ABSTRACT

Background: Nonablative laser resurfacing represents one of the major advances in procedural dermatology over the past decade. However, its use in darker skin types is limited by safety concerns and a relative lack of available data.

Aim: To provide evidence-based recommendations for the use of fractional lasers in darker skin types.

Evidence review: A broad literature search of PubMed/Medline database was conducted in April 2016 using the term fractional lasers. A free text search of keywords including fractional resurfacing, nonablative lasers, skin type, skin of color, ethnic skin, Fitzpatrick skin type, Asian skin, African Americans, Afro-Caribbean, and Hispanics was also executed. An in-depth review of all the relevant articles fitting the authors' inclusion/exclusion criteria was performed. Thereafter, each study was assigned levels of evidence per the Modified Criteria by Oxford Center of Evidence Based Medicine. A recommendation was made for a specific treatment based on the presence of at least one Level 1 study or more than three Level 2 or 3 studies that had concordant results.

[Abstract continued on next page]

REVIEW

Nonablative Fractional Laser Resurfacing in Skin of Color: Evidence-based Review

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NONABLATIVE LASER resurfacing represents one of the major advances in procedural dermatology over the past decade and has become the treatment of choice for a broad range of aesthetic indications. However, safety concerns related to their use in darker skin types remain. The vast majority of studies of fractional laser resurfacing in non-white patient populations involve Asian skin types or are limited to Fitzpatrick skin photo types (SPTs) IV. Published data related to the treatment SPTs V and VI are limited. Herein, the authors review studies involving nonablative fractional lasers in the treatment of skin of color (SPT IV–VI) and suggest optimal parameters that can be used safely in these patients.

FRACTIONAL LASERS

The concept of fractional lasers was introduced by Manstein et al in 2004.[1] Since then, it has revolutionized the field of laser resurfacing. Fractional lasers create microscopic heat columns causing areas of thermal damage known as microscopic thermal zones (MTZs). These MTZs range from 100 to 400µm in width and approximately 300 to 700µm in depth.[2]

The MTZs are separated by areas of normal skin, which acts as a reservoir for tissue regeneration and remodeling. These zones comprise up to 15 to 25 percent of the skin surface area per treatment session.[3,4]

Fractional lasers can be further subdivided into ablative and nonablative depending on their impact on stratum corneum. Ablative fractional lasers have longer wavelengths in the range of 2940 to 10600nm and lead to full thickness destruction of skin. Whereas, nonablative fractional lasers have wavelengths ranging from 1320 to 1927nm and leave a functionally and histologically intact stratum corneum compared to nonablative fractional lasers. Ablative fractional lasers are usually associated with greater efficacy but longer recovery time and higher risk of complications in SPTs IV to VI.[4–7]

Table 1 delineates the types of fractional devices currently used in

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[Abstract continued]

Findings: The available evidence strongly suggests that fractional lasers are a favorable treatment option for a variety of dermatological diseases in Fitzpatrick skin phototypes IV to VI. Level 1 evidence was found for the use of fractional lasers for treating acne, striae and skin rejuvenation. Level 2 evidence was found for their use in acne scars, melasma, and surgical/traumatic scars.

Conclusion: Fractional resurfacing is a safe and efficacious treatment option for various dermatological disorders in darker skin types; however, there is a paucity of high-quality studies involving skin types V and VI.

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Table 1: Types of fractional lasers[8–15]

ABLATIVE FRACTIONAL LASERS	NONABLATIVE FRACTIONAL LASERS
10,600nm fractional CO_2 laser	1410nm laser
2940nm fractional Er:YAG	1440nm Nd:YAG laser
1790nm fractional Er:YSGG	1540nm laser
	1550nm Erbium laser
	1927nm thulium fiber laser
	1927nm Diode laser

Table 2: Inclusion and exclusion criteria

INCLUSION CRITERIA	EXCLUSION CRITERIA
1. Studies limited to human subjects and English language	1. Traditional lasers and ablative fractional devices
2. Articles assessing the use of nonablative fractional lasers for any dermatologic indication	2. Studies limited to SPT I–III
3. SPT IV or more	3. Studies that did not mention SPT
	4. Review articles, non-therapy studies, guidelines

SPT: Fitzpatrick skin photo type

practice.[8–15]

Melanin-rich skin types are more susceptible to pigmentary alterations post laser resurfacing due to direct (e.g., melanosome disruption) and indirect (e.g., postinflammatory) effects of treatment. A higher risk of keloid or hypertrophic scarring in patients of African or Asian ancestry is also a safety consideration in laser resurfacing involving dermal injury. Nonablative fractional lasers are mid infra-red lasers that target water instead of melanin and hence these lasers are safe for use in darker skin types.[8,16]

METHODS

The primary objective of this comprehensive review is to provide evidence-based recommendations for the use of nonablative fractional lasers in SPTs IV–VI. The authors sought to obtain all the published articles that studied nonablative fractional lasers in skin of color patients. A broad literature search of PubMed/Medline database was conducted in April 2016 using the term fractional lasers. An extensive PubMed search was conducted using the following search combinations: fractional lasers and acne vulgaris,

fractional lasers and acne scars, fractional lasers and melasma, fractional lasers and skin rejuvenation, fractional lasers and photodamage, fractional lasers and striae, fractional lasers and traumatic/surgical scars. The term fractional lasers was also combined with skin type search: fractional lasers and dark skin, fractional laser and ethnic skin, fractional laser and Fitzpatrick skin photo types, fractional lasers and skin of color and fractional lasers with Asian skin. A free text search of keywords, including fractional resurfacing, nonablative lasers, Fitzpatrick skin type, skin of color, ethnic skin, Asian skin, African Americans, Afro-Caribbean, and Hispanics was also executed. Appropriate filters were used to limit the search to only English language and studies involving human subjects. All the titles and abstracts were screened for relevance to our topic. Thereafter, full texts of all the relevant articles were reviewed to fit their inclusion/exclusion criteria (Table 2).

The inclusion criteria required articles to assess the use of nonablative fractional lasers for any dermatological indication in skin of color subjects. Where applicable, studies comparing nonablative fractional lasers with other treatment modalities were also included.

Articles limiting themselves to traditional lasers and ablative fractional lasers were excluded. The authors also excluded studies that were limited to SPTs I to III or failed to mention the SPT of their target population. Review articles, commentaries, letters, and posters were also excluded. References of all the included articles were reviewed to ensure completeness. An overview of the literature search is outlined in Figure 1.

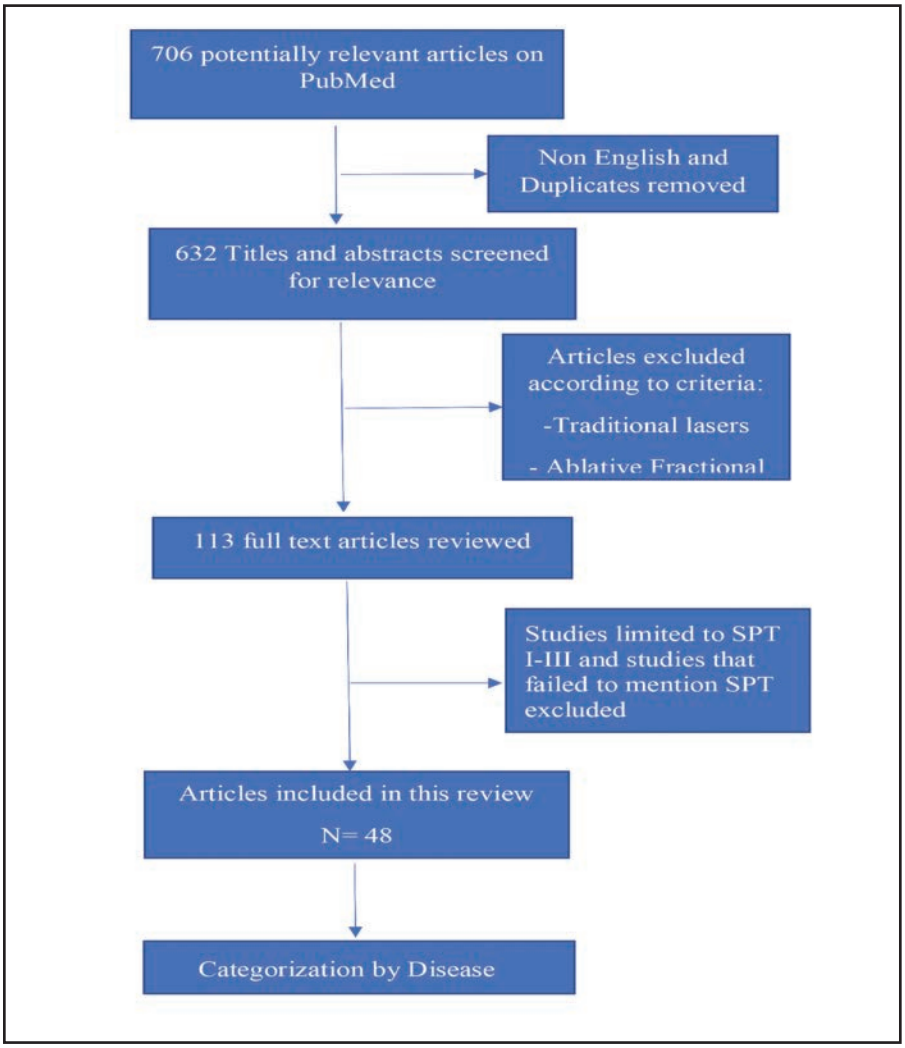

Figure 1. Overview of literature search

DATA EXTRACTION AND ANALYSIS

Forty-eight articles that met the authors' inclusion/exclusion criteria were identified. These were classified according to their study design, dermatologic indication and SPTs included (Figures 2, 3 and 4).

Randomized controlled trials (RCTs) and prospective right/left comparison studies (PRLCs) were further determined to be either high quality or low quality depending on whether they were placebo controlled and double blinded. Open-label trials (OLTs) were classified based on the number of patients involved in the study.

Thereafter, each study was assigned levels of evidence according to the Modified Criteria published by Oxford Center of Evidence Based

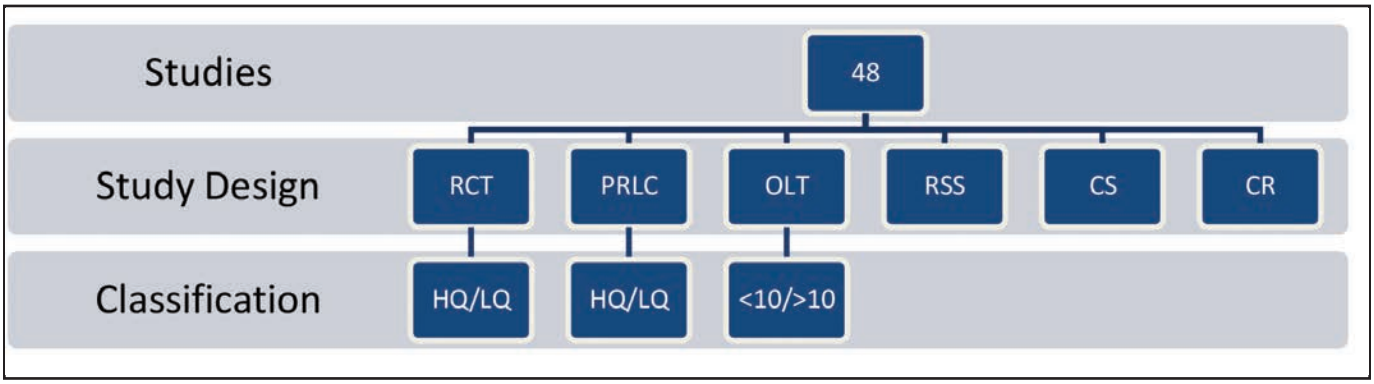

Figure 2. Classification of studies according to study design

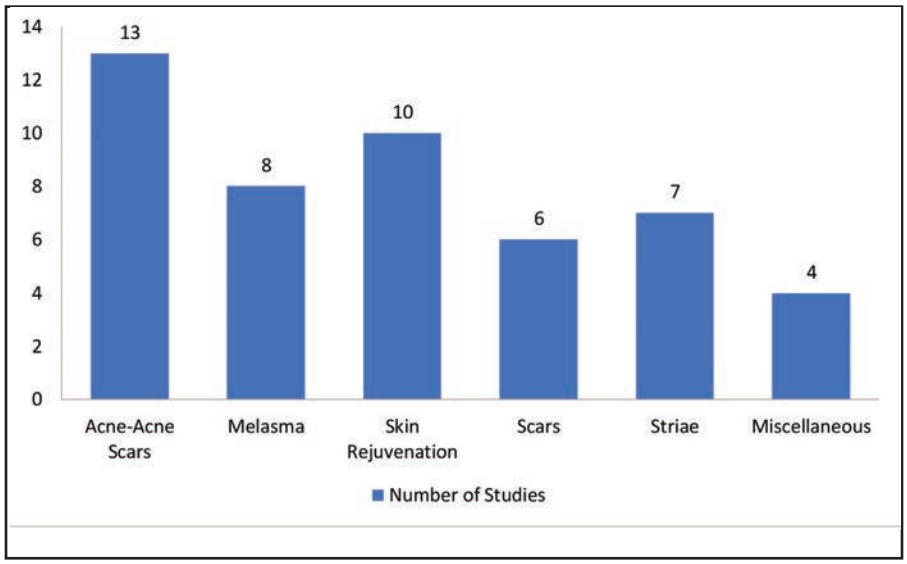

Figure 3. Categorization of studies according to disease entity

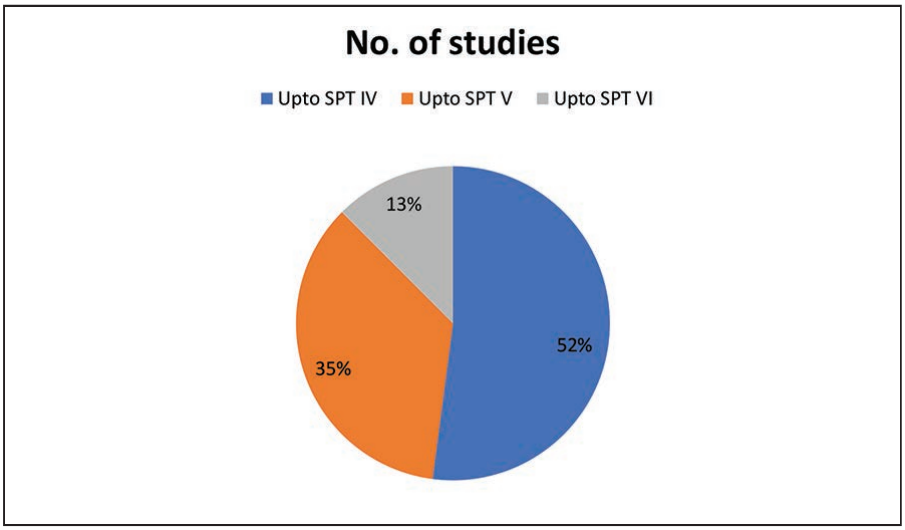

Figure 4. Number of studies including subjects with SPT IV, V and VI

Medicine (Table 3). A recommendation was made for a disease based on the presence of at least one Level 1 study or more than three Level 2 or 3 studies that had concordant results.

ACNE AND ACNE SCARS

Acne scars are a result of destruction of collagen secondary to inflammation. It is a potentially disfiguring condition and can be difficult to treat in skin of color patients owing to a higher risk of scarring and pigmentary abnormalities.[40]

A large number of studies have demonstrated the safety and efficacy of fractional lasers in treating acne scars in lighter skin types. Only a limited number of studies have included skin types IV to VI. Table 4 depicts the relevant details of these studies.[17–29]

Based on the studies mentioned in Table 4, fractional nonablative lasers are a safe and effective treatment option for acne scars in skin type IV to VI. Kim et al[18] reported that nonablative fractional laser is superior to chemical

Table 3: Levels of evidence. Evidence and recommendations are based on Modified guidelines by Oxford Center of Evidence Based Medicine

LEVELS OF EVIDENCE	TYPES OF STUDIES	RECOMMENDATION
1a	• Systematic review of randomized controlled trials (RCTs) with homogeneity • ≥2 high-quality RCTs (homogenous, consistent results) • ≥2 high-quality prospective right/left comparison trials (PRLCs) (homogenous consistent results)	A: Strong, consistent level 1 studies
1b	• Individual high-quality RCT • Individual high-quality RCT	
2a	• PRLC with control being "no treatment" • Multiple low-quality RCTs and/or PRLCs with concordant results	
2b	• Low-quality RCT • Low-quality PRLC • ≥3 placebo-controlled, open-label trials (OLTs) with concordant results	B: Moderate, consistent level 2 studies
2c	• Placebo-controlled OLT	
3a	• OLT with control being "no treatment"	
3b	• ≥3 case series (homogeneity, consistent results) • OLT with no controls, patients <10	C: Weak, consistent level 3 studies
3c	• Retrospective uncontrolled observational study	
4a	• Individual case series • OLT with no controls, patients <10	D: Very weak, consistent level 4 studies
4b	• Case reports (cumulative patient number ≥3) with homogenous patients, treatment results	
5	• Expert opinion without explicit critical appraisal • Based on physiology, bench research or "first principles"	Inconclusive, no recommendations made

QUALITY OF STUDY	CRITERIA
High-quality randomized controlled trial (RCT)	• Placebo controlled • Double blinded (investigator blinded) • Lack of significant unaccounted drop out subjects • Free of selected reporting • Matched treatment and control groups • +/- follow up
Low-quality RCT	• Lack of high quality controls • Or lack of 2 or more of above criteria • Or inadequacy/obscurity in 3 or more of above criteria

[Table continued on next page]

Table 3 (continued): Levels of evidence. Evidence and recommendations are based on Modified guidelines by Oxford Center of Evidence Based Medicine

QUALITY OF STUDY	CRITERIA
High-quality prospective right/left comparison trials (PRLC): Each patient receives same treatment and control in split-face body method	• Randomization • Placebo controlled • Double blinded (or investigator blinded) • Lack of significant unaccounted drop out subjects • Free of selected reporting • Matched left- and right-sided lesions • +/- follow up
Low-quality PRLC	• Lack of high quality controls • Or lack of 2 or more of above criteria • Or inadequacy/obscurity in 3 or more of above criteria

reconstruction of skin scars (CROSS) in treating rolling type acne scars and recommended that type of scars should be kept in mind when choosing between treatment options. Mahmoud et al[19] reported a statistically significant improvement in acne scars from baseline following treatment with nonablative fractional laser but improvement was not statistically significant between the 10mJ and 40mJ groups. No difference in incidence of postinflammatory pigmentation was observed among the two groups but pain was significantly higher in 40mJ group. Patients with skin type V and VI reported higher average pain scores than skin type IV patients. Chan et al[20] compared full nonablative fractional resurfacing (NAFR) (3 sessions/8 passes/ 442.5 MTZ/cm^2) with mini-NAFR (6 sessions/4 passes/210.5 MTZ/cm^2) in Asian acne scar patients. There was no difference in clinical efficacy between three sessions of full-NAFR and six sessions of mini-NAFR at the end of follow up; however, the incidence of postinflammatory hyperpigmentation (PIH) was statistically lower in the mini-NAFR group as compared to the full-NAFR group. A recent split-face study performed by Alexis et al[28] compared the effect of different treatment densities (220MTZ/cm^2 vs 393 MTZs/cm^2) on acne scars while keeping the fluence constant at 40mJ. There was no statistically significant difference between different density groups in regards to acne scar improvement and incidence of PIH.

A few studies have demonstrated the efficacy of nonablative fractional laser in treating active acne vulgaris in darker skin types. Moneib et al[24] studied the use of fractional lasers as a treatment of active acne vulgaris in 24 patients (SPT II–V) in a randomized controlled split-face study. Each patient received four treatment sessions at two-week intervals and were followed up every three months for a total duration of one year. This study noted a complete clearance of acne during treatment which was maintained during the yearlong follow-up period. Histological analysis was also performed which showed a significant decrease in size of sebaceous glands along with improvement in skin texture and sebum production. Another split-face study by Dainichi et al[21] studied the effect of fractional lasers in 12 Asian patients and reported a significant improvement in acne and skin tightening effect after two sessions.

In conclusion, nonablative fractional laser is an effective modality to treat acne vulgaris (Level 1b evidence) and acne scars (Level 2b evidence) in skin of color. The risk of developing PIH depends on numerous factors including SPT, laser device, and energy and density settings. However, treatment density is a stronger factor than energy in determining PIH development. More studies and experience are needed to determine the optimum settings to maximize the risk-benefit ratio, especially in skin type V to VI.

Table 4: Nonablative fractional lasers for acne scar resurfacing in SPT IV–VI

AUTHORS, YEAR	SKIN TYPES	NO. OF PATIENTS	SPT (IV, V, VI)	TREATMENT MODALITY	POSTINFLAMMATORY HYPERPIGMENTATION (PIH %)
Lee et al, 2008[17]	IV–V	27	Not mentioned	1550nm Erbium doped fractional laser	No PIH observed
Kim et al, 2009[18]	IV–V	20	Not mentioned	Split face: 1550 Er:Glass on one side and CROSS on other side	Not mentioned
Mahmoud et al, 2010[19]	IV–VI	15	4,10,1	1550nm Erbium fractionated laser Group A: 10mJ Group B: 40mJ (other parameters constant)	40% No statistically significant difference in PIH among two groups
Chan et al, 2010[20]	III–V	47	36,1,0	1550nm erbium doped fractional laser Full NAFR: 3 sessions, 8 passes, 442.5 MTZ/cm^2 Mini-NAFR: 6 sessions, 4 passes, 210.5 MTZ/cm^2	Full-NAFR: 18.2% Mini-NAFR: 6%
Dainchi et al, 2010[21] **Acne**	III–V	12	Not mentioned	1540nm Er:Glass fractional laser	NM
Cho et al, 2010[22]	IV	8	8,0,0	Split face, single session: One side 1550nm Er:Glass laser, other side 10,600nm ablative fractional CO_2 laser	12.5% One patient developed PIH on both treatment sides
Alajlan et al, 2011[23]	III–V	82	Not mentioned	Retrospective study Group A: 1550nm fractional laser Group B: 10,600nm ablative fractional CO_2 laser	17%*/ 33%** 14%*/41%**
Moneib et al, 2014[24] **Acne**	II–V	24	12,5,0	Split face: One side 1550nm Er:YAG Laser, other side served as control	No PIH observed
Leheta et al, 2014[25]	III–IV	39	22,0,0	Randomized to 3 groups Group 1: PCI + TCA 20% Group 2: 1540nm fractional laser Group 3: 1540nm laser alternating with PCI/TCA	Not mentioned
Rongsaard et al, 2014[26]	III–V	20	2,3,0	Split face: One side 1550nm Er:Glass fractional laser and other side fractional bipolar radiofrequency	Fractional laser :5% RF: No PIH
You et al, 2015[27]	IV	58	58,0,0	Retrospective study Comparison of ablative lasers and nonablative lasers	Ablative Lasers: CO_2: 80% ErYAG: 60% Fractional lasers: Ablative Fractional–20% Nonablative fractional–10%
Alexis et al, 2016[28]	IV–VI	12 enrolled, 9 completed	3,4,2	Split face: same fluence 40mJ, different densities: 200MTZ/cm^2 vs. 393MTZ/cm^2	Lower density: 43% Higher density: 71%
Cachafiero et al, 2016[29]	II–V	46	10,0,0	Randomized to 2 groups: Group A – 1340 fractional laser Group B – dermaroller	Laser – 13.6% Microneedling – No PIH

*Incidence of PIH in patients routinely given prophylactic bleaching creams post-procedure
**Incidence of PIH in patients who were not given post-procedure bleaching creams
SPT: Fitzpatrick skin photo type

Table 5: Nonablative fractional lasers for melasma in SPT IV to VI

AUTHORS, YEAR	SKIN TYPES	NO. OF PATIENTS	SPT (IV, V, VI)	TREATMENT MODALITY	POSTINFLAMMATORY HYPERPIGMENTATION (PIH %)
Naito et al, 2007[31]	III–IV	6	3,0,0	1550nm Er:YAG fractional laser	16.6%
Goldberg et al, 2008[32]	III–IV	10	4,0,0	1550nm Er:Glass fractional laser	No PIH observed
Wind et al, 2010[33]	II–V	29	8,3,0	Split face: One side of face 1550nm Er:YAG laser and other side TCC	NAF: 31% No PIH on TCC side
Kroon et al, 2011[34]	III–V	20	5,2,0	Randomized trial Group A: 1550nm Er:Glass laser Group B: TCC	No PIH observed in either group
Hong et al, 2012[35]	III–IV	18	Not mentioned	Split face: One side 1550nm Er:YAG laser and other side 15% TCA peel	28 % (5 patients developed PIH on both sides)
Wanitphakdeedecha et al, 2012[36]	III–V	30	Not mentioned	Randomized Split face – 1410nm: Group A: 20mJ, 5% coverage Group B: 20mJ, 20% coverage	Group A: 8.33% Group B: 14.16%
Kim et al, 2013[37]	III–V	26	Not mentioned	Split face: One side of face – Q switched Nd:YAG Other side – Q switched Nd:YAG + 1550nm Er:YAG	
Tourlaki et al, 2014[38]	II–V	76	13,0,0	Combination of 1540 nm Er:Glass laser + TCC	No PIH observed

SPT: Fitzpatrick skin photo type

MELASMA

Melasma is a challenging condition for both patient and doctors alike. Quality-of-life studies have shown significant negative impact of melasma on emotional wellbeing, social life, and leisure activities.[30]

Sun protection, bleaching creams, and chemical peels remain the first-line treatment modalities. Combination therapies are generally needed to tackle melasma owing to its chronic relapsing nature. Limited numbers of studies in the past have assessed the use of fractional laser in skin of color melasma patients (Table 5).[31–38]

Goldberg et al[32] performed a histological and clinical analysis of the effect of nonablative fractional laser in melasma. They noted a relative decrease in the number of melanocytes in the and clinical improvement post treatment. Wind et al[33] performed a split-face study comparing 1550 nonablative laser with triple combination cream (TCC). Worsening of hyperpigmentation was reported in nine (31%) patients on the laser treatment side. Overall patient satisfaction was significantly lower on laser side as compared to TCC side. At the end of the study, most patients preferred TCC over laser.

Table 6: Nonablative fractional lasers for skin rejuvenation in SPT IV–VI

AUTHORS, YEAR	SKIN TYPES	NO. OF PATIENTS	SPT (IV, V, VI)	TREATMENT MODALITY	POSTINFLAMMATORY HYPERPIGMENTATION (PIH %)
Kono et al, 2007[41]	III–IV	30	Not mentioned	Split face: 1550nm Er:YAG laser Different energy and density settings	6.6%
Jih et al, 2008[42]	II–IV	10	Not mentioned	1550nm diode pumped erbium fiber laser	No PIH observed
Leheta et al, 2013[43]	I–IV	24	Not mentioned	Randomized study: Group A: Dermal fillers + lipolysis Group B: 1540nm Er:YAG laser + fillers/lipolysis	No PIH observed
Shin et al, 2012[44]	IV–V	22	Not mentioned	Group A: 1550nm Er:YAG laser+PRP Group B: 1550nm Er:YAG only	Group A: 25% Group B: 17%
Saedi et al, 2012[45]	I–VI	20	2,0,1	1440nm fractional laser	No PIH observed
Wattanakrai et al, 2012[46]	III–IV	22	12,0,0	Split face: One side 1550nm Yb/Er* doped Fiber laser Other side: 2940nm VSP** Er:YAG laser	10% on 2940nm Er:YAG side
Marmon et al, 2014[47]	III–V	10	Not mentioned	1440 diode based fractional laser	10%
Brauer et al, 2015[15]	I–VI	23	Not mentioned	1927 nonablative fractional diode laser	4%
Moon et al, 2015[48]	III–IV	44	14,0,0	Randomized study: Group A: ablative fractional 2940nm Er:YAG laser Group B: nonablative 1550 Er:YAG laser	Group A – 5.2% Group B – no PIH observed
Freidmann et al, 2016[49]	II–IV	16	1,0,0	1565 erbium doped fractional laser	No PIH observed

*Yb/Er=yetterbium/erbium **VSP=variable square pulsed
SPT: Fitzpatrick skin photo type

Another study by Kroon et al[34] compared nonablative fractional laser with triple combination cream in a randomized trial. Both fractional laser and TCC were reported to have similar efficacy and recurrence rates at six-month follow up. Hong et al[35] compared nonablative fractional laser with 15% trichloroacetic acid (TCA) peel in a split-face study. They concluded that they are equal in terms of clinical efficacy and neither of them is long lasting. Wanitphakdeedecha et al[36] reported a significantly higher incidence of PIH on the side treated with 20mJ/20% coverage as compared to 20mJ/5% coverage side. Tourlaki et al[38] assessed the efficacy of combination therapy, nonablative fractional laser and TCC in resistant melasma cases. They observed marked (>75%) and moderate improvement (51–75%) in melasma area sensitivity index (MASI) scores in 67 and 21 percent of patients,

Table 7: Nonablative fractional lasers for scar resurfacing in SPT IV–VI

AUTHORS, YEAR	SKIN TYPES	NO. OF PATIENTS	SPT (IV, V, VI)	TREATMENT MODALITY	POSTINFLAMMATORY HYPERPIGMENTATION (PIH %)
Lin et al, 2011[50]	I–VI	20	1,1,3	Randomized study with 1550nm Er:YAG Group A: 40mJ/26% coverage Group B: 40mJ/14% coverage	No PIH reported
Cervelli et al, 2011[51]	I–IV	60	2,0,0	Group A: fat grafts + PRP Group B: 1540nm fractional laser Group C: fat grafts + PRP + 1540nm fractional laser	6.66%
Kim et al, 2012[52]	III–IV	7	Not mentioned	Split scar: One half treated with 1550nm Er:Glass laser and other half with fractional 2940nm Er:YAG laser	No PIH observed
Bach et al, 2012[53]	IV	1	1,0,0	1550nm Er:YAG	No PIH observed
Verhaeghe et al, 2013[54]	I–IV	22	3,0,0	1540nm Er:YAG	5%
Ibrahim et al, 2016[55]	II–V	13	6,1,0	CO_2 laser followed by 1540nm fractional laser	No PIH observed

SPT: Fitzpatrick skin photo type

respectively.

In summary, available evidence supports that nonablative fractional lasers are comparable in efficacy to triple combination creams in the treatment of melasma. The ideal fractional laser settings for melasma treatment largely depends on the skin phototype and the type of melasma being treated. Higher treatment densities and SPT are associated with a greater risk of hyperpigmentation post procedure.[39] Patients with melasma should be counseled about the potential risk of worsening of their pigmentation post resurfacing.[40]

SKIN REJUVENATION

Aging presents with different features in different skin types and ethnicities. Age along with cumulative ultraviolet (UV) damage over the years leads to development of rhytids, skin laxity, textural changes, wrinkles and abnormal pigmentation. Due to the photoprotective effects of melanin, the appearance of wrinkles is usually delayed in ethnic skin and pigmentary changes tend to present earlier.[16] Nonablative fractional lasers are widely used for skin rejuvenation but only a few studies have been done to assess their impact in skin type IV to VI (Table 6).[41–49]

Kono et al[41] assessed the efficacy and complications of different energy and density settings of nonablative fractional laser. Pain, edema and erythema were more common in patients treated with higher energy and density settings. Patient satisfaction was reported to be significantly higher in groups treated with higher fluence but not with higher density. Shin et al[44] performed a randomized blinded study where patients were either treated with fractional laser and platelet rich plasma (PRP) or fractional laser alone. The group treated with fractional laser and PRP reported higher patient satisfaction when compared to laser alone. Saedi et al[45] performed a single center non-randomized study and determined that 1440nm fractional laser was safe and efficacious in improving visible facial pores and skin texture. Wattanakrai et al[46] compared non ablative fractional laser with

Table 8: Nonablative fractional lasers for striae distensae in SPT IV–VI

AUTHORS, YEAR	SKIN TYPES	NO. OF PATIENTS	SPT (IV, V, VI)	TREATMENT MODALITY	POSTINFLAMMATORY HYPERPIGMENTATION (PIH %)
Yang et al, 2011[56]	IV	24	24,0,0	One side of abdomen: 1550nm fractional laser Other side: 10600nm ablative fractional CO_2 laser	36.4 81.8
Kim et al, 2008[57]	III–IV	6	Not mentioned	1550nm erbium doped fractional laser	50
De Angelis et al, 2010[58]	I–IV	51	10,0,0	1540nm Er:Glass laser	15.6
Stotland et al, 2008[59]	I–IV	20	3,0,0	1550 Erbium doped fiber laser	No PIH observed
Malekzad et al, 2014[60]	III–V	10	3,1,0	1540nm erbium fractional laser	10
Alves et al, 2015[61]	IV	4	4,0,0	Nonablative 1540nm fractional laser	No PIH observed
Wang et al, 2016[62]	I–IV	10	Not mentioned	One side of abdomen: 1540nm fractional laser Other side: 1410nm fractional laser	Transient PIH observed in all patients

SPT: Fitzpatrick skin photo type

variable square pulsed 2940nm Er:YAG laser in a randomized open label trial. Although no difference was noted in efficacy, less downtime with fractional laser correlated positively with higher patient satisfaction.

In conclusion, there is strong evidence that nonablative fractional laser is a safe and effective modality for skin rejuvenation in skin of color.

SCAR RESURFACING

Keloids and hypertrophic scars are more prevalent in racial/ethnic populations with SPT IV–VI. Multiple treatment modalities such as intralesional steroid injections, silicone sheets, cryotherapy, excision and laser surgery are currently used to treat scars or improve their appearance. However, the response to these treatments is often unsatisfactory and unpredictable. The following studies assess the effectiveness of nonablative fractional laser for treating keloids, hypertrophic and surgical scars (Table 7).[50–55]

A randomized blinded study was performed by Lin et al[50] wherein linear surgical hypertrophic scars were divided into halves. One half of the scar was further randomized to receive either high density (40mJ/26% coverage) or low density (40mJ/14% coverage) treatment whereas the other half served as control. No significant difference was observed in the efficacy of high density and low density groups. Moreover, high density group reported high incidence of side effects such as erythema, pain, swelling and scabbing. This study also emphasized the importance of treating scars at an earlier stage as younger scars respond better to treatment. Cervelli et al[51] performed a randomized blinded study analyzing the combined effects of fractional resurfacing, fat grafting and use of PRP in

Table 9: Complications of fractional laser use[9,10,63,64]

MILD	MODERATE	SEVERE
Prolonged erythema	Infection	Scarring
Acneiform eruption	Pigmentary alteration	Disseminated infection
Delayed purpura	Eruptive keratoacanthomas	
Edema	Anesthesia toxicity	
Superficial erosions		

treating traumatic scars. They suggest that combining fractional lasers with platelet rich plasma yields better results as compared to a solitary approach.

In conclusion, there is moderate level evidence that nonablative fractional lasers are a safe and effective treatment option for scars with improvement in both texture and appearance of scars.

STRIAE DISTENSAE

Striae distensae or stretch marks are a result of rapid stretching of the dermis usually due to sudden changes in weight, use of corticosteroids, pregnancy and adolescent growth spurts. Striae develop through three stages: initial inflammatory stage when they are red in color known as Striae rubra, progressing to next stage of purple coloration and last stage of white atrophic striae referred to as striae alba (Table 8).[56–62]

Striae distensae are a challenging condition to treat. Fractional lasers lead to clinical as well as histopathological improvement in striae by promoting collagen regeneration.[58]

Yang et al[56] conducted a randomized blinded split study comparing nonablative and ablative fractional laser for the treatment of striae distensae on abdomen. No significant difference was seen between the two groups. Kim et al[57] performed a prospective right left comparison study with ErYAG laser treatment on one side and other side serving as control. They suggested ErYAG nonablative fractional laser is an safe and effective treatment for striae distensae. Another prospective open label trial by De Angelis et al[58] also confirmed the efficacy of nonablative fractional lasers in reducing striae distensae.

There is moderate evidence (2a) suggesting the efficacy of nonablative lasers for treating striae in skin of color. To the best of the authors' knowledge, none of the studies so far have included skin types VI and only one study treated skin type V patient. Therefore, more high quality studies are needed to establish the efficacy of nonablative fractional lasers for treating striae in darker skin types.

COMPLICATIONS

Fractional lasers represent a better standard of safety than the traditional lasers but they are not without side effects. Post-treatment side effects, such as transient erythema, edema and hyperpigmentation, have been well documented in almost all the studies. Graber et al[9] reported the incidence of complications from1550nm erbium doped laser treatments. They performed 961 consecutive treatments in 422 patients of SPT I to V. The most common complications were acneiform eruptions (1.87%), outbreaks of herpes simplex virus (HSV) (1.77%) and erosions (1.35%). Other less frequent side effects were prolonged erythema (0.83%), PIH (0.73%), prolonged edema (0.62%) and dermatitis (0.21%). Single cases of impetigo and purpura were also reported. Most of the side effects listed above were seen equally in all skin types except PIH, which was reported to be more common in skin of color patients.[2,9]

Recognition of the potential complications of fractional laser use is important owing to its growing popularity. Table 9 summarizes the commonly encountered side effects according to their degree of severity.[9,10,63,64]

RECOMMENDATION

Levels of evidence and strength of recommendation is summarized in Table 10.

Careful patient selection and setting realistic expectations prior to starting treatment are the most important preliminary steps to ensure a favorable outcome. The importance of post-procedure skin care cannot be overemphasized. Patients should be counseled and strongly encouraged to use broad spectrum sunscreen during the course of treatment. The use of pre-and post-procedure hydroquinone to prevent PIH has been advocated my several authors, but studies confirming the efficacy of hydroquinone in preventing resurfacing laser-induced PIH are currently lacking.[28]

Patients should be made aware that clinical improvement and side effects largely depend on what laser settings are used which are further determined based on the skin type and indication for treatment. Both energy and density are key parameters that determine the safety and efficacy of fractional resurfacing in skin of color patients although treatment density plays a more important role in determining the risk of PIH; the higher the treatment density (MTZ/cm^2), the higher the risk of PIH. Other parameters which can be modified to decrease the incidence of side effects are number of passes per treatment session, increasing treatment intervals and providing additional cooling between passes to reduce bulk heating. It is advisable to increase the duration between two treatment sessions if PIH occurs between two laser treatment sessions.[40]

Table 10: Summary of evidence-based recommendations

DISEASE ENTITY	HIGHEST LEVEL OF EVIDENCE	RECOMMENDATION
Acne	**1b**	**Strong** NAF is safe and effective for treating acne
Acne scars	**2b**	**Moderate** NAF is safe and effective for treating acne scars
Melasma	**2b**	**Moderate** **NAF vs. TCC :** NAF is comparable in efficacy and recurrence rate to TCC **NAF + TCC:** Good approach for resistant melasma Well maintained results compared to monotherapy
Skin rejuvenation	**1b**	**Strong** Safe and effective for superficial photodamage **NAF + PRP:** Good results, increased subject satisfaction **NAF + Fillers and Lipolysis:** Good results with combination therapy
Scars	**2a**	**Moderate** NAF leads to improvement in scars. Early intervention leads to better results **NAF+ PRP/fat grafts/ topical steroids:** better outcome than laser alone
Striae	**1b**	**Strong** NAF safe and effective for reducing striae

CONCLUSION

In conclusion, the available evidence strongly suggests that fractional lasers are a favorable treatment option for a variety of dermatological diseases in skin of color. As the patient population seeking laser procedures becomes more diverse, it is increasingly important to understand racial, ethnic and phototype variations in safety and overall treatment outcomes. Key strategies should include careful patient selection, appropriate device selection, use of conservative treatment settings and sunscreens. Fractional resurfacing has opened the door to laser treatment of numerous

dermatologic concerns in darker skin types that were previously contraindicated due to safety concerns. While considerable data exists for using fractional lasers in SPT I to IV, more studies that include SPT V to VI are sorely needed to further elucidate optimal treatment parameters for patients with skin of color.

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