Full-face Treatments With the 2790-nm Erbium:YSGG Laser System
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ABSTRACT

Background: Traditional full-face resurfacing has been limited to erbium-doped yttrium aluminium garnet (Er:YAG) and carbon dioxide (CO₂) lasers. These devices offer wavelength-specific advantages and disadvantages.

Methods: Nine patients were enrolled in a pilot study of a resurfacing system using a 2790-nm erbium:yttrium-scandium-gallium-garnet (Er:YSGG) laser system. Two treatments were carried out 1 month apart over the entire face. Test spots were performed prior to the full-face sessions to determine the optimal fluence for 1-pass laser resurfacing. Biopsies were performed at the time of treatment and at the final follow-up visit one month after the second treatment. Clinical endpoints included changes in pigment dyschromias, wrinkles, and skin tone. All outcomes were graded by blinded observers.

Results: Eight patients completed the 2 treatments. Biopsies showed thermal damage extending as deep as 80 µm below the stratum corneum. Reepithelialization was complete within 4 days. No scarring, post inflammatory hyperpigmentation (PIH), or infections were observed.

Conclusion: A 2790-nm laser can be used for skin rejuvenation with a 4 day recovery window.

INTRODUCTION

In the mid 1990s, carbon dioxide (CO₂) laser resurfacing was typically performed with 1 to 3 passes, and residual thermal damage (RTD) of 20 µm to 80 µm in the dermis was associated with predictable wrinkle reduction; however, patient downtime was 10 days to 14 days and, if complicated by infection or hyperpigmentation, could last much longer.¹ ² ³ ⁴ Some patients developed delayed hypopigmentation, particularly those patients with sun-damaged Fitzpatrick type 2 and 3 skin.

Later, the erbium-doped yttrium aluminium garnet (Er:YAG) laser became popular as an alternative ablative device. Studies comparing CO₂ lasers and Er:YAG lasers showed that for equivalent results, the Er:YAG laser required similar recovery times as the CO₂ laser.⁵ ⁶ The Er:YAG laser, when deployed with pulse widths ranging from 100 µs to 500 µs, shows an ablation threshold of about 0.5 J/cm². At radiant exposures above this threshold, little thermal damage has been observed (usually less than 20 µm). The lack of thermal damage with the short pulsed Er:YAG laser allows for a high rate of water loss from the skin surface.⁷ ⁸ ⁹ This lack of a barrier is associated with immediate oozing and postoperative discomfort. On the other hand, this same absence of thermal damage permits rapid healing. With 1 pass, the CO₂ laser, at fluence ranges of 4 to 10 J/cm² and a pulse width of about 1 ms, achieves 50 µm to 80 µm of thermal damage and little true tissue ablation (vaporization). With multiple passes, the damage extends about 100 µm into the dermis, and the wounds heal in about 8 to 14 days (time for reepithelialization).

By decreasing the radiant exposures with both CO₂ and Er:YAG lasers, mini laser peels evolved where only partial epidermal injury was achieved, and healing times ranged from 1 to 6 days. These superficial injuries are associated with low rates of infection, erythema, and most importantly, pigmentation alterations. Recently, fractional devices have gained popularity. The associated pixilated injury severity depends on the density of microspots, wavelength, microbeam radiant exposure, microbeam diameter, and the ratio of ablation to coagulation for the microcraters. As these procedures treat only a fraction of the skin’s surface (normally in the range of 10% to 50% surface coverage per treatment session), serial treatments optimize cosmetic improvement.¹⁰ ¹¹ ¹² ¹³ ¹⁴ Compared to their nonablative counterparts, ablative fractional, devices, particularly with deeper craters and higher densities, tend to achieve better 1-time cosmetic enhancement, but recovery times can approach traditional deep ablative interventions.

The erbium:yttrium-scandium-gallium-garnet (Er:YSGG) laser has a tissue absorption coefficient roughly 5 times that of CO₂ laser and 1/3 that of the Er:YAG laser (Figure 1).¹⁵ The erbium YSGG laser, when deployed with a pulse width of 200 µs to 800 µs, shows an ablation threshold of about 3 J/cm². Representing a hybrid between CO₂ and Er:YAG lasers, the authors treated patients in this study with 1 pass of the erbium YSGG laser in a protocol designed to achieve wrinkle and dyschromias reduction with no more than a 4-day interval for complete reepithelialization. This paper reports the results of a pilot evaluation of the safety, efficacy and histological effects with this new device.
METHODS
The institutional review board of Scripps Clinic approved the pilot study. Nine subjects were enrolled, only 8 completed the study, with skin types 1 through 3, aged 32 to 77 years, with mild to moderate photodamage. Six of the subjects were females and 2 were males. Informed consent was obtained from each subject. Patients received 2 full-face treatments, 3 weeks apart, with a 2 790 nm Er:YSGG laser system (Cutera; Brisbane, Calif). Prior to the full-face sessions, 3 preauricular test areas (1 X 1 cm²) were irradiated over a range of settings. The test spots were observed 3 days after treatment and were used to assess depths of ablation and coagulation as well as to evaluate the short-term response to treatment. Control and test area biopsies were taken from each subject immediately after the test area laser pulses. Although a range of fluences was applied for the test spots (1.5-3.5 J/cm²) in every patient, only 1 spot was biopsied per patient immediately after irradiation, where the fluence for the biopsy site was randomly assigned among 8 patients completing the study. Among the patients’ test spot biopsies, 3 patients were irradiated at 3.5 J/cm², 3 patients were irradiated at 2.5 J/cm², and the remaining 2 patients were irradiated at 1.5 J/cm². Biopsies were also performed at the final follow-up visit using the same fluence as the immediate posttreatment test area for a particular patient. Standardized photographs were taken at each visit with a Nikon D80 SLR digital camera (Nikon, Tokyo, Japan) equipped with a flash unit (Twinflash®). All photographs were taken in aperture priority mode (f29) with the same subject to lens distance throughout the study.

Full face treatments were performed at least 30 minutes after application of a topical lidocaine 5% anesthetic cream. After removal of the topical anesthetic with gauze, an acetone wipe was performed to ensure that any remaining anesthetic was removed. Each subject was treated with a single pass extending from the hairline to the jawline. The fluence was chosen based on the response at the test sites. The highest fluence that showed reepithelialization after 3 days was used for the full-face treatments. Pulses were applied contiguously using scan patterns consisting of 6-mm diameter individual laser pulses with an overlap of 20% (overlap between spots within the scan) to avoid any untreated areas. The pulse duration was 400 µs. No wiping was performed after treatment.

Outcome measures included wrinkle reduction, reduction in pigment inhomogeneities, and improvement in tone and texture. Assessments were carried out by review of photographs (pretreatment and posttreatment) presented in random order to a group 3 observers blinded to the order of the photographs. The raters were asked to make an assessment of which photographs showed the best cosmesis, after which the graders were asked to score the changes based on percentage of improvement in each category. If the raters chose the pretreatment and posttreatment photographs in reverse order, then any changes were reported as negative values. The results were tallied as means and standard error of mean (SEM) and standard deviation (SD). A paired t test was used for each category to assess statistical significance. Patients completed a diary during and after treatment. Also, pain scores were recorded on a visual analog scale (VAS) during treatment.
Eight patients completed the study. One patient dropped out after the test spots due to unexpected family commitments. Test spots evaluated 3 days after treatment showed a trend toward longer reepithelialization times with increasing fluences; however, even with the highest settings, there was almost complete reepithelialization after 4 days. Biopsies taken from the test area immediately after irradiation demonstrated a zone of vacuolated and coagulated epidermis. The total depth of these 2 zones ranged from approximately half of the epidermal thickness at a fluence of 1.5 J/cm² to the full-epidermal thickness at 3.5 J/cm² (Figure 2). Additional histological analysis demonstrated that 3 passes (1 over the other without wiping with at least a 5 second delay between pulses) at 3.5 J/cm² resulted in complete epidermal coagulation and residual thermal damage extending 10 microns into the dermis. Based on the test spot results, the mean fluence for the full face treatments was 2.2 J/cm².

During treatment, the skin showed an immediate whitening response with a tendency toward slight browning (char) only within the overlapping crescent regions within the scan pattern. This coagulated tissue remained on the skin after treatment. The treatment time for a full face ranged from 10 to 15 minutes. Once the petrolatum product was applied, the skin showed a sunburn–like red appearance. Subjects were instructed to keep the treated area covered with petrolatum or a similar ointment until reepithelialization was complete.

Pain was mild during the full-face treatment for most patients and VAS (1-10) ranged from 2 to 8 (first treatment: mean=3.4, median=3; second treatment: mean=4.6 [median 5]). There was no relationship between pain and fluence. Postoperatively, patients reported (from a wound diary) progressive daily healing. By day 1 posttreatment, the mean pain decreased to 1.5. In patients where less moisture was applied, parchment paper-like slough was observed between days 2 to 4. With more aggressive application of moisturizer, the daily changes were more...
subtle, and sloughing was less obvious. For most subjects, complete reepithelialization occurred on the third or fourth day after treatment. All subjects were followed at 1 day, 4 days, and 7 days after the first treatment. All subjects experienced mild to moderate erythema. Some subjects experienced mild to moderate edema and 1 subject developed contact dermatitis, which resolved after 3 days of topical corticosteroid use.

Eight patients completed the follow-up visit at 1 month after the second treatment. All of the subjects rated the discomfort during treatment as either mild or moderate. Except for 1 subject that developed contact dermatitis, all subjects indicated that discomfort had resolved by the first or second day after treatment and that they were comfortable returning to work between 1 day and 4 days after treatment. All 8 of the subjects reported improvement in overall skin tone and texture and as well as an improvement in brown spots (Figure 3 shows a series of photographs in a representative patient). Five subjects reported improvement in fine lines.

The objective clinical results are reported in Figure 4. All categories showed significant improvement compared to their pretreatment values ($P < .05$). Biopsies from the final follow visits showed thickening of the epidermis (pretreatment epidermal thickness mean = 42 µm ± 12 µm and post-treatment mean = 55 µm ± 15 µm). No changes in number of fibroblasts or vessels per high power field were noted.

**DISCUSSION**

The water absorption coefficient for the Er:YSGG laser is greater than that of a CO$_2$ laser but less than that of an Er:YAG laser. We speculated that this absorption coefficient would allow for a) less discomfort and b) finer control of the damage depth compared to a CO$_2$ laser, while providing greater residual thermal damage than an Er:YAG laser. The histology supports this contention, as the ratio of the depth of coagulation to ablation always exceeded unity. In fact true ablation (tissue removal) at these fluences was not observed, but rather was observed vacuolization of the upper portions of the epidermis. The stratum corneum was observed in all specimens, indicating that no gross tissue removal occurred.

With the Er:YSGG laser at these settings, the coagulated layer acts as a natural dressing and provides patient comfort and protection in the early healing period. The histology demonstrates that this device can evenly coagulate the epidermis using low-fluence settings. Thermal damage can reach the dermis if high-fluence passes are used. With the present fluence-spot size configuration, rapid confluent full-face treatments were optimized. Improvement in brown spots, skin tone and texture, and fine lines was reported with limited downtime.

Although the investigators in this study did not directly compare existing “traditional” Er:YAG and CO$_2$ macrowounding technologies (wounds greater than 1 mm in diameter, to differentiate from...
microwounding fractional techniques), our decade-long laser resurfacing experience permits the following comments: Compared to CO2 laser, our clinical outcome and microscopic results are similar to those achieved with lower fluence ranges (ie, 1-2 J/cm²) at 10 600 nm. Although the very low fluence CO2 laser shows similar wound healing, intraoperative pain is increased versus Er:YSGG and Er:YAG counterparts. With similar Er:YAG lasers, fluences of 2 to 4 J/cm² typically result in pure ablation of 3 µm/J/cm², so that a purely ablative wound approximately 15 µm deep would be observed with about 15 µm of RTD. Although the total depths of injury between this type laser and the Er:YSGG are similar, the ratio of coagulation to ablation with the Er:YSGG laser is associated with less immediate postoperative pain and oozing.

In sum, the advantage of the Er:YSGG laser in this parameter configuration (2-3.5 J/cm², 1 pass) is optimizing cosmetic enhancement within the context of inoperative postoperative pain management, as well as delaying desquamation so that reepithelialization occurs in concert with sloughing for seamless healing.

**DISCLOSURE**

E. Victor Ross is a speaker for Cutera Inc. Dr. Ross has also received an honorarium, research support, and equipment support from Cutera Inc.

**REFERENCES**