Noninvasive Rejuvenation of Photodamaged Skin Using Serial, Full-Face Intense Pulsed Light Treatments

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BACKGROUND. Photodamaged skin is characterized not only by rhytides, but also by epidermal and dermal atrophy, rough skin texture, irregular pigmentation, telangiectasias, laxity, and enlarged pores. There is growing interest in the development of noninvasive methods to treat photodamaged skin. Skin photorejuvenation is the visible improvement of photodamaged skin using a laser or other light source. A noncoherent, broadband, pulsed light source is effective in the treatment of vascular and pigmented lesions of the skin. This study evaluates the role of intense pulsed light in the rejuvenation of photo aged skin.

OBJECTIVE. The purpose of this study was to evaluate and quantify the degree of visible improvement in photodamaged skin following a series of full-face, intense pulsed light treatments.

METHODS. Forty-nine subjects with varying degrees of photodamage were treated with a series of four or more full-face treatments at 3-week intervals using a nonablative, nonlaser intense pulsed visible light source. Fluences varied from 30 to 50 J/cm^2. Subject evaluation and skin biopsies were used to assess treatment results.

RESULTS. All aspects of photodamage including wrinkling, skin coarseness, irregular pigmentation, pore size, and telangiectasias showed visible improvement in more than 90% of subjects with minimal downtime and no scarring. Eighty-eight percent of subjects were satisfied with the overall results of their treatments.

CONCLUSION. Treatment of photodamaged facial skin using a series of full-face treatments with intense pulsed light is a new and effective noninvasive method of skin rejuvenation with minimal risk and no patient downtime.

PHOTODAMAGE IS the result of chronic ultraviolet (UV) light exposure inducing characteristic epidermal and dermal changes. The visible signs of photodamage are characterized by thinning of the epidermis and dermis, coarse skin texture, wrinkling, pigmentation alterations, telangiectasias, and in some cases actinic keratoses and epidermal malignancies. The clinical picture of photodamaged skin is more than just rhytides. Consequently treatments that focus only on improvement in rhytides will, by nature, produce results limited to improving only one visible component of photodamaged skin. Conversely a treatment that is able to improve each of the different components of photodamaged skin will result in a more dramatic visible improvement.

Numerous treatments have been developed to improve the appearance and health of photoaged skin. These include various topical agents such as glycolic acid,[1] retinoids,[2,3] ascorbic acid,[4] a variety of chemical peeling agents,[5] dermabrasion,[6] epidermabrasion and laser skin resurfacing.[7–9] To date the most effective methods for improving photodamaged skin have been invasive. The major disadvantage of invasive treatments is the requisite recovery period following procedures such as laser skin resurfacing. In addition, scarring has been reported with each of the invasive procedures including laser resurfacing.[10,11]

There has been great interest in the development of noninvasive and nonablative methods to effectively improve the appearance of photodamaged skin without patient downtime. Recently a 1320 nm laser has shown some promise in the nonablative treatment of wrinkles.[12,13] In addition, the pulsed dye laser has been used to treat selected facial rhytides.[14,15] Electrosurgery has also been used to improve rhytides in a nonablative method.[16] A noncoherent, nonlaser, filtered flashlamp emitting a broadband visible light has been shown to be highly effective in the treatment of a variety of vascular and pigmented lesions of the skin.[17] Most recently, Goldberg[18] reported the results of intense pulsed light in the treatment of superficial rhytides.

This study describes a new application of intense pulsed light technology and evaluates the visible improvements seen in photodamaged skin following a series of full-face treatments. The role of intense pulsed light in skin rejuvenation and the advantages and potential benefits of this procedure in the amelioration of photodamage are discussed.

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Methods

Subjects

Forty-nine successive patients (43 female and 6 male), ages 30–64 years, with varying degrees of photodamage and wrinkling who completed between four and six full-face treatments participated in the study. All patients were of Fitzpatrick skin types I–III. All patients had visible evidence of photoaging (wrinkling, irregular pigmentation, telangiectasias). All patients to be treated underwent physician history and examination to exclude recent oral retinoid drug use, sensitivity to infrared radiation or visible light, use of photosensitizing medications, or the presence of any suspicious lesions. Patients were placed on a simple skin care regimen with a gentle cleanser, moisturizer, and sunblock. Patients using topical tretinoin or topical or oral medications for rosacea continued these treatments as needed. No other treatments were permitted. All patients gave informed consent for treatments and photographs.

Treatment Protocol

A noncoherent, filtered broadband pulsed flashlamp (Vasculight, ESC/Sharplan, Norwood, MA) emitting in the range of 500–1200 nm was used for all treatments. Each patient underwent at least four and up to six full-face treatments. The average number of treatments for the 49 patients was 4.94.

Treatments were administered at 3-week intervals. The entire face including the lower eyelids, but excluding the upper eyelids, was treated at each session. Eyelids were protected by small external plastic shields. Treatment fluences varied between 30 and 50 J/cm^2. Energy was delivered in double or triple pulse trains of 2.4–4.7 msec with pulse delays of 10–60 msec. Cut-off filters of 550 or 570 nm were used for all treatments. A chilled colorless ultrasonic gel was applied directly to the light guide of the cutoff filter prior to application to the skin. Specific treatment parameters were changed at each treatment for each patient depending on the results of the previous treatment. At each subsequent treatment the fluence was generally increased by 1–2 J/cm^2. The entire face was treated at each session except in some of the male subjects (50%) who elected to avoid treatment of the beard area because of potential hair loss. Treatment parameters were chosen to minimize or prevent purpura.

In working with the double-pulse parameters, it was observed that lengthening the second pulse duration (to 4.0 msec or more) and/or the interpulse interval (to 20 msec or more) and maintaining a fluence of 36 J/cm^2 or less almost entirely eliminated the appearance of purpura. In addition, it was observed that carefully maintaining a skin/light guide distance of 1 mm or more was also very important in preventing purpura or blister formation. The object of each treatment was to prevent any patient downtime while maximizing the improvement in the vascular and pigmented lesions and overall skin appearance. Subjects were asked to evaluate the degree of change visible in their skin for each of the following criteria: fine wrinkling, skin smoothness, skin laxity, irregular pigmentation, redness, flushing, presence of telangiectasias, and pore size. Subjects were also asked to rate their overall improvement as well as the degree of discomfort, any adverse outcomes, and any "downtime" as defined as any time missed from usual activities due to treatments. Pretreatment with a 4% lidocaine cream (ELA-Max, Ferndale Labs, Ferndale, MI) for topical anesthesia was used 30 minutes prior to treatment. Subject evaluations were obtained 3–4 weeks after the final treatment. Skin biopsies were obtained from the forehead of one patient prior to treatment and 4 weeks after the final treatment. Subject photographs were obtained pretreatment after two treatments and 3–4 weeks after the final treatment.

Results

A total of 49 subjects completed the series of treatments and the questionnaire. The average number of treatments was 4.94. A total of 242 full-face treatments were performed. Patients were asked to rate the severity of fine wrinkles, skin texture, skin laxity, irregular pigmentation, pore size, telangiectasias, facial redness, and facial flushing on a nine-point scale before and after all treatments were completed. Patients were also asked to rate the percentage improvement observed after treatments for each of the above criteria. Table 1 shows the pre- and posttreatment severity scores for each criteria. Figure 1 shows the percentage improvement observed for fine wrinkles. Overall 64% of subjects reported at least a 25% or greater improvement in fine wrinkles, 46% of subjects reported a 50% or greater improvement in fine wrinkles, and 18% of subjects reported 75% or greater improvement in wrinkles. From the data, all subjects reported at least some degree of improvement in fine wrinkles. Figure 2 shows the improvement in skin smoothness. Nearly 72% of subjects reported a 50% or greater improvement in skin smoothness; 44% reported a 75% or greater improvement. Figure 3 shows the improve-

Table 1. Pre-and Posttreatment Severity Scores

	Severity	
Clinical Criteria	*Pretreatment*	*Posttreatment*
Fine wrinkles	5.00	2.83
Skin coarseness	5.68	2.69
Skin smoothness	5.10	2.00
Skin laxity	5.53	2.00
Pore size	4.78	2.27
Irregular pigmentation	5.41	2.00
Telangiectasias	5.14	2.02
Facial erythema	5.40	2.15
Facial flushing	4.60	2.37

Scale 1–9: 1–3 mild, 4–6 moderate, 7–9 severe.

N=22

Percentage Improvement	Percent Reporting
0%	0%
<10%	9.1%
10-25%	27.3%
25-50%	18.2%
50-75%	27.3%
75-90%	18.2%
>90%	0%

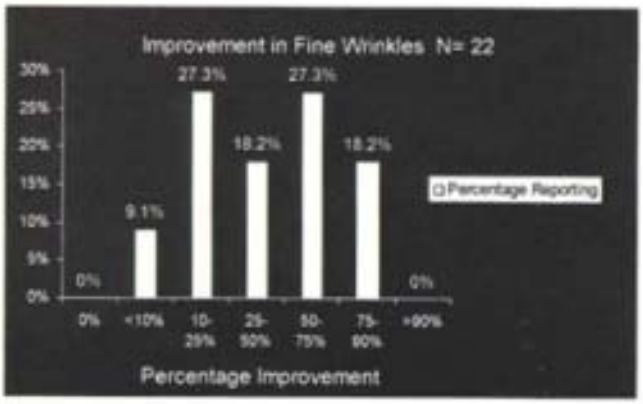

Figure 1. Improvement in fine wrinkles (n = 22).

ment in telangiectasias. Seventy percent of subjects reported a 50% or greater improvement in the appearance of telangiectasias. Thirty-eight percent reported a 75% or greater improvement in their telangiectasias. Figure 4 shows the improvement in the appearance of pores. Sixty-seven percent reported at least a 50% improvement in the appearance of their pores. Figures 5 and 6 show the percentage improvement in facial erythema and flushing, respectively. Fifty-nine percent reported 50% or greater improvement in facial ery-

N=37

Percentage Improvement	Percent Reporting
0%	0
<10%	2.7
10-25%	8.1
25-50%	19
50-75%	32.4
75-90%	21.6
>90%	13.5
100%	2.7

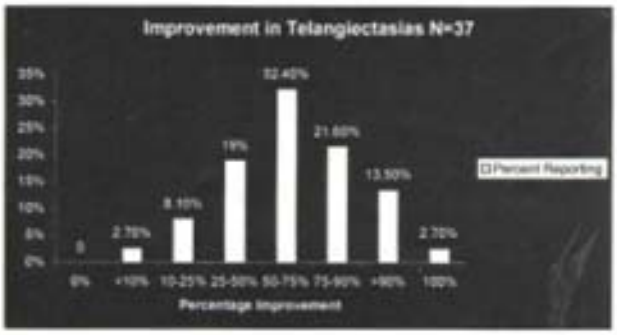

Figure 3. Improvement in telangiectasias (n = 37).

thema and 60% reported at least a 50% improvement in flushing. Figure 7 shows overall improvement. Seventy-five percent reported a 50% or greater overall improvement, while 45% reported a 75% or greater improvement. Figures 8–10 show the typical improvement in fine wrinkles, skin smoothness, erythema, and telangiectasias seen following a series of full-face intense pulsed light treatments.

Skin biopsies of pre- and posttreatment forehead skin were obtained in one subject. Figure 11 shows photomicrographs of forehead skin biopsies taken before and after pulsed light treatments. Figure 12 shows photomicrographs of treated versus untreated forehead

N=43

Percentage Improvement	Percent Reporting
0%	2.3
<10%	8.2
10-25%	9.3
25-50%	11.6
50-75%	27.8
75-90%	27.8
>90%	13.9
100%	2.3

Figure 2. Improvement in skin smoothness (n = 43).

N=44

Percentage Improvement	Percent Reporting
0%	3.2
<10%	9.6
10-25%	9.6
25-50%	9.6
50-75%	35.2
75-90%	22.4
>90%	9.6
100%	0

Figure 4. Improvement in pore size (n = 44).

N=44

Percentage Improvement	Percent Reporting
0%	0
<10%	4.6
10-25%	11.5
25-50%	16.1
50-75%	25.3
75-90%	19.9
>90%	13.8
100%	0

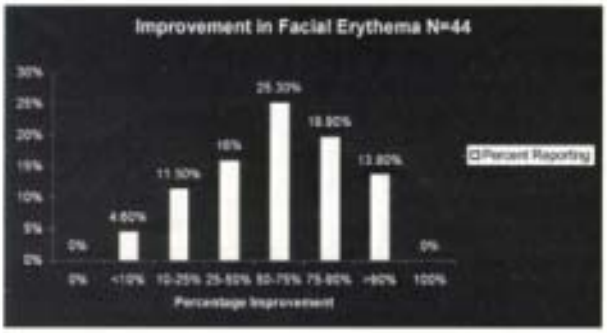

Figure 5. Improvement in facial erythema ($n = 44$).

skin in the same subject. Table 2 reports the adverse effects encountered. Whereas erythema and swelling were common immediately following treatment, these effects generally resolved within 12–24 hours and were generally mild enough that subjects experienced no limitations in their activities. Temporary discoloration consisted of a darkening of lentigines and freckles following treatments. These effects were common and expected, and resolved completely within 7 days. Only 2 of a total of 242 full-face treatments resulted in any patient downtime. Two subjects reported a "downtime" of 1 and 3 days due to moderate to severe swelling. The same subjects had no downtime with any of their four other treatments. The most severe swelling observed following treatment occurred in one subject who had just completed a course of antibiotic (zithromax).

N=25

Percentage Improvement	Percent Reporting
0%	0
<10%	4
10-25%	24
25-50%	12
50-75%	20
75-90%	32
>90%	8
100%	0

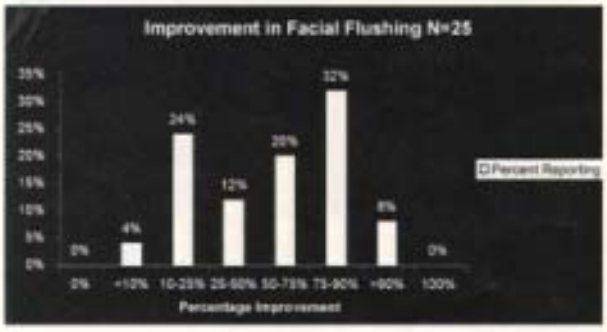

Figure 6. Improvement in facial flushing ($n = 25$).

N=49

Percentage Improvement	Percent Reporting
0%	0
<10%	4.1
10-25%	8.2
25-50%	12.3
50-75%	30.6
75-90%	30.6
>90%	10.2
100%	4.1

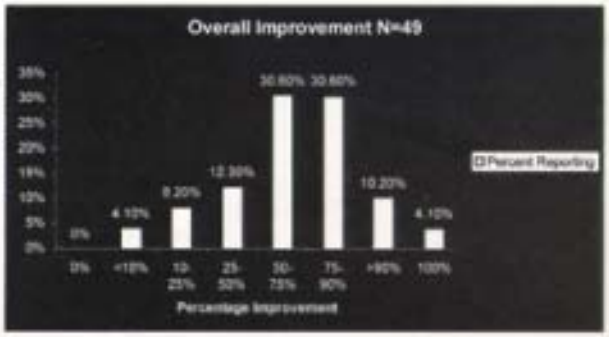

Figure 7. Overall improvement ($n = 49$).

Subject satisfaction is reported in Table 3. Overall 100% of subjects reported some degree of satisfaction. Eighty-eight percent of subjects (43 of 49) were satisfied while 61% were very satisfied with the results of their treatments. Ninety-six percent of subjects would recommend the treatments.

Discussion

This study evaluates the efficacy and safety of a new application of a filtered, noncoherent pulsed light source in the nonablative rejuvenation of photoaged facial skin. Skin photorejuvenation is the improvement of photodamaged skin using a laser or light source. True skin rejuvenation is the improvement not only of rhytides, but also improvement in all elements of photodamage including skin texture, irregular pigmentation, and telangiectasias. The optimal goal of skin rejuvenation is the visible improvement in all elements of photodamage. This study evaluated a previously described technique using intense pulsed light to treat photodamaged skin.[19,20] In this technique a series of five full-face treatments are performed at 3-week intervals using specific parameters. Relatively short pulses of 2.4–4.7 msec with interpulse delays of 10–60 msec and fluences of 30–50 J/cm^2 are used with a 550 or 570 nm cutoff filter. Fluences were varied depending on the immediate skin reaction observed. In general, a mild amount of erythema and darkening of freckles and lentigines developing within 1–2 minutes of a pulse

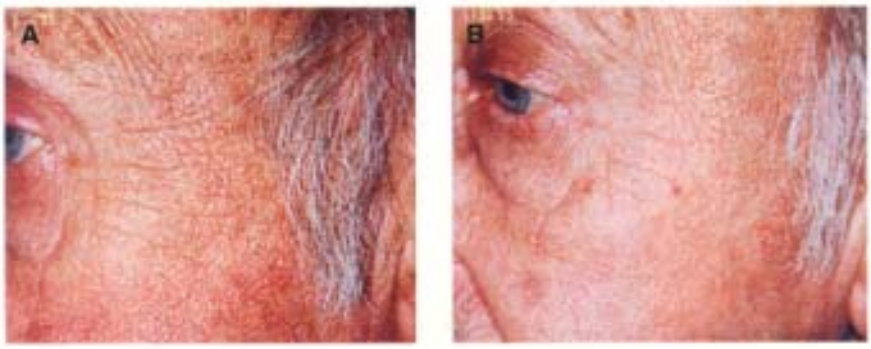

Figure 8. A 59-year-old man: A) before and B) after five full-face intense pulsed light treatments. Note improvement in rhytides, skin texture, telangiectasias, and lentigines.

Figure 9. A 40-year-old woman: A) before and B) 3 weeks after four full-face intense pulsed light treatments. Note overall improvement in pigmentation, skin texture, and periorbital rhytides.

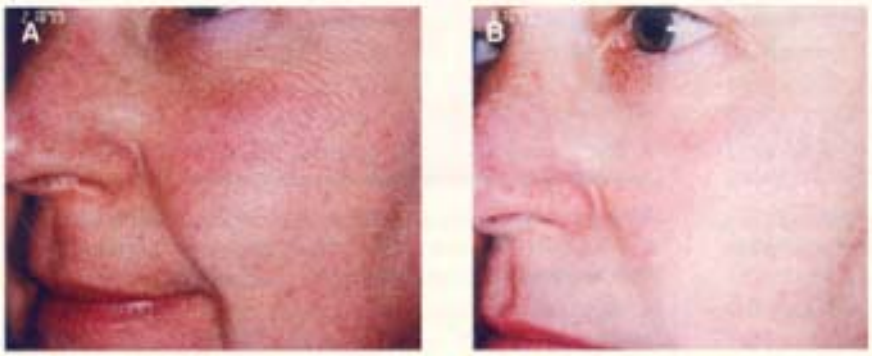

Figure 10. A 54-year-old woman: A) before and B) 4 weeks after five full-face intense pulsed light treatments. Note improvement in fine wrinkles and skin texture.

were the guidelines used to determine the clinical end point of each treatment. This immediate result could be obtained by varying the fluence and the distance between the skin and the light guide of the handpiece.

In this study, 49 subjects underwent a total of 242 full-face treatments. Patient evaluation demonstrated consistent, visible improvement in all aspects of photodamaged skin. Fine wrinkling, irregular pigmentation, skin texture, pore size, telangiectasias, and facial erythema all showed visible improvement as rated by patient assessment. While no subjects reported a 100% improvement in fine wrinkles, all subjects reported at least some degree of improvement. Wrinkle scores improved from a pretreatment score of 5.00 (moderate) to 2.83 posttreatment (mild to moderate). The percentage improvement reported by subjects varied from less than 10% (9.1%) to a maximum of 75–90% (18.2%); 45.5% reported 50% or greater improvement and 64% reported 25% or greater improvement in wrinkles.

Skin texture improved to some degree in 97.7% of subjects, with 72% reporting a 50% or greater improvement. The appearance of pores showed similar results, with 97% of subjects reporting some degree of visible improvement in appearance; 67% reported a 50% or greater degree of improvement in the appearance of their pores.

Of interest, subjects reported improvement in skin laxity. Pretreatment severity scores improved from 5.53

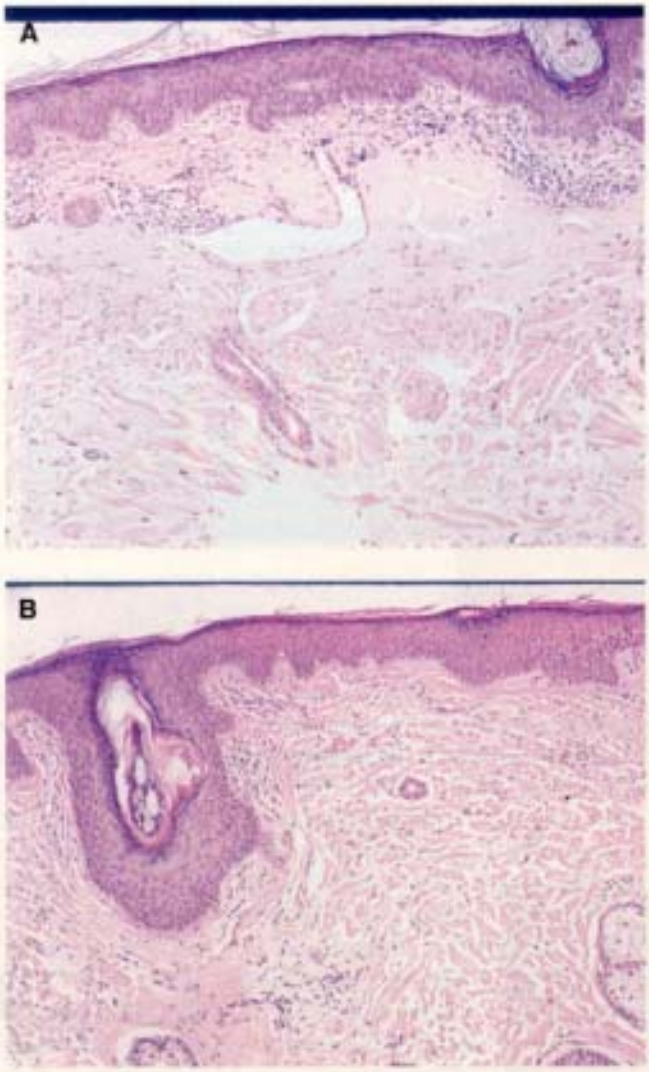

Figure 11. Photomicrographs of biopsy specimens of forehead skin A) before and B) 4 weeks after five intense pulsed light treatments in a 59-year-old man.

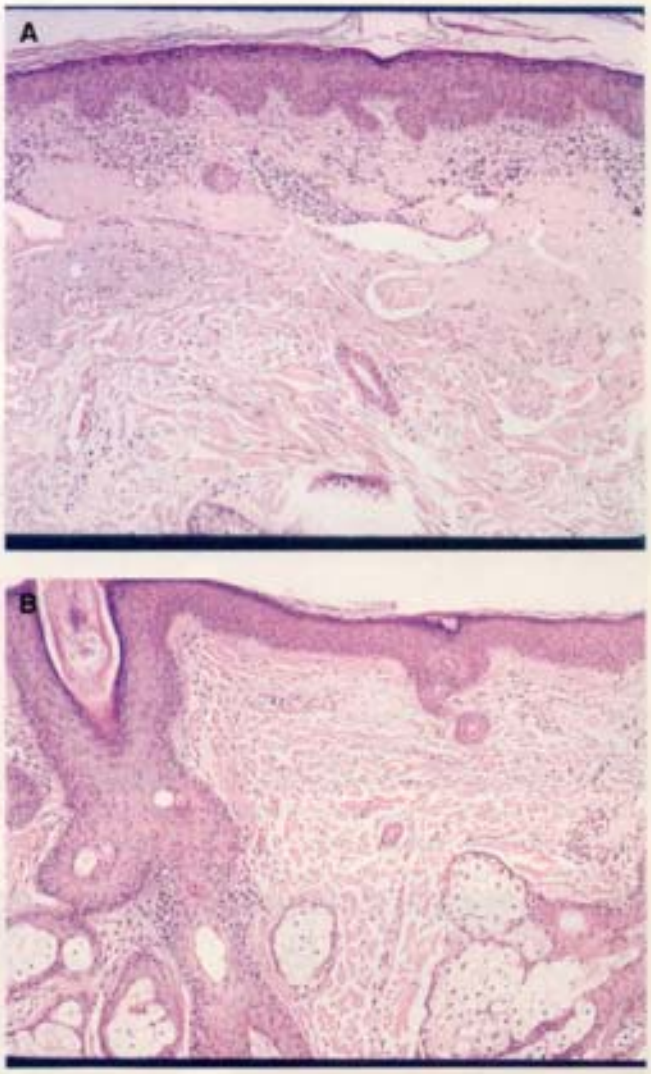

Figure 12. Photomicrograph of biopsies of forehead skin from the A) untreated forehead and B) treated forehead 4 weeks after the fifth intense pulsed light treatment.

(moderately severe) to 2.00 (mild). All subjects responding ($N = 15$) reported at least some degree of improvement in skin laxity.

As would be expected, facial telangiectasias showed a high degree of improvement, with 50% or greater improvement reported by 70% of subjects and 75% or greater improvement in 38% of subjects. Of particular interest was the substantial degree of improvement noted in subjects with facial erythema and flushing. Fifty-nine percent of subjects reported a 50% or greater improvement in erythema and 60% reported a 50% or greater improvement in flushing. While facial erythema and flushing are not exclusive to photodamage, they are common findings in the Caucasian population. Many patients with photoaging also have some degree of concomitant erythema with or without flushing. Likewise, patients with rosacea frequently also show some degree of photoaging. Treatments for facial erythema and flushing have been of limited success. In addition, current noninvasive and invasive methods for skin rejuvenation show limited or no improvement in erythema or flushing and may even exacerbate these symptoms.[10] The improvement in telangiectasias, erythema, and flushing seen with the technique described is an added benefit of skin rejuvenation with intense pulsed light.

The results in this study show a high degree of patient satisfaction. All subjects reported some degree of overall improvement, with 69% reporting much or very much overall improvement. Overall satisfaction was equally high, with 88% of subjects satisfied, 61% very satisfied, and 27% extremely satisfied. Ninety-six

Table 2. Adverse Effects

Criteria	*Percent Reporting*
Temporary discoloration	66%
Temporary swelling	
None	49%
Mild	39%
Moderate	10%
Severe	2.1%
Blisters	
None	84%
Mild	16%
Moderate or severe	0%
Scarring	
None	100%
"Downtime" in Days	
n = 242 treatments	Number
None	240
1 day	1
3 days	1

N = 49.

Table 3. Subject Satisfaction

	Number	*Percent*
Not satisfied	0	0
Slightly satisfied	6	12
Satisfied	13	27
Very satisfied	17	34
Extremely satisfied	13	27

N = 49.

percent of subjects indicated they would recommend the treatments.

The histology presented in this study showed a greater degree of change than expected or previously reported. New collagen was observed not only in the papillary dermis but throughout the full thickness of the reticular dermis. In addition, resolution of the superficial dermal inflammatory infiltrate and papillary dermal melanophages was noted. Additional studies are needed to further evaluate the histologic improvement in photodamaged skin with intense pulsed light.

The absence of purpura with this technique is a major advantage over the pulse dye laser and permits treatment of the entire face with no downtime. The epidermal and dermal improvements observed with intense pulsed light treatments produces an entirely different result than is seen with the Nd:YAG laser at 1320 nm. At this wavelength the Nd:YAG laser has some effect on wrinkles but lacks the benefits of intense pulsed light on the epidermis, hyperpigmentation, and telangiectasias.

The present study differs in several important ways from a recently published study evaluating the use of intense pulsed light in the treatment of rhytides.[18] In this study of 30 female subjects with Fitzpatrick type I–II and class I–II skin types, Goldberg concluded that intense pulsed light could improve some rhytides, however, less dramatically than is seen with ablative techniques. Twenty-five of 30 subjects showed some improvement in periorbital, perioral, or forehead rhytides, with 9 subjects showing substantial improvement. One to four treatments to selected regions of the face were performed over 10 weeks. Using a 645 nm cutoff filter, light was delivered in triple 7-msec pulses with 50-msec interpulse delays and fluences of 40–50 J/cm^2.

The technique in the study by Goldberg differs in several important ways from the technique described in this study. First, the parameters used in this study were of shorter pulse durations (2.4–4.0 msec versus 7.0 msec) and shorter interpulse intervals (10–20 msec versus 50 msec). Furthermore, double-pulse modes were used versus triple-pulse modes and a 550 nm cutoff filter was used versus a 645 nm filter. With shorter pulses lower fluences are used (30–42 J/cm^2) to minimize direct epidermal injury.

In theory, the parameters used in this study would be expected to have a substantially different effect on the skin. Whereas a 645 nm filter and longer pulse durations with longer interpulse intervals would have a greater thermal effect on larger diameter and deeper vessels, a 550 nm filter with shorter pulses and short interpulse intervals would have a relatively greater effect on epidermal and superficial dermal melanin and more superficial, smaller diameter vessels. The latter parameters would be expected to produce a greater overall textural change as well as a greater effect on epidermal and superficial dermal hyperpigmentation. Indeed, with the parameters used in this study it was observed that to more effectively eradicate larger and deeper vessels a higher cutoff filter (570 nm) with longer pulses (3.5–4.7 msec) and longer interpulse intervals (60 msec) was occasionally needed. On the other hand, improvement in skin texture, fine wrinkling, pore size, and irregular pigmentation was most effective with a 550 nm cutoff filter and shorter pulses.

A second important difference between the present study and the Goldberg study is that the entire face was treated in the technique described in this study. To observe an overall improvement in all symptoms of photoaging it is necessary to perform full-face treatments rather than partial-face treatments. It is suggested by this study that the high degree of patient satisfaction is at least due in part to the improvement seen in the entire facial skin.

A third difference observed with the technique for skin rejuvenation described in this study is that it is necessary to do a series of five or more multiple se-

quential treatments. This allows for a gradual, progressive visible improvement while enabling treatments to be gentle enough to avoid adverse effects or patient downtime. This contrasts with the Goldberg study where some subjects had only one treatment. Finally, the Goldberg study focused on intense pulsed light treatment of wrinkles. In contrast, this study investigated a new and unique application of intense pulsed light in the visible improvement of photoaged facial skin, including wrinkles.

Though it is not known whether additional treatments beyond the five described in this study would produce substantially greater results, observations to date suggest that at least some patients continue to show progressive improvement with additional treatments.

In conclusion, the technique described in this study shows efficacy in visibly improving all aspects of photoaging, including fine wrinkles, irregular pigmentation, skin texture, pore size, and telangiectasias. A series of full-face intense pulsed light treatments are safe and readily tolerated by patients with minimal adverse effects, minimal downtime, and minimal risk of scarring. Treatments are relatively easy for patients to undergo. The average treatment duration is 20 minutes, and the discomfort of treatments is made quite tolerable with the pretreatment use of Ela-Max cream (the author's unpublished data).

The ultimate goal of any cosmetic procedure is a satisfied patient. In the treatment of photoaged skin, patients are seeking some degree of visible improvement in all aspects of aging. While patient expectations may vary, to some degree all patients desire a visible improvement in wrinkling, skin texture, irregular pigmentation, and telangiectasias. In addition, patients are increasingly seeking noninvasive or minimally invasive methods to improve the effects of aging. A treatment that can accomplish consistent visible improvement in the skin with no downtime is highly desirable. This study shows that the technique for skin rejuvenation using serial, full-face treatments with a filtered, noncoherent pulsed light source achieves a high degree of patient satisfaction noninvasively, with no downtime and minimal adverse effects. Further investigation to evaluate long-term results, increased benefits of additional treatments, degree of histologic improvement, and additional benefits from combined technologies is presently under way.

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Commentary

The concept of rejuvenation of photo-aged skin is one of the hottest topics among dermatologic surgeons and the general public. Those of us who treat patients in cosmetic dermatology know of the daily multiple requests to improve texture, color, pore size, broken blood vessels, and wrinkling. As dermatologists we have endeavored to improve and perfect numerous techniques such as chemical peeling, ablative and non-ablative resurfacing, dermabrasion, and various visible light and near IR laser treatments. More recently we have pursued newer modalities such as micro-abrasion to accomplish skin textural improvement with no patient "downtime."

What perfect sense to use a light source (IPL, intense pulsed light) which combined many wavelengths (yellow, red, and near IR wavelengths) to accomplish improvement of many aspects of photo-aging. Dr. Patrick Bitter, Jr's retrospective study of 49 patients treated with standardized parameters and technique with one light source breaks new ground in the concept of IPL rejuvenation of photodamaged skin. While dermatologic surgeons like Dr. Mitchel Goldman and Dr. Margaret Weiss and many others have helped improve IPL parameters since 1994 and have observed great utility for use in reduction of telangiectasias and poikiloderma,[1] observations of accompanying improved skin texture and reduced wrinkling were anecdotal. Dr. Bitter has put this all together with a coordinated series of 5 treatments with careful evaluation of photographs, patient self-assessment, and some histology. Although photographs may be difficult to interpret for fine wrinkling and textural changes, his distribution of improvement scores appears to be valid. Telangiectasias were improved in the vast majority by 50–90 % which is similar to what we have observed. Reductions in facial flushing hint that IPL may also help alleviate symptoms of rosacea. Improvement of mottled pigmentation was not quantitated but is illustrated dramatically in the accompanying figures. Most significantly is the concept of multiple treatments to allow for gradual improvement with treatment parameters below the threshold for serious adverse effects.

Until others confirm these findings, however, there will be much controversy over the quantity and quality of results. But studies such as Zelickson and Kist[2] showing increased collagen I, III, collagenase, elastin, hyaluronate receptor, and pro-collagen in histologically examined skin after treatment with pulsed yellow dye laser and IPL give additional evidence in support of the results reported in this article. Studies are presently underway with even more sophisticated techniques, ie, skin surface microscopy, to document textural and pore size changes with IPL.

What remains for us now is to elucidate how to best utilize all the non-invasive modes of collagen remodeling and textural improvement—IPL, pulsed dye laser, 1320 nm, light chemical peels, and micro-abrasion to develop the optimal regimen for photodamaged patient. What is clear is that IPL can treat many of the signs and symptoms of photo-aging, what is equally clear is that the dermatologic surgery community will be the group that discerns the best indications for and sequence of the various minimally invasive modalities available in the coming years.

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