

Lasers for Facial Rejuvenation

David J. Goldberg

Department of Dermatology, Mount Sinai School of Medicine, New York, New York, USA

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Abstract

Laser and laser-like assisted facial rejuvenation has become very popular during the last decade. Although a myriad of techniques are available, such approaches can be divided into four basic approaches. There are those that (i) ablate the epidermis, cause dermal wounding, and provide a significant thermal effect (CO₂ lasers); (ii) ablate the epidermis, cause dermal wounding, and minimal thermal effects (short pulsed Erbium:Yttrium-Aluminum-Garnet [Er:YAG] lasers); (iii) ablate the epidermis, cause dermal wounding, and provide variable thermal effects (combined CO₂/Er:YAG lasers, variable pulsed Er:YAG lasers, and ablative radiofrequency devices); and (iv) do not ablate the epidermis, cause dermal wounding, and provide minimal thermal effects (non-ablative lasers and light sources). Each of the four modalities has now been shown to be effective in promoting facial rejuvenation. As would be expected, each has some advantages and disadvantages.

CO₂ lasers, because they ablate the epidermis, cause a dermal wound, and provide a significant thermal effect, appear to be most useful for those individuals with advanced photoaged skin. Such lasers provide the greatest degree of skin tightening for these individuals. However, it is that very same thermal effect that leads to the possibility of delays in healing sometimes noted with these systems. Short pulsed Er:YAG lasers, because they promote so little thermal damage, when used in a superficial manner, lead to the possibility of quicker healing than is seen with CO₂ lasers. However, less clinical improvement and more bleeding may be noted. Combined CO₂/Er:YAG lasers, variable pulsed Er:YAG lasers, and ablative radiofrequency devices lead to an effect somewhere in between that of pulsed CO₂ lasers and short pulsed Er:YAG lasers.

The newest group of systems includes the non-ablative devices that do not ablate the epidermis, cause dermal wounding, and provide for a minimal thermal effect. This area of technology is still evolving. Although such techniques, because they do not ablate the epidermis, are cosmetically elegant, the clinical results are usually not quite as good as the more aggressive ablative techniques.

There are a variety of lasers, and electrosurgical and non-laser light devices that are currently being used for facial rejuvenation.

These devices are divided into those that:

- ablate the epidermis, cause dermal wounding and provide a significant thermal effect (CO₂ lasers);
- ablate the epidermis, cause dermal wounding, and provide minimal thermal effects (short pulsed Erbium:Yttrium-Aluminum-Garnet [Er:YAG] lasers);
- ablate the epidermis, cause dermal wounding, and provide variable thermal effects (combined CO₂/Er:YAG lasers, variable pulsed Er:YAG lasers and ablative radiofrequency devices);

- do not ablate the epidermis, cause dermal wounding, and provide minimal thermal effects (non-ablative lasers and light sources).

Each of the four modalities has some advantages and disadvantages as described below (see sections 1-5).

1. CO₂ Lasers

CO₂ lasers produce laser irradiation at 10 600nm, in the far infrared portion of the electromagnetic spectrum. These lasers destroy tissue by rapidly heating and vaporizing tissue water. The CO₂ laser has been used extensively in dermatologic surgery over the past 30 years because of its ability to efficiently vaporize and cut tissue.

Early models of the CO₂ laser were available only in the continuous, non-pulsed mode and clinical results were unpredictable. These older lasers produced a zone of thermal necrosis measuring 0.2-1 mm in thickness resulting from tissue temperatures reaching 120-200°C (or more) during ablation, with subsequent char formation. Nonspecific heat diffusion into surrounding skin resulted in unwanted thermal necrosis and unacceptable rates of scarring and pigmentary change.¹

In the mid-1990s, in response to the theory of selective photothermolysis, technical advances brought about two major competing technologies. Both provided a CO₂ wavelength (10 600nm) absorbed by the targeted water chromophore, emitted sufficient energy (vaporization threshold of 5 J/cm²) to damage the targeted tissue, and delivered this energy at a rate faster than the thermal relaxation time of tissue (under 1ms). Both technologies shared the theoretical ideals of providing precise tissue vaporization with minimal residual thermal damage. One technology, of which the UltraPulse 5000[®] laser was the prototype, represents high energy pulsed technology using single pulses with peak energies up to 500mJ, delivered within pulse durations of 600µs to 1ms. When used with a collimated stand-alone 3mm spot size, energy fluences of 5-7 J/cm² can be achieved. A computerized pattern generator, attached to the laser delivery system, can rapidly and precisely place 2.25mm spots in any of several patterns while maintaining appropriate ablation parameters. Newer versions of this model now deliver similar energies through an even smaller spot size. A competing second type of technology uses a flash scanner that is used in conjunction with a lower power CO₂ laser in the continuous mode. An example of this technology, the SilkTouch[®]M/FeatherTouch[®] laser system, achieves high peak powers by focusing the laser beam to a small spot size, and rapidly scans the focused beam over a predetermined geometric pattern, exposing the individual tissue sites for less than 1 ms.

Cutaneous CO₂ laser resurfacing, as currently performed, has been shown to be highly effective in the treatment of photodamaged skin. In addition to superficial ablation, there is a 'tissue tightening' effect following use of these lasers. This effect is thought to be related to heat-induced collagen shrinkage, which occurs maximally at 630C .]2-4]

Fitzpatrick et al. were among the first to evaluate clinical improvement in mild, moderate, and severe perioral and periorbital wrinkles seen after pulsed laser resurfacing.^[3] In this study, multiple passes of confluent single pulses using a pulsed CO₂ laser (UltraPulse 50000) were utilized with 10% overlap and a 3mm collimated beam. Pulse energies of 450mJ were used for the first pass and subsequent passes were treated at 450mJ (perioral) and 350mJ (periorbital). Tissue was cleansed and debrided with normal saline between passes. Patients (73 females with perioral wrinkles, 38 females with periorbital wrinkles) were evaluated postoperatively for up to 12 months (average follow-up of 89 days for perioral wrinkles and 74 days for patients with periorbital wrinkles). Patients with mild, moderate, and severe wrinkles responded equally well, demonstrating an average wrinkle reduction of 45-50% for both treatment areas. The authors noted the unexpected finding of tightening of loose and folded skin and attributed it to heat-induced collagen shrinkage.

Walford et al., in a retrospective review, evaluated the clinical results in 47 patients with fine to deep glabellar, perioral, and periorbital rhytides after treatment with the SilkTouch[™] laser.⁴ One to three passes were provided with a 3mm spot size (energy 7.5W, pulse duration 0.2 seconds) or a 6mm spot size (18-20W). Between passes, the vaporized skin was removed with water-soaked gauze. The authors graded improvement based on a 0-4 scale and demonstrated a mean improvement score of 3.4 for patients with periorbital wrinkles (85% improvement), 3.2 for perioral wrinkles (80% improvement), and 2.7 for glabellar wrinkles (60% improvement). They concluded that the greatest improvement was seen in the periorbital area of patients and the least improvement was seen in the glabellar area.

Gardner et al. noted tissue contraction visible to the naked eye following a pulsed CO₂ laser impact.⁵ This was the most evident after the first and second dermal passes, once the epidermis has been removed. Subtracting the small amount of tissue contraction resulting from tissue volume loss, the remainder was thought to result from collagen contraction. This study compared 305 human tissue samples with matched controls and found a positive linear correlation between the number of passes and the degree of skin shrinkage. A linear regression model showed a 6% size reduction per pass with the SilkTouch[™] laser and a 5% reduction per pass

1 Use of tradenames is for product identification only and does not imply endorsement.

with the UltraPulse® laser. Rehydrating the tissue between passes resulted in only slight correction of the shrinkage.

In another study, reporting a long-term follow-up in 2123 patients after CO₂ laser resurfacing, Weinstein noted that clinical improvement obtained from laser resurfacing was evident at 6 months and tended to last for a long-term period; up to or longer than a five-year period.[7] She concluded that the wrinkles that responded best to resurfacing were non-dynamic lines, those caused by actinic damage, and those located in the following regions of the face: periocular, perioral, cheeks, and forehead (horizontal lines).

2. Erbium:Yttrium-Aluminum-Garnet (Er:YAG) Lasers

Laser resurfacing of facial rhytides is a treatment option for many patients with wrinkles, photo aging, and acne scarring. The search for alternative methods of skin resurfacing, to minimize the occasional prolonged healing and erythema seen after CO₂ laser resurfacing, has led to the popularity of the short-pulsed Er:YAG

At a wavelength of 2940nm, the Er:YAG laser has 10 times greater affinity for water than does the CO₂ laser. With its higher affinity for water, the 250-400µs short-pulsed Er:YAG laser is absorbed more superficially in the skin and causes almost pure ablation. Ablation depth of the short pulsed Er:YAG laser is directly proportional to the total fluence delivered to the skin.¹

The human adult epidermis is usually at least 60 microns in thickness. Generally 4 microns of tissue is ablated with each 1 J/cm². Thus, fluences of at least 15 J/cm² are required to completely ablate the epidermis.[11] At typical fluences (5 J/cm²), only a shallow zone of thermal damage (5-20 microns) is left behind. The thermal damage zone is fixed and very small. This thermal damage is so shallow that it is insufficient to coagulate dermal capillaries. This explains why Er:YAG lasered skin bleeds.

Since the Er:YAG laser ablates more efficiently than does the CO₂ laser, one might hypothesize that lesser total fluences are required with the Er:YAG laser compared with the CO₂ laser. This is not the case. Fleming has shown that to achieve equal depth of injury, the Er:YAG laser must ablate deeper than the CO₂ laser because there is minimal Er:YAG laser induced thermal damage.¹

The most significant advantage of Er:YAG resurfacing is the precise removal of skin, providing safety and reliability. The minimal associated thermal damage is another great advantage, which may account for the rapid healing and decreased adverse effects.

The greatest limitation of Er:YAG resurfacing is the need for multiple passes to obtain improvement (especially for deeper wrinkles and acne scars), making the procedure potentially slower

than CO₂ resurfacing. Other limitations include dermal bleeding with deeper resurfacing, the associated noise level, and the large amount of plume produced. The lack of thermal damage may also be considered a disadvantage when treating patients with severe wrinkles because studies suggest that CO₂ thermal damage is responsible for the associated improvement.¹

Teikemeier and Goldberg were among the first to evaluate the role of the Er:YAG laser for the treatment of patients with superficial rhytides.[8] Twenty patients with mild periorbital, perioral, or forehead rhytides were treated with a 350µs pulse duration Er:YAG laser. Pulses of energy varying from 400-800mJ and spot sizes of 2.5 and 5mm were chosen. The endpoint of treatment was disappearance of clinical rhytides. Patients were evaluated at 2 days, 1 month, and 2 months for degree of improvement, time of healing, and resolution of erythema. At 2 months, all 20 patients were found to have improvement of their wrinkles. Re-epithelialization occurred between 4 and 10 days. Postoperative erythema resolved in less than 2 weeks. This early study demonstrated that the Er:YAG laser was efficacious in improving superficial rhytides. The quicker re-epithelialization and resolution of erythema was attributed to the minimal thermal damage resulting from Er:YAG laser resurfacing.

Goldberg et al. expanded on the previous study by evaluating the Er:YAG laser for the treatment of Class III rhytides.^[13] Class III rhytides were defined as generalized deep lines (greater than 4) with distinctive textural changes of dermal elastosis. Twenty patients were treated with four 250µs Er:YAG laser passes at 5 J/cm², a spot size of 7mm, and a repetition rate 10Hz. Three months after the initial treatment, a second treatment with similar parameters was performed. Six months after the initial treatment, a third treatment with identical parameters was performed. Sites included periorbital, perioral, and cheek regions.

Although no improvement was seen after the initial laser session, mild to excellent improvement was noted 6 months after the final treatment. Fourteen patients had mild improvement, four patients had moderate improvement, and two patients had excellent improvement. The authors concluded that with multiple sessions, the Er:YAG laser can successfully treat Class III rhytides.

In a series of 625 patients treated with Er:YAG laser resurfacing, Weinstein noted that long-term (>6 months) improvement in wrinkles and acne scars could be achieved.[11] Total fluences were quite high. Periocular wrinkles required the least total fluences (20-40 J/cm²), perioral rhytides required the greatest total fluences (40-80 J/cm²), and the forehead required intermediate fluences (30-60 J/cm²). Weinstein concluded that although the Er:YAG laser can successfully remove both superficial and deeper wrinkles with great accuracy, there was often significant bleeding associated with deeper Er:YAG laser resurfacing. She suggested

that deeper wrinkles were best treated with either a combined CO₂/Er:YAG, variable pulsed Er:YAG, or CO₂ lasers.

3. Combined CO₂/Er:YAG and Variable Pulsed Er:YAG Lasers

CO₂ laser studies have demonstrated that this modality ablates approximately 100 microns of skin, leaving an additional 50-300 microns of collateral thermal damage.^[122-14] As described in section 1, this thermal damage promotes collagen contraction and remodeling.^[15-17] However, it can also lead to prolonged recovery time and complications.^[8-20]

Studies with short-pulsed Er:YAG lasers, with their higher water absorption rate and shorter pulse duration than CO₂ lasers, demonstrate tissue ablation of 20-40 microns with each pass, and collateral thermal damage of 5-30 microns^[21,22] This amount of tissue ablation and thermal damage is typically much less than that seen with CO₂ laser resurfacing.

In theory, combining the deep tissue penetration of a CO₂ laser with the fine depth-control of an Er:YAG laser may improve clinical outcome, and decrease both recovery time and associated complications. The use of combinations of CO₂ lasers and Er:YAG lasers prompted the development of alternative laser resurfacing technology. One such system, the Derma-K' laser, is a combined CO₂/Er:YAG laser. This system combines simultaneous low fluence CO₂ laser and short pulsed Er:YAG laser delivery.^[23,24] Such a laser delivers the combined deep thermal damage, and associated collagen remodeling, of a CO₂ laser with the more precise ablative capacity of an Er:YAG laser.^[25] Another approach to laser resurfacing is the CO₃ and Contour variable pulsed Er:YAG lasers. The CO₃ laser is a single variable pulse width Er:YAG laser. The Contour' laser is, in fact, two separate Er:YAG lasers that fire almost simultaneously. One of these lasers is a short pulsed Er:YAG laser. The other laser emits a longer variable pulse width Er:YAG laser pulse.^[26] The variability seen with both of these lasers allows the user to chose various levels of tissue ablation and/or thermal effect. These choices can provide a unique degree of control in resurfacing that is not provided by either standard short pulsed Er:YAG or CO₂ lasers.

Manuskiatti et al. performed one of the earliest clinical evaluations of sequential CO₂ and Er:YAG laser treatment.^[27] In this study, 30 patients were treated with full-face CO₂ laser resurfacing. Some were then treated with a short pulsed Er:YAG laser in an attempt to remove a portion of the CO₂ laser-induced residual thermal damage. Postoperative follow-up varied with each patient. According to the authors, all deep rhytides and all deep acne scars responded better to a sequential CO₂/Er:YAG laser treatment

compared with CO₂ laser treatment alone. Healing times were on average 2-3 days faster with sequential treatment.

Goldman and Marchell were among the first to evaluate the effect of combined CO₂/Er:YAG lasers.^[24-21] In one study,^[29] eleven patients were treated with two passes of a combined CO₂/Er:YAG laser. The patients were monitored for 2 weeks postoperatively and then re-evaluated at 3-6 months. Physician evaluation revealed moderate improvement in all patients' skin color and marked improvement in all patients' skin texture and wrinkling. Most of the patients felt that they had a 75-100% improvement in their skin texture. The overall patient satisfaction rating was 75-100% in 10 of 11 patients, with one patient giving a rating of 50-74%. There was no hypopigmentation or scarring demonstrated in this study. Similar results may be seen with the variable pulsed Er:YAG lasers.

There is now increasing accumulated data about both the combined CO₂/Er:YAG lasers and variable-pulsed Er:YAG lasers. Their effect and healing response appear to be a nice compromise between the more aggressive, yet highly effective, CO₂ lasers and the less aggressive, albeit not as effective, short-pulsed Er:YAG lasers.

4. Electrosurgical Systems

One of the most recent additions to the facial resurfacing arsenal is electrosurgery. One recently popularized electrosurgical device is the Visage' electrosurgical device. This device utilizes an electrosurgical instrument with a bipolar, multi-electrode configuration that generates radio frequency energy to achieve tissue ablation.^[30] This technology has been referred to as coblation, radio frequency resurfacing, or electrosurgical resurfacing, all of which refer to one aspect of the mechanism behind this method of resurfacing. Electrosurgical resurfacing appears to be a more appropriate designation for this technique.

Grekin et al., in a prospective multicenter study, evaluated the efficacy and safety of electrosurgical resurfacing for the treatment of facial wrinkles.^[31] The Visage' electrosurgical device was utilized. Ninety five patients with Fitzpatrick class I-III perioral and/or periorbital rhytides were treated with one to three passes of the electrosurgical probe. The investigators demonstrated statistically significant improvement in the treatment of both perioral and periorbital areas in patients with Fitzpatrick type II and III photodamage. They also noted that increased improvement was associated with an increased number of passes.

It would appear that there are several benefits associated with the use of this technology. These include complete hemostasis during the procedure, lack of a smoke plume, no need for eye protection required with laser procedures, and compact solid state



Fig. 1. (a) Class III rhytides before C02 laser resurfacing; (b) 2 years after C02 laser resurfacing.

technology.^[37] Electrosurgical resurfacing may also have a decreased morbidity and shorter recovery time compared with C02 laser resurfacing. Because there are so few reported studies, further clinical studies looking at electrosurgical resurfacing and comparing electrosurgical resurfacing to other modalities are necessary.

5. Non-Ablative Lasers and Light Sources

Despite the clinical improvement seen after treatment with the aforementioned devices, the wound healing and erythema that are commonly seen following any of these treatments have tempered the enthusiasm for these systems.

If a dermal wound and new collagen formation are the primary mechanisms behind the improvement seen after laser resurfacing, techniques that induce a dermal wound without epidermal ablation and without significant thermal effect should theoretically lead to cosmetic improvement of dermal photodamage. This arena of non-ablative dermal remodeling is a very new area of laser technology.

In one of the first studies evaluating a non-ablative approach to dermal remodeling, a 1064nm Q-switched Neodymium:Yttrium-Aluminum-Garnet (Nd:YAG) laser was used in an attempt to improve rhytides.^[33] Eleven patients with perioral or periorbital rhytides were evaluated using a Q-switched Nd:YAG laser at 5.5 J/cm² and a 3mm spot size. All patients were of skin phenotypes I and II and all had Class I or II rhytides. The authors sought a non-specific clinical endpoint of pinpoint bleeding. Patients were treated only once and were evaluated 7, 30, 60, and 90 days after

treatment. At follow-up, each patient was evaluated for improvement of rhytides, healing, pigmentary changes, and erythema. In three patients (two with perioral and one with periorbital rhytides), the authors noted improvement that was thought to be comparable to that following ablative resurfacing. In six patients (three perioral and three periorbital), clinical improvement was noted but was not thought to be as significant as that seen with an ablative laser system. In two patients (one perioral and one periorbital), no clinical improvement was noted. No pigmentary changes or scarring was noted in any of the treated patients. At one month, 3 of 11 patients showed persistent erythema at the treated sites. At 3 months, all erythema was resolved.

Dermal remodeling is thought to occur through increased collagen I deposition with collagen reorganization into parallel arrays of compact fibrils. Such an effect can occur with non-ablative as well as ablative laser systems. Of note, the greatest improvement seen in this study occurred in those individuals who had the most persistent erythema. This suggested that the degree of improvement following any dermal wounding approach might be directly related to the degree of induced wound.

The aforementioned study was expanded when the non-ablative, dermal remodeling effects of a Q-switched Nd:YAG laser were potentiated by the use of a topical carbon-assisted solution.^[34] A total of 242 solar damaged anatomic sites on 61 patients were treated with three 1064nm Q-switched Nd:YAG laser treatments. Parameters of treatment included a fluence of 2.5 J/cm² pulse duration of 6-20 nanoseconds, and a spot size of 7mm. The treatment sites were evaluated at baseline, 4, 8, 14, 20, and 32

weeks for skin texture, skin elasticity, and rhytid reduction. All sites were treated at a baseline visit, and later at 4 and 8 weeks. Adverse events were recorded throughout the study.

In this study, a low fluence Q-switched Nd:YAG laser was utilized for treating mildly solar-damaged skin. Unlike the previous study, there was no epidermal disruption when the lower fluences were used. The Q-switched Nd:YAG laser energy is not well absorbed by tissue water; it is non-selectively placed within the dermis. The 1064nm wavelength results in relatively deep penetration into the skin, which indicates minimal laser/tissue interaction. As a result: (i) cellular damage is localized to the tissue immediately adjacent to the carbon; (ii) non-targeted tissue is minimally affected; and (iii) less than 10% of the typical energy output from CO₂ lasers is required for the treatment. At 8 months, the investigators reported improvement in skin texture and skin elasticity as well as rhytid reduction, compared with baseline. The majority of adverse events were limited to mild, brief erythema.

Friedman et al. recognized the inherent limitations of photographic and clinical evaluation of improvement after non-ablative treatment^[35] They looked at the results in two patients after five treatments with a low fluence Q-switched Nd:YAG laser. Clinical results were analyzed using a 30mm, three-dimensional microtopography imaging system. Six month results, as measured by this 3-dimensional method, showed a decrease in skin roughness of 26%.

Further studies have been performed with a non Q-switched millisecond Nd:YAG laser at fluences of 100-130 J/cm², pulse durations of 3-8 msec and up to five treatments over an 8 week

period.^[16] Ten patients with Fitzpatrick types II-III skin were followed for 6 months after their final treatment. Adverse effects were minimal with only one patient showing post-treatment blistering. This healed without scarring. Most patients showed some degree of clinical improvement.

Other non-ablative lasers, such as the pulsed dye laser, have been shown to lead to new dermal collagen formation.^[37] Histopathologic examination of 585nm pulsed dye laser treated scars reveals improvement in dermal collagen. There is also an increase in the number of regional mast cells in pulsed dye laser irradiated scars. Since mast cells elaborate a variety of cytokines, their presence following irradiation and accompanying tissue revascularization may provide an explanation for therapeutic improvement following laser treatment. Using this concept, Zelickson et al.^[37] evaluated the use of a pulsed dye laser in the treatment of rhytides. In this study, the authors treated ten patients with a 585nm, 450µs pulsed dye laser. Laser treatment was undertaken at 3.0-6.5 J/cm² using a 7-10mm spot size. Nine of ten patients with mild to moderate rhytides showed 50% or more improvement with three of ten showing 75% or greater improvement. All patients maintained their level of improvement for 6 months, as did five of six patients evaluated at 12 months after treatment. The results seen in patients with moderate to severe rhytides were particularly worthy of note. At 12 weeks, only three of ten patients had clinically observable improvement. The study results were tempered by cosmetically unacceptable post-treatment purpura and swelling. This lasted for 1-2 weeks. Two patients were also noted to have postinflammatory hyperpigmentation. Histologic exami-



Fig. 2. (a) Early photo damage in a patient before short pulsed Erbium:Yttrium-Aluminum-Garnet (Er:YAG) laser resurfacing; (b) improvement 1 year after short pulsed Er:YAG laser resurfacing.



Fig. 3. (a) Class II rhytides before variable pulsed Erbium:Yttrium-Aluminum-Garnet (Er:YAG) laser resurfacing; (b) 1 year after Er:YAG laser resurfacing.

nation of biopsies taken 6-12 weeks after treatment showed a thickened epidermis and a thickened layer of superficial dermal collagen. There was also an increase in mucin deposition in the superficial dermis.

Bjerring et al. have shown increased levels of collagen precursors following treatment with a 350 μ s pulsed dye laser.^[31] In their study ten patients, of an average age of 38 years, underwent 350 μ s pulsed dye laser treatment on their arm. Laser treatment was undertaken at 2.4 J/cm² with a 5mm spot size. Suction blisters, taken after laser treatment, revealed increased pro-collagen III levels. In addition to the suction blister study, the authors also evaluated the clinical facial response to this laser. Thirty patients, with Class I-II rhytides and an average age of 46, were treated with the same laser parameters as the first group. Only the periorbital area was treated. Patients were evaluated immediately after treatment and at 7, 30, 90, and 180 days. There was no significant post-treatment pain or noted purpura. There was no reported incidence of any pigmentary changes or textural changes. Clinical improvement was noted in all skin types.

Another non-ablative near infrared laser is the 1540nm Erbium:Glass laser. Fournier et al. evaluated this laser in 60 patients.^[29] Patients were Fitzpatrick skin types I-IV and were treated four times at 6 week intervals. Clinical improvement was noted by photography and through profilometry and ultrasound methods. A 40% reduction in wrinkles was noted by profilometry at 6 weeks after the fourth treatment. Ultrasound imaging demonstrated a 17% increase in dermal thickness. Histologic evidence of new collagen formation was also noted. There were no significant adverse effects.

In a study evaluating the effect of intense pulsed non-laser light in the treatment of rhytides, 30 female patients aged 35-65 with Fitzpatrick Type I-II and Class I-II skin phenotypes were treated. Treatment areas included the periorbital, perioral, and forehead regions.^[39] One to four treatments were provided over 10 weeks. Non-coherent intense pulsed light was delivered to the skin using a 645nm cutoff filter. This leads to emission of light with wavelengths between 645 and 1100nm. Light was delivered through a bracketed cooling device, in triple 7ms pulses, with a 50ms interpulse delay between the pulses. Delivered fluences were between 40-50 J/cm². The author evaluated the degree of improvement 6 months after the last treatment. Complications were also evaluated at this time. Clinical improvement was divided into four categories: (i) no improvement; (ii) some improvement; (iii) substantial improvement; and (iv) total improvement.

Six months after the final treatment, five patients were noted to have no improvement. Similarly, no patients were noted to have total improvement. Sixteen patients showed some improvement while nine patients showed substantial improvement. All patients were evaluated for pigmentary changes, post-treatment blistering, erythema, and scarring. Immediately following treatment, 3 of 30 patients had blistering. All 30 patients had post-treatment erythema. Six months after treatment, no pigmentary changes, erythema, or scarring was noted. The author concluded that intense pulsed light could improve some rhytides. New collagen formation and improvement of age-related vascular and pigmented lesions can follow treatment with this non-laser technology.^[40,41] However, the dermal changes appeared to be subtler than those seen with

ablative techniques. There was no correlation between blistering and the final results.

The first specifically non-ablative laser to be solely marketed to the physician community is a 1320nm Nd:YAG laser.^[42] The goal of this system, similar to that of the previously described systems, is improvement of rhytides without the creation of a wound. The 1320nm wavelength is advantageous in its high scattering coefficient. Thus, the laser irradiation scatters throughout the treated dermis after nonspecific absorption by dermal water.

In Nelson and colleagues' study, one or more passes of a 1320nm Nd:YAG laser were used on photoaged skin.^[42] The waveform consisted of 3200 μ s laser pulses at a 100Hz repetition rate. Laser energy was delivered through a 5mm spot size with fluences up to 10 J/cm². A dynamic cryogen cooling technique was applied immediately prior to laser treatment in order to produce selective subsurface skin heating without epidermal damage. Immediately after treatment, mild edema and erythema appeared in the treated skin. These adverse effects were resolved within 2 days. At 2 months after treatment, facial rhytides were improved. No persistent erythema or pigmentary changes were noted. The currently available model of this 1320nm Nd:YAG laser (CoolTouch II) is accompanied by a unique hand piece with three portals. One portal contains the cryogen spray that cools the epidermis prior to and during treatment, one portal emits the 1320nm Nd:YAG laser irradiation; and one portal contains a thermal sensor. Patients are usually treated at 2-4 week intervals and generally show the degree of improvement expected from a non-ablative approach.^[41-41] Consistent with the noted clinical improvement is the histologic replacement of the irregular collagen bands with organized new collagen fibrils. Because this laser produces new collagen formation, it has also been used as part of a full-face anti-aging approach.^[41]

A recent study evaluated a new 1450nm mid-infrared diode laser in an attempt to (i) determine its efficacy in promoting non-ablative dermal remodeling and (ii) determine if the laser-induced injury was selective or whether a cryogen injury alone could produce the same effect as the laser with cryogen.^[41] The laser emitted a pulse width of 160-260ms and the utilized spot size was 4mm.

Twenty patients, nineteen women and one man, with skin types I-IV and an age range of 42-70 years, were enrolled in the study. Class I and II rhytides were treated in 12 patients with periorbital rhytides and eight patients with perioral rhytides. One side was treated with the laser and cryogen while the contralateral side was treated with cryogen alone. Chosen sides were randomized throughout the study. Pre-, intermediate-, and post-laser cryogen cooling ranging from 40-80ms in total was provided. Two to four laser treatment sessions were performed, separated by monthly intervals. Evaluated acute clinical reactions included erythema, blistering, and edematous skin changes.

Evaluated 6 month, post-treatment complications included hyperpigmentation, hypopigmentation, erythema, and scarring. Clinical improvement of rhytides was designated as none, mild (same number of rhytides, but lessened in depth), moderate (decreased number of rhytides) or significant (no rhytides after treatment). Optical profilometry moldings were undertaken before and 6 months after the final treatment.

Immediate erythema was seen in 19 of 20 treated patients. It was subjectively evaluated as either mild or severe and was noted on both the laser/cryogen treated site as well as the site treated with cryogen only. No immediate post-treatment blisters were noted; post-treatment edema, usually visible as small edematous papules, was seen at various times in 6 of 20 patients treated with laser/cryogen. Its duration was anywhere between 1-7 days. Six month post-treatment, post-inflammatory hyperpigmentation was noted



Fig. 4. (a) Class II rhytides before electrosurgical resurfacing; (b) 1 year after electrosurgical resurfacing.

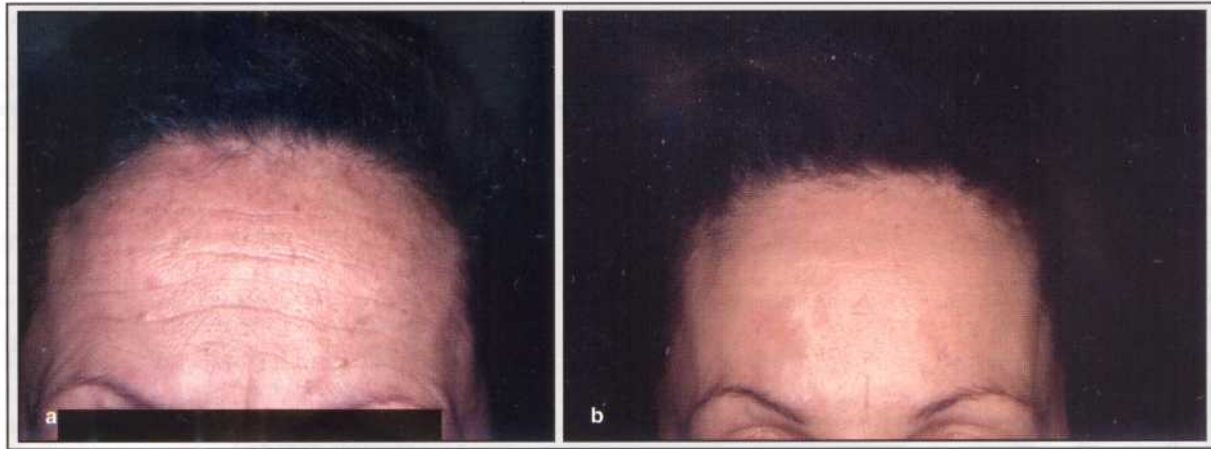


Fig. 5. (a) Class II rhytides before non-ablative dermal remodeling; **(b)** Improvement in skin tone 6 months after non-ablative dermal remodeling.

only in one patient and only at the laser/cryogen site. No hypopigmentation, erythema, or scarring was noted 6 months after final treatment.

Of the 20 laser/cryogen treated sites, seven showed no obvious clinical improvement, ten showed mild improvement and three sites were noted to have moderate improvement. None of the sites treated with cryogen alone were noted to show any improvement 6 months following the final treatment. Clinical improvement was consistent with optical profilometry findings. No perioral sites were noted to have more than mild improvement.

6. Conclusion

There is now a widely available array of lasers, electrosurgical devices, and non-laser intense pulsed light sources for facial rejuvenation. CO₂ lasers are highly effective when used for the treatment of Class I-III rhytides. However with the availability of other ablative, less aggressive, treatment modalities, some tend to restrict the use of CO₂ lasers only to those with Class III (figure 1 a and b) rhytides. Short pulsed Er:YAG lasers are highly effective when used for the treatment of Class I and early Class II rhytides. Because these lasers provide a predominantly ablative effect, they are ideal for resurfacing those with early photodamage (figure 2 a and figure b). The combined CO₂/Er:YAG lasers and variable pulsed Er:YAG lasers are highly effective when used for the treatment of Class I-III rhytides (figure 3 a and figure b). By varying parameters, these ablative lasers can be used successfully in the treatment of Fitzpatrick skin types I-V. The electrosurgical radiofrequency devices appear to provide an effect between short pulsed Er:YAG lasers and the combined or variable systems (figure 4 a and figure b).

All ablative procedures require some form of anesthesia. Localized areas can be treated with local anesthesia. Although some physicians perform full-face procedures with local anesthesia, our

preference is to do these procedures under sedation. In theory, any area of the body could be ablated. In reality, the 'safest' areas are those on the face. Extensive experience is required before one considers treating neck, chest, and hand areas. As is true for all laser procedures, appropriate eye protection is mandatory.

Non-ablative lasers and light sources represent the newest approach to improve photodamaged skin. Because the degree of collagen remodeling is not expected to be as great as that seen with other more destructive, ablative approaches, the non-ablative technique is appropriate for the treatment of those individuals who wish to improve the quality of their sun-damaged skin but do not wish to take time away from their daily activities (figure 5 a and figure b). The technique is not intended for those with extensive, solar-induced, epidermal pigmentary changes. Those individuals are best treated with either an ablative laser or a specific, pigmented lesion laser. Newer systems using low-power diodes and radiofrequency are currently being investigated. In the future, lasers may be created that can cause the same degree of improvement as that seen with ablative systems without the potential complications and down time from such systems.

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- Correspondence and offprints: Dr *David J. Goldberg*, Skin Laser & Surgery Specialists of NY/NJ, 20 Prospect Ave., Suite 702, Hackensack, NJ 07601, USA.
[E-mail: info@skinandlasers.com](mailto:info@skinandlasers.com)