars
Lasers fractional erbium	Types 1 and 2 scars
Lasers fractional CO_2	Types 1–4 scars
Lasers—QS Nd:YAG	Pigmentation in QS mode and types 1 and 2 scars in quasi pulse mode
Microneedle RF	Types 2–4 scars
PRP	Adjuvant for better healing and neocollagenesis
Transepidermal drug delivery	For hydration, pigmentation, repair, and textural improvement

RF = Radio frequency

Platelet-rich plasma

Autologous platelet-rich plasma (PRP) injected or delivered into the scars after laser treatment enriches the skin with potential bioactive growth factors and chemokines released on platelet activation and enables faster wound repair.[33] Studies indicate faster reduction of post-laser edema, erythema, and PIH.[34] Synergizing AFR with PRP is also known to actively reduce atrophic acne scarring[33] [Table 4] [Figure 6A–D].

Autologous growth factors and secretory proteins, chemokines, and cytokines released on platelet activation facilitate wound repair and rejuvenation in cosmetic dermatology, they act by stimulation of dermal fibroblast proliferation and increase type I collagen synthesis.[8,13,35] Both topical and intradermal PRP injections have been studied with variable results for acne scars.[9,36,37] Fractional CO_2 laser creates thermal wounds on the skin and also facilitates absorption gradient by a damaged epidermis and PRP is known to aid in wound healing, combining the two increases therapeutic outcome.[9,36,38-40]

Tips for treating pigmented acne scars with AFRCL are as follows:

- Use the fluence judiciously in darker skin (Fitzpatrick skin types 3–6). Parameters to be chosen with caution as chances of post-inflammatory pigmentation are very high.
- Priming with lightening agents and sunscreen should be started at least 3–4 weeks before first treatment, oral sunscreens can be added.

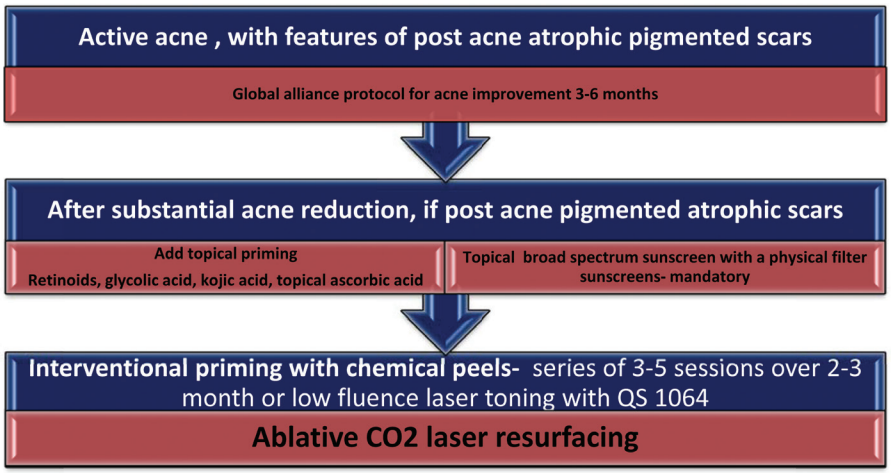

Chart 1: Algorithm for treating pigmented acne scars

- Interventional priming with chemical peels and laser toning before AFR helps to reduce photodamage, recent tan, and pigment at scar base, thus minimizing risk of PIH after AFR.
- Low-fluence, high-density treatments are safer for pigmented acne scars.
- History of oral isotretinoin and keloids formation to be elicited.

1. Oral isotretinoin should be discontinued at least 6–12 months before resurfacing procedures.[42] This is recommended based on earlier reports of keloid formation and atypical scar formation after treatment with argon lasers and dermabrasion, which are more invasive and ablative procedures.[42,43] Some of the recent studies suggest the safety of different procedures such as laser hair removal and dermabrasion in patients recently treated with oral isotretinoin.[44]
2. Postprocedural delivery of vitamin C, antioxidants and emollients, and PRP acts to facilitate better healing, rejuvenation.
3. Postprocedural emollients and sunscreen with antiviral and antibacterial prophylaxis when indicated minimize side effects.

Combinations with subcision, topical drug delivery, PRP, nonablative, and QS Nd:YAG lasers act by synergism and facilitate safer treatments and better outcomes. Charts 1–3 show the algorithm of combination treatments.

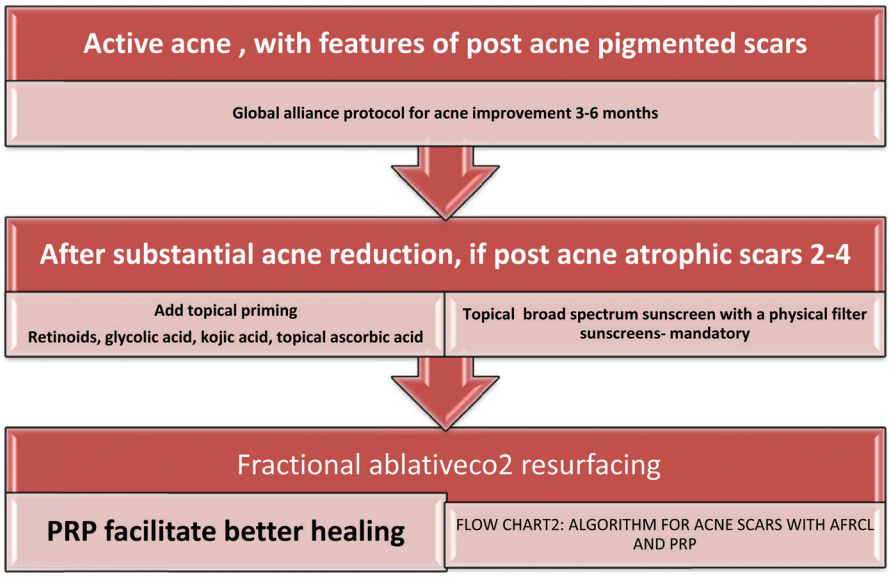

Chart 2: Algorithm for acne scars with AFRCL and PRP

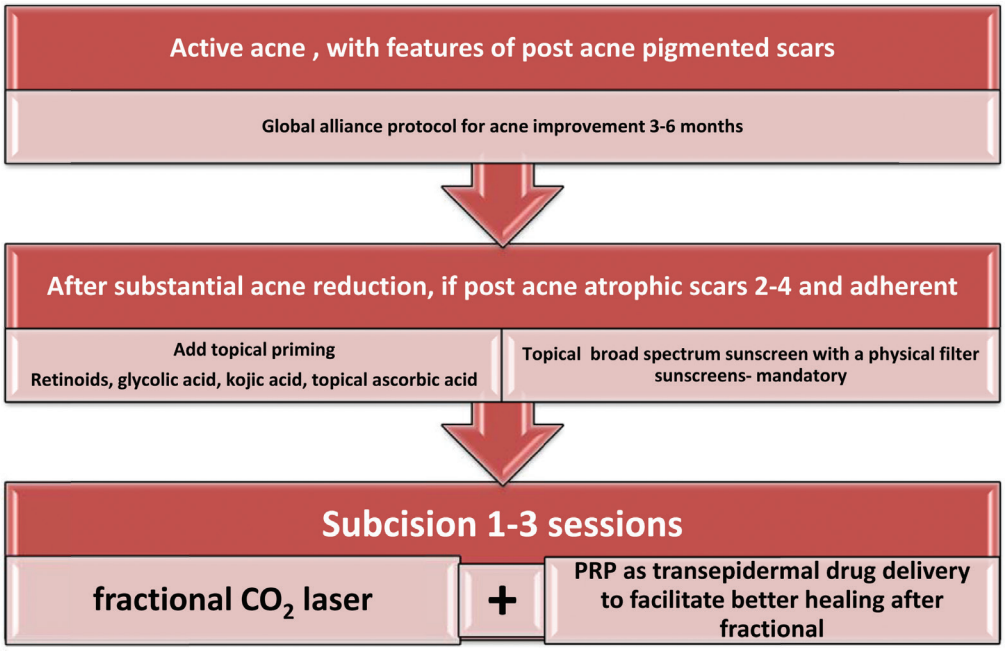

Chart 3: Algorithm for combining with subcision and PRP

Conclusion

The management of acne vulgaris and consequent scarring is a long-term process that must be individualized to each patient. Often we are dealing with patients who have coexisting active acne with acne scars. Problems while handling skin of color need great consideration while choosing aggressive modalities of treatment to avoid complications. For Indian patients, the current trends revolve around less aggressive and combination of various treatment modalities.

Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent forms. In the form the patient(s) has/have given his/her/their consent for his/her/their images and other clinical information to be reported in the journal. The patients understand that their names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

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