Preliminary Observations on Fractional Ablative Resurfacing Devices: Clinical Impressions

Jill Waibel MD[a], Kenneth Beer MD[a], Vic Narurkar MD[b], Tina Alster MD[c]

[a.] Palm Beach Esthetic Dermatology and Laser Center, West Palm Beach and Jupiter, Florida
[b.] Bay Area Laser Institute, San Francisco, CA
[c.] Washington Institute of Dermatologic Laser Surgery

ABSTRACT

Fractional resurfacing has become an increasingly popular treatment for photodamage. Non-ablative and ablative fractional resurfacing modalities both have a variety of different devices that may be utilized for treatments. Each modality has its own benefits and drawbacks. In this article, the authors offer preliminary observations from hands-on experience with several different ablative fractional lasers presently available.

INTRODUCTION

Photodamage and rhytids are treated by many laser and non-laser modalities. Each is associated with a distinct efficacy and side-effect profile. Although traditional ablative CO_2 laser resurfacing was widely considered the gold standard, the increased risk for prolonged wound healing, scarring, infection and pigmentary alteration spurred the search for better options. Ablative fractional laser resurfacing, the newest category of resurfacing, may offer the potential for clinical efficacy without the attendant risk associated with traditional ablative resurfacing.

There is a plethora of fractional ablative devices presently on the market with more in the offing. Each promises rejuvenation with minimal postoperative recovery and a small degree of risk. Some offer differences that are clinically relevant while others offer technology that is far from novel. This article compares eight fractional ablative resurfacing devices for the treatment of mild-to-severe photoaging and rhytids in an effort to provide objective information to aid dermatologic surgeons in making better decisions when differentiating among lasers and to help improve patient outcomes.

The concept of the laser for dermatological procedures was introduced in the early 1960s by Dr. Leon Goldman with Q-Switched ruby laser for tattoo removal.[1] Throughout the next decade, a variety of continuous-wave or pulsed laser sources were developed for a variety of dermatological applications, including argon, carbon dioxide and neodymium:yttrium-aluminum-garnet (Nd:YAG) laser sources.[2,3] These devices created bulk heating that frequently led to unacceptable patient scarring.

The modern era of laser surgery was born when Anderson and Parrish[4] published their theory of selective photothermolysis, which described how delivery of thermal injury could destroy the tissue targets while minimizing collateral damage to surrounding tissue. Technical innovation and medical exploration led to the development of a broad range of devices and applications, including those intended to safely target benign-pigmented lesions, vascular lesions, hair follicles and tattoos through selective absorption.

Cutaneous laser surgery further diversified as new carbon dioxide (CO_2) laser technology became widely recognized as an effective option for treating photodamaged skin. CO_2 laser delivery typically employed shorter pulse durations or, in the case of continuous-mode CO_2 laser devices with scanning technology, shorter dwell times in order to minimize thermal damage and increase patient safety.[5,6] Through better control of laser energy, superior efficacy for treatment of rhytides, acne scarring and actinic damage was observed.[7,8] Fitzpatrick *et al.* reported that the heat caused a tissue-tightening effect that improved deep rhytides.[9]

The effectiveness of CO_2 laser devices was undermined, however, by their side-effect profile, which included significant risk for prolonged erythema, infection, delayed onset hypopigmentation and scarring.[10] For this reason, the Er:YAG laser was explored as an additional tool for ablative resurfacing, with the potential for reduced downtime and recovery with respect to the CO_2 laser.[11] The absorption coefficient of water for the 2940 nm wavelength Erbium laser source results in shallow absorption in tissue, with epidermal ablation and minimal thermal effects in the dermis. As a result, the traditional Er:YAG laser does not impart the same degree of clinical success as does the CO_2 laser for dermal tissue targets. Zachary et al. described modulation of the Erbium laser in order to increase the depth of ablation and increase hemostasis, thus improving the side-effect profile.[12] The Erbium was a good tool for resurfacing but was an underperformer for rhytides and tightening versus the CO_2. Several other modifications were made to both the ablative devices, including combining them, but side effects continued to

TABLE 1.

Fractional ablative laser device specifications

Manufacturer	Wavelength (nm)	Pulse Duration	Delivery Method	Beam Spot Size	Scanner Area	Depth
Alma Pixel XL Harmony	2940 nm Er :YAG	1, 1.5 or 2 ms	Scanned	250 µm	11 mm x 11 mm	300 µm
Deka Smartxide Dot	10,6000 nm CO_2	200 µs – 2.0 ms	Scanned Conventional	350 µm	15 mm x 15 mm	500-800 µm
Ellipse Juvia	10,600 nm CO_2	2.0 – 7.0 ms	Scanned	500 µm	7 x 7 MTZ/cm^{2}9 x 9 MTZ/cm^{2}11 x 11 MTZ/cm^2	400 µm
Lasering USA Mixto SX	10,600 nm CO_2	2.5 – 16 ms	Scanned (four quadrant)	180 µm 300 µm	20 x 20 mm	Ablation: 200 µm Thermal damage: addn 300 µm
Lumenis	10,600 nm CO_2	< 1 ms	Scanned			
Active FX				1300 µm	9 x 9 mm	10-300 µm
Deep FX				120 µm	10 x 10 mm	150 – 1600 µm (if pulse stack 3200 µm)
Lutronic	10,600 nm CO_2	Changes automatically with energy	Stamping Dynamic	120 µm 300 µm 1000 µm	14 x 14 mm	2500 µm
Palomar Lux 2940	2940 nm Er :YAG	0.2 – 5.0 ms	Stamping	100 µm	10 x 10 mm 6 x 6 mm	200 µm
Solta Repair	10,600 nm CO_2	0.15 to 3 ms 0.8-1.8 ms	IOTS (paintbrush) continuous motion	<140 µm	n/a	1600 µm
Sciton Profractional	2940 nm Er :YAG	Changes automatically	Scanned	250 µm 430 µm	20 x 20 mm	1500 µm

be a significant barrier to these technologies.[13] One of the most profound reported side effect was delayed hypopigmentation—not presenting until two years post-operatively.[14]

In spite of the technologic advances, the side-effect profile and significant downtime led to a decreased use of these devices in the U.S. Non-ablative lasers were introduced with an increased safety profile, but decreased efficacy, in 2000.[15]

Fractional photothermolysis was first described by Manstein et al. as a new method for delivery of laser energy with the potential for improved safety and efficacy.[16] Through delivery of microscopic, non-contiguous zones of thermal damage using a 1550 nm, mid-infrared laser source, it was observed that surrounding islands of dermal and epidermal cells facilitated post-treatment collagen remodeling and rapid healing. The first commercially available device for fractional non-ablative resurfacing treatment was first introduced, in 2004, by Reliant Technologies (Mountain View, CA).

It is known that the depth of epidermal and dermal coagulation, proportional to treatment energy (mJ), is directly associated with the depth of collagen denaturation and subsequent neocollagensis. Regardless of depth of penetration, the coagulative laser tissue interaction results in an intact stratum corneum for decreased risk of infection and increased safety.[17]

Despite the success of minimally ablative and fractional technologies, there remained a need for more aggressive tissue ablation for the purposes of rejuvenation of severely photodamaged skin and deeper rhytids. Ablative fractional resurfacing devices have been introduced in the market over the past two years.

Many questions remain regarding the efficacy and role of these devices and how they compare to traditional ablative technologies and to each other. This retrospective review compares several of the fractional ablative devices.

METHODS

In a retrospective case-series analysis, 18 patients with Fitzpatrick skin types I through IV, ranging in age from 43 to 70 years, underwent one treatment with an ablative fractional resurfacing device (Alma Caesarea, Israel; Deka, Dallas TX; Ellipse, Horsholm Denmark; Lasering USA, San Ramon CA; Lumenis, Santa Clara CA; Palomar, Burlington MA; Reliant, Mountain View CA, Sciton. Palo Alto CA) for treatment of mild-to-severe photodamage and rhytids.

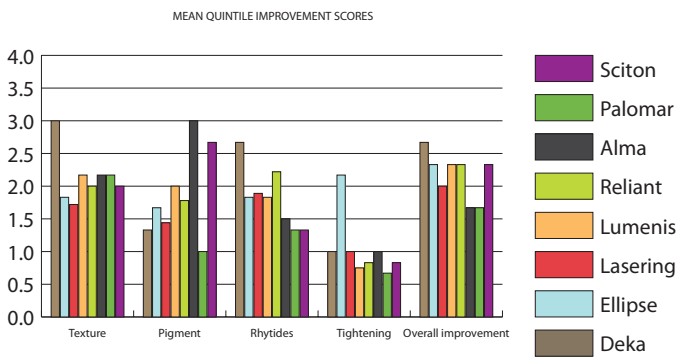
Mid-range energy settings were used for each device. These settings were determined based on published guidelines and recommended parameters from each company.

Post-treatment improvement of texture, wrinkles, pigmentation, tightening and overall appearance were graded on a quintile scale. These evaluations were performed by three blinded physicians, all of whom possess experience with fractional lasers. In addition to evaluating improvements in patient skin, subjects were also evaluated for potential complications including erythema, edema and post-inflammatory hyperpigmentation (Table 1). Patients were each sent a questionnaire to evaluate the mean duration of number of days of downtime, number of days to return to work and number of days to apply make-up.

RESULTS

Overall, subjects exhibited moderate clinical improvement with minimal adverse effects (Figure 1 and Table 2). Erythema and edema were consistently observed following treatment with each device and were most pronounced 24 to 48 hours post-treatment for all subjects. Post-treatment petechiae and oozing were particularly evident in subjects treated with the Solta CO_2 device. Downtime—as measured by the presence of erythema, edema, desquamation and crusting—ranged between 2 and 14 days. Subjects treated with the Alma (Alma Caesarea, Israel) and Ellipse (Ellipse A/S, Hoersholm, Denmark) lasers exhibited only mild erythema and edema, with rapid resolution of post-treatment responses. No scarring or delayed onset hypopigmentation was observed, although mild, local infection developed in one subject treated with the Palomar (Palomar Medical Technologies, Burlington, MA) device. Moderate to significant improvement in the appearance of photodamage was observed in 78% (14/18) of subjects. Although the limited number of subjects did not allow for statistical confirmation of relative efficacy, it appears that these devices may differ in their utility for specific conditions, such as rhytids, pigmentation, texture and laxity. Independent investigator quintile scoring indicated that the five CO_2 lasers delivered superior efficacy for rhytides (2.05±0.20), with respect to the three Er:YAG lasers (1.50±0) tested.

FIGURE 1. Independent-investigator evaluation of baseline and three-month photographs according to a standard quartile improvement scale (0-4)



DISCUSSION

This analysis compares the different devices of ablative fractional resurfacing for mild-to-severe photodamage and rhytids. Subjects and investigators both noted improvements in texture, rhytids and overall. Due to the small sample size and conservative treatment parameters, the authors were unable to draw statistically significant conclusions, but several noteworthy trends were observed. Overall, all of the devices delivered moderate clinical improvement with minimal adverse events. The postoperative recovery times were significantly decreased over those of traditional ablative technologies.

The rapid recovery times seen with fractional ablative resurfacing are most likely due to the healing of the wound. Traditional ablative laser wounds healed via migration of stem cells from the hair follicles. With fractional ablative resurfacing, it is hypothesized that the rapid recovery is due to re-epithelization from neighboring cutaneous stem cells. Additional histologic and molecular studies need to be performed to better characterize and understand the healing mechanisms involved.

The CO_2 lasers were found to be superior to the Erbium devices for treatment of rhytides. When an ablative beam of light contacts the epidermis it heats and vaporizes the skin. The vaporization results in a "hole" in the tissue. Erbium lasers have an increased absorption coefficient of water versus CO_2 dioxide lasers. Traditionally, the ablative erbium devices were so efficient at converting light energy into heat energy they had limited depth. With the ablative fractional devices it was proposed that perhaps the "cold holes" of erbium followed by a second thermal injection of heat would bring the performance of the erbium lasers on par with that of the CO_2 lasers. Because there is no

TABLE 2.

Subject self-assessment of post-treatment responses

Category	Days of Downtime	Days to Return to Work	Days to Apply Make-up
Fractional CO_2 (n = 14)	5.43±4.2	9.43±6.3	6.07±3.9
Fractional Er:YAG (n= 4)	7.0±5.2	9.25±2.2	9.50±4

FIGURE 2. A 70-year-old, skin type 2 female at baseline (left); 3 months following one treatment with the Fraxel re:pair® fractional ablative CO_2 laser (right)

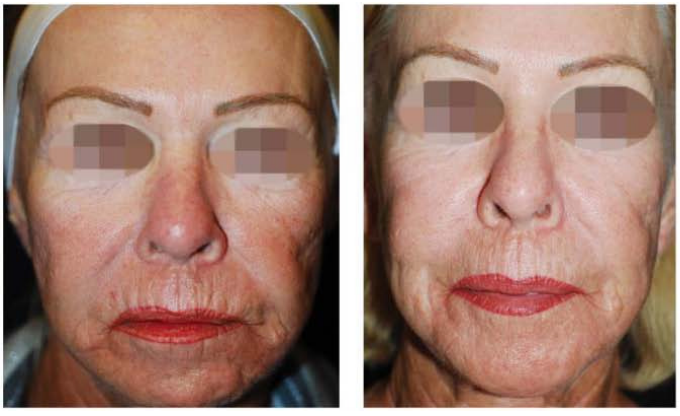
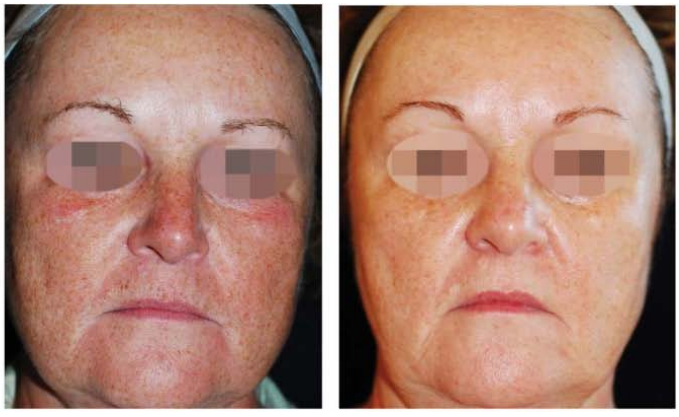


FIGURE 3. A 55-year-old, skin type 2 female at baseline (left); 3 months following one treatment with the Alma Pixel® XL Harmony Er:YAG laser (right)



coagulation with erbium lasers, these devices yield increased bleeding post-operatively. In addition, there was concern that the "hot" holes of the CO_2 devices may cause too much thermal damage and lead to possible scarring, and even melanocyte damage, in years to come. In this small patient group, the CO_2 lasers exhibited results that were superior to those of the erbium lasers in rhytids. The erbium technology fared better with hyperpigmentation.

The question remains if removing volume via ablation is ultimately the most effective way to erase a surface rhytid or not. As tissue is immediately ablated, there is immediate tissue contraction. There will be bimodal improvement—one from the immediate skin contraction and a second at three-to-six months post-treatment from collagen remodeling.

The depth of collagen remodeling needed for rhytids is still under debate. Traditional ablative technologies, which are considered the gold standard in laser wrinkle removal, only penetrated about 200 microns. It may be that photorejuvenation treatment may not require deep penetration whereas treatment for scars may necessitate additional penetration depth for success. One factor to consider it that since the wound healing response for fractional ablative therapies may be molecularly quite different from that of traditional ablative therapy, it may not be possible to correlate the depth of ablation to clinical improvement in the same manner.

As to the different ablative devices on the market, they all offer significant differences in their depths of penetration. Another unanswered question with these new technologies is whether the depth of ablation or the depth of thermal damage is the most important. Presumably with massive heating of collagen there will be a subsequent fibroblast proliferation and, eventually, new collagen formation. Again further histologic and molecular studies need to be performed to determine which device, level of ablation and thermal damage are needed to stimulate maximal neocollagenesis.

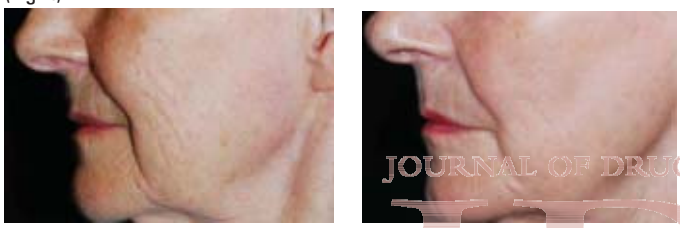
Perhaps the most important difference between the devices is the delivery technology with which to create the cutaneous wound. The degree of injury is governed by the parameters set for each device, including spot size, geometry of the lesion, pulse density, pulse width and depth. Additional histopatholgic analyses, as well as clinical results, will help answer how the different patterns of making an injury will optimally improve collagen remodeling and clinical outcomes. The one area that still needs to be evaluated would be optimal parameters to yield optimal clinical results.

Based on this small sample size, the best clinical improvements seemed to correlate with devices with smaller beam-spot sizes. Theoretically the small spot size allows for deep dermal penetration and minimized thermal damage to surrounding normal tissue. The authors believe that there exists an "effective fractional spot size" which we define as the product of the fraction of the spot size that is actually treated and the area of the spot size. For instance, if a 1 cm spot size has a 50% fractional treatment, the effective fractional spot size is 0.5 cm. This measurement may help to compare various modalities in an objective and meaningful manner.

Another parameter to keep in mind is pulse duration. With longer pulse durations more heat is imparted to the skin. Shorter pulse durations deliver less energy and, therefore, heat. Too much heat could potentially lead to scarring, especially in off-face locations. Many devices offer the ability to change both pulse duration and density, thus allowing the physician to tailor the treatment to each specific patient and body location being treated.

Overall, fractional ablative treatments appear to have a better safety profile versus than that of traditional ablative resurfacing.

FIGURE 4. A 66-year-old, skin type 2 female at baseline (left); 3 months following one treatment with the Ellipse® Juvia CO_2 laser (right)



The authors know from experience from ablative resurfacing that off-face treatments have a higher tendency to scar. The jury is still out on the safety profile of treating off-face with fractional ablative devices. Will there be any delayed onset hypopigmentation, for example? The authors will continue to watch the complication rates closely and what parameters may be associated with scarring.

CONCLUSION

A myriad of new ablative fractional resurfacing devices with distinct technological characteristics seek to deliver maximal safety and efficacy. No serious adverse events were observed and recovery time appeared to be significantly decreased over traditional ablative technologies. Limitations of this review include small sample size, unequal groups and moderate parameters. While this preliminary evaluation indicates that fractional ablative devices may be broadly considered as an option for treatment of photoaging and rhytids, their unique technological characteristics deliver a wide range of clinical responses.

With better understanding of which parameters are the most clinically important it will be learned how to optimize the devices. In order to fully characterize the potential of the new ablative fractional category and better understand the optimal applications for each device, further investigations are necessary. Relative safety and efficacy may only be established by extensive split-face, intra-subject comparison.

This is a preliminary observation of the new class of fractional ablative lasers recently introduced into the market. It should serve as a starting point for further studies of this modality for this indication. While these data are not statistically significant due to the very small number of patients, future large-scale studies will help to define the various risks and benefits associated with different devices used for this procedure.

REFERENCES

1. Saks NM, Roth CA. Ruby laser as a microsurgical instrument. *Science.* 1963;5:141:46-47.
2. Goldman L, Wilson RG, Hornby P, Meyer RG. Radiation from a Q-switched ruby laser. Effect of repeated impacts of power output of 10 megawatts on a tattoo of a man. *J Invest Dermatol.* 1965;44:69-71.
3. Goldman L. Current instrumentation in laser dermatology. *Med Instrum.* 1983;17(6):413-414.
4. Anderson RR, Parrish JA. Selective photothermolysis: Precise microsurgery by selective absorption of pulsed radiation. *Science.* 1983;220(4596):524-527.
5. Lask G, Keller G, Lowe N, Gormley D. Laser skin resurfacing with the SilkTouch flashscanner for facial rhytides. *Dermatol Surg.* 21(12):1021-1024.
6. Shim E, Tse Y, Velazquez E, *et al.* Short-pulse carbon dioxide laser resurfacing in the treatment of rhytides and scars. A clinical and histopathological study. *Dermatol Surg.* 1998;24(1):113-117.
7. Dover JS, Hruza GJ. Laser skin resurfacing. *Semin Cutan Med Surg.* 1996;15(3):177-188. Review.
8. Lowe NJ, Lask G, Griffin ME, *et al.* Skin resurfacing with the Ultrapulse carbon dioxide laser. Observations on 100 patients. *Dermatol Surg.* 1995;21(12):1025-1029.
9. Fitzpatrick RE, Rostan EF, Marchell N. Collagen tightening induced by carbon dioxide laser versus erbium:YAG laser. *Lasers Surg Med.* 2000;27(5):395-403.
10. Alster TS. Cutaneous resurfacing with CO_2 and erbium:YAG lasers: Preoperative, intraoperative and postoperative considerations. *Plast Reconstr Surg.* 1999;103(2):619-632.
11. Khatri KA, Ross V, Grevelink JM, *et al.* Comparison of erbium:YAG and carbon dioxide lasers in resurfacing of facial rhytides. *Arch Dermatol.* 1999;135(4):391-397.
12. Zachary CB. Modulating the Er:YAG laser. *Lasers Surg Med.* 2000;26(2):223-226.
13. Tanzi, EL, Alster TS. Side effects and complications of variable-pulsed Erbium:yttrium-alumninum-garnet laser skin resurfacing: Extended experience with 50 patients. *Plast Reconstr Surg.* 111(4):1524-1529.
14. Nanni CA, Alster TS. Complications of carbon dioxide laser resurfacing. An evaluation of 500 patients. *Dermatol Sur.* 1998;24(3):315-320.
15. Zelickson BD, Kilmer SL, Bernstein E, *et al.* Pulsed dye laser therapy for sun damaged skin. *Lasers Surg Med.* 25(3):229-236.
16. Manstein D, Herron GS, Sink RK, *et al.* Fractional Photothermolysis: A new concept for cutaneous remodeling using microscopic patterns of thermal injury. *Lasers Surg Med.* 2004:34(5):426-438.
17. Graber EM, Tanzi EL, Alster TS. Side effects and complications of fractional laser photothermolysis: Experience with 961 treatments. *Dermatol Surg.* 2008;34:301-307.

ADDRESS FOR CORRESPONDENCE

Kenneth R. Beer, MD, FAAD
Palm Beach Esthetic Dermatology and Laser Center
1500 North Dixie Highway, Suite 305
West Palm Beach, FL 33401
Phone: ..... (561)655-9055
E-mail: ..... kenbeer@aol.com