Split-Face Comparison of Intense Pulsed Light With Short- and Long-Pulsed Dye Lasers for the Treatment of Port-Wine Stains

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Background: So far, pulsed dye lasers have been regarded as the gold standard in the treatment of port-wine stains (PWS). Recently, intense pulsed light (IPL) has been reported to achieve more pronounced fading in some patients.
Objectives: To evaluate the efficacy and the side effects of IPL treatment of PWS in a direct comparison to the short-pulsed dye laser (SPDL) and the long-pulsed dye laser (LPDL).
Methods: Test spots ($n = 158$) were applied with IPL ($\lambda_{em} = 555–950$ nm, pulse duration: 8–14 milliseconds (single pulse), fluence: 11–17.3 J/cm^2), the SPDL ($\lambda_{em} =$ 585 nm, pulse duration: 0.45 milliseconds, fluence: 6 J/cm^2), and the LPDL ($\lambda_{em} = 585/590/595/600$ nm, pulse duration: 1.5 milliseconds, fluence: 12/14/16/18 J/cm^2) in a side-by-side modus in untreated ($n = 11$) and previously treated ($n = 14$) patients with PWS. Lesion clearance was evaluated by three blinded investigators based on follow-up photographs 6 weeks after treatment. Incidence of side effects was assessed.
Results: In previously untreated PWS as well as in pretreated PWS, IPL treatments were rated significantly ($P<0.05$) better than treatments with the SPDL. In both groups, IPL and LPDL treatments did not differ significantly. Side effects were few in all settings.
Conclusions: In PWS resistant to dye laser therapy, IPL showed additional lesion clearance. The use of IPL increases the therapeutic possibilities in PWS. Lasers Surg. Med. 42:720–727, 2010. © 2010 Wiley-Liss, Inc.

Key words: port-wine stain; lasers; pulsed dye laser; flashlamp-pumped

INTRODUCTION

Port-wine stains (PWS) are benign congenital vascular malformations that are localized in the dermis and affect 0.3–0.5% of newborns [1,2]. PWS do not involute spontaneously and are characterized by an abnormal dermal plexus of layers of dilated blood vessels, which increase in diameter with age [3,4]. PWS are commonly located on the face or the neck (83%) but can basically affect any part of the body [5]. Especially if located on the face, PWS implicate a high psychological relevance for affected individuals.

The standard treatment of PWS is laser therapy [5]. The basic principle is the preferential absorption of laser light by hemoglobin and the subsequent conversion of the absorbed light into thermal energy, leading to the coagulation of blood vessels. Selectivity and spatial confinement to spare the tissue surrounding blood vessels is achieved by selecting an appropriate wavelength, pulse duration, spot size, and fluence [5–7]. This process is called selective photothermolysis (SP) and was first described by Anderson and Parrish [6]. Flashlamp-pumped dye lasers can be short- or long-pulsed. Short-pulsed dye lasers (SPDL) with a wavelength of 585 nm and a pulse duration of 0.45 milliseconds or the long-pulsed (tunable) dye laser (LPDL; pulse duration: 1.5 milliseconds; tunable wavelengths: 585–600 nm) have become the method of choice for the treatment of PWS [5,8–12] because of their proven efficacy and the relatively low incidence of side effects. Although clinical results are excellent in some cases, complete clearing of PWS is hardly ever achieved [5,8]. PWS almost universally require multiple sessions of laser treatment for maximal lightening, and reports indicate that the majority of PWS clearance is achieved after approximately 4–5 treatment settings [9,13–16]. Moreover, about 20% of PWS are resistant to dye laser treatment; especially lesions in adults and in patients with darker skin types are difficult to treat [7,12,14,16,17]. Therefore, improvement of PWS treatment is highly desirable.

Incoherent polychromatic filtered flashlamp (intense pulsed light, IPL) devices developed in the early 1990s proved to be a safe and effective treatment of several skin conditions, such as vascular lesions [18–30], photoaging [31–35], or the removal of hair [36–38]. The emission

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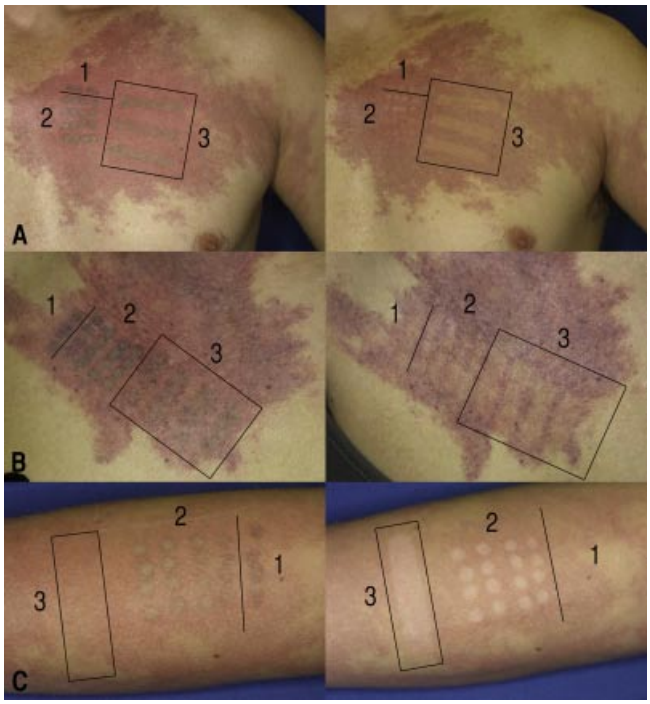

Fig. 1. Clinical photographs of PWS located on the chest (**A**), the décolleté (**B**), and the forearm (**C**) immediately after treatment (left column) and 6 weeks after treatment (right column). SPDL (1) and LPDL (2) resulted in circular test spots, IPL (3) in quadratic test spots. Note the purpuric reaction of the treated area. In (C), SPDL treatment (right column of test spots) induced no clearance of the lesion 6 weeks after treatment. However, LPDL and IPL induced hypopigmentation in this case.

spectrum of IPL devices ranges from 500 to 1,300 nm with pulse durations in the millisecond range. With the aid of convertible cut-off filters, the IPL device can be easily adjusted to the desired wavelength, which accounts for a high versatility. Adjustment to the absorption spectrum of hemoglobin allows the use of IPLs for vascular lesions. Several studies confirm that IPLs may be used for the treatment of PWS [20,22,24,27,28,39,40]. However, controlled randomized clinical trials that allow a side-by-side comparison of the impact of IPL versus the standard treatment, that is, the dye laser, are rare in the literature.

The aim of this study was to assess the effectiveness and safety of IPL in the treatment of untreated and previously treated PWS in a direct comparison to the SPDL and the LPDL.

PATIENTS AND METHODS

Patients

Eleven patients with previously untreated PWS and 14 patients who had been previously treated with laser were included in this study (Figs. 1 and 2). All patients had Fitzpatrick skin types I–III. None of the patients was suntanned. The PWS were located on the face and neck region (72%; $n = 18$), the trunk (12%; $n = 3$), or the extremities (16%; $n = 4$). Previously untreated lesions were pale red (18%; $n = 2$), red (72%; $n = 8$), or purple (9%; $n = 1$) in color. All patients were given written and verbal information on the nature of the laser and IPL treatment. Signed informed consent was obtained prior to treatment from patients or their parents. Treatments were conducted from May 2007 to April 2009 at the Department of Dermatology, University Hospital Regensburg, Germany.

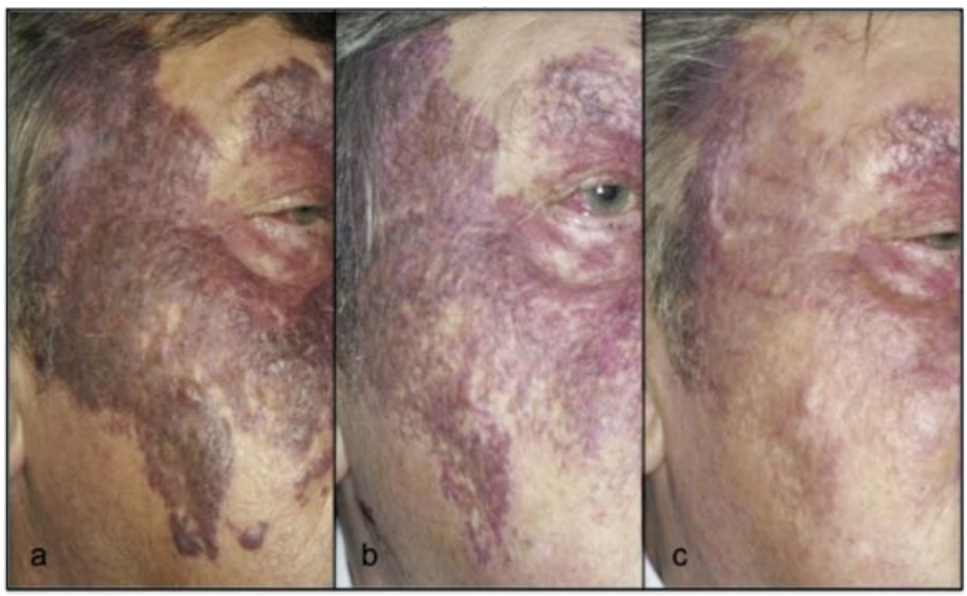

Fig. 2. Clinical photographs of a patient suffering from a facial PWS (**a**) at first consultation (already pretreated at another clinic) and (**b**) after multiple full lesion dye laser sessions (in our clinic). Due to dye laser resistance IPL treatment was performed. **c**: Clinical setting after a single IPL treatment.

Laser Devices and Treatment Parameters

Lesions were photo-documented prior to treatment. Areas representative with regard to the color and surface structure of the PWS were chosen for laser treatment. Each previously untreated patient received treatment with the IPL, the SDPL, and the LPDL in a split-lesion modus. Pretreated patients were treated with the IPL and, in dependence on the pretreatment, additionally with the SPDL or the LPDL, or both. If pretreatment with the SPDL or the LPDL turned out to be ineffective (no clearance or clearance <25%), the respective light device was omitted. Depending on the lesion site, different dividing procedures take place: In case the PWS was symmetrical along the median axis, it was divided through the median axis. In case the PWS was located unilaterally or non-symmetrically, it was divided through the sagittal or transversal axis when located on extremities or trunk, or through an axis running through the central part of the face when located on the face.

The treatment settings in terms of fluence rate and pulse duration were chosen according to the manufacturer's recommendations and the clinical appearance of the lesion. For IPL treatment, the Ellipse Flex PPT ($\lambda_{em} = 555–950$ nm; Danish Dermatologic Development, Hoersholm, Denmark) with a rectangular foot print (spot size: 10 mm×48 mm), a pulse duration of 8–14 milliseconds (single pulse), and a fluence of 11.0–16.7 J/cm^2 was used depending on the clinical appearance of the PWS and the skin type. At least one pulse was applied for each used set of parameters. The emitted wavelength band is produced by a xenon arc flashlamp and shows a median wavelength of the power spectrum at 705 nm. A 1–2 mm thick layer of colorless optical coupling gel (Danish Dermatologic Development) was applied to the treatment area before each shot to protect the epidermis from thermal injury and to allow uniform light delivery. The handpiece was always kept parallel to the skin to ensure even light application. Treatments were conducted without applying any mechanical pressure to the skin surface to avoid expelling blood from the treatment area. In close proximity, SPDL treatment ($\lambda_{em} = 585$ nm, cbeam™, Candela Corp., Wayland, MA) with a pulse duration of 450 microseconds and a fluence of 6 J/cm^2 was applied (circular foot print, diameter: 7 mm). Side-by-side, lesions were treated with the LPDL (Sclero™, Candela Corp.), if possible with each of the four applicable wavelengths ($\lambda_{em} = 585$, 590, 595, and 600 nm) with a circular foot print (diameter: 5 mm), 1,500 microseconds pulse duration, and a fluence depending on the respective wavelength (12 J/cm^2 (585 nm), 14 J/cm^2 (590 nm), 16 J/cm^2 (595 nm), and 18 J/cm^2 (600 nm)) (Fig. 1). The epidermis was cooled with the integrated cooling system of the respective device. Treatments were conducted without anesthesia. All patients avoided UV exposition for 8 weeks after laser treatment.

Assessments and Response Evaluation

Results were photo-documented and clinically evaluated 6 weeks after treatment. Photographs of all treatment sites were taken under standardized conditions (magnification, lightening, and positioning) with the same camera (Canon Digital Camera EOS D30, Canon Macro Lens, EF-50 mm 1:2.5, and lens mounted ring lite (MR-14EX); all Canon, Tokyo, Japan). Assessment and response evaluation for this study were carried out on basis of the patient record and the photo-documentation (Fig. 1). Effectiveness was retrospectively evaluated by three independent and blinded investigators (trained dermatologists) other than those conducting the laser treatments. If the investigators documented different values, the mean was calculated. As the investigators could infer from the spot size on the used laser, a stencil was used so that equal skin areas of the respective spots were visible for evaluation. Lightening was graded in comparison to the untreated area as excellent (>75%, score 5), good (51–75%, score 4), fair (25–50%, score 3), bad (<25%, score 2), or no clearance (score 1).

Side effects (hypopigmentation, hyperpigmentation, atrophy, scar, hypertrophic scar, keloid formation, and infection) in the treated areas were assessed. Therapy sequelae, such as blistering, purpura, or crusting were documented as reported by the patient.

Statistical Methods

All data were analyzed using Sigma Plot 11.0 (Systat Software, Inc., Chicago, IL). Ratings of the treatment results are given as medians, 25% percentiles (x_{25}), 75% percentiles (x_{75}), minimum (min), and maximum (max). All other data are given as means ± standard deviation. Data for primary treatments and pretreated patients were separately analyzed using One-Way Analysis of Variance (ANOVA) on Ranks and multiple pairwise comparisons using Dunn's method. Subgroups (wavelengths 585, 590, 595, and 600 nm for LPDL, irradiation times 8, 10, and 14 milliseconds for IPL) were also analyzed using One-Way ANOVAs on Ranks. Differences between the treatment modalities for primary treatments and pretreated patients were analyzed using Mann–Whitney Rank Sum test. A P-value below 0.05 was considered significant, $P<0.01$ was considered highly significant and results marked with one or two asterisks within the graphs, respectively.

RESULTS

Patients

The primary treatment group ($n = 11$) consisted of 4 male (36.3%) and 7 female (63.6%) patients, the youngest patient being 1.5 and the oldest being 66 years old. In the pretreated patient group 4 (28.6%) male and 10 (71.4%) female patients were included, the youngest patient being 2 and the oldest being 69 years old. Mean age was 24.2 ± 17.5 years for the primary treatment group and 28.4 ± 18.9 years for the group of pretreated patients.

Subgroup Analysis

There was neither a significant difference between the ratings of LPDL treatments using different wavelengths (585, 595, 590, and 600 nm) for primary ($P = 0.698$) nor for

TABLE 1. Parameters of Light Devices, Number of Treated Patients, Outcome, and Side Effects of Treatment of Previously Untreated Patients

Photo-physical parameters						Outcome					
Light device	Wave-length (nm)	Pulse duration (milliseconds)	Fluence (J/cm^2)	Spot size (mm)	No of treatments (n)	Excellent (n)	Good (n)	Fair (n)	Bad (n)	None (n)	Side effects
SPDL	585	0.45	6	7	11	0	1	2	6	2	2
LPDL					38	4	7	13	9	5	
	585	1.5	12	5	10	1	1	4	3	1	1, 2, 3
	590	1.5	14	5	9	1	2	4	2	0	1, 2, 3
	595	1.5	16	5	10	1	2	2	2	3	1, 1, 2, 3
	600	1.5	18	5	9	1	2	3	2	1	1, 1, 2, 3
IPL					35	3	14	14	3	1	
	555	8	11.0–16.1	10 × 48	20	0	11	6	3	0	Crusts
	555	10	14.3–16.9	10 × 48	15	3	3	8	0	1	1

Side effects: 1, hypopigmentation; 2, hyperpigmentation; 3, midget scar; 4, scar; 5, hypertrophic scar; 6, keloid; 7, infection.

follow-up ($P = 0.857$) treatments. Based on this analysis, the results for the different wavelengths applied in LPDL treatments were grouped as LPDL treatment results. In addition, there was neither a difference between the ratings of IPL treatments using different irradiation times (8, 10, and 14 milliseconds) for primary ($P = 0.972$) nor for follow-up treatments ($P = 0.513$). Again, treatment results for the different irradiation times applied in IPL treatments were grouped as IPL treatment results, accordingly.

Primary Treatments

Table 1 summarizes the used parameters of the respective light devices, the number of treated patients, treatment outcome, and side effects of treatments of previously untreated patients. SPDL treatments were rated ($n = 11$) as 2.00 ($x_{25} = 2.00$; $x_{75} = 2.75$; min = 1.00; max = 4.00), LPDL treatments ($n = 38$) as 3.00 ($x_{25} = 2.00$; $x_{75} = 4.00$; min = 1.00; max = 5.00), and IPL treatments ($n = 35$) as 3.00 ($x_{25} = 3.00$; $x_{75} = 4.00$; min = 1.00; max = 5.00). IPL treatments were rated significantly ($P<0.05$) better than treatments using SPDL. No other statistically significant differences could be detected (Fig. 3a). Excellent (> 75%, score 5) or good (51–75%, score 4) clearance was obtained in 1 out of 11 (9.1%) test spots applied with the SPDL, in 11 out of 38 (28.9%) test spots applied with the LPDL, and in 17 out of 35 (48.6%) test spots applied with the IPL (Table 1). According to a patient based analysis, IPL treatment showed excellent or good clearance in at least one test spot in 7 out of 11 patients, LPDL treatment in 5 out of 11 patients, and SPDL treatment in 1 out of 11.

Treatments of Pretreated Patients

Table 2 summarizes the used parameters of the respective light devices, the number of treated patients, treatment outcome, and side effects of treatments of previously untreated patients. SPDL follow-up treatments ($n = 12$) were rated as 1.50 ($x_{25} = 1.00$; $x_{75} = 2.00$; min = 1.00; max = 3.00), LPDL treatments ($n = 32$) as 2.00 ($x_{25} = 1.50$; $x_{75} = 3.00$; min = 1.00; max = 4.00), and IPL treatments ($n = 30$) as 3.00 ($x_{25} = 2.00$; $x_{75} = 3.00$; min = 1.00; max = 4.00). IPL treatments were rated significantly ($P<0.05$) better than treatments using SPDL. No other statistically significant differences could be detected (Fig. 3b). Excellent (> 75%, score 5) or good (51–75%, score 4) clearance was obtained in 5 out of 32 (15.6%) test spots applied with the LPDL, and in 7 out of 30 (23.3%) test spots applied with the IPL. SPDL test spots showed no clearance > 50% (Table 2). According to a patient-based analysis, IPL treatment showed excellent or good clearance in at least one test spot in 4 out of 14 patients, and LPDL treatment in 1 out of 14 patients.

Comparison of the Modalities for Primary Treatments and Pretreated Patients

There was no significant difference with regard to the ratings for primary and follow-up SPDL ($P = 0.088$). Results using LPDL for primary treatments were significantly better than for follow-up treatments ($P = 0.043$). There was a highly significant difference between the results for primary IPL treatments as compared to the use of IPL for pretreated patients ($P = 0.004$), that is, results for primary IPL were significantly better as compared to follow-up treatments using IPL.

Side Effects

In the group of previously untreated patients, IPL treatment ($n = 35$) induced hypopigmentation in one single case. SPDL treatment ($n = 11$) led to hyperpigmentation in one patient. LPDL treatment ($n = 38$) induced hypopigmentation (6 out of 38), hyperpigmentation (4 out of 38), and minimal scarring (4 out of 38). In the group of pretreated patients, SPDL treatment ($n = 12$) induced no side effects, LPDL treatment ($n = 32$) induced minimal scarring in one patient, and IPL treatment ($n = 30$) led to

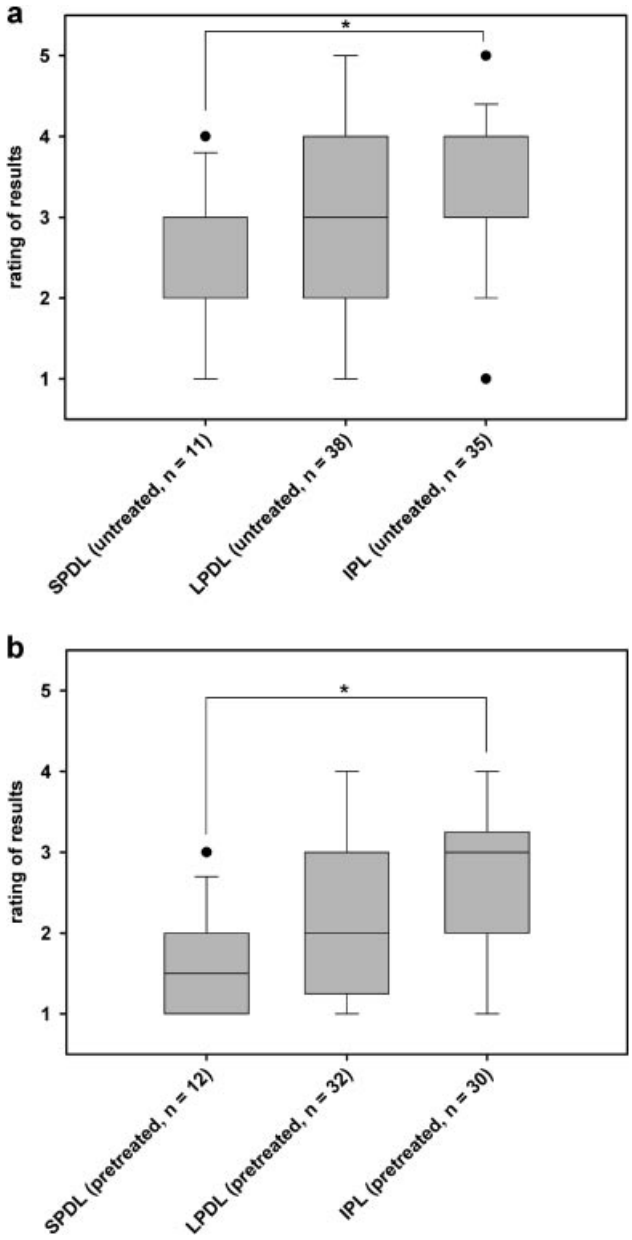

Fig. 3. **a**: Treatment results of primary treatment. Primary IPL and LPDL treatments yielded better results than primary SPDL treatments, the difference between IPL treatments and SPDL treatments was significant ($P<0.05$). Clearance was rated as excellent ($>75\%$, score 5), good (51–75%, score 4), fair (25–50%, score 3), bad (<25%, score 2), or no clearance (score 1) (*$P<0.05$). **b**: Treatment results of pretreated PWS. IPL follow-up treatments yielded significantly better results as compared to SPDL follow-up treatments ($P<0.05$). LPDL primary treatments showed significantly better results than LPDL follow-up treatments ($P=0.043$). In analogy, primary IPL treatments yielded significantly better results than follow-up IPL treatments ($P=0.004$). No other statistically significant differences could be detected. Clearance was rated as excellent ($>75\%$, score 5), good (51–75%, score 4), fair (25–50%, score 3), bad (<25%, score 2), or no clearance (score 1) (*$P<0.05$).

hyperpigmentation (2 out of 30) or hypopigmentation (1 out of 30). Crusting was reported only by one patient after IPL treatment and was completely reversible 6 weeks after treatment.

DISCUSSION

This study compares the effectiveness and safety of IPL, the SPDL, and the LPDL in untreated as well as in previously treated PWS. Treatment was conducted in a side-by-side modus so that the clearance rate of the three treatment modalities could be directly compared in each patient. As a varying number of treatment settings are a source of bias, evaluation of this study was based on a single treatment setting. To further homogenize study parameters, the collective was divided into untreated and previously treated patients. SPDL and LPDL were used with approved parameters [8,41]. Even if fluence rates of 7–8 J/cm^2 may readily be used with SPDL, in this study a fluence of 6 J/cm^2 was used as a standard setting at our department. This may have contributed to the lower response rates of PWS to SPDL treatments in this study. The IPL device used in this study contained a dual mode light filter that filtered out wavelengths shorter than 555 nm and longer than 950 nm. Thus, the emitted wavelength band (median wavelength: 705 nm) was suitable for absorption in hemoglobin, while absorption in water and subsequent unselective epidermal heating could be reduced [20]. Response was classified in percent clearance as accepted in the literature [20,22,24,27,28,39,42].

In previously untreated PWS, a single IPL or LPDL treatment induced an average clearance rate of 25–50%; a single SPDL treatment induced an average clearance rate of <25%. IPL treatments were rated significantly ($P<0.05$) better than treatments with the SPDL. There was no statistically significant difference between the clearance rate of IPL and LPDL. Remarkable is the fact that a clearance rate of 50% or more was achieved in 48.5% of test spots applied with IPL versus 9.1% with the SPDL versus 28.9% with the LPDL. In previously treated PWS, a single IPL treatment induced an average clearance rate of 25–50%; a single LPDL or SPDL treatment induced an average clearance rate of <25%. IPL treatments were rated significantly ($P<0.05$) better than treatments with the SPDL. Again, there was no statistically significant difference between the clearance rate of IPL and LPDL. In this group, IPL treatment showed excellent or good clearance in at least one test spot in 4 out of 14 patients, and LPDL treatment only in 1 out of 14 patients while SPDL treatment induced no clearance >50%.

Several studies in the literature confirm the potential of IPLs in fading PWS [20,22,24,27,28,39,40,43]. Only three studies provide data from controlled side-by-side comparisons of IPL and the standard therapy, that is, the dye laser [39,40,43].

Faurschou et al. [39] treated 20 patients with PWS in a side-by-side trial using a pulsed dye laser (PDL) versus IPL (StarLux, Palomar Medical Technologies, Burlington, MA; pulse duration: 5–10 milliseconds, fluence: 7–14 J/cm^2).

TABLE 2. Parameters of Light Devices, Number of Treated Patients, Outcome, and Side Effects of Treatment of Pretreated Patients

Photo-physical parameters						Outcome					
Light device	Wave-length (nm)	Pulse duration (milliseconds)	Fluence (J/cm^2)	Spot size (mm)	No of treatments (n)	Excellent (n)	Good (n)	Fair (n)	Bad (n)	None (n)	Side effects
SPDL	585	0.45	6	7	12	0	0	1	5	6	
LPDL					32	0	5	8	11	8	
	585	1.5	12	5	9	0	1	3	2	3	
	590	1.5	14	5	7	0	1	1	4	1	
	595	1.5	16	5	9	0	2	2	4	1	
	600	1.5	18	5	7	0	1	2	1	3	3
IPL					30	0	7	11	8	4	
	555	8	11.0–16.7	10 × 48	19	0	5	7	6	1	2
	555	10	12.8–17.3	10 × 48	8	0	1	4	2	1	1, 2, 2
		14	12.0–16.2	10 × 48	3	0	1	0	0	2	

Side effects: 1, hypopigmentation; 2, hyperpigmentation; 3, midget scar; 4, scar; 5, hypertrophic scar; 6, keloid; 7, infection.

They found out that both PDL and IPL significantly lightened PWS, but the median clinical improvements were significantly better with the PDL (65%) than with the IPL (30%). Even though they performed a combined analysis of pretreated ($n = 12$) and previously untreated ($n = 8$) PWS, the PDL still yielded better results. According to our study, we would rather have expected the inclusion of pretreated PWS in a combined analysis of the data to be in favor of IPL. Unfortunately, the authors did not differentiate the outcome between both groups. Another important difference is the fact that they used a pulse duration of 0.45 milliseconds ($n = 5$) and 1.5 milliseconds ($n = 15$) (according to the clinical appearance) but did not differentiate between both groups. We could show that SPDL treatment resulted in a lower clearance rate than LPDL therapy. Therefore, both light devices should be evaluated separately. However, according to our data the combined analysis of both short- and long-pulsed PDL should have favored IPL in their study. A further difference is the emitted wavelength band of IPL. Faurschou et al. used an IPL that emitted light of 500–670 and 870–1,400 nm, whereas our IPL emitted light of 550–950 nm. Therefore, the IPL used by Faurschou et al. divided the applied energy on a much broader wavelength spectrum, which could be a reason for the lower clearance rate of the IPL in their study. On the other hand, the difference between both studies might be explained by the fact that Faurschou et al. used a more current PDL device that has a larger spot size and delivers higher energies (pulse duration of 0.45 milliseconds), making it more efficacious than the PDL devices used in our study.

McGill et al. [43] conducted a study on patients ($n = 18$) with previously treated PWS, comparing a single-passed pulsed dye, a double-passed pulsed dye, an alexandrite, a KTP, and a Nd:YAG laser as well as an IPL device (Lumina, Lynton Lasers, Cheshire, UK; $\lambda_{em} = 550–1{,}100$; spot size: 10 mm × 10 mm, fluence: 28–34 J/cm^2, double pulsed 10 milliseconds delay) in a split-lesion modus. One single observer evaluated the effectiveness by means of Munsell color charts. In this study, the alexandrite laser was the most effective treatment modality, resulting in PWS fading in 10 patients, although hyperpigmentation ($n = 4$) and scarring ($n = 1$) was frequent. IPL resulted in PWS fading in six patients; five patients showed further PWS fading after double-passed PDL treatment and three patients showed further PWS fading after single-passed PDL treatment. KTP and Nd:YAG lasers were the least effective with fading seen in two patients for both systems. These results correspond to our findings, in which IPL therapy induced a significantly better clearance rate of pretreated PWS than a single-passed SPDL treatment.

In a controlled trial, Strempel and Klein [40] investigated SPDL therapy with a high-energy gas discharge lamp in 32 patients with PWS. The authors included pretreated ($n = 25$) and untreated ($n = 7$) patients in their study. In 6 patients, the gas discharge lamp induced better lightening of the PWS, in 6 patients both devices induced a similar effect, and in 20 patients better lightening was achieved by SPDL treatment. Again, these results are not differentiated with regard to pretreatment and are thus not comparable to our results. However, the combined analysis of pretreated and previously untreated patients with PWS should again have favored broad spectrum light therapy. It has to be mentioned that the authors used a high-energy gas discharge lamp (570–1,200 nm) with a light dose of 40 J/cm^2 and a pulse length of 5 milliseconds. Therefore, parameters are different from those used in our study and it is hard to compare data. A general problem in the discussion of different IPL trials is the fact that a comparison of IPLs on the basis of their wavelength spectrum, fluence ranges, pulse durations, etc. is physically nonsensical and does not provide any evidence for their clinical effectiveness. A serious comparison is much more complex and should account for the fluence per area for every emitted wavelength, for every possible pulse duration, and for every possible pulse shape against the

background of the real on-off time, fluence, and spectral jitter during an impulse. Eadie et al. [44] measured the spectral and temporal characteristics of an IPL device and showed a shift in spectral distribution within a pulse and between pulses, which is caused by a variable current delivered to the xenon flashlamp. The delivery of a variable current can be omitted if a large capacitor bank is used within the IPL device. Therefore, technical details of the used IPL device have to be taken into account when comparing different IPL devices. The work of Bjerring et al. [20] should be more suitable for a comparison because the same IPL device (Ellipse Flex, Danish Dermatologic Development; $\lambda_{em} = 555–950$ nm; spot size: 10 mm×48 mm; pulse duration: 8–30 milliseconds; fluence: 13–22 J/cm^2) was used by this group as in our trial to treat 15 patients with PWS resistant to dye laser therapy. Four treatment settings induced a lightening of more than 50% in 7 out of 15 patients according to their results. In the corresponding cohort of our study, a clearance rate of more than 50% was induced in 4 out of 14 patients after one single treatment setting. This discrepancy might be explained by repeated treatments and by the higher fluence used by Bjerring et al. The authors observed no scarring; hypopigmentation occurred in 9%, hyperpigmentation in 3% of patients. In our study, side effects were even less frequent with hypopigmentation in 2% and hyperpigmentation in 4% of patients. The lower incidence of side effects might be due to the rather conservative treatment parameters in our study. However, minimal scarring was sometimes observed after LPDL treatment in our study. This may be due to the relatively high-energy settings used for LPDL.

In conclusion, this study, which was conducted as a direct side-by-side comparison, gives strong evidence for the effectiveness and safety of IPL in the treatment of PWS. Furthermore, the study shows the non-inferiority of the used IPL device when compared to the PDLs used in this study. The PDLs used, and that has to be emphasized, do not represent the most current PDL technology. However, these are devices used in a lot of clinics and practices. Therefore, data obtained with these devices are more relevant to daily practice than using high-end PDL, which are rarely used outside research or selected other facilities. Beside the therapeutic effectiveness of IPL, its higher skin coverage rate than the SPDL and the LPDL proves its high potential. Further advantages are that the longer wavelengths emitted by IPLs enable a deeper penetration, that oxyhemoglobin is activated over a broad band of wavelengths, and that pulse length is adjustable, allowing the adjustment of treatment parameters to the respective clinical finding.

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