Combining Confluent and Fractionally Ablative Modalities of a Novel 2790nm YSGG Laser for Facial Resurfacing

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Background: Several laser technologies exist for improving rhytides, pigmentation, and skin texture. Recent advances in technology introduced a new wavelength, 2,790 nm, erbium:yttrium–scandium–galium–garnet (Er:YSGG) for treatment of photoaging. 2,790 nm Er:YSGG has a water absorption coefficient between CO_2 laser and Er:YAG laser and has both ablative and fractional-ablative capabilities.
Objectives: To evaluate the efficacy and safety of combining the ablative (confluent) and fractional-ablative modes of 2,790 nm Er:YSGG laser for treatment of photoaging.
Study Design/Materials and Methods: In this uncontrolled, open label, prospective study, 10 subjects were enrolled and had a single treatment of combined confluent and fractional-ablative 2,790 nm lasers for photoaging. The primary clinical end point of the study was the change in Fitzpatrick wrinkle score from baseline at different time points as determined by blinded reviewer assessments. Secondary clinical end points were the improvement in fine lines, tone/texture, and pigmentation; the subjects' self assessment; the incidence of side effects; and the tolerability of treatments.
Results: Based on blinded photo-assessments by two independent dermatologists, subjects showed clinically and statistically significant mean improvement of 1.9 (95% CI: 1.1–2.6), 1.6 (95% CI: 0.8–2.3), and 1.2 (95% CI: 0.5–2.0) in Fitzpatrick wrinkle scores at 6 weeks, 3 and 6 months, respectively. Of the 90% of subjects who showed improvement in Fitzpatrick wrinkle scores, 78% continued to have improvement at the 6-month follow-up visit. Mild erythema observed post-treatment was resolved by the 6-week follow-up visit in all subjects. No transient or permanent post-inflammatory hyperpigmentation (PIH); or serious adverse events were reported.
Conclusion: A combined confluent and fractional-ablative 2,790 nm Er:YSGG laser treatment improves photodamaged skin for at least 6 months. The treatment was well-tolerated and PIH was not found in our study. Lasers Surg. Med. 43:273–282, 2011.   © 2011 Wiley-Liss, Inc.

BACKGROUND AND OBJECTIVE

Fractional photothermolysis is an emerging technology for improving photoaging. Fractional lasers are classified into non-ablative and ablative fractional devices. Fractional non-ablative lasers offer less downtime and risk, but typically require several treatments to achieve improvement in mild-to-moderate rhytides, pigmentation, and texture [1–6]. Fractional-ablative lasers achieve decreased downtime and risk, compared to wavelength-equivalent ablative laser treatments, by only treating microscopic areas of tissue with large areas of untreated tissue surrounding each lesion [7,8]. Typically only performed once, fractional-ablative resurfacing has improved efficacy with respect to rhytides [9–28]. However, a single fractional-ablative treatment without full coverage limits the ability of these devices to improve texture imperfections and large areas of pigmentation.

Confluent (non-fractional) ablative lasers at wavelengths of 10,600 nm carbon dioxide (CO_2) laser and 2,940 nm erbium:yttrium–aluminum–garnet (Er:YAG) laser have been used for many years for photoaging [29]. These lasers treat the entire surface area in a single treatment, eliminating the need for multiple treatment sessions for large areas of pigmentation and texture imperfections. However, the 2,940 nm Er:YAG laser does not provide sufficient thermal damage to coagulate tissue significantly beyond the zone of ablation since it has a very high water absorption coefficient. On the other hand, the CO_2 lasers have a significantly lower water absorption coefficient which leads to increased depth of thermal damage, downtime, and complication rates [29–41].

The new laser crystal erbium:yttrium–scandium–gallium–garnet (Er:YSGG) emits laser energy at a wavelength

of 2,790 nm. This wavelength has a water absorption coefficient between 2,940 nm Er:YAG and 10,600 nm CO_2 lasers. This result in more coagulation and thermal stimulation than 2,940 nm Er:YAG treatments while being able to limit the depth and thermal injury to less than caused by 10,600 nm CO_2 treatments [29–34,42–47].

The 2,790 nm Er:YSGG laser device also has both ablative (confluent) and fractionally ablative capabilities which can be combined in the same treatment session. Combination treatment results in vaporization of the entire superficial epidermis, coagulation of the deeper epidermis, and fractional coagulation in the deeper dermis. The comparison of the photothermal effects of the combination confluent and fractional-ablative 2,790 nm Er:YSGG laser and fractional-ablative 10,600 nm CO_2 and 2,940 nm Er:YAG lasers are shown in Figure 1. The purpose of this uncontrolled, open label, prospective study was to evaluate the safety and efficacy of combining the confluent and fractionally ablative modes of 2,790 nm Er:YSGG laser in a single treatment with the goal of addressing both superficial and deeper skin changes associated with photoaging. The primary clinical end point of the study was the change in Fitzpatrick wrinkle score from baseline to 6 weeks, 3 months, and 6 months post-treatment as determined by blinded reviewer assessments. The secondary endpoints of the study were the improvement in fine lines, tone/texture, and pigmentation; the subjects' self-assessment; the incidence of side effects; and the tolerability of treatments.

MATERIALS AND METHODS

This study investigated a single treatment combination of confluent and fractionally ablative 2,790 nm Er:YSGG lasers (Pearl and Pearl Fractional[TM] Lasers, Cutera Inc., Brisbane, CA) for the treatment of photoaging. The Pearl[TM] laser was cleared by the FDA for wrinkles and skin resurfacing and the Pearl Fractional[TM] laser was cleared for skin resurfacing. The protocol was approved by the Western Institutional Review Board (WIRB, Olympia, WA), and informed consent was obtained prior to subject participation.

Subjects

Ten subjects were enrolled in the study as they presented themselves to the investigator's office either for treatment or in response to advertising. Inclusion criteria were as follows: females, at least 35 years of age with Fitzpatrick skin types I–III presenting with mild-to-moderate facial and/or neck photoaging (scores of 3–7 on Fitzpatrick's wrinkle scale, solar lentigines, and pigmentation). Table 1 shows the baseline subject characteristics.

Exclusion criteria includes Fitzpatrick skin types IV–VI, infection in the treatment area, history of poor wound healing, history of keloid formation, history of HIV, history of hepatitis, immuno-compromised, pregnant or lactating, use of Isotretinoin in the past 12 months, use of tissue fillers within 6 months, use of deep chemical peels, or laser resurfacing procedures that were in excess of
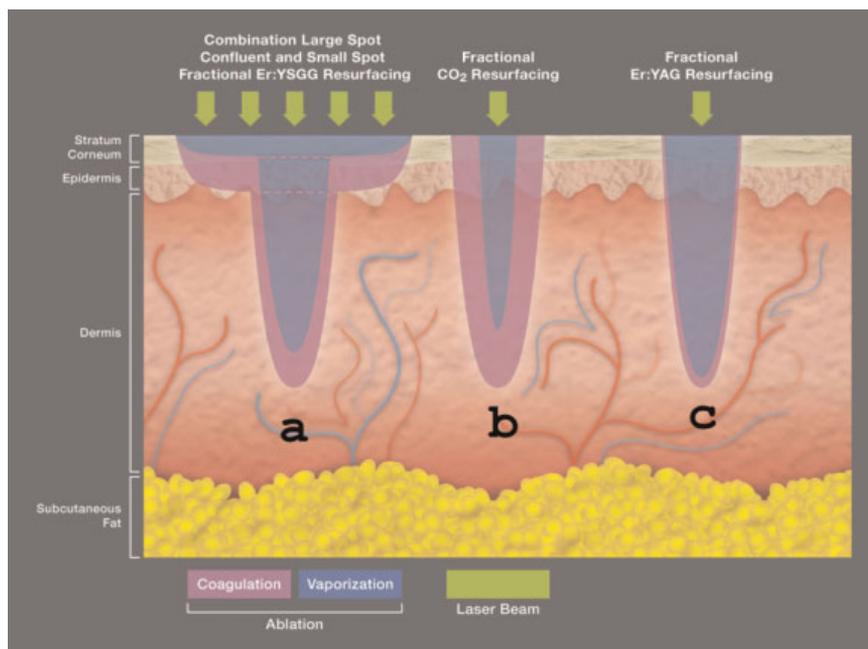

Fig. 1. (**a**) Combination large spot confluent and small spot fractional Er:YSGG resurfacing and comparison with (**b**) fractional CO_2 resurfacing and (**c**) fractional Er:YAG resurfacing.

TABLE 1. Subject Baseline Characteristics

n	10
Mean age (range)	58 (48–74)
Fitzpatrick skin type (n, %)	
I	1 (10%)
II	5 (50%)
III	4 (40%)
Baseline Fitzpatrick Wrinkle Score (n, %)	
4	1 (10%)
5	3 (30%)
6	4 (40%)
7	2 (20%)

90 μm deep or previous treatments targeting the dermis (except for vascular and hair reduction treatments).

Treatment

Subjects with a history of cold sores had prophylactic therapy with valcyclovir 500 mg bid for 5 days started 1 day prior to treatment. One subject took oral Ativan (Lorazepam) and nine subjects took Darvocet 1 hour prior to treatment. Topical anesthetic of compounded 20% benzocaine/6% lidocaine/4% tetracaine was applied on the face including the eyelids for 45–60 minutes. Subjects then washed the anesthetic off with a mild cleanser. After cleansing, medical grade acetone was used to remove any residual anesthetic and hydration from the skin. Metal intra-ocular eye shields were inserted after the topical was removed to provide additional safety while treating over the eyelids. Then, a line was drawn marking the inferior most extent of resurfacing (usually at the junction of the upper and middle third of the neck). Eyebrows and eyelashes were protected with Vaseline. Forced cold air was used in conjunction with all treatments.

Each subject first received a single pass confluent 2,790 nm laser treatment (median fluence 3.3 J/cm^2 and 10% overlapping) over the entire face and eyelids. Pulses were feathered over the jawline to create a natural taper. Each pulse was approximately 6 mm in diameter with multiple pulses delivered sequentially in a pre-selected scanned pattern of up to 3 cm by 3 cm. Confluent treatment was followed immediately by 2–3 passes of fractional-ablative 2,790 nm laser treatment on areas with significant photoaging using the energy level of 120 mJ and density of 8–12% per pass. The fractional handpiece has a microspot diameter (spot size) of 300 μm, scan size of 10 mm × 14 mm, with a pulse width of 600 microseconds. Treatment was concentrated on the upper and lower eyelids and perioral regions. Eyelids were held on stretch with a tongue depressor and two passes made over the lids such that the second pass was oriented at 45° to the first. The upper lid was treated from the inferior border of eyebrow to the eyelid margin; the lower lid was treated up to eyelid margins. The third pass was performed at the crow's feet if desired. Pulses were delivered using a scanner which precisely placed pulses in areas of approximately 2.4 cm by 2.4 cm. The scanner handpiece

was moved and the procedure was repeated at different locations until the entire area was treated. Total density of the fractional treatments varied from 8% to 36% for each subject.

Immediately post-treatment, Aquaphor® ointment was applied to the treated skin and subjects were instructed to perform diluted white vinegar soaks several times a day while reapplying Aquaphor® between soaks to prevent scabbing or drying. After re-epithelialization, subjects were allowed to discontinue vinegar soaks, wear make-up, and were instructed to wear daily sunscreen and minimize sun exposure.

Photographs

Standardized photographs, to be used for the blinded evaluations, were taken at baseline and 6 weeks, 3 months, and 6 months post-treatment using a 12.8 megapixel EOS 5D digital camera (f-stop 20, Canon Inc., Tokyo, Japan) and EF-24-70 lens (Canon Inc.). To control the consistency of photographs between various time points, the same photographer took photographs in the same room using a tripod set-up which allowed the camera to be positioned at a fixed distance and height relative to both the lighting and the subject. Consistent head positions and the angles were ensured by direct capture of the photographs onto the computer screen using Capture One Pro 3.7.7 Software (Phase One Inc., New York, NY). Subjects were asked to wash off any make-up before photographs were taken including baseline and follow-up photographs.

Assessment of Outcomes

Wrinkles, fine lines, tone/texture, and pigmentation at 6 weeks, 3 months, and 6 months following treatment were evaluated as follows: (1) blinded assessment of standardized before and after treatment photographs by two independent dermatologists and (2) subjects' self-assessment of improvement (collected from questionnaires).

Photo-assessments were performed by two independent dermatologists blinded to the order of before and after treatment photographs. The reviewers were also blinded to the treatment parameters and the subject data. A computer randomization program was used to determine the order of photographs in the binder. Three different views of the face in 8 × 10, high resolution (300 dpi) prints were used: the frontal, the right lateral (at 45°), and the left lateral (at 45°) views. The views for each subject were in the same order: all three views were either ordered as "before and after" or "after and before" treatment. The photo-assessments of three different time points were completed such that there was at least a 4 week separation between assessments. After the independent reviewers determined the chronological order of before and after photographs, they rated each photo using the Fitzpatrick wrinkle scale (Table 2).

Additionally, the improvement in wrinkles, fine lines, tone/texture, and pigmentation was assessed by the independent reviewers and the subjects using the quartile 5-point rating system: 0 = no improvement (0%), 1 = mild

TABLE 2. Fitzpatrick Wrinkle Assessment Scale

Class	Wrinkling	Score	Degree of elastosis
I	Fine wrinkles	1–3	Mild (fine textural changes with subtly accentuated skin lines)
II	Fine to moderate-depth wrinkles, moderate number of lines	4–6	Moderate [distinct papular elastosis (individual papules with yellow translucency under direct lighting) and dyschromia]
III	Fine to deep wrinkles, numerous lines with or without redundant skin folds	7–9	Severe [multipapular and confluent elastosis (thickened yellow and pallid) approaching or consistent with cutis rhomboidalis]

improvement (1–25%), 2 = moderate improvement (26–50%), 3 = significant improvement (51–75%), 4 = dramatic improvement (76–100%). If the before photo was incorrectly selected as the after photo, a negative value was assigned to the improvement score.

Pain levels were taken immediately post-treatment and during 7 and 11 days post-treatment visits using the pain scale of 0–10 (0 = no pain to 10 = severe pain). During the same follow-up visits, subjects were also evaluated for the presence of erythema, edema, purpura, crusting, oozing, bleeding, blistering, hyperpigmentation/hypopigmentation, and scarring on a 4-point scale (0 = none, 1 = mild, 2 = moderate, 3 = severe).

Statistical Analysis

Statistical analysis was performed using Minitab statistical package, version 15.1.20.0 (Minitab Inc., State College, PA). For statistical testing, one-way ANOVA for repeated measures (General Linear Model) was performed, and P-value <0.05 were considered statistically significant. Kappa statistics were used to evaluate the magnitude of agreement between the two reviewers (inter-reviewer reliability) and agreement with the gold standard photo (correct label of the photo) between the two reviewers (inter-reviewer validity) [48,49]. Kappa agreement analysis was used instead of simple percentage agreement because kappa coefficient takes into account that reviewers will sometimes agree simply by chance and calculates agreement above and beyond that expected by chance alone.

The primary clinical endpoint was the change in Fitzpatrick wrinkle score from baseline based on blinded photo evaluations by two independent reviewers at three different time points. Data were displayed as individual time series plot for each subject showing the wrinkle score at baseline and at three different follow-up visits. Additionally, the longitudinal data were analyzed to demonstrate whether there was statistically significant difference in Fitzpatrick wrinkle scores between four time points. The results were reported as mean differences and 95% confidence intervals. Tukey test at familywise error rate of 0.05 was used to adjust for multiple pairwise

comparisons. Pearson's correlation (r) was calculated to determine the association between the scores given by two independent reviewers. The secondary clinical points including the percentage improvement in wrinkles, fine lines, tone/texture, pigmentation; the level of subject satisfaction; the incidence of side effects; and the tolerability of treatments, were descriptively displayed using box plot, frequency distributions and averages with ranges. The median value and the spread of the improvement scores by condition and time point was illustrated in box plot graphs. Additionally, frequency distribution of improvement scores (percentage of subjects) was provided. Since there were more than two categories and they were ordinal, instead of kappa statistics a simple percentage match was used to evaluate the magnitude of agreement between two reviewers. For each condition, the range of agreement was determined based on pairwise comparisons between reviewers.

RESULTS

All 10 subjects completed follow-up visits at 7 days, 11 days, 6 weeks, and 9 subjects also completed the 3- and 6-month follow-up visits as scheduled. One subject missed the 3-month follow-up visit and another subject missed the 6-month follow-up due to scheduling conflicts. Clinical evaluations by the principal investigator and subject questionnaires were later collected on these two subjects at their earliest availability; however, standardized photographs could not be taken to be used for blinded photo-assessments.

Photographic Assessment by Independent Reviewers

Both reviewers correctly labeled all photographs taken at 6 weeks. The photographs taken at 3- and 6-month follow-up visits were correctly labeled on 8 of 9 subjects and 1 mislabeled photograph was from the same subject at both time points. The consistency resulted in "very good" inter-reviewer reliability (kappa of 1) across different time points (Table 3). The validity was "good" to "very good" (kappa of 0.77–1).

TABLE 3. Kappa Agreement Analysis of Before and After Photo-Assessments Between Two Independent Reviewers

Follow-up post-treatment	Total number of subjects assessed	Number of correct identifications (each reviewer)	Kappa coefficient[a]	
			Inter-reviewer reliability	Inter-reviewer validity
6 Weeks	10	10	1	1
3 Months	9	8	1	0.77
6 Months	9	8	1	0.77

[a]Kappa coefficient (strength of agreement): poor: <0.20, fair: 0.21–0.40, moderate: 0.41–0.60, good: 0.61–0.80, and very good: 0.81–1.00.

Change in Fitzpatrick Wrinkle Score From Baseline Based on Blinded Photo-Assessments by Independent Reviewers at Three Time Points

The individual time series plot in Figure 2 shows the Fitzpatrick wrinkle score for each subject over time. 90% (9/10) subjects had improvement and 78% (7/9) continued to have improvement at the final follow-up visit. 22% (2/9) showed decreased improvement over time. One subject (1/10) had no improvement. The mean change in Fitzpatrick wrinkle scores at each time point were correlated between two independent reviewers ($r = 0.58$, $P < 0.01$).

A general linear model analysis indicated that the mean Fitzpatrick score was statistically different between time points ($P < 0.01$). According to Tukey simultaneous tests involving all pairwise comparisons among four time points, the mean Fitzpatrick score was significantly lower at 6 weeks, 3 months, and 6 months after treatment than that of at the baseline. However, the mean Fitzpatrick scores at 6 weeks, 3 months, and 6 months were not significantly different from each other (Table 4).

To determine the validity of wrinkle score assessments performed on 2D photographs, the average baseline wrinkle score given by the two reviewers during photo-assessment was correlated to the wrinkle score given by the investigator during clinical assessment at baseline. The wrinkle scores collected using two different methods had linear association ($r = 0.87$, $P < 0.01$), in that, a high score in photo-assessment tended to also have a high score in clinical assessment.

Improvement in Wrinkles Including Periorbital and Perioral Wrinkles, Fine Lines, Tone/Texture, and Pigmentation (Quartile Improvement Scale of 0–4)

On average (median), a moderate improvement was maintained over 6 months post-treatment in all conditions and time points. The variability of improvement
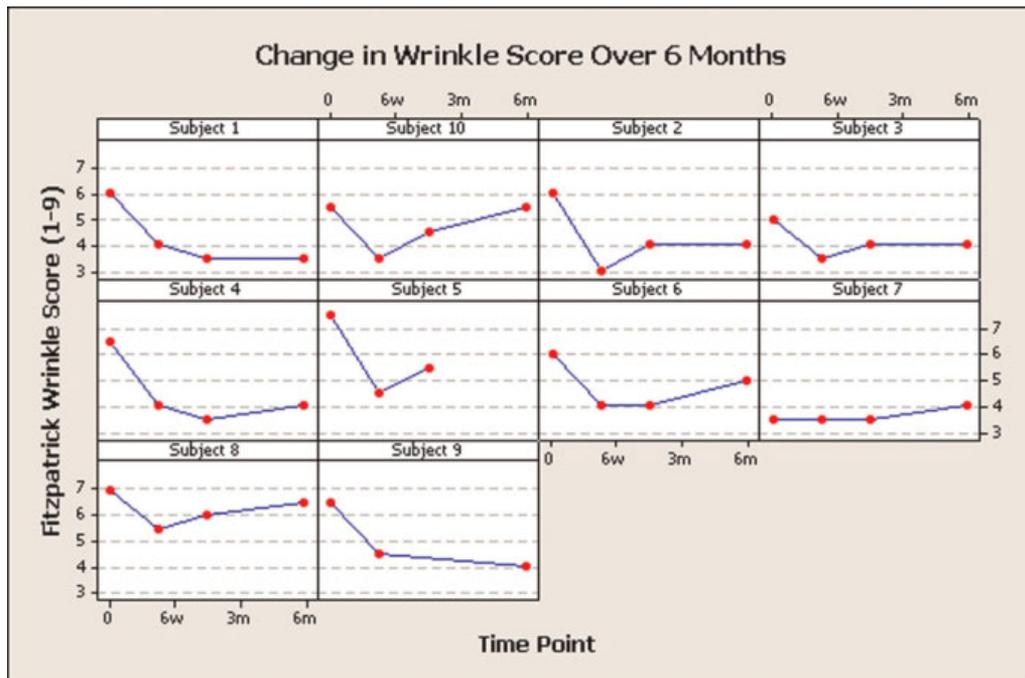

Fig. 2. Individual plot of wrinkle scores at 0 = baseline, 6 weeks (6w), 3 months (3m), and 6 months (6m) post-treatment based on blinded photo-assessments.

TABLE 4. Pairwise Comparisons of Fitzpatrick Wrinkle Scores at Different Time Points

		Wrinkle score	
Time (a)	Time (b)	Mean difference (a − b)	95% confidence interval[a]
Baseline	6 Weeks	1.9*	(1.1, 2.6)
	3 Months	1.6*	(0.8, 2.3)
	6 Months	1.2*	(0.5, 2.0)
6 Weeks	Baseline	(−1.9)*	(−2.6, −1.1)
	3 Months	0.3	(−1.0, 0.4)
	6 Months	0.6	(−1.4, 0.1)
3 Months	Baseline	(−1.6)*	(−2.3, −0.8)
	6 Weeks	−0.3	(−0.4, 1.0)
	6 Months	0.3	(−1.1, 0.4)
6 Months	Baseline	(−1.2)*	(−2.0, −0.5)
	6 Weeks	−0.6	(−0.1, 1.4)
	3 Months	−0.3	(−0.4, 1.1)

[a]Adjustment for multiple comparisons: Tukey with family error rate of 0.05 (equivalent to a 95% joint confidence level).
*Significant at the 0.05 level.

Fig. 4. Median improvement in periorbital, perioral, and overall wrinkles over time. (The box illustrates the interquartile range (IQR) extending from the 25th percentile to the 75th percentile with a line placed at the median (50th percentile). The bottom and top end of whiskers show the minimum and maximum data points, respectively. Stars indicate the outliers.)

scores was slightly higher at the 6-month follow-up visit across conditions (Figs. 3 and 4). The periorbital and perioral wrinkles also indicated a moderate improvement at all time points.

The percentage of subjects who showed "Moderate" to "Very Significant" improvement is presented in Figure 5. The improvement score of each subject was based on average values by two blinded reviewers. The percentage of subjects with "Moderate" to "Very Significant" improvement in wrinkles, fine lines, pigmentation and overall

condition was 90% and 65% at 3- and 6-month follow-up visits, respectively. Seventy-eight percent of the subjects maintained the "Moderate" to "Very Significant" improvement in tone/texture at 3 and 6 months post-treatment.

Two reviewers agreed on the amount of improvement (quartile improvement scores 0–4) 56–100% of the time at 6 months time point when the percentage match was calculated via "match with at most one score difference" (Table 5).

Subjects' Self-Assessment

At the 6-month follow-up visit, 80% of subjects reported "moderate" to "very significant" improvement in all
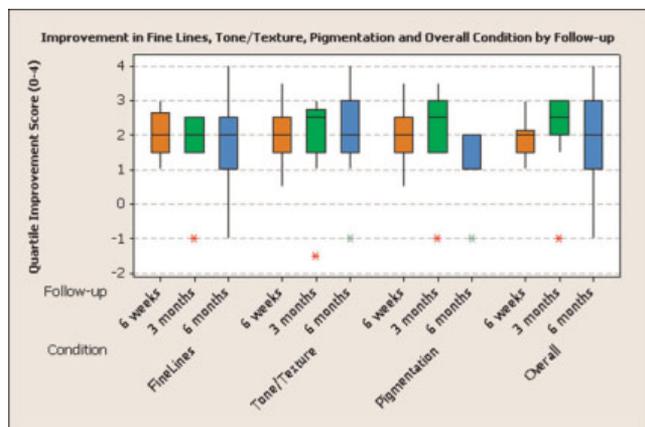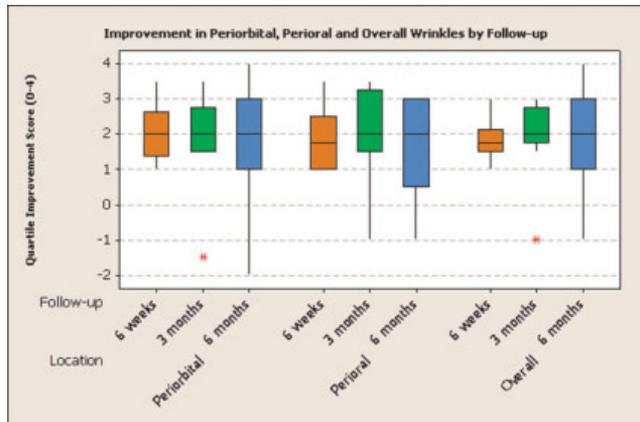

Fig. 3. Median improvement in fine lines, tone/texture, pigmentation, overall condition over time. (The box illustrates the interquartile range (IQR) extending from the 25th percentile to the 75th percentile with a line placed at the median (50th percentile). The bottom and top end of whiskers show the minimum and maximum data points, respectively. Stars indicate the outliers.)
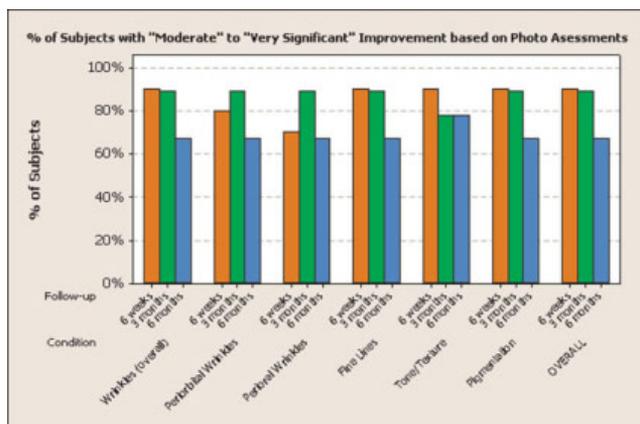

Fig. 5. Percentage of subjects with "Moderate" to "Very Significant" improvement based on photo-assessments by two independent reviewers.

TABLE 5. Percentage of "Perfect Match" and "Match With at Most One-Score Difference" Between Independent Reviewers at Three Time Points (Quartile Improvement Score 0–4)

Condition	6-Week follow-up		3-Month follow-up		6-Month follow-up	
	Perfect match (%)	Match with at most one-score difference (%)	Perfect match (%)	Match with at most one-score difference (%)	Perfect match (%)	Match with at most one-score difference (%)
Wrinkles (overall)	20	70	44	78	23	78
Wrinkles (periorbital)	30	70	11	78	12	67
Wrinkles (perioral)	20	70	44	89	34	67
Fine lines	30	70	33	89	34	56
Dyschromia	0	70	22	89	56	89
Tone/texture	10	90	22	56	34	78
Overall	40	70	44	78	45	100

conditions including wrinkles, fine lines, pigmentation, tone/texture, and overall improvement (Fig. 6).

Adverse Events

Immediately post-treatment, 50% of subjects had mild pinpoint bleeding and 30% had mild oozing, all of which resolved within 24 hours. At the 7-day follow-up visit, all subjects had re-epithelialized. The mild erythema (90%) and edema (20%) observed at the 11-day follow-up visit were resolved by the 6-week visit, and no incidence of post-inflammatory hyperpigmentation (PIH) was observed at the 6 weeks, 3 months, or 6 months follow-up visits. On two subjects, after the last treatment, the investigators did note the presence of a persistent "microdot" pattern resembling the scanner pattern of the fractional handpiece. This has been reported by other investigators using this wavelength in the fractional mode [51]. This was most evident in the malar area and resolved spontaneously 2 months after the last treatment with no sequelae. There were no cases of infection, permanent scarring, or other adverse effects reported. Moderate discomfort during treatment was noted with a mean pain score of 4.2 (SD 2.5) on a scale of 0–10. The subjects were

Fig. 6. Percentage of subjects with "Moderate" to "Very Significant" improvement based on assessments by the subjects.

able to wear make-up, on average, 6 days post-treatment (ranging 3–8 days).

DISCUSSION

The results of this safety and efficacy study suggest that the 2,790 nm Er:YSGG laser enables safe and effective combination treatment with both confluent and fractional ablative modes [42–47]. The combination delivers the benefit of fewer treatments of confluent treatment with the limited downtime and safety of fractionally ablative treatments in a single treatment session (Fig. 7).

The confluent 2,790 nm Er:YSGG device causes ablation in the superficial epidermis and coagulation in the deeper epidermis by primarily targeting water. The depth of ablation can be controlled by the operator by adjusting the laser fluence, such that the depth of thermal injury increases as fluence levels increases from approximately half of the epidermal thickness at a fluence of 1.5 J/cm^2 to the full epidermal thickness at 3.5 J/cm^2 [43]. Compared to ablative 2,940 nm Er:YAG and CO_2 lasers, this wavelength causes more coagulation and thermal stimulation than 2,940 nm Er:YAG while limiting depth and thermal injury to prevent increased downtime associated with CO_2 treatments [29–34].

On the other hand, the fractional-ablative treatment mode of 2,790 nm Er:YSGG ablates the dermis via 300 μm diameter laser columns and results in a penetration depth of 300–1,500 μm with 40–60 μm of residual thermal damage. Final density of the fractional mode is determined by the combined annulus of coagulation plus the ablation crater. The fact that the two mechanisms function in unique ways on different depths of tissue allows the treatment of both superficial and deeper layers in a single session.

When two modalities are combined, the 2,790 nm Er:YSGG laser produces vaporization of the entire superficial epidermis and coagulation in the deeper epidermis; and fractional coagulation in the deeper dermis. The combination treatment was sequenced as full-face confluent treatment followed by fractional on targeted areas. This order enables more consistent confluent treatments
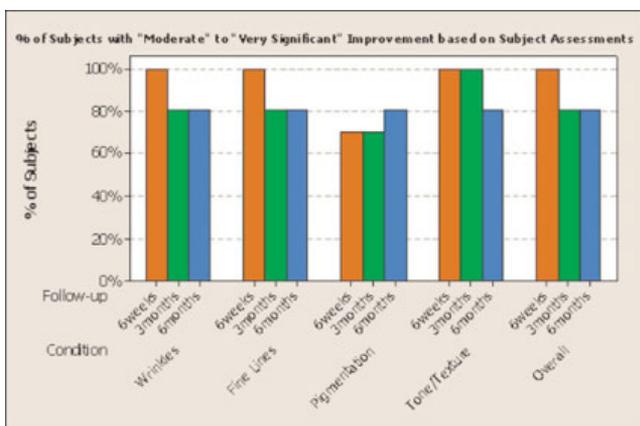
Fig. 7. Pre-treatment (4a, 6a, and 9a) and 6 months post-treatment (4b, 6b, and 9b).

since fractional ablative treatment can result in mild oozing and pinpoint bleeding that could interfere with subsequent laser delivery. The confluent treatment is intentionally limited in depth to treat the entire thickness of the epidermis without weeping and oozing associated with deeper treatments.

The treatment outcomes observed in this study are similar to that from studies with fractional CO_2 devices with small and big size spot treatments. However, unlike the dual mode fractional devices, the confluent Er:YSGG treatments offer full coverage with the parameters used in this study resulting in similar outcomes with less side effects and better patient experience [19,50,51].

Ninety percent of subjects showed improvement in Fitzpatrick wrinkle scores; which was the primary clinical outcome of this study. The results were supported with high inter-reviewer reliability and validity. The subject

with the baseline score of 4 (the lowest wrinkle score in this study) was also the only subject the reviewers had difficulty in correctly identifying the before and after photographs which showed she has no improvement. The majority of the subjects who maintained the improvement over time had a baseline score of 6. Two subjects, who had baseline scores of 5 and 7, showed a decrease in improvement over time. Our study indicated mean wrinkle score improvement of 1.6 (95% CI: 0.8–2.3) and 1.2 (95% CI: 0.5–2.0) at 3 months and 6 months post-treatment, respectively. Rahman et al. [15] reported similar results [mean reduction of 1.47 (SD 1.1) in Fitzpatrick Wrinkle Score] at 3-month follow-up after 1–2 treatment sessions of full-face fractional CO_2 laser treatments.

The quartile improvement scores of wrinkles including periorbital and perioral wrinkles, fine lines, tone/texture, and pigmentation indicated that the magnitude of improvement was likely to have at most a one-score difference for the majority of the cases if they were graded by different reviewers. The percentage of perfect match between independent reviewers was the lowest in tone/texture at the 3-month time point and in fine lines at the 6-month time point. The subjectivity and the limitation of 2D photo-assessments might be among the possible reasons for the low percentage match especially for the conditions like fine lines and tone/texture which are difficult to capture in photographs.

Only topical anesthesia was used for the combination of confluent and fractional-ablative laser treatments and treatments were highly tolerable. All subjects were re-epithelialized within 1 week similar to what is observed in treatments with other laser resurfacing technologies. No persistent erythema was observed even though the subjects underwent a combination laser treatment. No transient or permanent PIH was reported over the course of this study.

The finding of no PIH is consistent with other confluent 2,790 nm Er:YSGG studies using both low and high fluence on skin types I–III [42–46,52]. Conversely, studies comparing single pass CO_2 laser with multiple pass 2,940 nm Er:YAG found that 24–40% of subjects developed PIH in subjects with skin types I and II [33] and the incidence of PIH was higher in periorbital areas than in perioral areas [34]. Karsai et al. [9] reported marked PIH on the periorbital site treated with fractional CO_2 laser. Those subjects were Fitzpatrick skin types I and II. In a recently published study, 13% of the subjects (skin types I–III) developed PIH after dual depth fractional-ablative CO_2 treatments of wrinkles in the periorbital area [53]. On the other hand, Dierickx et al. [25] reported no long-term dyspigmentation at 3 months post-treatment with fractional 2,940 nm Er:YAG and fractional 2,790 nm Er:YSGG in perioral and periorbital areas in skin types I–III.

Recently, Kono et al. [51] reported the incidences of hyperpigmentation and residual micro dots in Asian patients after fractional treatments of acne scarring at fluences of 160–200 mJ with densities 12% and 16%.

Although the number of passes was not indicated, the incidences of hyperpigmentation observed could have been due to the higher fluences used in darker skin types. Goldberg et al. [52] who performed full-face treatments on 10 subjects (skin types II and III) with two passes of Er:YSGG laser at 160 mJ (a total density of 16–24%) and perioral treatments with a 160 mJ first pass and a second and third pass of 200 mJ (a total density of 32–36%) reported no hyperpigmentation. Residual microdots were observed in two patients in our study and resolved spontaneously without sequelae.

Lack of PIH after combination treatment with single pass confluent and multi-pass fractionally ablative treatments in skin types I–III appears favorable to other resurfacing technologies used alone. Although no incidence of PIH was found in our study, subgroups of varying skin types, including darker skin type IV, should be included in future studies with larger sample sizes. Longer follow-up data (minimum of 12 months) should be collected to demonstrate the incidence of pigmentary changes. This is especially necessary for hypopigmentation which often has a delayed onset of 6–12 months post-treatment [31].

This was the first study evaluating the safety and efficacy of combining the ablative (confluent) and fractional-ablative modes of 2,790 nm Er:YSGG laser for treatment of moderate photoaging. The results from this sample of 10 subjects indicated that combination treatments within the parameters used in this protocol could safely and effectively improve the photoaging of the face, and perioral and periorbital regions, particularly the periorbital eyelid area which presents itself with thinner epidermis thickness. However, studies with larger sample sizes which allow subgroup analysis of varying treatment settings and photoaging classes, including the perioral and periorbital areas, are required to further optimize treatment parameters [9,25,34,53–55]. Additionally, objective data such as wrinkle depth measurements through profilometry and calibrated measurements of the eyelid as well as subjective data such as wrinkle and eyelid redundancy scorings of the periorbital area should be included in the analysis [9,53–55].

CONCLUSIONS

The results from this study suggest that the combination of confluent and fractionally ablative laser treatment effectively treats rhytides and texture imperfections in a single session. Further, it seems to be highly tolerable with less downtime and side effects than alternative treatment modalities with comparable results.

Future work should consider large-scale studies as well as the investigation of combination treatments on the full-face. Moreover, comparison studies in randomized split face design should be conducted to determine the superiority of the combination treatments to treatments with alternative devices and protocols.

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