

Facial Photo Rejuvenation Using Two Different Intense Pulsed Light (IPL) Wavelength Bands

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Background and Objectives: Intense pulsed light (IPL) systems are increasingly used for treatment of photo damaged skin. In the present study, we investigated the clinical efficacy and safety of two different wavelength bands generated by the same IPL device.

Study Design/Materials and Methods: An IPL device was equipped with either a 555–950 nm filter (VL), or a 530–750 nm filter (PR).

Results: Fair, good or excellent clearance of visible telangiectasias was obtained in 81.8% of the patients (PR) and in 58.8% (VL). In the treatment of diffuse erythema, fair, good or excellent clearance was obtained in 72.7% (PR) and in 35.0% (VL). The PR filter was more efficient ($P = 0.025$) in reduction of diffuse erythema. The average number of treatments was 1.75 (PR) and 1.82 (VL). For the treatment of irregular pigmentation, fair, good or excellent clearance was obtained in 54.5% (PR) and in 61.9% (VL). Multiple treatments of irregular pigmentation were also evaluated. Using the VL filter more than two treatments did not induce further clinical improvement. The patients also scored their over-all satisfaction. Either fair, good or excellent results were reported by 66.7% (PR) and by 76.2% (VL). No skin atrophy, scarring or pigment disturbances were noted after the treatments. Swelling and erythema were registered by 2/3 (PR) and 1/3 (VL) of the patients.

Conclusions: The two IPL wavelength bands were both found to be effective in the treatment of photo damaged facial skin. The clinical efficacy and safety of the two different treatment procedures were comparable to those reported in earlier studies, and finally treatment with these filter combinations required less than half the fluence, no active cooling and fewer treatments. *Lasers Surg. Med.* 34:120–126, 2004. © 2004 Wiley-Liss, Inc.

Key words: photo rejuvenation; skin rejuvenation; treatment; pigment; vascular lesions; telangiectasia; diffuse erythema; IPL; intense pulsed light

INTRODUCTION

Non-invasive techniques for skin rejuvenation have now been established as a new standard in the treatment of rhytids and skin toning. Different treatment modalities using lasers and intense pulsed light (IPL) have resulted in varying degrees of clinical effects. The devices used include

lasers emitting light at 532, 578, 585, 810, 900, and 1,064 nm wavelengths as well as filtered white light generated by IPL systems equipped with different cut-off filters.

Treatment of photo damaged skin has been divided into: Type I photo rejuvenation, which includes treatment of pigmented disorders, reduction of telangiectasias and erythema, and Type II photo rejuvenation, which concerns treatment of dermal structures such as rhytids and skin pore size [1]. Finally, ablative resurfacing methods, resulting in long recovery times and associated with substantial risks of severe side effects have during more than 10 years been performed with the CO₂ laser [2,3] and later also with the Er:Yag laser [4]. The effect of these treatments includes both Type I and Type II photo rejuvenation.

A continually increasing demand for treatment of photo damaged skin without down-time has lead to the development of new non ablative techniques [5]. New lasers emitting 1,320 [6], 1,450 [7], and 1,540 [8] nm using interstitial and intracellular water as target chromophores and pulsed dye lasers [9] using oxyhemoglobin as the primary chromophore are now employed for Type II photo rejuvenation only. The clinical efficacy of these non-ablative modalities are less than for the ablative methods, however, in one study up to 90% of the patients showed clinically observable improvement in wrinkles [10]. Other studies showed clinical effect in only 40% of the treated subjects [11].

Recently, different IPL systems have been introduced for photo rejuvenation [12–18]. Until now, reduction of facial wrinkles (Type II) obtained with IPL devices has shown to be inferior to laser treatments [15], but for Type I photo rejuvenation (treatment of vessels), IPL systems have in general shown considerably better results than laser systems operating at subpurpuric energy levels [19,20].

Bitter [14] reported that after 4–6 full-face IPL treatments, 90% of Caucasian subjects obtained visible

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improvements such as reduction of telangiectasias, pigmented lesions, skin texture, and skin elasticity.

Negishi et al. [14] observed 60% improvements in pigmentation, telangiectasias, fine wrinkles, and skin texture. The over-all skin rejuvenation effect after five IPL full facial treatments, with a wavelength band of 560–1,200 nm, was more than 80% in 73 Asian patients. In another study [16], 90 and 83% of 97 Asian patients gave the ratings good or excellent, respectively for improvements of pigmentation and telangiectasias.

The present study was aimed at further improving the skin rejuvenation procedure by splitting the treatment procedure into two treatment sessions with different treatment parameters: one aimed at the vascular target [22] of the skin and the other aimed at the epidermal pigment.

MATERIALS AND METHODS

Patients

The study included 35 healthy patients (mean age: 46.6 years, SD: 9.5 years, range: 33–72 years), 33 females and 2 males, all with substantial photo damaged facial skin. The patients were divided into three groups having either predominantly irregular pigmentation (10 patients, group 1), vascular lesions 13 patients, group 2) or both (12 patients, group 3). All patients belonged to the Fitzpatrick photo skin types I–III, and their actual degree of pigmentation varied from light to medium. Informed consent was obtained from all patients, and the study was approved by the institutional review board of Aarhus University Hospital, Denmark.

IPL System

All treatments were performed with an Ellipse Flex (DDD, Denmark), which is a second-generation IPL system designed for long-term depilation, treatment of vascular and pigmented lesions as well as skin/photo rejuvenation. Due to US patent issues, the device is available worldwide except for the USA.

Two different wavelength bands were compared for efficacy and safety:

1. A wavelength band ranging from 555 to 950 nm (VL filter) taking advance of the principle of dual mode filtering [22] with a median wavelength of the power spectrum positioned at 726 nm. This spectrum covers only the oxyhemoglobin absorption peak at 577 nm (Fig. 1) and is normally used as the standard vascular filter.
2. A restricted wavelength band from 530 to 750 nm (PR filter) with a median wavelength of the power spectrum positioned at 660 nm. This new photo rejuvenation wavelength band employed a new double water-cooled filter technique. This filter combination emits light, which is absorbed by two of the oxyhemoglobin absorption peaks (542 and 577 nm) and further eliminates most near-infrared wavelengths (Fig. 2).

For both wavelength bands the spot size on the skin surface was 10 × 48 mm.

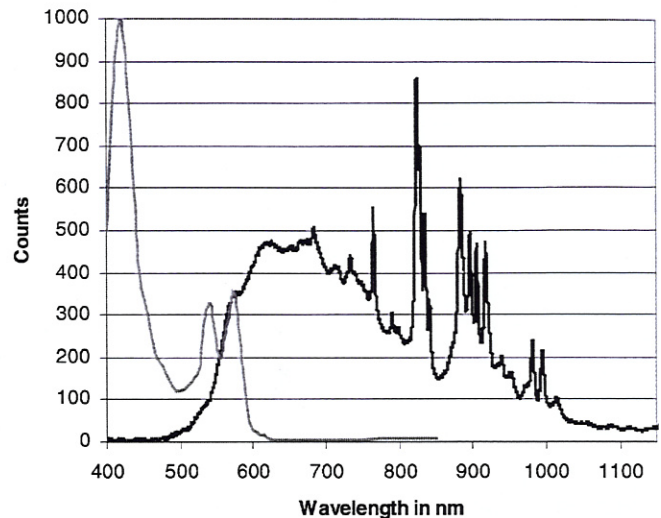


Fig. 1. Absorption spectrum of oxyhemoglobin (red) and emission spectrum of the 555–950 nm wavelength band (blue) at an output of 15 J/cm².

Photo Documentation System

All photographic documentation was performed with a facial photo fixture (DDD, Denmark). This fixture ensures a fixed distance and fixed angles between the camera and the face of the volunteer. Two flash lamps placed in fixed positions to the camera ensured even, diffuse illumination of all parts of the face.

Experimental Procedure

The patients were allocated to treatment with either the VL filter (23 patients) or a new 530–750 nm wavelength band (12 patients). The treatment regime consisted of two different types of treatment sessions selected according to

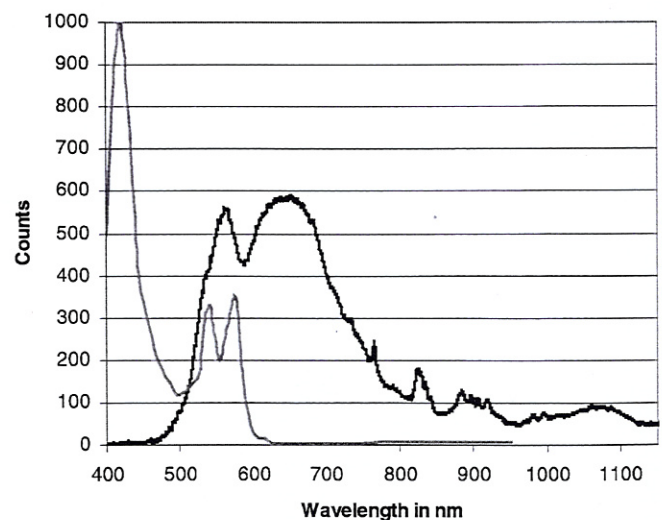


Fig. 2. Absorption spectrum of oxyhemoglobin (red) and emission spectrum of the 530–750 nm wavelength band (blue) at an output of 15 J/cm².

the patient's predominant problem—either irregular pigmentation or erythema and telangiectasias.

Session 1: Treatment of telangiectasias (only if present)

Session 2: Treatment of irregular pigmentation (all patients).

1. Treatment of telangiectasias. Only patients having skin areas with individual, visible telangiectasias were initially treated with this modality. Treatment settings were chosen in order to first treat the thickest vessels using pulse durations of 15–30 millisecond. The average energy level was 14.6 J/cm^2 , SD: 2.7 J/cm^2 (VL filter) [22], and 14.3 J/cm^2 , SD: 0.6 J/cm^2 (PR filter). These treatments were repeated with monthly intervals until no further improvement could be registered. The average number of treatments was 1.82, SD: 0.70 (VL filter) and 1.75, SD: 0.7 (PR filter).

2. Treatment of epidermal pigmentation and diffuse erythema. All patients were eventually treated with this modality, using short pulse durations of 2.5 millisecond and double light pulses with 10 millisecond interval. The average energy level was 9.9 J/cm^2 , SD: 0.9 J/cm^2 (VL filter) and 7.9 J/cm^2 , SD: 0.3 J/cm^2 (PR filter). These treatments were performed as full-face treatments with intervals of 3–4 weeks. The average number of treatments was 1.43, SD: 0.51 treatments with the VL filter, and a fixed number of 3 treatments using the PR filter.

Treatment Procedure

Before treatment the skin surface was covered with a thin layer of transparent hydro-gel (DDD, Denmark) to perform optical index-matching. Care was taken not to apply any mechanical pressure to the skin surface with the IPL system's optical light guide. Mechanical compression displaces the superficial capillaries in the skin and hence reduced the primary optical target.

Clinical Evaluation

Efficacy. The clinical outcome was evaluated in a blinded manor by a Board Certified dermatologist, experienced in cosmetic dermato-surgery, who did not participate in the treatment of the patients. The evaluations were based on close-up photography taken prior to the first treatment and at the follow-up visit. The clinical evaluation of efficacy was performed 3 months after the last treatment by dividing the treatment results into five groups: 0%, 1–24%, 25–49%, 50–74%, and 75–100% clearance, which corresponded to the following grouping of the effect: none, poor, fair, good, and excellent. The evaluation was performed individually for each of the following parameters: reduction of visible vessels, clearance of diffuse redness, and clearance of irregular pigmentation.

Safety. The following side effects were evaluated: pigment disturbances (hypopigmentation, hyperpigmentation), atrophy, and scarring (atrophic or hypertrophic). The side effects were individually evaluated on the following scale: none, slight, moderate, severe.

Patient Evaluation

At the follow-up visit all patients were placed in front of a mirror with a built-in illumination and asked to evaluate the outcome based on a comparison with photos taken before treatment. The volunteers evaluated the degree of "over all improvements" as either: none, poor, fair, good, or excellent.

Statistical Evaluation

The Student's *t*-test was used, and statistical significance was accepted at the 5% level for improvement differences between the two treatments.

RESULTS

Fair, good or excellent clearance of telangiectasias (Fig. 3) was obtained in 81.8% of the patients treated with the PR filter compared to 58.8% of the patients treated with the VL filter (Fig. 4).

For diffuse erythema, fair to excellent clearance was obtained in 72.7% of the patients treated with the PR filter compared to 35.0% of the patients treated with the VL filter (Fig. 5).

For treatment of irregular pigmentation, fair, good or excellent clearance was obtained in 54.5% of the patients treated with the PR filter compared to 61.9% of the patients treated with the VL filter (Figs. 6 and 7), Table 1.

In 10 patients the effect of additional treatments of irregular pigmentation was evaluated. Using the VL filter,

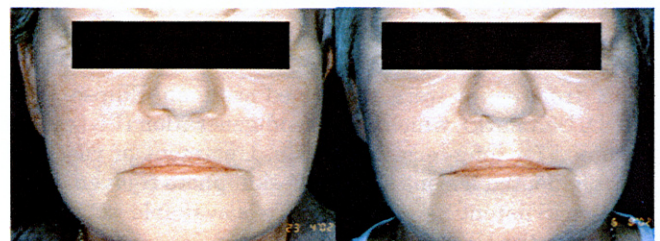


Fig. 3. Treatment of telangiectasias before and 3 months after a single intense pulsed light (IPL) treatment.

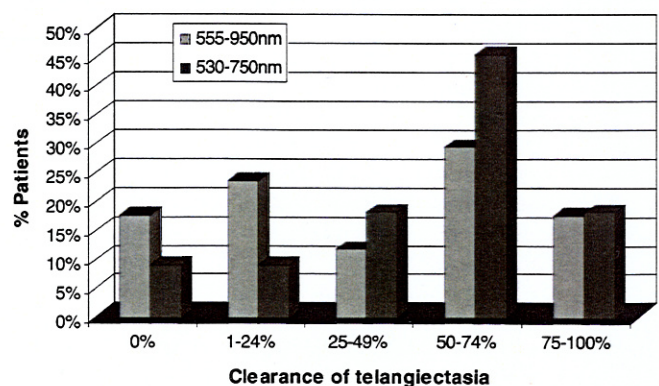


Fig. 4. Comparison between two different IPL treatments using either 530–750 nm or 555–950 nm wavelength bands.

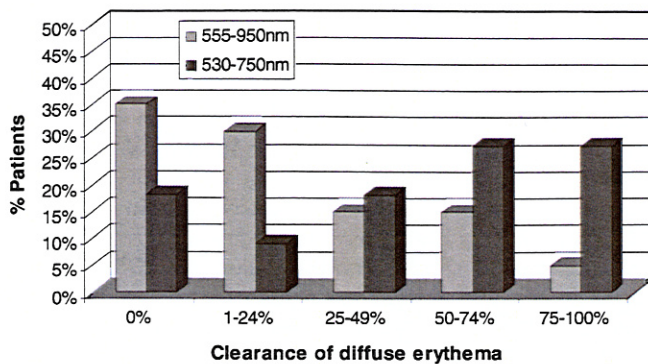


Fig. 5. Comparison between two different IPL treatments of diffuse erythema. The 530–950 nm wavelength band was shown to be statistically superior ($P = 0.025$) to the 555–950 nm wavelength band.

we found that more than two treatments did not result in further clinical improvement of epidermal pigmentation. The 530–750 nm wavelength band was significantly more efficient ($P = 0.025$) for the reduction of diffuse erythema. A trend towards a better effect by the 530–750 nm wavelength band in the reduction of visible vessels was observed; however, this result was not statistically significant ($P = 0.258$). For the reduction of irregular pigmentation, both wavelength bands were found to be effective, and there was no statistical difference ($P = 0.481$) between the efficacy of the two wavelength bands.

The patients also scored their over-all satisfaction with the treatment. For the PR filter 66.7% and for the VL filter 76.2% of the patients rated the treatment a being either fair, good or excellent (Fig. 4). The difference between the clinical effects of the two filters was not statistically different ($P = 0.242$), Figure 8.



Fig. 6. Treatment of epidermal melasma before and 1 month after a single treatment. Note the few missing overlaps.

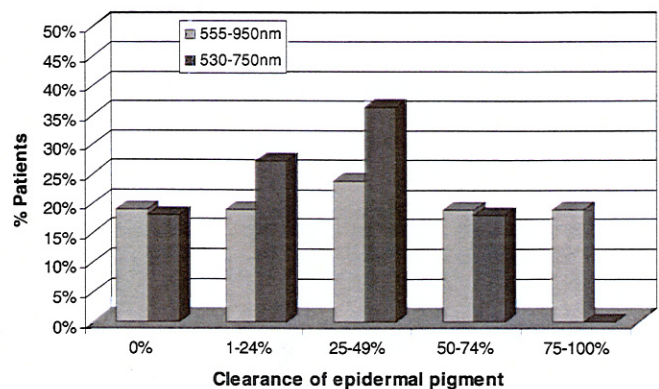


Fig. 7. Comparison between two different IPL treatments of irregular epidermal pigmentation. No statistically difference between the two wavelength bands ($P = 0.481$) was found.

Side Effects

No skin atrophy, scarring, or pigment disturbances could be found after the treatments.

Acute side effects comprised only oedema and erythema for 2/3 and 1/3 of the patients treated with the PR filter and the VL filter, respectively. Oedema was reported to last on average 41.5 hour (SD: 29.1 hour), and erythema lasted 14.7 hour (SD: 20.2 hour). Patients whose primary problem was mottled pigmentation, experienced photo-oxidation of the pigment, resulting in further darkening of pigmented spots. After a few days the darker pigment disappear as a dry desquamation with no oozing or blistering (Fig. 9).

DISCUSSION

Recently, IPL sources have received significant interest in the treatment of photo damaged skin [1]. However, light spectra, pulse duration, number of pulses as well as fluency and the use of skin cooling vary considerably among the published investigations, making direct comparisons difficult.

In the present study on photo rejuvenation Type I, we investigated the effect of different pulse durations and different wavelength spectra on clinical efficacy and side effects. We showed that IPL treatment with a relatively narrow wavelength band (530–750 nm) had certain advantages over a conventional IPL filter combination

TABLE 1. Clinical Evaluation of IPL Treatment Using Two Different Filter Combinations According to a Score System Ranging From 0 to 4

Clinical improvement of	IPL wavelength band (555–950 nm)	IPL wavelength band (530–750 nm)
Visible vessels	2.06 (SD: 1.43)	2.58 (SD: 1.16)
Diffuse erythema	1.23 (SD: 1.26)*	2.25 (SD: 1.48)
Irregular pigmentation	1.95 (SD: 1.37)	1.67 (SD: 1.67)

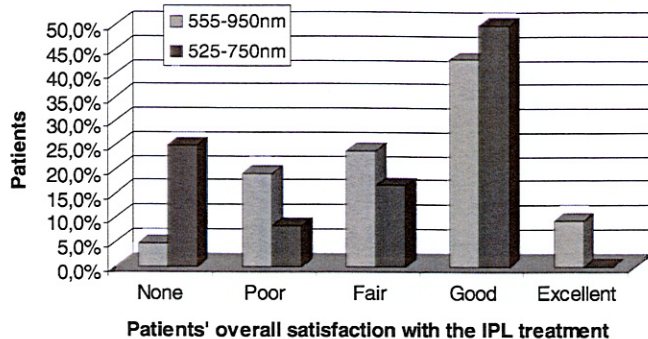


Fig. 8. Patient satisfaction with the treatment series, 66.7 and 76.2% of the patients rated the treatment series as being either fair, good or excellent.

(555–950 nm VL filter) for the treatment of visible telangiectasias and diffuse erythema (small vessels), but not for the treatment of epidermal melanin pigmentation.

Also, we showed that a single set of treatment parameters was not optimal for all indications. Although restrictions may apply in comparing data between different studies with different treatment devices and efficacy scoring systems used, the general conclusions mentioned below can be drawn from published data (Table 2).

Treatment of Visible Telangiectasias

By restricting the wavelength band from 560–1,200 (Negishi et al. [14], Bitter [21]) to 555–950 nm (Bjerring [22]) fluence could be reduced by at least 30% (32–22 J/cm²). Further shift of the spectrum towards lower wavelengths to cover the two absorption peaks of the oxyhemoglobin absorption spectrum (542 and 577 nm) a total reduction of 50% of the fluence can be obtained with comparable clinical results (84.4, 83.4, 70, and 81.8%, respectively, (Table 2)). Furthermore, the most restricted wavelength band (PR filter) also induced a reduction in number of treatments necessary from 5 [14] and 4.94 [21], to 2.54 [22] and in the present study 1.75 (SD: 0.7) treatments.

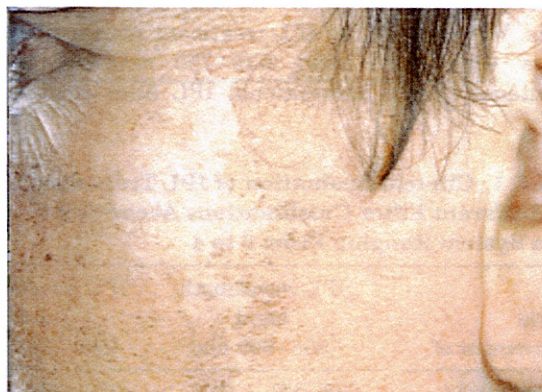


Fig. 9. IPL-induced photo-oxidation of epidermal melanin, resulting in further darkening of lentigines. After a few days the darkened pigment disappears as a dry desquamation.

Treatment of Diffuse Erythema

Compared with previously published treatment parameters, the treatment fluence can be reduced by at least 37% by restricting the wavelength band from 560–1,200 [21] to 555–950 nm [22] (a reduction from 30–50 J/cm² to 12–17 J/cm², Table 2). By shifting the light spectrum towards even shorter wavelengths to cover both of the two absorption peaks of the oxyhemoglobin absorption spectrum at 542 and 577 nm a fluence reduction of 73.3% could be obtained—and even shows a slightly increased efficacy (59–72.7% [21], Table 2).

The obtained efficacy of only 35% in the present study using the VL filter, is in contrast to the findings of an efficacy of 61.9% in a previous study [22] using the exactly the same filter. This might be due to the use of longer pulse duration (10 millisecond), where pulse durations of 2 × 2.5 millisecond with intervals of 10 millisecond was used in the present study. These results indicate that further optimizing of the pulse duration, based on calculations of thermal damage time (TDT) for the target, might have an impact on the clinical outcome, and presumably the optimal pulse duration might be found somewhere in the range of 2.5–10 millisecond. However, this issue needs further investigation.

Melanin Pigmentation

Melanin pigmentation as part of photo aging can be epidermal or dermal, and often is a combination of both. In early solar damage, melasma is a regular constituent; often with both dermal and epidermal pigment deposition—and in later stages of solar degeneration the solar lentigo, which is mainly located in the epidermis, is a prominent feature.

Both in the study by Negishi et al. [14] and in the present study significant clearing of pigmentation was found after 3 treatments (60.3% (560–1,200 nm), 61.9% (VL filter), and 54.4% (PR filter). However, Negishi et al. obtained 80.9% pigment clearance after an additional two treatments, while more than three treatments in our hands did not further increase the clinical efficacy. This indicates that the longer wavelengths might be necessary to penetrate sufficiently into the deep dermis. The treatment of deep dermal pigmentation and melanocytic nevi is outside the scope of the present study.

CONCLUSIONS

The present study shows that photo rejuvenation can be performed most efficient a sequential combination of two different irradiation modalities instead of a series of identical treatments.

Two different IPL wavelength bands were found to be highly effective in the treatment of telangiectasias, diffuse erythema, and irregular epidermal pigmentation. However, one of the filters (530–750 nm) was found to be most efficient for the treatment of ectatic vessels, while the other (555–950 nm) induced reduction of irregular pigment with fewer treatments.

Careful selection of wavelength bands opens the possibility to reduce fluence to less than 1/2 of previously used

TABLE 2. Comparison of Clinical Efficacy in Different IPL Studies

	Present study		Bjerring et al. [22]	Bitter [21]	Negishi et al. [14] (3 treatments)	Negishi et al. [14] (5 treatments)
Wavelength band (nm)	555–950	530–750	555–950	550/570–1,200	560–1,200	560–1,200
Average number of treatments for telangiectasias	1.82 (SD: 0.7)	1.75 (SD: 0.7)	NA	NA	NA	NA
Average number of treatments for pigment disorders	1.43 (SD: 0.5)	3.0 (SD: 0.9)	NA	NA	NA	NA
Average number of total treatments performed	2.67 (SD: 1.0)	3.62 (SD: 0.89)	2.54 (SD: 0.96)	4.94	3	5
Telangiectasia (% patients with clearance > 50%)	58.8	81.8	83.4	70	53.1 (clearance > 60%)	84.4 (clearance > 60%)
Fluency (J/cm ²)	11.5–20 (Average: 14.6 SD: 2.7)	13–15 (Average: 14.3 SD: 0.6)	13–22 (Average: 17.1 SD: 2.0)	30–50	28–32	28–32
Pulse duration (millisecond)	15–30	15	15–30	2.4, 4.7 Delay: 10–60	3.6, 5 Delay: 20/40	3.6, 5 Delay: 20/40
Diffuse erythema (% patients with clearance > 50%)	35.0	72.7	61.9	59	NA	NA
Fluence (J/cm ²)	Average: 9.9 (SD: 0.9)	Average: 7.9 (SD: 0.3)	12–17	30–50	23–27	23–27
Pulse duration (millisecond)	2 × 2.5 Delay: 10	2 × 2.5 Delay: 10	8–12	2.4, 4.7 Delay: 10–60	3.2, 6 Delay: 20	3.2, 6 Delay: 20
Pigmented lesions (% patients with clearance > 50%)	61.9	54.4	NA	NA	60.3 (Clearance > 60%)	82.2 (Clearance > 60%)
Fluence (J/cm ²)	8–10 (Average: 9.9 SD: 0.9)	7–8 (Average: 7.9 SD: 0.3)	NA	NA	23–27	23–27
Pulse duration (millisecond)	2 × 2.5 Delay: 10	2 × 2.5 Delay: 10	NA	NA	3.2, 6 Delay: 20/40	3.2, 6 Delay: 20/40

energy levels, without compromising the clinical efficacy, and safe treatments can be performed without variability in treatment parameters induced by contact cooling.

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