

# Fractional Laser Resurfacing Now and in the Future: Clinical, Cellular, and Histologic Review

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Fractional photothermolysis has been the most remarkable breakthrough in clinical laser science since selective photothermolysis. Fractionated laser beams create microscopic wounds that reach greater dermal depths and promote a rapid healing effect. This method of skin resurfacing using a laser has led to clinical efficacy in aesthetic procedures and scar treatment with high physician and patient satisfaction. Fractional lasers have a better safety profile than traditional resurfacing techniques. Research over the last 8 years has improved our understanding of the clinical effects, histologic changes, molecular cascades, and risks associated with fractional laser resurfacing. Over the next 5 years, developments in fractional devices will be exciting as we continue to research and understand the potential of these devices. We will see more applications of fractional lasers in both aesthetic and medical procedures. The next frontier of fractional devices will be laser-assisted delivery systems using the channels to deliver drugs and other bioactive materials. Other light sources will be fractionated, and tunable, high-peak, power-variable pulse duration devices may enter the market.

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A new wound type was introduced via laser in 2004; for the very first time in human history a fractional wound was produced on the body.<sup>1</sup> This new kind of trauma promoted rapid wound healing and required

minimal time for postoperative recovery. Fractional lasers produce a series of microscopic wounds on the surface of the skin. Because the wounds are so small, there is a rapid healing response, a unique molecular healing cascade, and prolonged neocollagenesis.<sup>2</sup> Today, fractional lasers are used for the treatment of photoaging as well as scars.

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## HOW IT WORKS: FRACTIONAL LASER PHYSICS

Fractional laser technology was introduced into our armamentarium as a unique concept to create a pattern of hundreds of microscopic thermal injuries to skin. Fractional lasers can be either nonablative or ablative. The nonablative modality delivers less thermal damage and works chiefly by coagulation of tissue. Thermal

damage resulting from coagulation leads to an increased expression of heat shock proteins, which transiently activate epidermal stem cells that are located in the basal layer and cells within the dermis.<sup>3</sup> Once stimulated, these cells begin to proliferate and replace the damaged tissue. Fractionated laser beams can reach substantial dermal depths with a rapid healing response. The series of wounds that are created lead to newly synthesized collagen and granulation tissue, then eventual regeneration of the epidermis.<sup>4</sup> Repeated treatments have continued effects with the greatest being on collagen formation.

The mechanism of action for ablative fractional therapy appears to be more complex. With temperatures reaching more than 100°C, the treated areas of the epidermis and dermis are vaporized. In essence, ablative fractional lasers create microscopic full-thickness wounds. Elimination of damaged epithelia and shrinkage of collagen fibers occur immediately after ablation. Over the next 3 to 6 months, new collagen formation ensues. Remodeling after ablative fractional resurfacing is uniformly started by regrowth of the epidermal compartment, followed by partial to complete replacement of ablated zones in the dermis with newly synthesized type III procollagen. The healing cascade leads to upregulation of heat shock protein 47 and subsequently increased deposition of types I and III collagen.<sup>2</sup>

Traditional ablative laser resurfacing is the gold standard for aging and photodamaged skin. At a 2010 dermatology meeting, Orringer<sup>5</sup> quantitatively compared the relative efficacy of ablative fractional resurfacing and traditional ablative laser resurfacing. The goal of this research was to analyze the molecular changes that result from ablative fractional CO<sub>2</sub> laser resurfacing and compare them to traditional ablative laser resurfacing. The results revealed that ablative fractional resurfacing produced molecular improvements that were 65% as effective as traditional resurfacing. He concluded that this experiment provides strong quantitative evidence of the value of ablative fractional resurfacing techniques.<sup>5</sup> Newer improved ablative fractional laser therapies are associated with shorter periods of hyperemia, resulting in shorter recovery times.<sup>6</sup> Reported side effects are minor and infrequent. Both nonablative and ablative fractional resurfacing technologies provide notable improvement with high patient satisfaction.<sup>6</sup>

The study and application of fractional photothermolysis is important because a deeper understanding of fractional photothermolysis will enable optimization of laser parameters, leading to even better results and safer treatment environments for a wider range of patients.

## IMPORTANT QUESTIONS IN THE STUDY AND APPLICATION OF FRACTIONAL PHOTOTHERMOLYSIS

### What Is the Best Shape and Size for Fractional Wounds?

Based on the surface to volume ratio, the best shape for fractional wounds seems to be a cylinder; however, other shapes and additional means for delivering fractional wounds continue to be explored. Additional research is required to determine the optimal density (spots per square centimeter) of the damage zones from fractional treatments. When evaluating the extent of thermal injury, the surrounding coagulation zone must be considered in addition to the ablation zone. If the fractional spot size is too large or the density of the damage zone is too high, it is possible that a contiguous coagulation zone will be created in the dermis. In this case, the therapy is no longer fractional because there are no areas of untreated skin; there also is a slower healing response, which appears to lead to complications. We must continue to challenge ourselves in what we are actually doing to the skin and what the clinical outcomes are when we start to push laser parameters.

### Is Ablation or Coagulation More Important?

Although there still is a tremendous role for nonablative fractional devices because they are associated with quick healing effects and minimal downtime, there seems to be a consensus among experts that ablative fractional lasers produce superior clinical results with fewer treatment sessions. Ablative fractional lasers create ablated channels. Devices with shorter pulse durations give faster ablation velocity with less time for thermal conduction and subsequently a smaller coagulation zone. A continuous laser takes a long time to heat volume and gives more thermal conduction (ie, coagulative) damage with a larger coagulation zone. The longer it takes to reach ablative threshold the more thermal damage the tissue will sustain, which may be one reason the safety profile is improved with fractional ablative devices.<sup>7</sup> Ablative fractional devices may have a CO<sub>2</sub> or erbium:YAG (Er:YAG) wavelength. An in vivo histologic study revealed that different wavelengths cause different wounds.<sup>8</sup> CO<sub>2</sub> devices inflict more collateral cellular injury surrounding ablated columns than Er:YAG systems. These different patterns of injury create unique environments and clinical opportunities for each wavelength.

### How Can We Optimize Laser Parameters?

As the energy of the fractional laser is increased, the depth of injury is deeper. If a wound is too deep, an anaerobic environment may be created, which could delay wound

healing and contribute to scar formation; in these cases, more may not always be better. A decrease in laser energy results in a more shallow depth of injury. Wrinkles appear to respond better to more superficial depths and thus may be treated with less fractional energy and higher densities. Scars tend to do best with deeper depths and lower density. Pursuit of knowledge concerning photothermolysis will accelerate the application and use of fractional laser therapy in cosmetic dermatology for tremendous patient benefit.

## SECOND-GENERATION DEVICES

Fractional laser technology has been subject to ongoing innovation with new laser technology. In the last year, the second generation of ablative fractional lasers has emerged. The industry has taken these devices to the next level. Many improved second-generation devices are entering the market and will improve patient outcomes. The following are a few of the highlights of the newest devices.

One of the first second-generation devices put forth was the CO<sub>2</sub>RE (Candela/Syneron Corporation) fractional CO<sub>2</sub> laser. A unique feature of the CO<sub>2</sub>RE is its ability to have 1 laser pulse with 2 simultaneous penetration depths to treat both the epidermis and the dermis at the same time. The CO<sub>2</sub>RE combines circles of surface and deep ablative wells to promote remodeling and rejuvenation simultaneously at all levels of the skin. This technology occurs through synchronization with the laser pulse generator; an inboard scanner allows parts of the same scan matrix to be placed at distinct depths and to create different treatment shapes accurately and dependably.

The new Lux2940 (Palomar Medical Technologies, Inc) Er:YAG laser plus groove optic is the first device to induce noncylinder fractional injury (Figure 1). This device has a new groove fractional pattern that operates at 3 to 5 mJ/100 μm length, 5 lines per 6×6-mm spot size, and 3 pulse widths (250 microseconds, 3 milliseconds, and 5 milliseconds). The fractional grooves generate a directional injury and crossed patterns with multiple orientations that can be customized by the operator.

A second-generation UltraPulse FX (Lumenis Aesthetic) fractional CO<sub>2</sub> laser is being developed and will have improved scanners as well as even greater versatility. Research also is being conducted for the development of instant feedback of depth, heat, and target for physicians simultaneously while treating the patient.

Other recent innovations include placement of ablative and nonablative devices on the same platform. Physicists and manufacturers are hard at work developing devices that are faster with ergonomically improved handpieces. With the development of new devices, practitioners can



**Figure 1.** Lines of ablative damage with the Lux2940 (Palomar Medical Technologies, Inc) erbium:YAG laser plus groove optic.

expect to see intelligent systems that can provide immediate feedback to the physician and perhaps even real-time imaging.

Fractionated radiofrequency and other light devices also are emerging in the marketplace. A better understanding of the effects of radiofrequency and ultrasound on collagen and other tissues in the human body will come with the development of these devices.

## CLINICAL USES

Fractional lasers are indicated for the improvement of skin texture and wrinkles (Figure 2), but this technology can be used anywhere on the body for rejuvenation. In addition to the treatment of wrinkles, fractional lasers also can be used to treat scars (Figure 3). The treatment of scars has the potential to become the largest laser consumer market. Military and civilian research has revealed that fractional lasers can lead to both functional and cosmetic improvement.<sup>9</sup> For example, patients often report improved range of motion with decreased pain and itching after treatment. It also has been observed that scars continue to improve with each laser session. Alghamdi<sup>10</sup> published a study on nonablative fractional laser treatment of atrophic scars from cutaneous leishmaniasis. The results revealed that after 3 sessions, patients observed 40% improvement; after 10 sessions, patients demonstrated more than 90% improvement.<sup>10</sup>





**Figure 2.** Patients with wrinkles before (A and C) and 3 months after 1 Lumenis UltraPulse fractional ablative laser treatment (B and D).



**Figure 3.** A scar before (A) and 6 months after 1 combination laser treatment with an ablative fractional laser (UltraPulse FX, Lumenis Aesthetic) and Candela/Syneron Corporation 595-nm pulsed dye laser (B).

### TRANSFORMATIONAL TECHNOLOGY: STEM CELL DELIVERY

Ultimately, fractional lasers are a transformational technology. The use of fractional lasers has remarkably increased the ability of physicians to treat and improve the

appearance of scars, which has been a focus for fractional laser application in my office. I often use 2 or 3 different laser devices in the same treatment session to synergistically improve healing. The use of lasers, especially ablative fractional lasers, has successfully improved the

appearance of hypertrophic scars, keloid scars, atrophic scars, and pigmentation disorders, and often improves joint mobility in contracture scars.

Although many scars do improve with laser treatment, hypopigmented scars, severely atrophic scars, and extensive poor-healing grafted sites continue to be a challenge. In a quest to tackle these obstacles, a clinical research team—consisting of Evangelos Badiavas, MD, PhD; Professor Stephen Davis, BS; and myself—is working to find new laser-assisted solutions for treating acute and mature scar injuries and many other disorders.

Our recent provisional patent technology uses ablative fractional lasers to deliver bioactive agents to patients via channels of predetermined depth into the tissue. Small ablative fractional channels provide a means through the barrier function of the skin allowing molecules to achieve direct local and systemic delivery into the body. An important benefit of lasers is that they are tunable, meaning the desired depth of penetration of an organ can be controlled, which allows for defined levels of penetration to specific anatomic levels in any organ. This technology platform uses fractional lasers to predictably disrupt the barrier properties of the skin, creating deep channels that allow the delivery of cellular materials and agents through the disrupted barrier.

We are studying fractional ablative laser-assisted delivery systems for a variety of drugs, topicals, and other living tissue such as stem cells. Our pilot studies have been a success and subsequent studies have revealed that stem cells migrate to organs other than the skin. With the use of fractional laser technology, we found that cells can be delivered both to the skin and systemically, and the stem cells remain functional. These findings hold promise for the use of fractional lasers for the treatment of a multitude of disorders using cell- and drug-based approaches.

## CHALLENGES

Although fractional resurfacing has opened many doors, challenges still remain. Perhaps the greatest is that there are no real clinical end points when treating patients with these devices. We rely on standard protocols and our own observational learning to discover optimal parameters for

patient outcomes. Overall, fractional lasers are a safe class of devices, but we have seen complications occur from overheating of tissue. Lasers are complex technological devices based on precise physics. Physicians are well-trained professionals; however, the wrong settings can yield devastating results.<sup>11</sup>

## CONCLUSION

Fractional photothermolysis has been the most remarkable breakthrough in clinical laser science since selective photothermolysis. The next 5 years will be exciting as we continue to explore the aesthetic and medical applications of fractional devices in cosmetic dermatology.

## REFERENCES

1. 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;34:426-438.
2. Helbig D, Bodendorf MO, Grunewald S, et al. Immunohistochemical investigation of wound healing in response to fractional photothermolysis. *J Biomed Opt*. 2009;14:064044.
3. Hantash BM, Mahmood BM. Fractional photothermolysis: a novel aesthetic laser surgery modality. *Dermatol Surg*. 2007;33:525-534.
4. Kwon SD, Kye YC. Treatment of scars with a pulsed Er:YAG laser. *J Cutan Laser Ther*. 2000;2:27-31.
5. Orringer JS. Molecular effects of fractionated carbon dioxide laser resurfacing: a quantitative comparison with traditional ablative laser resurfacing. Presented at: American Society for Dermatologic Surgery/American Society of Cosmetic Dermatology & Aesthetic Surgery Joint Annual Meeting; October 22, 2010; Chicago, IL.
6. Neaman KC, Baca ME, Piazza RC III, et al. Outcomes of fractional CO<sub>2</sub> laser application in aesthetic surgery: a retrospective review. *Aesthet Surg J*. 2010;30:845-852.
7. Metelista AI, Alster TS. Fractionated laser skin resurfacing treatment complications: a review. *Dermatol Surg*. 2010;36:299-306.
8. Farkas JP, Richardson JA, Burrus CF, et al. In vivo histopathologic comparison of the acute injury following treatment with five fractional ablative laser devices. *Aesthet Surg J*. 2010;30:457-464.
9. Kwan JM, Wyatt M, Uebelhoefer NS, et al. Functional improvement after ablative fractional laser treatment of a scar contracture. *PM R*. 2011;3:986-987.
10. Alghamdi KM. Successful treatment of atrophic scars from cutaneous leishmaniasis using a fractional laser. *J Cutan Med Surg*. 2010;14:303-306.
11. Lee SJ, Kim JH, Lee SE, et al. Hypertrophic scarring after burn scar treatment with a 10,600-nm carbon dioxide fractional laser [published online ahead of print June 2, 2011]. *Dermatol Surg*. 2011;37:1168-1172. ■