Fractional Resurfacing in the Asian Patient: Current State of the Art

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Background and Objective: Fractionated photothermolysis (FP) has revolutionized modern laser technology. By creating selective columns of microthermal damage, fractionated devices allows for greater treatment depths to be achieved without the prolonged downtime and risk of complications seen in traditional fully ablative laser resurfacing. Fractional resurfacing is a proven method to treat a variety of cutaneous conditions. In the Caucasian patient, a wide range of devices and treatment settings can be utilized safely and effectively. However, ethnic skin requires special consideration due to its unique pigmentary characteristics and clinical presentations. In this review article, we detail the current indications and strategies to optimize results and mitigate complications when utilizing fractional resurfacing for the Asian patient.
Methods: A review of the MEDLINE English literature was conducted on fractionated laser devices studied in the Asian population. Articles included describe non-ablative devices including fractionated erbium glass, thulium fiber, diode, and radiofrequency devices; and ablative devices including fractionated carbon dioxide (CO_2) laser, erbium yttrium aluminum garnet (Er:YAG), and yttrium scandium gallium garnet (YSGG) laser. These data were integrated with the expert opinion of the authors.
Conclusion: Taking into account the unique characteristics and cosmetic concerns of the Asian population, fractional resurfacing can be considered a safe and effective option for the treatment of atrophic and hypertrophic scarring, and photorejuvenation in ethnic skin types. Select cases of melasma may be treated with fractionated non-ablative devices, but utilized with caution. The predominant complication associated with fractional resurfacing for these conditions is post-inflammatory hyperpigmentation (PIH) and rebound worsening of melasma. A greater number of treatments at lower density settings and wider treatment intervals typically produce the lowest risks of PIH without compromising treatment efficacy. Lasers Surg. Med. 49:45–59, 2017.
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Key words: fractional laser; acne scarring; hypertrophic scarring; melasma; erbium glass; thulium fiber; Asian skin; fractional photothermolysis; photorejuvenation; resurfacing

BACKGROUND

Fractionated photothermolysis (FP), introduced in 2004, represented a landmark development in modern laser technology [1]. Filling the gaps left by non-fractionated fully ablative (FA) and non-ablative (NA) modalities, fractional resurfacing aims to produce the clinical benefits of FA therapy while minimizing the adverse effects and downtime. Traditional FA lasers have proven efficacy in photorejuvenation and scar treatment for fair skinned individuals. However, the prolonged recovery period and increased risk of complications including possibility of infection, dyspigmentation, and scarring have limited its usage. In the Asian patient, these risks are further magnified, rendering FA treatment even less desirable for routine clinical use.

Ethnic skin is unique in that increased epidermal melanin and melanocyte reactivity results in a pronounced tendency to hyperpigment in response to trauma or light stimuli that can be persistent [2]. Features of aging and cosmetic desires for the Asian population are also distinct from Caucasians. Photodamage is typically manifested as pigmentary aberration rather than rhytides. Lentigines, Hori's macules, and melasma are common cosmetic concerns. Wrinkling is encountered about 10–20 years later compared to age-matched Caucasians [3–5]. With the limited efficacy of non-ablative technologies and unacceptably high-risk profile of FA, fractional photothermolysis

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serves a pivotal role in laser resurfacing for the Asian patient.

Fractional photothermolysis creates selective columns of microthermal damage allowing interspersed untreated areas to serve as reservoirs whereby keratinocyte migration can achieve re-epithelialization within 24 hours. The advantage of a rapidly restored epidermal barrier allows for greater treatment depths to be safely achieved [1]. Fractional resurfacing can be broadly categorized into non-ablative (NAFL) and ablative (AFL) technologies. In this article, we discuss current indications for fractional resurfacing, potential adverse sequelae, and our experience in utilizing these techniques in the Asian population.

METHODS

A search of the MEDLINE English language literature with the keywords "fractionated," "fractional," "laser," "fractional photothermolysis" combined with "Asian," "Chinese," "Korean," "Japanese," "Indian," "Oriental," "East Asian" was performed. A total of 103 relevant studies were retrieved. The following items were extracted systematically from included articles: device type, study design, patient number, gender, treatment parameters, treatment sessions and interval, follow-up times, results, and adverse effects. An emphasis was placed toward higher quality studies with randomization, control or comparative arm, standardized endpoint measures, and adequate follow-up. Among included studies, ablative and non-ablative technologies have been most extensively studied in the treatment of atrophic acne scars ($n = 30$ studies) and photorejuvenation ($n = 30$ studies). Treatment of hypertrophic scars ($n = 6$ studies) and melasma ($n = 11$ studies) will also be discussed. NAFL and AFL devices will be discussed in the context of the aforementioned clinical conditions. An evidence-based "bottom line" recommendation will be provided for each section, which is based on a summary of relevant studies gathered from a systematic search of MEDLINE (all included studies listed in Table 1). Recommendations that reflect the authors' experience will be explicitly stated.

PREMISE OF FRACTIONAL PHOTOTHERMOLYSIS

Fractionated systems deliver pixelated laser energy in a grid-like pattern creating microscopic columns of ablative and/or coagulative damage, termed microthermal zones (MTZ) [1]. Immediately after treatment with NAFL, columns of coagulative damage traversing the epidermis and dermis are present with complete sparing of the stratum corneum. By 24 hours, there is formation of microscopic epidermal necrotic debris (MENDs) within the epidermis which serve as shuttles for the transepidermal elimination of coagulated epidermal/dermal material and melanin [6,7]. Genetic analysis of ex vivo skin from Asian patients 24 hours post-AFL also demonstrated upregulation of key players in wound healing including metalloproteinases-1 and 3 (MMP-1, MMP-3) and procollagens I and III [8]. Simultaneously, keratinocytes adjacent to each microscopic column migrate and rapidly repopulate the epidermal defect within 24 hours. Preservation of the epidermal barrier allows for greater treatment depths to be achieved safely while also reducing adverse effects and downtime. Complete extrusion of MENDs is seen in 7 days [1,6,7].

Repair of the dermal portion of MTZs requires 4–6 weeks, which corresponds to when clinical benefits first become evident [1]. Thermal ablation results in sequentially additive neocollagenesis and collagen contraction that can be seen up to 6 months following traditional ablative therapies. Procollagens I and III mRNA may reach 8–9 times the baseline levels from 3 weeks up to 6 months post-treatment explaining the prolonged treatment effects in traditional FA [9]. Likewise, this is also observed with fractionated CO_2 treatment. Histological studies on Asian patients found significantly increased levels of heat shock protein (HSP)-70 expression, neocollagenesis, and formation of nascent elastic fibers at 1 month following AFL, which persisted at 6 months following treatment [10].

DEVICES STUDIED IN ASIAN PATIENTS

There are a variety of fractionated devices currently available that have been studied in the Asian population (Table 1). Generally, these modalities are divided into fractional ablative (AFL) and fractional non-ablative (NAFL), although some devices and handpieces *confer* dual modes of treatment. AFL devices utilize near-infrared wavelengths that target water as a chromophore resulting in instant vaporization of columns of tissue including epidermal ablation. NAFL devices also target water containing tissues but create columns of coagulative damage within the dermis that are below the ablative threshold.

NON-ABLATIVE FRACTIONAL THERAPY

NAFL utilizes mid-infrared wavelengths that penetrate deep into the mid reticular dermis to induce neocollagenesis and remodeling. The major advantage is the preservation of an intact epidermis with minimal disruption of the dermal–epidermal junction (DEJ), which translates to shorter and milder adverse effects. In the Asian population, NAFL may be considered a first line treatment for atrophic scarring and wrinkle reduction. The favorable side effect profile and low risk of dyspigmentation make it the preferred option for the majority of Asian patients seeking photorejuvenation as well. NAFL may be reserved as a second line modality for the treatment of recalcitrant melasma.

Atrophic Acne Scarring

Non-ablative fractional photothermolysis is safe and effective in the treatment of atrophic acne scarring. Lee et al. conducted a prospective trial in which 27 patients underwent 3–5 treatments at 3–4-week intervals using a fractionated 1,550-nm erbium glass laser (Fraxel SR, Solta

TABLE 1. Fractionated Laser Devices Studied in the Asian Population

Device name	Manufacturer	Type	References
	Non-ablative		
Fraxel SR 750/1500	Solta Medical, Hayward, CA	1,550-nm erbium glass/ doped	[1,11–14,23,25,29, 32–34,50,64,94]
Fraxel Re:store	Solta Medical, Hayward, CA	1,550-nm erbium doped	[16,35–37,88]
Fraxel Dual	Solta Medical, Hayward, CA	1,550-nm erbium doped and 1,927-nm thulium fiber	[25,31,38–40]
Fraxel Xena	Solta Medical, Hayward, CA	1,550-nm erbium glass	[27]
Mosaic	Lutronic, Gyeonggi-do, Korea	1,550-nm erbium glass	[20,63,72]
Finescan	TNC Spectronics, Bangkok, Thailand	1,550-nm ytterbium and erbium-doped	[28]
Sellas	Dinona, Seoul, South Korea	1,550-nm erbium glass	[21,24,68]
Clear + Brilliant	Solta Medical, Hayward, CA	1,440-nm diode	[26,30]
Picosure (FOCUS Lens Array)	Cynosure, Westford, MA	755-nm alexandrite	[76,77,80–82]
Picoway (Resolve hand piece)	Syneron Medical, Yokneam, Israel	532/1,064-nm Nd:YAG	[74,75]
	Ablative		
Ultrapulse (Encore)	Lumenis, Yokneam, Israel	10,600-nm CO_2	[42–44,50,56–60, 84,92,94]
AcuPulse	Lumenis, Santa Clara, CA	10,600-nm CO_2	[45,58,59]
Fraxel Re:pair	Solta Medical, Hayward, CA	10,600-nm CO_2	[41]
Ellipse Juvia	Ellipse A/S, Horsholm, Denmark	10,600-nm CO_2	[46]
Mosaic eCO_2	Lutronic, Gyeonggi-do, Korea	10,600-nm CO_2	[50,53,54,61,63,65]
CICU2	Ilooda, Suwon, South Korea	10,600-nm CO_2	[62]
Edge Fractional	Jeisys, Seoul, South Korea	10,600-nm CO_2	[89]
SmartXide2	DEKA M.E.L.A., Calenzano, Italy	10,600-nm CO_2 and bipolar radiofrequency	[90]
CoScan-5000	Stratek, Anyang, South Korea	10,600-nm CO_2	[91]
Profractional-XC	Sciton, Palo Alto, CA	2,940-nm Er:YAG	[47]
Joule	Sciton, Palo Alto, CA	2,940-nm Er:YAG	[66,67]
Avvio	Won Tech, Daejeon, Korea	2,940-nm Er:YAG	[27]
Dualis SP	Fotona, Ljubljana, Slovenia	2,940-nm Er:YAG	[28]
SP Dynamis	Fotona, Ljubljana, Slovenia	2,940-nm Er:YAG	[45]
Action	Lutronic, Gyeonggi-do, Korea	2,940-nm Er:YAG	[55]
Pixel	Alma Lasers, Buffalo Grove, IL	2,940-nm Er:YAG	[48,93]
Pearl Fractional	Cutera, Brisbane, CA	2,790-nm YSGG	[49]
	Radiofrequency		
eMatrix (Matrix RF)	Syneron Medical, Yokneam, Israel	915-nm diode + bipolar radiofrequency	[16–18]
Accent	Alma Lasers, Caesarea, Israel	Microplasma RF	[19]
Secret	Ilooda, Suwon, South Korea	Microneedle RF	[62]

Nd:YAG, neodymium-doped yttrium aluminum garnet; CO_2, carbon dioxide, Er:YAG, erbium-doped yttrium aluminum garnet; YSGG, yttrium scandium gallium garnet; RF, radiofrequency.

Medical, Hayward, CA) [11]. Despite relatively low fluence settings (12–20 mJ), 89% of patients experienced significant to excellent improvement at 3 months following the final treatment session. Subsequent studies with the same system utilizing only a single treatment with short follow-up times also reported improvement in acne scarring although more modest [12,13].

Chan et al. compared standard NAFL treatment (Fraxel SR and SR1500, Solta Medical) using densities of 25–30% (average 442.5 MTZ/cm^2) delivered in eight passes to a low-density "mini" NAFL treatment utilizing half the density (average 210.5 MTZ/cm^2) delivered in four passes while fluence was kept constant in both groups (mean 50 mJ, up to 70 mJ) [14] (Fig. 1). This study demonstrated that six "mini" treatments had equivalent clinical efficacy to three "full" treatments in reduction of acne scars as well as homogenization of skin texture and pigment irregularity. Good to excellent improvement in acne scarring was noted in 87% of patients. Notably, adverse events were significantly lower in the "mini" NAFL group with 6% PIH (vs. 18%) and 14.8% erythema (vs. 33.3%).

Only two comparative studies in Asian populations have been performed with non-ablative fractional photothermolysis. The first compared a fractionated 1,550-nm erbium glass laser (Fraxel SR, Solta Medical) with a fractionated 10,600-nm CO_2 laser (Ultrapulse, Lumenis, Yokneam, Israel) in a split face trial involving eight patients [15]. Healing time was significantly longer after CO_2 laser and there was a trend toward increased efficacy which did not reach statistical significance. However, it is difficult to interpret the resulting data due to the small sample size in this trial. The second comparative study was a split face trial utilizing the fractionated 1,550-nm erbium doped laser (Fraxel Re:store, Solta Medical) and a fractionated radiofrequency device (eMatrix, Syneron Medical, Yokneam, Israel) [16]. Conservative laser settings of 30–50 mJ and 10–14% density were used on the NAFL side. Three treatments with each modality were performed at 4-week intervals and the downtime and final efficacy were both reported as equivalent after a short 1-month follow-up.

Fractional radiofrequency results in deep dermal heating while sparing the epidermis and represents another fractionated non-ablative energy modality that may reduce the risk of PIH [16–19]. Yeung et al. looked at a combination of bipolar radiofrequency and fractionated 915 nm diode (Matrix RF, Syneron Medical) and demonstrated that five treatments spaced 4 weeks apart can improve acne scarring in 52% of patients (Fig. 2). PIH was observed following 6 out of 92 treatments (6.5%) [18].

Bottom line. Non-ablative fractional resurfacing is an effective treatment for atrophic acne scarring. Higher fluences with lower densities are considered the optimal parameters to maximize efficacy and minimize complications. A longer series of low-density treatments can dramatically reduce rates of PIH and erythema without compromising clinical efficacy and is the preferred approach for NAFL resurfacing in Asian patients.

Hypertrophic Scarring

Fractional photothermolysis, both ablative and non-ablative, can be considered first line treatments for hypertrophic scarring resulting from surgery or trauma (Fig. 3). Choe et *al*. performed fractionated 1,550-nm laser treatments (Mosaic, Lutronic, Gyeonggi-do, Korea) on early thyroidectomy scars using four treatment sessions spaced 1 month apart and found that the cosmetic appearance was significantly improved at 6 months follow-up compared to untreated controls [20]. For surgical scars, early intervention with laser therapy at post-operative weeks 2 to 4 have been shown to optimize outcomes [21].

Bottom line. Non-ablative resurfacing of surgical or traumatic hypertrophic scars is best performed at 2–4 weeks after surgery or injury. Although NAFL is an effective standalone treatment, ablative FP is potentially

Fig. 1. Acne scars (**A**) and (**B**) 1 month after five treatments of 1,550-nm non-ablative fractional laser (pulse energy 70 mJ, treatment level 10, density/pass 42 MTZ/cm^2, eight passes, 1–3 months apart)—"Mini Fraxel."

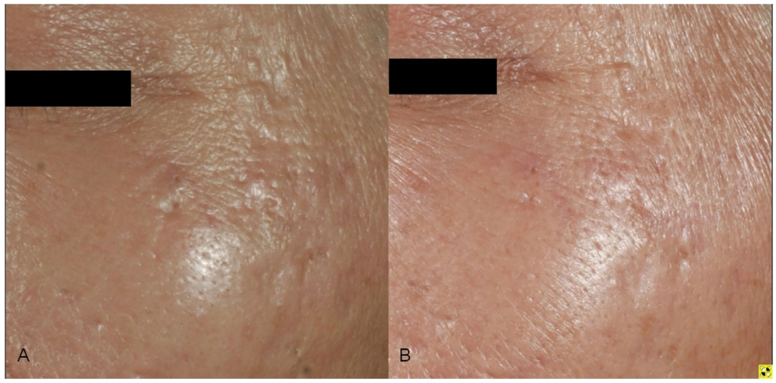

Fig. 2. Acne scars (**A**) and (**B**) 3 months after five treatments of radiofrequency (56–62 mJ/pin) and 915-nm fractionated diode laser (IR 60–70J/cm^2, RF 80–100 J/cm^3, two passes, 1–4 months apart).

superior due to the greater penetration depths and the delivery of a more powerful remodeling stimulus [22].

Rejuvenation

The first clinical study using an early 1,550-nm erbium fiber prototype demonstrated mild-to-moderate improvement in periorbital wrinkles and skin texture in Caucasian patients after four treatments [1]. Efficacy in improving wrinkles, skin texture, pore size, and dyspigmentation in the Asian population has similarly been demonstrated [14,23–28]. Given the increased risk of PIH, a greater number of treatments with lower density is the preferred approach in treating skin of color. Both density and fluence contribute to risk of PIH, but density has been shown to be the predominant factor [23,29].

In addressing patients seeking facial rejuvenation, it is important to consider the desired outcomes based on skin type and degree of photodamage. Photoaging in Asian patients typically manifest as pigmentary alteration, lentigines, and seborrheic keratoses rather than fine lines and deep rhytides as seen in Caucasian counterparts. Asian patients between the ages of 30 and 60 exhibit far less fine lines and rhytides compared to age-matched Caucasians, but reach equivalent rates of wrinkling beyond age 60 [3–5].

Common aesthetic concerns in the young to middle-aged Asian population typically include enlarged pore size, skin textural irregularities, and dyspigmentation. A series of low-energy, low-density NAFL treatments using fractionated diode devices is effective at addressing early signs of such. Marmon et al. demonstrated statistically significant improvement in wrinkles, pigmentation, and skin texture after four treatments using a fractionated 1,440-nm diode (Clear + Brilliant, Solta Medical), 4–9 mJ, density of 320–400 MTZ/cm^2, spaced 2 weeks

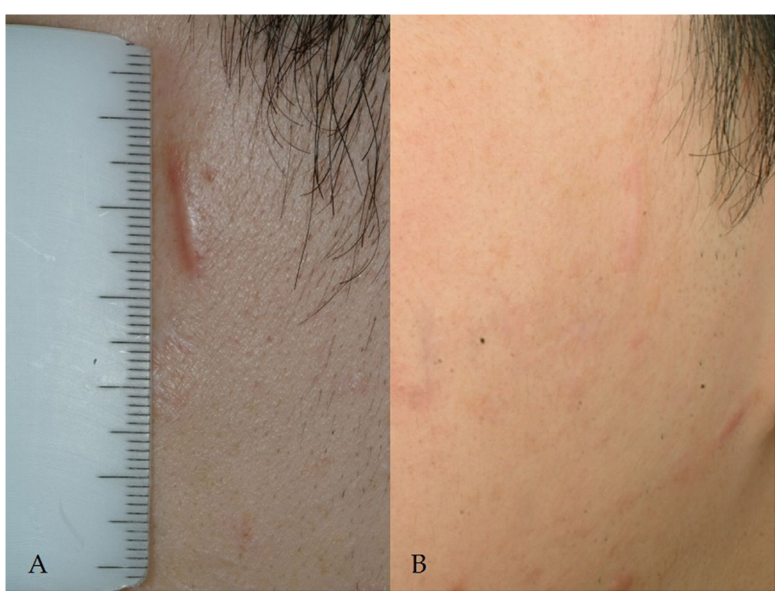

Fig. 3. Hypertrophic scar (**A**) and (**B**) 2 months after seven treatments of 1,550-nm non-ablative fractional laser (pulse energy 15–20 mJ, density/pass 62 MTZ/cm^2, four passes, 4–5 weeks apart).

apart [26] (Fig. 4). Although statistically significant, the clinical results were typically rated as mild to moderate. Notably, patient tolerability of the procedure increased with subsequent treatments. By the fourth treatment, pain and heat sensation was experienced in only 10% and 0% of patients, respectively [26]. A study using the same device in phototypes I–VI showed that six treatments are generally required before a significant reduction in pore size is detected [30].

More pronounced issues with acne scarring, skin texture, dyschromia as well as pore size can be simultaneously improved with low-density "mini" treatments utilizing 1,550-nm erbium glass (Fraxel Re:store, Solta Medical) over six sessions as discussed previously (see *Atrophic Acne Scarring*) [14]. When patients present predominantly with discrete or diffuse, mottled superficial dyspigmentation characterized mainly by macular seborrheic keratoses and solar lentigines, the fractionated 1,927-nm thulium fiber laser (Fraxel Dual, Solta Medical) has proven to be a treatment of choice [31]. The 1,927-nm wavelength can be combined with 1,550-nm to achieve both superficial and deep treatment depths, respectively, in a single session. In our experience, the fractionated 1,927-nm thulium fiber laser is safe and effective at a broad range of settings and treatment levels.

A series of NAFL treatments are also effective for reducing periorbital and forehead wrinkles [24], and may even approach the clinical efficacy of AFL with the appropriate settings [27,28]. A split face randomized controlled trial (RCT) comparing three sessions of a 1,550-nm ytterbium and erbium-doped laser resurfacing (Finescan, TNC Spectronics, Bangkok, Thailand) to three sessions of 2,940-nm Er:YAG (Dualis SP, Fotona, Ljubljana, Slovenia) treatment found no statistically significant difference in wrinkle score and patient satisfaction among Thai patients. Both devices produced significant improvement in periorbital wrinkles compared to baseline. However, Er:YAG was associated with longer duration of erythema, edema, and burning; and higher risk of desquamation or fine scaling (100%) and PIH (10%) [28]. A similar Korean RCT compared 1,550-nm erbium glass at 12 mJ/MTZ, 23% coverage (Fraxel Xena, Solta Medical) to long pulsed 2,940-nm Er:YAG at 2.5 mJ, 8% coverage (Avvio, Won Tech, Daejeon, Korea). NAFL was more effective for addressing wrinkles while AFL was superior in reducing pigmentation, uneven skin tone, and erythema. Both devices produced statistically significant, but equivalent improvements in photoaging and skin elasticity. Interestingly, patient satisfaction and clinician global assessment scores were higher in the NAFL group. Continuous improvement at 3 months compared to 1 month was observed in the NAFL group, but not in the AFL group. Mean pain scores and frequency of acneiform eruption was significantly higher in the NAFL group [27]. These results may be attributed to relatively conservative treatment parameters in the Er:YAG group compared to the erbium glass group and the far greater penetration depth therefore likely achieved by the latter.

The major advantage of NAFL is the favorable risk profile and short downtime. Erythema and edema are usually seen and resolve within 2–7 days, and even shorter with low-energy diodes. Transient acneiform eruption has been reported which resolved in 2–4 weeks [28]. In the Marmon et al. study using a low-energy fractionated diode [26], only one case of transient PIH (<1 month) was noted. In a retrospective review of 362 patients undergoing a total of 856 NAFL treatments with either 1,550-nm erbium or 1,927-nm thulium fiber laser, significant adverse events occurred in only 5%. This included prolonged erythema (>7 days) in 1.8%, PIH in 1.1%, and worsening of melasma in 0.9% [25].

Bottom line.

- Non-ablative fractional resurfacing can be considered among first line therapy for the reduction of fine lines and wrinkling, textural abnormalities, and pore size in Asian patients. A series of treatments with lower densities and adequate recovery intervals provide optimal results.
- In our opinion, appropriate patients are those presenting with mild-to-moderate photodamage, in the absence of other significant clinical features such as melasma, severe acne scarring, and/or thick hypertrophic scars
- In particular, very low-density and low-energy fractionated diodes produce minimal adverse effects and short recovery times making it a popular choice for patients in

Fig. 4. Fine lines and pigment under eye (**A**) and (**B**) 1 month after four treatments of 1,440-nm fractional diode laser (pulse energy 7–9 mJ, density/pass 40–50 MTZ/cm^2, eight passes, 2 weeks apart).

our practice with early signs of photoaging. However, a longer series of treatments (4–6) is generally required.

Melasma

Non-ablative fractional laser has been used with variable success for the treatment of melasma. Early reports engendered optimism for this therapeutic modality. Small pilot studies with the first generation 1,550-nm erbium doped laser (Fraxel SR, Solta Medical) reported good improvements in melasma at 3 months follow-up after three to six treatment sessions [32,33]. However, further studies revealed the often temporary nature of this improvement as well as the risk for potential rebound worsening. Lee et al. treated 25 melasma patients with four sessions of 1,550-nm NAFL (Fraxel SR, Solta Medical) at 15 mJ, 1,000 MTZ/cm^2, and eight passes at 4-week intervals and found that 24% had definite improvement at 1 month. However, by the 6-month follow-up, only 17% had definite improvement and 13% had worsened [34]. Similar findings of temporary efficacy and potential rebound were reported subsequently [35,36] with one study showing no difference between 1,550-nm NAFL (Fraxel Re:store, Solta Medical) and sunscreen for the treatment of melasma [37].

With the advent of the 1,927-nm thulium fiber NAFL (Fraxel Dual, Solta Medical), new hope arose but once again recurrence and rebound were observed. In a study conducted by Lee et al., an encouraging 28% overall reduction in MASI was noted after thulium fiber NAFL at 10 mJ, 30% coverage, three treatment sessions at 3-week intervals [38]. However, 18/25 patients were lost to follow up after 2 months, therefore, calling into question the reliability of these data. Among the patients who returned, a 5% worsening in MASI from 2 to 6-month follow-up was noted. Likewise, Ho et al. found that a single treatment with 1,927-nm thulium fiber at 10 mJ, 40–45% density was sufficient to achieve significant melasma improvement (11% reduction in mean MASI) at 2 months, but relapse was noted by 3 months [39] (Fig. 5). One retrospective study was able to achieve long-term remission using high-density and high-energy settings (up to 20 mJ and 70% coverage) in phototypes II–IV [40]. At 6 to 12-month follow-up time points, a 53.8% improvement in MASI was maintained. Despite this, patient self-assessment reported a 46.6% recurrence rate at a mean follow-up time of 10.2 months.

Bottom line. There is significant variation in the response of melasma to NAFL. Pigmentary clearance is typically temporary with 1,550-nm erbium and 1,927-nm thulium devices with the potential even for rebound hyperpigmentation at 3–6 months following treatment. In light of these findings, fractional resurfacing with 1,927-nm thulium fiber may be considered a last resort therapy or an adjunct to a combination regimen involving topical skin lightening agents, light chemical peel, and strict sun protection.

ABLATIVE FRACTIONAL THERAPY

There are currently three types of ablative fractionated lasers: 10,600-nm carbon dioxide (CO_2), 2,940-nm erbium:

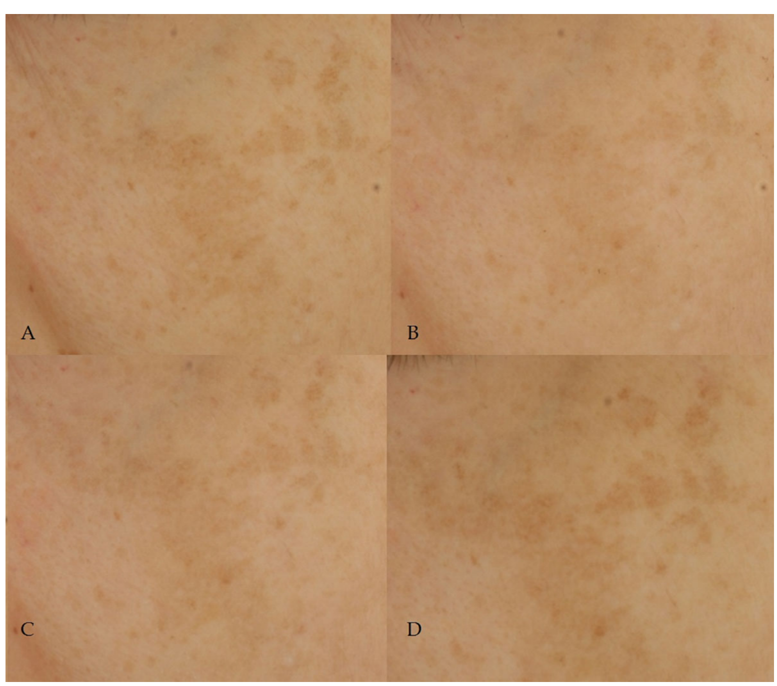

Fig. 5. Melasma (**A**) and (**B**) 5 days after one treatment of 1,927-nm non-ablative fractional laser (pulse energy 10 mJ, treatment level 6, density/pass 84 MTZ/cm^2, eight passes), and (**C**) 7 days later and (**D**) 1 month later showing signs of rebound.

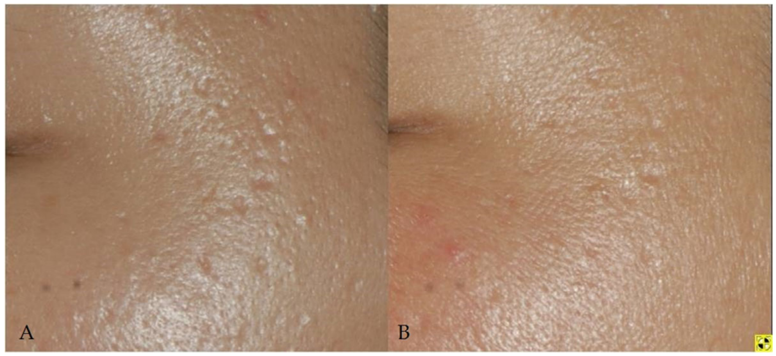

Fig. 6. Atrophic acne scar (**A**) and (**B**) 1 month after one treatment of CO_2 ablative fractional laser (pulse energy 30 mJ, treatment level 8, coverage/pass 7.5%, four passes).

yttrium aluminum garnet (Er:YAG), and 2,740-nm yttrium scandium gallium garnet (YSGG). Ablative fractional therapy should be used judiciously in the Asian patient. Areas where AFL may be considered include severe acne scarring, thick hypertrophic scars, and advanced photodamage. However, the increased risk of both prolonged erythema and PIH tends to favor the selection of a longer series of NAFL treatments over AFL to achieve similar efficacy with less downtime.

Atrophic Acne Scarring

Extensive studies have been conducted using CO_2, Er:YAG, and YSGG fractionated ablative devices for the treatment of atrophic acne scarring [41–45]. Overall, clinical efficacy can be excellent but is tempered by the inevitable prolonged downtimes and increased risk of complications such as herpes simplex virus (HSV) flare, persistent erythema, and PIH. Utilizing a fractionated CO_2 device (Fraxel Re:pair, Solta Medical) at a mean energy of 64 mJ and 30–40% coverage, Chan et al. demonstrated a statistically significant improvement in acne scars as well as skin texture, skin laxity, wrinkles, and enlarged pores after a single treatment session [41] (Fig. 6). Similarly, other studies have supported the one-treatment approach with CO_2 AFL even resorting to aggressive multipass superficial and deep ablation [42,43]). However, PIH rates after AFL are typically around 50% and can be as high as 92% [41,43,46]. Additionally, patients who undergo AFL must endure a limitation of daily activities and a dedicated healing period consisting of a variable amount of bleeding, oozing, crusting, and edema that lasts roughly 1 week.

Er:YAG AFL has also been used with some success in treating acne scarring [47,48]. A randomized split face trial comparing Er:YAG with CO_2 in an Asian population reported near equivalence [45]. However, as with any ablative modality, extended downtime is still the norm. The use of YSGG AFL is more limited, but has also been reported to be effective for acne scarring [49].

Although there is greater downtime associated with AFL, the clinical efficacy is generally viewed as superior to NAFL. A retrospective comparison of 58 patients receiving fractionated or non-fractionated resurfacing demonstrated greatest clinical improvement in acne scars with non-fractionated CO_2, but ultimately no statistical difference between non-fractionated CO_2 (Ultrapulse, Lumenis), non-fractionated Er:YAG (Contour Er:YAG, Sciton, Palo Alto, CA), and fractionated CO_2 (eCO_2, Lutronic) [50]. Clinical improvement scores were significantly lower in the NAFL group (Fraxel SR 1500, Solta Medical) which received a mean of 4 ± 1.3 treatments.

Bottom line. AFL can be an excellent treatment for atrophic acne scarring. However, patients undergoing these treatments must accept the need for dedicated healing time and an increased risk of unwanted complications—particularly PIH. Judicious patient selection is, therefore, important. For example, male Asian patients with acne scarring tend to be more tolerant of PIH than female counterparts with photoaging in our experience. In patients where this degree of risk and prolonged downtime is unacceptable, multiple NAFL treatments are a worthwhile alternative.

Hypertrophic Scarring

Injections of various cytostatic agents such as intralesional corticosteroids or 5-fluorouracil have long been a proven mainstay of therapy for hypertrophic scarring. Combination of these two agents has been shown to be superior to either agent alone [51]. In terms of energy devices, hypertrophic scarring responds very well to fractionated CO_2 laser, especially to improve scar pliability and thickness [52–54]. A split scar RCT showed significant reduction in Vancouver Scar Scale scores at 3 months, which remained stable at 6 months on the treated side compared to non-treated side. Four sessions of CO_2 significantly improved the pliability of the scars, which correlated histologically with collagen remodeling and upregulation of matrix metalloproteinase (MMP)-9 at 3 months [52]. Low density and high energy per treatment session is necessary to achieve the desirable outcome. Pulsed dye laser (PDL) is superior to AFL for addressing the erythema component of scars [54], while quality switched (QS) or picosecond lasers can be used to improve the pigmentary component. The optimal time for treatment is

2 to 4 weeks post-incision or injury [21]. In general, early intervention as soon as re-epithelization is complete is recommended. PIH rate ranged from 9% to 14% in these studies, which generally resolved within 1 month [53,54] (Fig. 7).

Bottom line. Ablative fractional CO_2 laser is currently the gold standard treatment for hypertrophic scarring. Combination of AFL treatments with other modalities is required to address the multifaceted components of a scar (vascularity, hyperpigmentation, thickness, and pliability). Key adjuncts include vascular lasers such as PDL and potassium titanyl phosphate (KTP), pigment lasers such as QS or picosecond alexandrite, and topical or injectable cytostatic agents such as 5-fluorouracil and triamcinolone acetonide [22].

Rejuvenation

Ablative fractional resurfacing with both Er:YAG and CO_2 lasers are effective for Asian photorejuvenation with improvements seen in fine lines and wrinkles, skin elasticity, mottled dyspigmentation, deep rhytides, pore size, and skin texture [41,55–57]). Li et al. performed a split-face trial utilizing a fractionated, 1.3 mm spot size, superficially ablative CO_2 laser with random computer pattern generated densities of levels 3–5 (roughly between 90% and 100% coverage), and pulse energies of 90–150 mJ in a single pass (UltraPulse, Active FX mode, Lumenis) and demonstrated improvements in all clinical parameters of photoaging at 3-month follow-up [56]. Erythema and edema persisted for up to 1 week and 25% of patients developed PIH that lasted between 7 and 50 days. In a long-term follow-up study, Tan et al. demonstrated a sustained clinical effect for up to 5 years using the same system and similar settings [57]. Patients required a mean healing time of 4.5 days, and 10% experienced PIH.

When the deep fractionated mode was studied (120 μm spot size, 15 mJ pulse energy, 5% density, UltraPulse, Deep FX mode, Lumenis), increased skin thickness and density, neocollagenesis and remodeling of collagen and elastic fibers were seen at a 3-month follow-up time point [10]. These results were found to be equivalent to a similar super pulsed fractionated CO_2 laser (Acupulse, Lumenis) [58]. The *ultra* pulsed laser was associated with higher rates of pain, oozing, edema, pinpoint bleeding, and PIH, whereas the super pulsed laser had more prolonged erythema, crusting, and healing times [59]. These data are in keeping with the different pulse structures of these devices.

Utilizing a different deep fractionated CO_2 laser system (Fraxel Re:pair, Solta Medical), Chan et al. showed statistically significant improvements in skin texture, skin laxity, wrinkles, and enlarged pores in 87.5% of patients at 3 months, a result that was sustained at 6 months [41] (Fig. 8). However, the improvements were graded as mild to moderate and the downtime was significant with oozing and crusting lasting up to 7 days, erythema for 1 month (22.2% with mild persistent erythema at 6 months), and 55.5% PIH at 1 month decreasing to 37.5% at 3 months.

In contrast, Lee et al. treated 29 patients with a series of fractionated Er:YAG treatments (Action, Lutronic) utilizing conservative settings of 100 spots/cm^2, 1–14 mJ, 5%

Fig. 7. Hypertrophic scar after induced burn injury (**A**) and (**B**) 3 months after three treatments of CO_2 ablative fractional laser (pulse energy 70 mJ, treatment level 4, coverage/pass 2.5%, four passes, 3–4 months apart) and 16 treatments of 1,550-nm non-ablative fractional laser (pulse energy 70 mJ, treatment level 11, density/pass 38–48 MTZ/cm^2, eight passes, 1 month apart). *In Krakowski AC, Shumaker PR (eds). The Scar Book: Formation, Mitigation, Rehabilitation, and Prevention. Wolters Kluwer Health, Philadelphia, PA (pending print release).*

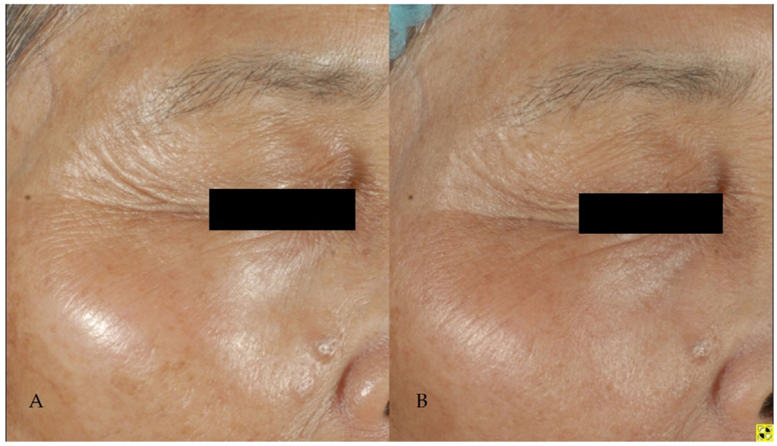

Fig. 8. Periorbital rhytides and skin texture (**A**) and (**B**) 2 months after single treatment of CO_2 ablative fractional laser (pulse energy 60 mJ, treatment level 5, coverage/pass 3.75%, four passes).

coverage, and 80 μm depth and reported mild improvements in photoaging at 2-month follow-up [55]. The majority of patients (83.3%) showed <50% improvement in all parameters of photoaging including wrinkles, dyspigmentation, and skin laxity. Erythema, edema, and microcrust resolved within 1 week and there were no reported incidences of PIH. Although adverse effects were minimal in this study, the laser settings were light and the improvements modest.

Bottom line. Ablative fractional resurfacing represents an effective single treatment for cutaneous rejuvenation in Asian patients with proven long-term clinical result. However, adverse sequelae (particularly PIH) are frequent and patients generally require dedicated healing time post-procedure. Because of these risks and associated downtime, we typically reserve AFL for elderly patients with advanced photodamage. In the authors' experience, middle aged Asians in the 40–60 age range typically exhibit photoaging with greater dyspigmentation as opposed to wrinkles and therefore less aggressive NAFL tends to be more suitable.

Melasma

The risk of PIH with AFL is generally too high to justify its use in pigmentary problems like melasma. A small split face trial in Thai patients explored whether pre-treatment with AFL may allow a secondary pigment laser to penetrate deeper and reach dermal melanocytes. A 950 ms CO_2 laser (Ultrapulse 5000C, Lumenis) utilizing a computerized pattern generator at 60W, 300–350 mJ, density of 5 to 6, single pass was combined with a subsequent pass of QS alexandrite laser (Accolade, Cynosure, Westford, MA) at 5–7 J/cm^2, spot size 3 mm, and pulse duration 60 ns on one side of the face. The contralateral face was treated with QS alexandrite only. Significant reductions in MASI score was observed on the combination side, but not with monotherapy. However, PIH developed in 50% (3/6) of cases on both sides which persisted for 3 months [60].

Bottom line. Although there is limited data suggesting that ablative fractional resurfacing may play a role in improving melasma, the risk-benefit ratio is unacceptably high. In our opinion, this modality should not be considered an option even for recalcitrant melasma in phototypes III–VI.

OTHER POTENTIAL INDICATIONS

A retrospective study demonstrated moderate to significant improvement (51–75%) in acneiform diseases in 12 Korean patients with recalcitrant acne vulgaris ($n = 7$), chronic recurrent furunculosis ($n = 2$), and hidradenitis suppurativa ($n = 1$) after one to three fractionated CO_2 treatments. Adverse effects included transient bleeding in 75% of patients and exudation of pus in acne patients. Persistent PIH (>4 weeks) was observed in all three cases of recurrent furunculosis of the buttocks which required additional treatment with QS Nd:YAG laser. There is a need to compare AFL with current standard of care before these preliminary findings be extrapolated [61]. Limited studies have also shown efficacy in the treatment of striae distensae using AFL in combination with radiofrequency or NAFL [62–64]. One to two sessions of fractionated CO_2 can be a safe means to remove periorbital syringomas [65]. Fractionated Er:YAG have also been investigated as a laser-assisted drug delivery option for photodynamic therapy in actinic keratosis and Bowen's disease in Korean patients [66,67]. Several NAFL treatments at monthly intervals may be as effective as 595-nm PDL for reducing facial erythema associated with inflammatory acne [68]. NAFL has also been reported to be successful in treating alopecia areata [69], but larger series have shown inconsistent results [70,71]. Increasing hair density and thickness have been shown in female pattern hair loss [72], but hair density returned to baseline levels among male pattern hair loss patients [73]. Although NAFL has been postulated to modulate anagen induction, animal studies have highlighted the potential for permanent injury to the hair follicle and ulceration with repeated treatments [71].

FRACTIONATED PICOSECOND LASER

Picosecond pulsed lasers were originally introduced for the treatment of tattoos and have proved to be a significant advancement on the previous generation of nanosecond QS lasers [74–77]. Additionally, these lasers are also safe and effective for the clearance of benign pigmentary lesions in both Asian and non-Asian skin types [78,79]. More recently, fractionated picosecond handpieces have been developed for the purposes of resurfacing and rejuvenation: a diffractive lens array for the 755-nm picosecond alexandrite laser (Picosure, Cynosure) and a holographic lens for the 532/1064-nm picosecond Nd:YAG laser (Picoway, Syneron Medical and Enlighten, Cutera, Brisbane, CA). Thus far, only a small number of studies have been conducted on these technologies. Brauer et al. utilized the fractionated 755-nm picosecond alexandrite laser to treat acne scarring in Caucasians and reported significant improvements that were sustained during the 3-month follow-up [80]. A series of six treatments were performed with the laser being fixed at 6 mm spot size, fluence of 0.71 J/cm^2, and 750 ps pulse duration. Similarly, Wu et al. used the same laser settings over a series of four treatments on phototypes I–III to achieve dramatic improvement of photodamage within the décolletage [81]. The only study published to date on the use of fractionated picosecond laser in skin of color is a retrospective series which demonstrated safety in the treatment of atrophic and hypertrophic scars and striae [82]. Our observations in clinical practice have been similar. Due to the potential of picosecond lasers to produce substantially less nonspecific photothermal damage, they may represent an excellent option for photo rejuvenation in Asian patients. Further studies with fractionated delivery systems in this patient population are required to evaluate this possibility.

FRACTIONATED RADIOFREQUENCY DEVICES

Aside from laser modalities, fractionated radiofrequency devices also serve an important role in the treatment of Asian types. Radiofrequency devices deliver sub-ablative wavelengths that induce coagulative damage to the dermis with relative sparing of melanin. Therefore, the risk of dyspigmentation may be minimized. Studies utilizing fractionated radiofrequency on Asian skin types have demonstrated promising results in the treatment of atrophic acne scarring [16–19,83–89], periorbital wrinkles [90], photoaging [91], and striae [92]. This large group of devices are valuable options in treatment of ethnic skin concerns, especially in combination with other modalities; however, their safety, efficacy, and indications are beyond the scope of this review.

COMPLICATIONS

Post-Inflammatory Hyperpigmentation

Ethnic skin is characterized by increased epidermal melanin, larger melanocytes, and increased melanocyte reactivity resulting in a marked tendency to hyperpigment in response to exogenous stimuli [2]. The degree of inflammation and disruption at the DEJ resulting in pigmentary incontinence is a major determinant of PIH risk. In FP systems, this is a function of fluence (mJ/MTZ) and density (MTZ/cm^2). Compared to FA modalities where nonspecific thermal damage, bulk tissue heating, and complete disruption of the DEJ may lead to PIH rates up to 37% even in fair skinned individuals [93], rates of PIH are far lower with FP devices. An optimal balance between clinical response and minimizing PIH risk is the predominant consideration in treating skin of color.

With NAFL, density is the prevailing determinant of PIH in Asian skin [23,29]. Histologically, high-density FP stimulates a marked inflammatory response and granulation, whereas low-to-moderate densities produce almost no inflammatory infiltrate [1]. Likewise, a split face RCT using AFL also demonstrated that increasing density from 10% to 20% prolonged PIH from a mean of 50.5 to 62.5 days [94]. A "mini" NAFL treatment protocol developed by Chan et al., whereby half the standard density delivered over a greater number of treatment sessions decreased PIH rate from 18% to 6% without compromising clinical efficacy [14].

Further strategies that can be employed to mitigate the risk of PIH include interventions at each stage of laser treatment. Pre-treatment, it is important to confirm the absence of active sun tan and to appropriately prepare the skin with topical bleaching agents. Intraoperatively, avoidance of multiple laser passes in small anatomical regions, use of appropriately low densities, and adequate epidermal cooling are important. Post-treatment care should be aimed at facilitating wound healing and mitigating inflammation by the use of topical corticosteroids [95], light emitting diode (LED) photomodulation [96], and diligent sun protection [97]. In the event of PIH persistence, a combination of topical lightening agents and pigment lasers can promote faster resolution.

Erythema, Crusting, Edema, and Pain

Erythema, crusting, edema, and pain are other common sequelae associated with both NAFL and AFL. In general, all adverse events are more marked in the setting of AFL as compared to NAFL. In our experience, high-fluence and high-density NAFL can lead to 3 to 7 days of superficial crusting, peeling, and edema, followed by a variable period of erythema that can persist up to a few weeks. On the other hand, full re-epithelialization following AFL can take 7 to 10 days with significant pinpoint bleeding, exudation, crusting, and edema. Erythema can persist for up to a month. One strategy to mitigate the risk of prolonged erythema is the use of LED photomodulation during the post-operative period [96]. Acneiform eruption, allergic contact dermatitis, and HSV infection may also occur following NAFL and AFL [46]. Lastly, we have also noticed the rare complication of dimpling or multiple pitted depressions with fractionated CO_2 that may be addressed with a 3-month course of topical retinoid.

COMBINATION OF ENERGY MODALITIES

Fractional resurfacing in combination with other laser and energy devices can achieve superior efficacy while maintaining safety and tolerability. However, studies with these combinations in Asian patients are sparse. One area that has shown promise is the use of fractionated laser for assisted topical drug delivery. This technique proved useful in combination with a topical prostaglandin F2 analog for the treatment of hypopigmented scars [98,99]. Additionally, acne scars can potentially be treated in superior fashion with combinations such as AFL plus radiofrequency or AFL plus NAFL [100,101]. Wang et al. combined AFL with intense pulsed light (IPL) for the treatment of both inflammatory acne lesions and acne scars [102]. These investigators found that the addition of IPL was useful for the inflammatory acne lesions but did not impact scar improvement. In our hands, a combination of fractionated 915 nm diode laser with fractionated radiofrequency (Matrix RF, Syneron Medical) was also shown to be effective at reducing acne scarring [18]. The rate of PIH following treatment was 6.5% and occurred mainly over bony prominences. For photorejuvenation, a combination of IPL, near infrared light, and fractionated Er:YAG was found to be superior to IPL alone [103]. However, the addition of AFL in this setting did lead to an additional 3–5 days of skin sloughing.

In our practice, we routinely combine a variety of long-pulsed, QS or picosecond lasers for the treatment of benign pigmentary lesions, vascular lasers for redness and telangiectasia, and low-energy, low-density NAFL for full face resurfacing and rejuvenation. Additionally, acne scars with erythema are best targeted by a combination of vascular laser and NAFL. Fractional resurfacing also produces excellent results in combination with non-invasive skin tightening modalities such as monopolar radiofrequency (Thermage, Solta Medical) and microfocused ultrasound with visualization (Ultherapy, Ulthera, Mesa, AZ).

Combination energy modalities have the potential to synergistically improve cutaneous structure and function. In our experience, multi-modal approaches are superior to monotherapy especially taking into account the multitude of pigment and skin textural aberrations that give rise to photoaging. In Caucasian populations, a large variety of combinations have been studied from aggressive full ablation to more conservative pulsed lights and radiofrequencies. However, more studies involving Asian patient populations are required to determine the optimal parameters and modalities.

CONCLUSION

Utilizing the correct treatment parameters and respecting the unique characteristics of Asian skin allow the laser surgeon to safely and effectively treat a variety of cutaneous issues with both non-ablative and ablative fractional resurfacing. In general, a greater number of lower density NAFL treatments administered over a longer time period should be the primary therapeutic modality for the Asian patient. Ablative options should be reserved for those patients who fail to achieve satisfaction following non-ablative treatment. Currently, fractional resurfacing can be considered first line therapy for the treatment of atrophic acne scarring, hypertrophic scarring, and photorejuvenation. NAFL may be reserved as a second line option for melasma, but the majority of evidence demonstrates only temporary improvement with possible rebound. Post-inflammatory hyperpigmentation is the most common complication of fractional resurfacing in the Asian patient. Appropriate pre-operative and post-operative skin care and selection of lower density settings over a greater number of treatments while allowing for full recovery between sessions play a critical role in mitigating this complication.

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