Evaluation of a Novel Fractional Resurfacing Device for Treatment of Acne Scarring

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Background and Objective: Pulsed carbon dioxide (CO_2) laser devices are considered highly effective treatment options for skin resurfacing. However, the high risk for significant treatment complications following CO_2 resurfacing has warranted the development of new treatment modalities. The concept of fractional photothermolysis was developed to address the shortcomings of ablative and non-ablative device modalities. This report evaluates a fractional approach to CO_2 laser resurfacing for the treatment of moderate to severe acne scarring. The primary endpoint of the study was the overall improvement in the appearance of acne scarring.
Study Design/Materials and Methods: Thirty subjects, with moderate to severe acne scarring, underwent up to three treatments with an FDA IDE and IRB approved 10,600 nm fractional CO_2 laser system. All subjects were Fitzpatrick skin types I–V and 18–75 years of age. Treatment parameters ranged from 20 to 100 mJ with total densities of 600–1,600 MTZ/cm^2. Improvement of acne scarring was evaluated at 1 and 3 months post-treatment.
Results: Twenty-three out of 25 subjects sustained clinical improvement in the appearance of acne scarring at the 3-month follow-up visits according to study investigator quartile improvement scoring. Subjects also had improvement in their overall appearance, including pigmentation and rhytides. Serosanguinous oozing resolved within 24–48 hours following treatment. All subjects had transient erythema, which resolved in the majority of subjects within 1–3 months. Post-operative downtime was significantly decreased compared to traditional ablative resurfacing. No serious complications were reported.
Conclusion: Fractional deep dermal ablation improves moderate to severe acne scarring. The added benefit is a considerable reduction both in downtime and risk of complications when compared to traditional CO_2 ablative resurfacing techniques. Lasers Surg. Med. 41:122–127, 2009. © 2009 Wiley-Liss, Inc.

Key words: acne scarring; fractional photothermolysis; fractional deep dermal ablation; skin resurfacing

INTRODUCTION

Facial acne scarring causes significant psychological distress due to disfigurement and social stigma. Historically, atrophic acne scars have been very difficult to treat, thus presenting a therapeutic challenge due to the limitations of available technology. Several modalities have been implicated to treat acne scarring, including surgical techniques (subcision, punch grafts, and excisions), autologous fat transfer, injection of dermal fillers, dermabrasion, chemical peels, and laser therapy (non-ablative, ablative) [1,2]. However, these techniques are limited in their efficacy, and there is currently no gold standard.

Traditional carbon dioxide (CO_2) ablative resurfacing is effective for the treatment of atrophic acne scars [3]. The high risk for significant treatment complications, such as infection, changes in pigmentation, scarring, and prolonged erythema associated with these devices has warranted the development of new treatment modalities capable of providing safer and more consistent alternatives [4]. The concept of fractional photothermolysis (FP) was initially developed to address the shortcomings of ablative and non-ablative devices. Rather than delivering homogenous thermal damage, FP is characterized by the creation of microscopic zones of thermal damage with spatial separation between damaged tissues. Mid-infrared fractional non-ablative resurfacing has been useful in the treatment of rhytides, photodamaged skin, surgical, and acne scarring without all of the side effects associated with pan-surface ablation [5–7]. However, several treatments are needed, and the clinical efficacy of these treatments has not yet reached that of full ablative procedures, especially with regard to deeper rhytides and scarring.

Recently, fractional deep dermal ablation treatment (FDDA^{TM} treatment) has been introduced to overcome

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extensive epidermal and dermal thermal damage associated with traditional ablative devices. It is theorized that an ablative fractional resurfacing device may offer increased efficacy with respect to mid-infrared fractional treatments while decreasing the risk and complications associated with traditional ablative resurfacing. FDDA utilizes high energy pulses delivered over very small beam diameters to induce tiny cylinders of vaporized tissue. Much of the energy is given off in the form of a super-heated plume, but sufficient energy remains to induce immediate tissue contraction and a sleeve of coagulated tissue [8,9]. In contrast to the superficial zones of ablation and coagulation achieved by traditional ablative resurfacing modalities, which are confined to the epidermis and upper dermis, columnar lesions result from ablative fractional resurfacing, exceeding 1.5 mm in depth of penetration [8]. Each treated area is surrounded by normal unaffected tissue, which results in very rapid healing with few associated long-term sequelae or complications. For the purposes of this article, the definition of "fractionated" or "fractional" is the delivery of energy in a manner sufficient to cause a thermal or ablated defect that extends into the dermis and is deeper than it is wide.

The safety and efficacy of fractional CO_2 resurfacing was previously demonstrated for the treatment of photodamaged skin of the face and neck [10]. In this study, we further evaluate a novel ablative fractional CO_2 device for the treatment of acne scars in order to characterize the safety and efficacy profile of this modality.

MATERIALS AND METHODS

The study protocol was Institutional Review Board (IRB) approved, and written informed consent was obtained from all subjects prior to commencement.

Subjects were recruited to be in the study if they demonstrated moderate to severe acne scarring, were between 18 and 75 years of age, and if their acne was quiescent. Exclusion criteria included pregnancy, a Fitzpatrick skin type of VI, active localized or systemic infections, compromised ability for wound healing, immunocompromised status, previous cosmetic procedures on the treatment area within 6 months of enrollment, oral isotretinoin within 12 months of enrollment, allergies to lidocaine or anti-virals, and smokers. A total of 30 subjects were enrolled at two separate clinical sites (CBZ and BDZ).

Prior to the procedure, subjects applied clobetasol ointment 0.05% to the face twice daily the day before treatment, as well as the morning of the treatment (BDZ site only). The clobetasol ointment was used to help decrease the post-treatment inflammatory response and also served as a vasoconstrictor to minimize post-treatment bleeding. Subjects were started on a 7-day course of bacterial and viral prophylaxis with cephalexin 500 mg bid and acyclovir 200 mg tid (CBZ) or valcyclovir 500 mg bid (BDZ). Pre-operative medications included lorazepam 1–2 mg, acetaminophen 500 mg (optional), acetaminophen/hydrocodone 5/500 mg, and ketorolac 30–60 mg IM (optional, CBZ site only). Methods for facial anesthesia included topical lidocaine 2.5%/prilocaine 2.5% applied 45–60 minutes prior to the procedure. Facial nerve blocks (supraorbital, infraorbital, mental, and infratrochlear) were also performed 15–45 minutes prior to treatment. Forced air cooling (SynerCool, Syneron Inc., Irvine, CA, USA) was used as well for added comfort during the procedure (BDZ site only).

Thirty subjects received up to three full face treatments with an FDA IDE and IRB approved 30 W, 10,600 nm fractional CO_2 investigational laser system (Fraxel re:pair™ prototype, Reliant Technologies, Inc., Mountain View, CA) by the principal investigators (CBZ, BDZ). Laser energy was delivered through numerous deflective and refractive elements and focused to a diffraction-limited $1/e^2$ spot size of approximately 120 μm in diameter with a pulse duration of up to 0.7 milliseconds [8,9]. Treatment parameters utilized in the study are outlined in Table 1. Non-overlapping (CBZ) and 50% overlapping passes (BDZ) were used to arrive at the total densities cited.

Immediately after treatment, subjects' faces were rinsed with sterile water, and a thick layer of zinc oxide (CBZ) or Aquaphor® (BDZ) was applied. Subjects were instructed to gently pat their face with dilute white vinegar soaks and then reapply the zinc oxide or Aquaphor every 2–3 hours for 72 hours after treatment. They were also instructed to limit sun exposure and apply daily sunscreen (with zinc oxide) for the remainder of the study.

During the treatment, subjects were asked to rate their overall pain level on a ten-point pain scale (0 = no pain to 10 = severe pain). After treatment, clinical appearance and post-treatment responses were also documented by on-site investigators evaluating for the presence of erythema and edema on a 3-point scale (0 = absent, 1 = mild, 2 = moderate, and 3 = severe) as well as the presence or absence of hypo/hyperpigmentation, blistering, and scarring. Standardized digital facial photographs (Visia (f-stop 16), Canfield Scientific, Inc., Fairfield, NJ, USA (BDZ), FinePix S2 Pro (f-stop 27), Fujifilm, Corp. (CBZ), Valhalla, NY) were taken at baseline, after each treatment, and at each follow-up visit to document clinical responses.

Subjects were seen for follow-up evaluation 72 hours, 1 week, and 1 month after their initial treatment, 1 month after subsequent treatments, and 3 months after their final treatment. Assessments of clinical improvement in atrophy, skin texture, and overall improvement in acne scarring were completed by the investigator and subjects at the 1- and 3-month follow-up visits based on a quartile scale of improvement (Table 2). Two independent blinded dermatologists also evaluated subject photographs taken at

TABLE 1. Treatment Parameters

Treatment energy (mJ)	Treatment density (MTZ/cm^2/pass)	Total density (MTZ/cm^2)
≤20	≤400	≤1,200
20–40	≤200	≤1,200
41–70	≤100	≤800
71–100	≤100	≤400

TABLE 2. Scale of Clinical Improvement

0 = No improvement
1 = 1–25% Improvement
2 = 26–50% Improvement
3 = 51–75% Improvement
4 = 76–100% Improvement

baseline and at the 3-month follow-up visit using the same quartile scale of improvement.

At the 1-month follow-up visit after the first treatment, the investigator conducted an evaluation of the treated area. If there was <26–50% improvement in the overall appearance of the skin and no side effects were observed, the subject was then eligible for a second treatment. Treatment procedures were identical to the first treatment. The same process was repeated 1 month after treatment 2, for a maximum of three treatments 4–12 weeks apart. Otherwise, if the subject was not eligible or did not desire further treatments, then a 3-month follow-up visit was scheduled.

RESULTS

The mean age of subjects was 40 years (range 22–61); 23 subjects had skin types I–III, 7 had skin types IV–V. Six subjects received one treatment, 7 subjects received two treatments, and 17 subjects received three treatments. One treated subject missed his 3-month visit and was lost to follow-up; one subject electively withdrew from the study for personal reasons after one treatment and the 1-month follow-up visit; and one subject was lost to follow-up after his first treatment and 1-month follow-up visit. Therefore, 27 subjects overall completed the entire study.

Treatment energies ranged from 20 to 100 mJ with total treatment densities of 600–1,600 microthermal treatment zones (MTZ)/cm^2 (Table 3). The average pain score reported over all three treatments was 5.9, corresponding to "moderate" pain based on a 10-point scale. All subjects reported that any discomfort associated with the procedure was only during active intervention and resolved immediately post-procedure. Increased pain scores correlated with increased density, but not increased energy.

Immediate effects of the procedure included serosanguinous oozing and punctuate bleeding, swelling, and mild to moderate erythema in all subjects (Fig. 1). Serosanguinous oozing and bleeding resolved within 24–48 hours following treatment. Erythema was transient and resolved completely in the majority of subjects within 1–3 months. Edema was also transient and resolved in 1 month or less (Table 4). There were 10 cases (32.1%) of post-inflammatory hyperpigmentation (PIH) at the 1-month follow-up visit and three cases (12.0%) at the 3-month follow-up visit. Four of these subjects had a Fitzpatrick skin type of I–III and six subjects had skin types IV–V. Treatment coverage was increased throughout the treatment series for these subjects, using treatment energies ranging from 20 to 40 mJ/pulse for treatment 1 and 40–100 mJ/pulse for treatments 2 and 3, with total densities of 600–1,200 MTZ/cm^2. PIH resolved on its own, or with topical hydroquinone. There were no incidences of infections, scarring, hypopigmentation, or other serious complications.

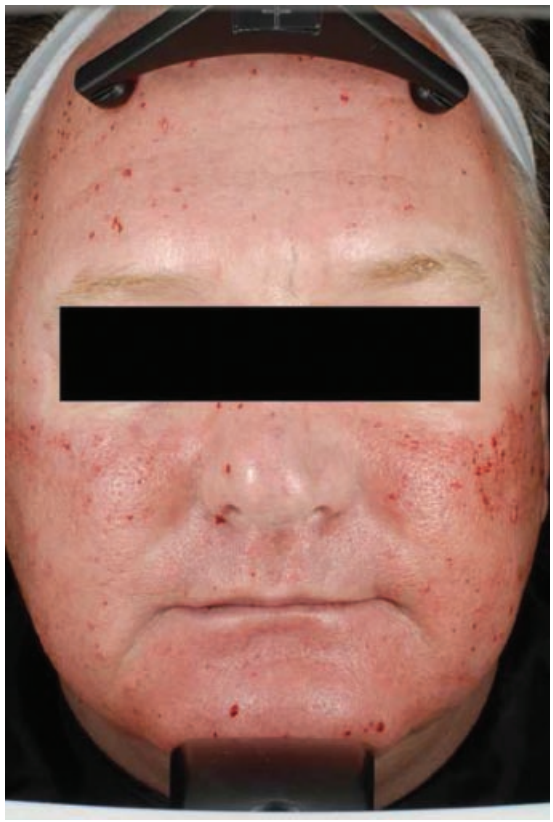

Fig. 1. Immediately after treatment with the 10,600 nm fractional CO_2 device.

TABLE 3. Average Energy, Total Density, and Pain Scores for Each Treatment

	Treatment energy (mJ)	Total density (MTZ/cm^2)	Pain score (0–10)
Treatment 1	30.0	963.4	6.6
Treatment 2	33.8	934.7	5.4
Treatment 3	40.6	688.2	5.0

Average investigator scores of improvement on the quartile scale at 1 month were 1.63 (±0.85) for surface texture, 1.09 (±0.82) for degree of atrophy, and 1.73 (±0.84) for overall improvement in acne scarring. Average clinical improvement at 3 months was 1.32 (±0.9) for surface texture, 1.22 (±0.84) for degree of atrophy, and 1.42 (±0.75) for overall improvement, corresponding to mild (1–25%) to moderate (26–50%) improvement in each of these areas (Figs. 2 and 3, Table 2). Subjects' assessment of improvement was slightly higher than investigators, particularly with regard to surface texture changes

TABLE 4. Erythema and Edema Severity Scoring (0–3) 3 Days, 1 Week, 1 Month, and 3 Months Post-Treatment

	Erythema (%)				Edema (%)			
	72 hours post-tx 1	1 week post-tx 1	1 month	3 months	72 hours post-tx 1	1 week post-tx 1	1 month	3 months
Mild (1)	25	39.3	64.3	16.7	46.4	50.0	17.9	0
Moderate (2)	67.9	3.6	0	0	21.4	10.7	0	0
Severe (3)	0	0	0	0	0	0	0	0

(Table 5). Table 6 shows 3-month clinical improvement scores for study investigators and blinded evaluators.

DISCUSSION

Fractional deep dermal ablation, at the treatment parameters investigated in this pilot study, resulted in clinical improvement in atrophic acne scarring approaching that of traditional CO_2 or erbium:yttrium–aluminum–garnet (Er:YAG) laser surgery. Improvement was also seen in overall surface texture, including fine lines and wrinkles. The incidence of complications was much lower than that seen following traditional ablative resurfacing [3,4,11]. These findings are consistent with a recent study by Chapas et al. [12] who also examined this device for the treatment of acne scarring.

Clinically, the affected areas are erythematous and mildly edematous after treatment. Punctuate bleeding and serous oozing are also commonly present, but resolve within 24–48 hours. This rapid healing is likely related to the persistence of healthy unaffected tissue that remains between the ablated pulses after ablative fractional resurfacing [8,9]. Erythema and edema are transient and usually subside within 1 month, but with more aggressive treatment energies and densities, some mild erythema may still be present at 3 months. Although we did not detect further improvement at the 3-month time point, this prolonged erythema seen in some patients suggests further collagen remodeling and deposition [10]. At one of the treatment sites (BDZ), it was also noted that several subjects experienced a bronzed or tanned appearance that was evident at the 1- and 3-month follow-up visits. The exact etiology of this is unclear, but may be secondary to desiccation and/or optical changes in portions of the epidermis and dermis, along with the underlying erythema and wound healing response. Inadvertent sun exposure may also have played a role, as many subjects had their first treatment during the winter months with follow-up visits occurring in the summer.

There have been no reports of clinical infections thus far, which is a significant advantage over traditional CO_2 resurfacing lasers. The rapid rate of re-epithelialization imparted by fractional treatment of the epidermis may tend to prevent infections, although we are fairly certain that some infections will occur in the future use of this and similar devices [8].

There have been reports of a 10–12% incidence of PIH following mid-infrared FP [13], which is consistent with our rate of 12.0% at 3 months post-treatment. This complication is most common in subjects with a history of PIH or melasma, and in subjects with darker skin types. Treating with lower densities seems to minimize the risk of developing PIH [14]. Utilization of lower treatment densities, as well as topical hydroquinone pre- and post-treatment, should help to limit the incidence of PIH [14,15]. Having said this, the incidence of PIH with this device

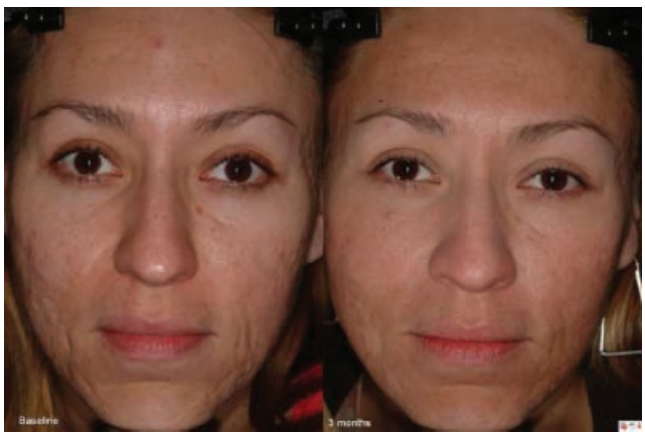

Fig. 2. Before (left photo) and 3 months after three treatments (right photo).

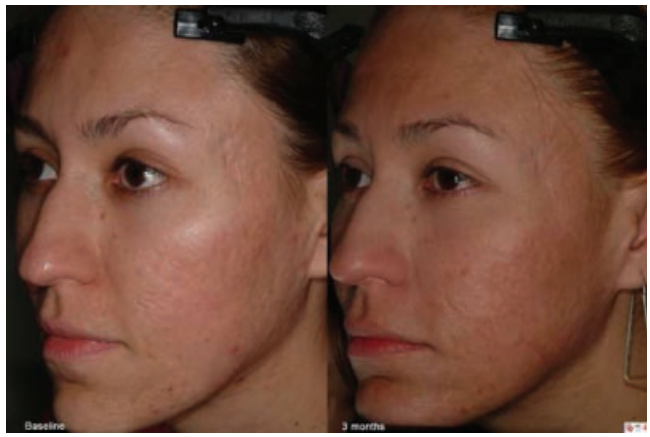

Fig. 3. Before (left photo) and 3 months after three treatments (right photo).

TABLE 5. Subjects' Average Assessment of Clinical Improvement (0–4)

Characteristic (0–4)	1 month (SD)	3 months (SD)
Improvement in degree of atrophy	1.67 (1.08)	1.67 (1.11)
Improvement in skin texture	2.12 (1.22)	2.16 (0.85)
Improvement in overall appearance of acne scarring	2.22 (1.17)	2.0 (1.0)

appears to be significantly less than with traditional fully ablative CO_2 or Er:YAG lasers [11].

Overall, treatments are well tolerated when appropriate measures are taken, with pain scores comparable to those experienced with other fractional devices. It has been our experience with this device that pain levels generally increase slightly as the energy level is increased. Interestingly in this study, higher pain scores did not necessarily seem to correlate with higher treatment energies (Table 3). This discrepancy may be a reflection of a smaller sample size, as well as the wide range of factors that play a role in a subject's perception of pain. However, higher pain scores in this study did seem to correlate with higher treatment densities, which may possibly be the primary contributing factor to pain that subjects experience with this device.

In this study, overall treatment energies were increased as the safety of the device was established, and as the investigators became more confident with the device. As a result, subjects were treated with a variable range of treatment energy levels and densities. At present, the optimal parameters for the most significant clinical improvement remain uncertain as efficacy was demonstrated using both lower and higher treatment energies and densities.

Study investigators noted mild-to-moderate improvement overall in acne scarring. Blinded evaluators' assessment of improvement was somewhat less than study investigators. This is not surprising given the inherent limitations of assessing acne scarring in two-dimensional photographs. Additionally, inconsistent subject positioning and photographic lighting can make assessment even more difficult, which was evident in some of the evaluated photographs. Insufficient lighting and shadowing can make scars appear deeper, whereas too much light exposure can diminish the appearance of scars. Quantitative methods for assessing surface topography have been developed, such as optical profilometry with the use of silicone rubber replicas, as well as a three-dimensional optical profiling device (PRIMOS; GFM, Teltow, Germany) [16,17]. However, optical profilometry depends greatly on the technical skills of the operator and may produce a variety of artifacts, and even with PRIMOS, minimal positional changes can lead to variability in baseline and follow-up images [17]. Nonetheless, quantitative methods may have provided additional useful data in this study to help assess clinical outcomes. Additionally, although clinical improvement in acne scarring was observed, further clinical studies are needed to help delineate whether the treatment efficacy fully matches that of pan-surface ablation. Whatever the long-term benefits of FDDA, they appear to be appreciated without many of the adverse outcomes associated with traditional ablative laser resurfacing, such as delayed onset permanent hypopigmentation.

TABLE 6. Average Investigator Assessment of Clinical Improvement 3 Months Post-Treatment

Characteristic (0–4)	Study investigator	Independent investigator
Improvement in degree of atrophy	1.22 ± 0.84	0.75 ± 0.59
Improvement in skin texture	1.32 ± 0.90	0.79 ± 0.47
Improvement in overall appearance of acne scarring	1.42 ± 0.75	0.83 ± 0.59

Certain types of acne scarring may also respond more favorably to this treatment. While not specifically examined in this study, it appears as if boxcar and superficial undulating scars, as well as thickened scars, respond best to this modality. This procedure would also be well suited to be combined with fillers for deeper tissue loss from acne scars as well as excision of ice pick scars.

Besides improvement seen in photodamaged skin [10] and acne scarring, another possible indication for FDDA is tightening of lax tissues. These treatments may help to tighten the skin by removing deep dermal tissues. This was demonstrated in several of our subjects (Figs. 4 and 5). FDDA removes micro-columns of tissue deep within the dermis that have a surrounding annular zone of coagulation. It is hypothesized that this configuration of coagulated and tightened collagen may provide deep tissue contraction and tightening due to favorable tensile forces. Further studies are needed as well to examine this hypothesis [8,9].

CONCLUSION

Fractional deep dermal ablation provides a safe and effective treatment of moderate to severe facial acne

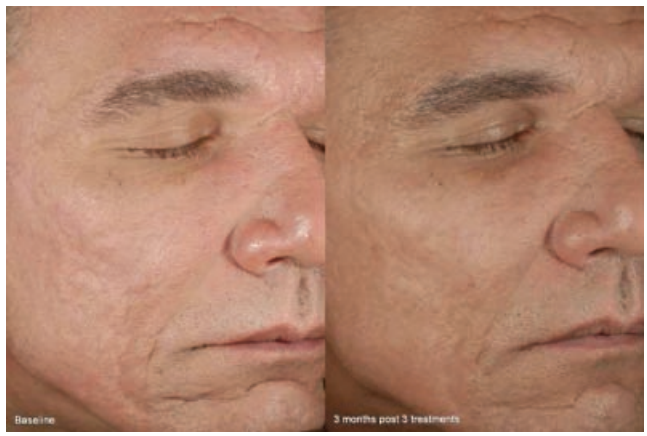

Fig. 4. Before (left photo) and 3 months after three treatments (right photo).

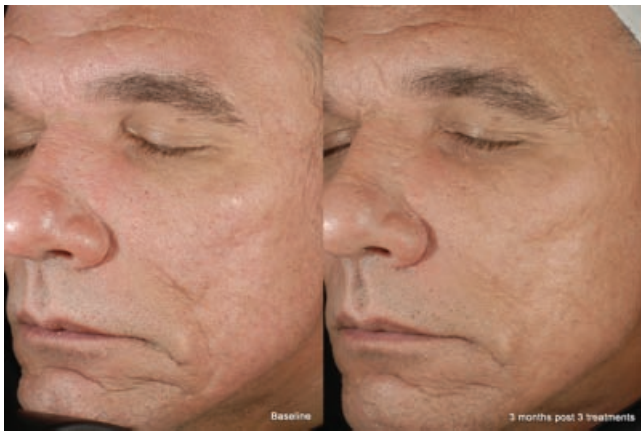

Fig. 5. Before (left photo) and 3 months after three treatments (right photo).

scarring. The incidence of adverse side effects and length of subject downtime is significantly less than conventional ablative resurfacing [3,4,11], while approaching similar efficacy. Further studies will help define the optimal treatment parameters and other potential indications for this device.

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