# CLINICAL STUDIES

**TITLE**: Intense Pulsed Light (IPL): A Review

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## ABSTRACT

**Background**: Intense pulsed light (IPL) devices use flashlamps and bandpass filters to emit polychromatic incoherent high-intensity pulsed light of determined wavelength spectrum, fluence, and pulse duration. Similar to lasers, the basic principle of IPL devices is a more or less selective thermal damage of the target. The combination of prescribed wavelengths, fluences, pulse durations, and pulse intervals facilitates the treatment of a wide spectrumof skin conditions.

**Objective**: To summarize the physics of IPL, to provide guidance for the practical use of IPL devices, and to discuss the current literature on IPL in the treatment of unwanted hair growth, vascular lesions, pigmented lesions, acne vulgaris, and photodamaged skin and as a light source for PDT and skin rejuvenation.

**Material and Methods**: A systematic search of several electronic databases, including Medline and PubMed and the authors experience on intense pulsed light.

**Results**: Numerous trials show the effectiveness and compatibility of IPL devices.

**Conclusion**: Most comparative trials attest IPLs similar effectiveness to lasers (level of evidence: 2b to 4, depending on the indication). However, large controlled and blinded comparative trials with an extended follow-up period are necessary.

**Key Words**: laser; IPL; incoherent light; skin; light source

# CLINICAL STUDIES

## INTRODUCTION

The use of polychromatic infrared light was first described in 1976 by Muhlbauer et al. [1] for the treatment of vascular malformations. The photothermolysis of pigmented structures, cells, and organelles by selective absorption of pulsed radiation has been described in detail in 1983 [2]. In 1990, Goldman and Eckhouse described a new high-intensity flashlamp as suitable tool for treating vascular lesions. Therefore, intense pulsed light (IPL) was commercially launched as a medical device in 1994 [3]. In the following years, multiple technical modifications allowed an easier handling, increased safety, and widened the spectrum of potential indications. IPL devices use flashlamps and computer-controlled capacitor banks to generate pulsed polychromatic high-intensity light. Electrical energy stored in the capacitor bank is passed through xenon gas within a gas-discharge lamp so that bright light is emitted; thus, electrical energy is converted into optical energy. The emission spectrum of IPLs ranges from 500 to 1,300 nm. With the aid of convertible cut-off filters, IPLs can be easily adapted to the desired wavelength range since IPLs are polychromatic. This allows for a certain versatility.

First generation IPL devices emit light of the infrared part of the spectrum, which prevalently led to epithelial damage and a high incidence of side effects. In second generation IPL devices, water filters out the infrared portion, significantly reducing the risk of side effects. In IPL devices, similar to lasers, the basic principle is the absorption of photons by endogenous or exogenous chromophores within the skin and the transfer of energy to these chromophores. This transfer generates heat and subsequently destructs the target structure. We have to keep in mind that the absorption of light is not bound to the coherence of light and that the evoked photobiologic reaction takes place independently of the heating source. Besides, the key chromophores of human skin (hemoglobin, melanin, water) show broad absorption spectrums. Thus, monochromaticity is not a requirement for photothermolysis. As IPL devices emit a spectrum of wavelengths, the three key chromophores can be activated with one single light exposure. This versatility implies a reduced selectivity.

The patient's skin type and the skin condition present determine the choice of suitable cut-off filters and therefore the spectrum of wavelengths to be emitted. Pulse duration can be set in relatively wide ranges (depending on the particular device) in the millisecond range.
Similar to laser devices, pulse duration should be lower than the thermal relaxation time of the target structure to prevent unselective damage to the surrounding tissue. The combination of particular wavelengths, pulse durations, pulse intervals, and fluences facilitates the treatment of a wide spectrum of skin conditions, such as acne vulgaris, pigmented lesions, vascular lesions, unwanted hair growth, photodamaged skin, scars [4], and angiokeratoma [5]. This versatility advantageous for a skilled and experienced dermatologist. For untrained physicians and even

more for non-medical staff, however, the wide range of selectable treatment settings implies the risk of evoking side effects because of non-specific thermal damage.

Further advantages to lasers are the lower purchase price and the more robust technology. The large spot size is also a great advantage in terms of treatment duration but a disadvantage in terms of handling and maneuverability. Another disadvantage of IPL devices is the heavy weight of the handpiece as it contains the lamp and the lamp-cooling device. Other disadvantages in daily practice are the requirement of gel application and the direct skin contact with the handpiece, which hampers the observation of the immediate local response. These points along with the fact that a skin reaction like purpura is induced rather seldom make it difficult to indicate where the last pulse was delivered and therefore to accurately place the pulses immediately adjacent to one another. Also disadvantageous is the fact that the emitted spectrum and fluence can be inconsistent from pulse to pulse, in particular in IPL devices containing a small capacitor bank (Table 1) [6].

## COMPARISON OF DIFFERENT IPL DEVICES

A large number of IPL devices are available. A comparisonof IPLs just on the basis of their wavelength spectrum, fluence ranges, pulse durations, etc. is physically senseless 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. The emission of, for example, a sigmoidal-shaped pulse is clearly disadvantageous because such a pulse implies a shift in the spectral and fluence distribution within the pulse. Eadie et al. [6] 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.

Favorable characteristics of IPL devices are a large capacitor bank, allowing a constant current delivered to the flashlamp and thus the emission of a roughly square-shaped pulse. Also desirable is the omission of wavelengths beyond 950nm as higher wavelengths are preferentially absorbed by water and therefore contribute to significant epidermal heating.

# CLINICAL STUDIES

**TABLE 1. Advantages and Disadvantages of IPLs**

| Advantages | Disadvantages |
|---|---|
| Lower purchase price | Inconsistence of emitted spectrum and fluence |
| Large spot size | Weight of handpiece |
| High skin coverage rate | Large spot size |
| High versatility | Light can not be focused |
| Robust technology | Gel application required[a] |
| | Direct contact of handpiece to the skin required[a] |

[a]Disallows observation of immediate local response.

## PRACTICAL ASPECTS

Patient handling, pretreatment, and post-treatment are comparable to the procedure in laser treatment. As a matter of course, the diagnosis of the entity to be treated has to be determined, and a clear indication for IPL treatment is required. Both verbal and written information on the nature of IPL treatment, on the chance of success, and on alternative treatment options have to be provided. A signed informed consent is mandatory.

Therapy sequelae, such as blistering, purpura, or crusting, and potential side effects, such as erythema, hypopigmentation, hyperpigmentation, atrophia, scarring, hypertrophic scarring, or keloid formation, as well as the risk of infection have to be mentioned. Pregnancy, breast feeding, the intake of retinoids or photosensitizing medications, diseases or genetic conditions causing photosensitivity or tending to aggravate after light exposure [7], as well as suntan are exclusion criteria for IPL treatment. Patients suffering from long-term diabetes, hemophilia, or other coagulopathies and patients with implants in the treatment area or with a heart pacemaker should be treated with special care. Patients with a history of herpes simplex require an antiviral prophylaxis for holohedral facial treatments [8].

The skin type of the patient has to be documented according to the Fitzpatrick scale [9] because photophysical parameters need to be adjusted depending on the individual patient's skin type. Diagnosis and clinical appearance have to be documented in the patient record. Photodocumentation is mandatory prior to each single treatment.

The treatment area has to be free from makeup and shaved; in case of hair removal, the area of hypertrichiosis needs to be marked, preferentially with a white wax pencil. For IPL treatment, an optical coupling gel needs to be applied.

Eye protection with appropriate goggles is mandatory for IPL treatment. However, the fact that polychromatic light cannot be filtered as effective as monochromatic light makes the eye protection that is safety standard at present perfectible. More

# CLINICAL STUDIES

rapid shutting glasses are in development right now; they might solve this problem. Whenever treatment parameters are introduced for the first time, a test shot should be conducted. The test site should be placed at an inconspicuous site in the treatment area and the skin reaction should be observed.

If necessary, the treatment parameters should be adjusted, followed by another test shot. Six weeks after the test shot, the reaction will be evaluated. The patient should be asked about any discomfort or local reaction. In case the treatment was successful, the whole area can be treated with the parameters tested previously.

Each spot should overlap the previous one by 10%. When treating circumscribed smaller lesions, the use of a perforated plastic shield with varying aperture sizes may be helpful. An aperture matching the lesion to be treated allows a precise application of light [10]. If a melanocytic lesion is apparent within the treatment area, the nevus should be omitted from treatment or covered with wet white gauze or nonabsorbent white paper. If desired, the treated area can be cooled after IPL therapy. After the treatment, the patient has to stay out of the sun or, at least, use sufficient UV protection over the following 8 weeks [8].

Retreatment is conducted only after 4–6 weeks. Dependent on the treated entity and the success of the treatment, multiple sessions may be necessary. Consequent UV abstinence or UV protection is essential over the entire treatment course. An almost constant side effect of IPL treatment is the sense of pain during treatment. Routinely, pain is not a severe problem, solely in children or if the patient's sense of pain coerces the therapist into a treatment break. However, cooling (during or after treatment or both) or topical anesthesia (not recommended in PDT) can produce relief in most patients.

Common side effects, which may last for a few days after treatment, are swelling and erythema. Blistering and crusting are signs of overfluenced treatment; in case of blisters and crusts, patients must strictly avoid scratching, which may result in infections and scar formation. Antimicrobial ointments help loosening the crusts and prevent bacterial superinfections. Potential side effects that might last longer or may even be irreversible are pigmentary changes, such as hypopigmentation or hyperpigmentation. These side effects can be mostly prevented by adjusting wavelengths and fluences to the patient's skin type and treatment area.

Unsuitable patients (due to suntan or skin type) are excluded from therapy as well as patients who are unable or unwilling to strictly avoid post- operative UV exposition. Scarring occurs rarely and is almost always evoked by overfluenced treatments or by crusting with subsequent manipulation and infection [8]. In general, the most important measure to prevent side effects is the application of test shots for every chosen set of parameters and even for the same set of parameters applied at different parts of the body.

# CLINICAL STUDIES

As the incidence of sebaceous glands and skin thickness vary from region to region, the susceptibility to IPL treatment and therefore the incidence of side effects also changes from region to region (Table 2), making parameter-related and region-related sample treatments necessary. The following sections discuss the current literature on IPL for the treatment of unwanted hair growth, vascular lesions, pigmented lesions, acne vulgaris, and photodamaged skin as well as light sources for PDT and skin rejuvenation. If available, we focus on controlled studies comparing IPL devices to the respective standard treatment.

## TABLE 2. Factors Influencing the Susceptibility of the Skin to IPL Treatment

Skin type

Skin thickness
Individual skin resistance
Skin temperature
Blood perfusion
Frequency of sebaceous glands
Presence of hair follicles
Presence of a tattoo
Presence of melanocytic nevi
Suntan

## HAIR REMOVAL

Hair removal has become a key indication for IPL devices. A number of medical papers document the effectiveness of IPL treatment for hair removal, yet only few provide data from randomized controlled trails (RCT) or controlled trials (CT). Level of evidence IIB is reached. In a split-face study with female participants (n¼9), Cameron et al. [11] compared a diode laser (Santa Clara, CA; 20–45 J/cm2, pulse duration 30 milliseconds) with an IPL device (Cheshire, UK; lem¼625–1,100 nm, 32 J/cm2, pulse train: 8————————————4 milliseconds, total train time: 95 milliseconds). Six weeks after the treatments (n¼3; 6-week intervals), laser and IPL therapy had substantially
reduced the hair count (average hair counts in a 16 cm2 area [laser vs. IPL vs. control]: 42.4 vs. 38.1 vs. 45.3 [baseline] and 10.4 vs. 20.4 vs. 44.7 [after treatment]). Despite higher pain scores and more inflammation, laser treatment was preferred by five patients; two patients preferred IPL, and one had no preference.

# CLINICAL STUDIES

McGill et al. [12] conducted a randomized split-face comparison of facial hair removal with an alexandrite laser (Wayland, MA; 15 mmspot size, fluence: 10–30 J/cm2; pulse duration: 3 milliseconds) and an IPL device (Cheshire, UK; lem¼650–1,100 nm, fluence: 16–42 J/cm2; three pulses of 55 milliseconds, delay: 20 milliseconds) in women (n¼38) with polycystic ovary syndrome (PCOS). The authors reported that alexandrite laser treatment resulted in longer median hair-free intervals than IPL therapy (7 weeks vs. 2 weeks; P<0.001). Decrease in hair counts was significantly higher after Alexandrite laser treatment than after IPL therapy at 1, 3, and 6 months (52%, 43%, and 46% vs. 21%, 21%, and 27%; P<0.001). Patient satisfaction scores were significantly higher for the alexandrite laser (P

0.002). The authors assumed that the specific wavelength, short pulse duration, and single pulse delivery of the alexandrite laser is responsible for higher follicular destruction. Unfortunately, no histological investigations were done and the treatment duration was not documented.

Toosi et al. [13] compared the clinical efficacy and side effects of an alexandrite and a diode laser as well as an IPL device (Gothenburg, Sweden; filter: 650 nm, fluence: 22–34 J/cm2, double pulse, pulse duration: 20 milliseconds, delay: 10–40 milliseconds) for hair removal in 232 patients. Six months after treatment (3–7 sessions), no significant difference could be seen between the average hair reduction of IPL (66.917.7%), alexandrite (68.816.9%), and diode laser (71.718.1%) (P¼0.194). The incidence of side effects was significantly higher after diode laser treatment (P¼0.0001). In a CT, Amin and Goldberg [14] evaluated the efficacy of an IPL device (red filter), an IPL device (yellow filter), a 810nm diode laser, and a 755nm alexandrite laser in patients (n¼10) with unwanted hair on the back or thigh. Hair counts at 1, 3, and 6 months after the second treatment showed a significant decrease in hair counts (50%) for all light devices (no statistical difference). An evidence-based review published in 2006 summarizes 9 RCTs and 21 CTs on the efficacy and safety of hair removal by means of ruby, alexandrite, diode, or Nd:YAG lasers or IPL (for IPL only 1 RCT and 1 CT) [15]. Based on the data available for IPL, the authors concluded that no sufficient evidence exists for long-term hair removal after IPL treatment.

Bjerring and Christiansen [16] compared in a split-face study the effectiveness of an IPL device (Ellipse Relax Light 1000, Danish Dermatologic Development, Hoersholm, Denmark; lem¼600–950 nm; 10mm————————48mm spot size; 18.5 J/cm2) to a normal mode ruby laser (Tel Aviv, Israel; lem¼694 nm, spot size 5mm, pulse duration 0.9 milliseconds) for hair removal in 31 patients (three treatments). The authors reported an average hair count reduction of 49.3% (IPL) versus 21.3% (ruby laser) after three treatments and concluded that IPL treatment was 3.94 times more effective for hair removal than ruby laser therapy. Some very recent articles focused on the safety of IPLs in hair removal.

# CLINICAL STUDIES

Feng et al. [17] investigated the short-term efficacy and side effects of an IPL-device (Santa Clara, CA; $\lambda = 550-1,200$ nm) for epilation in Chinese patients (n = 18) with Fitzpatrick skin types III–V and black hair. Patients were treated four times at 4- to 6-week intervals on the axillae (n = 13) and the upper lip (n = 5) with 14–22 J/cm2. The authors reported an average hair reduction of 49.9% for all sites after one session, 58.6% after two sessions, 79.3% after three sessions, and 83.8% after four sessions (P = 0.001). No significant complications or adverse events were reported.

Radmanesh et al. [18] investigated the side effects of IPL (London, UK) for hair removal among 1,000 female hirsute patients. Patients were treated every 4–6 weeks for eight sessions or more (fluence: 16–30 J/cm2, according to Fitzpatrick skin types and tolerance) and followed-up lasted up to 20 months. The authors documented burning as a frequent side effect, followed by post-inflammatory hyperpigmentation (n = 75), bulla and erosion (n = 64), leukotrichia (n = 40), folliculitis (n = 35), post-inflammatory hypopigmentation (n = 10), and finally scar formation (n = 1). Unexpectedly, paradoxical hypertrichosis occurred frequently in every 100th patient (n = 12). Consequently, the same author focused in another article [19] on paradoxically increased hair density and coarseness after IPL photoepilation. Hirsute female patients (n = 991) were treated with a multifunctional laser and an IPL system (Santa Clara, CA) with the cut-off filters 695, 755, and 645nm over a period of 23 months. Serial digital photographs, schematic diagrams, and hair counts before and after treatment assessed paradoxical hypertrichosis and terminal hair change after a few sessions of IPL therapy among 51 out of 991 patients (5.1%).

Willey et al. [20] reported in her retrospective study increased hair growth in 57 out of 543 (10.5%) patients treated with an alexandrite laser, a long-pulsed Nd:YAG laser, or an IPL device Unfortunately, their results were not proportionally allotted to the different light devices. The increased hair growth appeared within as well as outside the treatment area. The authors assumed that sub-therapeutic thermal energy is delivered to nearby follicles, inducing terminal hair growth. The subsequent application of cold packs surrounding the treatment area during treatments minimized the incidence of terminal hair growth in their clinic.

Willey et al. [20] stated that the presence of fine hair prior to treatment appeared to be the most important risk factor for increased terminal hair growth. Terminal hair growth occurred most often in the low maxillary area, the neck, the lateral cheeks, and the chin areas in young women with skin types II–IV. According to these results, the risk of paradoxically increased hair density due to IPL treatment should be mentioned in the consent form.

An innovative concept was presented by Karsai et al. [21]. In a retrospective study, they assessed the short- and long term effectiveness of an electro-optical synergy device (IPL ($\lambda = 680-980$ nm)/bipolar radiofrequency—RF) for hair removal in patients (n = 24) with unwanted facial hair. Each area was treated consecutively with

# CLINICAL STUDIES

two passes of a combined-energy system. The authors reported that 22.2% of the treatment areas showed no or poor clearance, 28.9% moderate, 46.7% good, and 2.2% excellent clearance after a mean of 5.2 treatments and 3.2 months follow-up. The authors concluded that two passes with this combined energy system are an effective treatment option for the removal of thin, thick, fair, and dark hair. However, the authors did not point out any significant advantages of the electro-optical synergy device over other methods available for hair removal. Alster and Tanzi [22] evaluated the safety and efficacy of a portable IPL device for home-use hair removal in women (n¼20; skin phototypes I–IV) with dark terminal hair in non-facial sites (axillae, forearms, inguinal region, legs). Three treatments at 2-week intervals were self-administered by the patients by means of a handheld IPL (Kfar Saba, Israel; lem¼475–1,200 nm, fluence: 3–5 J/cm2, pulse duration: <1 millimilliseconds, spot size: 20mm——————————30 mm). The authors claimed that safety mechanisms would make eye protection and cooling unnecessary. A nurse assessor was present during each treatment. Matching untreated skin sites served as a control. Hair counts and clinical photographs were obtained prior to treatment and 1, 3, and 6 months after the third treatment. The authors reported that hair counts were reduced 37.8–53.6% 6 months after the treatments. No hair reduction was noted in untreated matching areas. Beside erythema (25%), no other side effects or complications were encountered. Patient satisfaction scores were reported as high. This approach might be trend setting as costs and the inconvenience of office treatment remains a major obstacle for many patients.

However, even if the potential of self-administered home use devices is obvious, further investigation of their safety and effectiveness in a home setting is of the highest importance. A clear drawback of this method is the fact that, due to the minimization of the apparatus' size, for instance, a smaller capacitor bank has to be used, evoking fluence and spectral jitter within each pulse. A patient with hypertrichiosis who was successfully treated with IPL in our hospital is shown in Figure 1.



*Fig. 1. Fifty-seven-year-old women with hypertrichiosis treated with IPL (Hoersholm, Denmark; lem¼600–950 nm; spot size: 10mm——————————48mm; pulse duration: 20 milliseconds; fluence: 13.5 J/cm2).*

## PIGMENTED LESIONS

In the treatment of pigmented lesions, the first and foremost step is a doubtless diagnosis of the entity to be treated and the exclusion of a malignant process. Besides it has to be emphasized, that naevomelanocytic lesions are not a routine indication for laser treatment. For the treatment of benign pigmented, non-naevomelanocytic lesions, Quality-switched laser systems are clearly the method of choice.

The fact that IPL devices emit light with pulse durations in the millisecond range make them second best for the treatment of pigmented lesions. However, several reports indicate the effectiveness of IPL devices in the treatment of pigmented lesions. Here, a darkening and sloughing of the treated spots can be expected after treatment in contrast to Q-switched lasers. Li et al. [23] studied the efficacy and safety of an IPL device (Santa Clara, CA; fluence: 13–17 J/cm2; 560-/590-nm filters, double pulse or 590-/615-/640-nm filters and triple pulse, 3–4 milliseconds pulse duration; 25–40 milliseconds pulse delay) in the treatment of melasma in Chinese patients (n¼89). Patients received IPL treatments (n¼4) at 3-week intervals. Sixty-nine out of 89 patients (77.5%) showed 51–100% improvement according to the overall evaluation by dermatologists. Self-assessment by the patients indicated that 63 of 89 patients (70.8) considered 50% or more improvement. Melasma area and severity index (MASI) decreased substantially from 15.2 to 4.5.

Park et al. [24] determined the effectiveness of combined IPL and Q-switched ruby laser (QSRL) therapy for targeted pigment dissolution and global photorejuvenation in Korean women (n¼25) with two or more types of facial pigmentary disorders. Initial treatment was conducted with an IPL followed by repeat treatments every 3–4 weeks as required. QSRL treatments were added either during the same session or within 1 week of IPL treatment. According to their results, 19 out of 25 patients (76%) reported a good to excellent response. Two independent physician assessed that 15 out of 25 patients (60%) showed 76–100% improvement, whereas 19 out of 25 patients (76%) showed at least 50% improvement. Side effects were minimal: 3 out of 25 patients showed transient post-inflammatory hyperpigmentation (12%) and 1 out of 25 patients (4%) had linear hypopigmentation.

Galeckas et al. [25] conducted a multiple-treatment splitface comparison using a FPDL with a compression handpiece versus an IPL device (Burlington, MA; fluence: 35.6 J/cm2, pulse duration: 10 milliseconds). Patients (n¼10) were treated three times at 3- to 4-week intervals. One month after the final treatment, improvement was assessed by blinded investigators who reported 86.5% versus 82.0% for FPDL

versus IPL for dark lentigines, 65.0% versus 62.5% for light lentigines, 85.0% versus 78.5% for vessels <0.6mm, 38.0% versus 32.5% for vessels >0.6mm,and 40.0% versus 32.0% for texture. Mean third treatment times were 7.7 (FPDL) minutes versus 4.6 (IPL) minutes (P¼0.005). Mean pain ratings were 5.8 (FPDL) versus 3.1 (IPL) (P¼0.007). The rate of side effects was lower with the IPL (infraorbital edema: 50% vs. 0%, post-treatment purpura 10% vs. 0%; FPDL vs. IPL).

Bjerring and Christiansen [16] evaluated the effectiveness of an IPL device (Danish Dermatologic Development; lem¼400–720 nm; spot size:
10mm————————————48mm; pulse duration:
2————————————7 milliseconds, delay: 25 milliseconds; fluence: 10–20 J/cm2) in the treatment of lentigo solaris (18 patients) and benign melanocytic nevi (8 patients). Two months after one single treatment, evaluation by means of close-up photographs showed a pigment reduction in 96% of patients and an average clearance of 74.2% for lentigo solaris and 66.3% for melanocytic nevi. In a recent case report, an IPL device (Caesarea, Israel; filter: 570 nm, pulse duration: 15 milliseconds, fluence: 10–12 J/cm2) was successfully used to treat pigmentary ochre dermatitis secondary to chronic venous insufficiency [26]. The normal skin color was restored, no repigmentation was observed within the 6 months follow-up and no side effects occurred.

As a remarkable side effect after IPL treatment, dyschromasia of both upper eyelids was reported by Pang and Wells [27]. Both eyelids were treated with an IPL at a beauty salon without the application of eye shields. The iris shows a high pigment content and is therefore particularly vulnerable during light treatment. The absorption of high intense light led to bilateral ocular iritis with subsequent irreversible ocular damage.

## TATTOOS

Tattoo removal requires very short pulse duration and high light intensities. Only Q-switched lasers fulfill these requirements. IPL devices are not suitable for tattoo removal as Q-switching is not possible in incoherent light sources. IPL devices emit pulse durations in the millisecond range, resulting in a prolonged heating of the pigment particles and subsequently in heating the surrounding tissue. This fact needs to be considered if IPL devices are used for hair removal on tattooed skin areas [28].

## VASCULAR LESIONS

In addition to the treatment of unwanted hair, vascular malformations are a key indication for IPL therapy. The mechanism of action of IPLs is related to their

selective absorption by hemoglobin within the blood vessels. The thermal effect of IPLs on skin vessels (diameters: 60, 150, 300, 500 mm) was calculated for different wavelengths by Baumler et al. [29] by means of the finite element method (pulse duration: 30 milliseconds; fluence: 15 or 30 J/cm2). These authors found that the investigated spectra provided homogeneous heating in the entire vessel that was sufficient for coagulating vessels >60 mm. There is evidence in the literature for successful treatment of essential telangiectasias [30], rosacea [31,32], port-wine stains (PWS) [33–37], spider nevi [38], angiomas [39–41], and erythrosis [30]. For the treatment of essential telangiectasias, PWS, and rosacea level of evidence IIB is reached. In 2007, the European Society for Laser Dermatology (ESLD) published guidelines for the use of IPLs in the treatment of vascular malformations [8]. Immediately after the treatment of vascular lesions, a dark blue to gray discoloration of the treatment area can be expected, which is a sign for appropriate photophysical parameters.

## Port-Wine Stains (PWS)

In a controlled comparative split-face study (data not published yet), group compared an IPL-device (Danish Dermatologic Development; lem¼ 555–950 nm; spot size: 10mm————————————48mm; pulse duration: 8 or 10 milliseconds; fluence: 11.0–16.9 J/cm2) to the standard treatment of PWS, that is, the flashlamp-pumped pulsed dye laser (FPDL) and the long-pulsed tunable dye laser (LPTDL), in patients (n¼11) with previously untreated PWS. In one single treatment setting, different photophysical parameters were tested, and a total of 84 test treatments were conducted. One single IPL treatment induced a mean PWS clearance of 25–50%. IPL treatments were rated significantly better than therapy with the standard treatment, the FPDL, (P<0.05) and were equally effective to LPTDL treatments. Side effects (hypopigmentation in 2%, hyperpigmentation in 4% of treatments) occurred rarely (data not published yet). Two other articles provide data from controlled sideby- side comparisons of IPL and the standard therapy, the dye laser [42,43].

Faurschou et al. treated 20 patients with PWS in a side-by-side trial with a pulsed dye laser (PDL) versus IPL (Palomar Medical Technologies; pulse duration: 5–10 milliseconds, fluence: 7–14 J/cm2). The researchers found that both PDL and IPL significantly lightened PWS, whereas median clinical improvements were significantly better with the PDL (65%) than with the IPL (30%). The lower effectiveness of the IPL in that article might be explained by the fact that the authors did not only include previously untreated (n¼8) but also previously treated (n¼12) patients in this study without distinguishing between the two groups. Besides, Faurschou et al. used an IPL that emitted light of 500–670nm and 870–1,400 nm. Therefore, the IPL used by Faurschou et al. divided the applied energy on a much broader wavelength spectrum including the near infrared range, which could be a reason for the lower clearance. In a controlled comparative split-face study group

focused on patients (n¼14) with previously treated PWS and compared an IPL-device (Danish Dermatologic Development; lem¼555–950 nm; spot size: 10mm————————————48mm; pulse duration: 8–14 milliseconds; fluence:11.0–17.3 J/cm2) to the FPDL) and the LPDTL. A total of 74 treatments were conducted; again IPL treatments were rated significantly (P<0.05) better than treatments using FPDL. Excellent (>75) or good [51–75] clearance was obtained in 5 out of 32 (15.6%) test spots applied with the LPTDL, and in 7 out of 30 (23.3%) test spots applied with the IPL. FPDL test spots showed no clearance >50%. 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 LPTDL treatment in 1 out of 14 patients (data not published yet).

Bjerring et al. [34] treated 15 patients with dye laser resistant PWS four times with the same IPL device (Danish Dermatologic Development; lem¼555– 950 nm; spot size: 10mm———————————— 48mm; pulse duration: 8–30 milliseconds; fluence: 13–22 J/cm2). These researchers reported 7 out of 15 patients exhibiting a lightening of more than 50%, which corresponds to our results. No scarring was observed, hypopigmentation (9%) or hyperpigmentation (3%) occurred only rarely. McGill et al. [44] compared a pulsed dye, an alexandrite, a KTP, and a Nd:YAG laser as well as an IPL device (Cheshire, UK; lem¼550–1,100 nm; spot size: 10mm————————————10mm, fluence: 28–34 J/cm2, double pulsed 10 milliseconds delay) in a split-lesion modus in patients (n¼18) with PWS. In this study, the alexandrite laser was the most effective and resulted in fading PWS in 10 patients, although hyperpigmentation (n¼4) and scarring (n¼1) was frequent. IPL resulted in PWS fading in six patients, the KTP and Nd:YAG lasers were the least effective with fading seen in two patients for both systems; five patients showed further PWS fading after doublepassed PDL treatment.

## Rosacea

Papageorgiou et al. [32] assessed the efficacy of an IPL device (London, UK; lem¼560–1,200 nm, spot size: 34mm————————————8mm, double pulses of 2.4 and 4.0, 5.0, or 6.0 (depending on the skin type), fluence: 24–32 J/cm2) for the treatment (four treatments at 3 weeks interval) of stage I rosacea (flushing, erythema, and telangiectasia) in 34 patients. Photographic assessment showed significant improvement of erythema (46%) and telangiectasias (55%). The severity of rosacea was reduced on average by 3.5 points on a 10-point VAS. The results were sustained at 6 months. Side effects were minimal and self-limiting.

Schroeter et al. [31] approved these positive results in the treatment of rosacea, testing the effectiveness of IPL devices (London, UK; lem¼515–1,200 nm; pulse duration: 4.3–6.5 milliseconds; fluence: 25–35 J/cm2) in the treatment of facial telangiectasia in rosacea patients (n¼60). On average, 4.1 treatments were applied per area (n¼508) and clinically as well as photographically evaluated. A mean

clearance of 77.8% was achieved and was maintained for a follow-up period averaging 51.6 months (range 12–99 months). Within this remarkable long follow-up period, only 4 of the 508 treated areas showed recurring lesions. Minimal side effects occurred.

In a randomized controlled single-blind split-face trial, Neuhaus et al. [45] compared a PDL (spot size: 10mm, fluence: 7 J/cm2, pulse duration: 6 milliseconds) with an IPL device (560nm filter, pulse train: 2.4 and 6.0 milliseconds, delay: 15 milliseconds, fluence: 25 J/cm2) in the treatment of facial erythemato-telangiectatic rosacea.
Patients (n¼29) underwent three monthly treatment sessions. In this study, PDL and IPL therapy significantly reduced cutaneous erythema, telangiectasia, and patient reported associated symptoms. No significant difference was noted between PDL and IPL treatments.

## Telangiectasias

In a randomized split-lesion trial, Nymann et al. [46] compared the efficacy and side effects of a long-pulsed dye laser (LPDL) with an IPL device (Danish Dermatologic Development; lem¼530–750 or 555–950 nm; spot size: 10mm————————48mm; pulse duration: 10–20 milliseconds; fluence: 8–20 J/cm2) in patients (n¼13) with telangiectasias after radiotherapy for breast cancer. Patients underwent three split-lesion treatments at 6-week intervals. The authors reported median vessel clearances of 90% (LPDL) versus 50% (IPL) (P¼0.01) 3 months after treatment. LPDL treatments were associated with lower pain scores than IPL treatments. Even if patients' satisfaction did not differ significantly, more patients preferred the LPDL (n¼9) to IPL (n¼2) (P<0.01).

Bjerring et al. [47] evaluated the effectiveness and side effects of an IPL device (Danish Dermatologic Development; lem¼555–950 nm; spot size: 10mm————————48mm; pulse duration: 10–30 milliseconds; fluence: 10–26 J/cm2) in patients (n¼24) with facial telangiectasias. 2.540.96 treatments were conducted at 1-month intervals. 79.2% of the patients obtained more than 50% reduction in a number of vessels, and 37.5% obtained reduction between 75% and 100% 2 months after the last treatment. Side effects were rare (moderate erythema and edema), and no scarring or pigmentary disturbances occurred.

In a prospective side-by-side study, Fodor et al. [48] compared an IPL device (Lumenis, London, UK; filter: 515, 550, or 570 nm, fluence: 15–38 J/cm2; pulse duration: not stated) to a Nd:Yag laser in patients (n¼25) with telangiectases, leg veins, or cherry angiomas. Patients with telangiectases, cherry angiomas, or leg veins <1mm were more satisfied after IPL treatment, whereas patients with leg

# CLINICAL STUDIES

veins >1mm were more satisfied after Nd:YAG treatment. The Nd:YAG treatment was reported as more painful.

Retamar et al. [49] investigated the effectiveness and safety of an IPL device (515–1,200 nm) in the treatment of linear and spider facial telangiectasias in 140 patients. In this study, 94 (67.1%) patients responded excellent (80–100%), 43 (30.7%) good (40–80%), and 3 (2.1%) poor clearance (<40%). Post-treatment side effects were minimal and transient. A patient with essential facial telangiectasia who was successfully treated with IPL in clinic is shown in Figure 2.



*Fig. 2. Fifty-one-year-old man with essential facial telangiectasias treated with IPL (Hoersholm, Denmark; lem¼555–950 nm; spot size: 10mm————————————48mm; pulse duration: 14 milliseconds; fluence: 13.5 and 14.2 J/cm2). (a): patient prior to treatment, (b) test spots on the left cheek, (c) patient 6 weeks after four treatments.*

## Erythrosis

Madonna Terracina et al. [50] used IPL (fluence: 9–12 J/cm2, pulse duration: 10–20 milliseconds, spot size:20mm——————————— 50mm) in the treatment of face and neck erythrosis in women (n¼22) and men (n¼12). Patients underwent five treatments at intervals of 3 weeks. In 22 patients, a total regression of the erythrosis was achieved after five applications, while the erythema persisted in five patients after the end of treatment.

Wenzel et al. [30] reported successful treatment of patients with progressive disseminated essential telangiectasia (n¼4) and erythrosis interfollicularis colli (n¼5) by means of an IPL device (Danish Dermatologic Development; lem¼555–950 nm; spot size: 10mm————————————48mm; pulse duration: 14–18 milliseconds; fluence: 11.7–17 J/cm2). According to their results, clearance rates were 76–90% in six out of nine patients, 51–75% in two patients, and 50% in one patient. For both indications, 2.8 treatments were applied on average. Adverse events were rare, only one patient suffered from transient crusts and blisters, which resulted in transient hypopigmentation; another patient showed transient

hyperpigmentation. A patient with facial erythrosis who was successfully treated with IPL in our clinic is shown in figure 2.

## PHOTODYNAMIC THERAPY (PDT)

PDT is especially useful for the treatment of nonmelanoma skin cancers like actinic keratoses (AKs) or superficial basal cell carcinomas [51]. Aminolevulinic acid (ALA) or its methyl ester (MAL) are prodrugs that have to be converted into their active form, that is, protoporphyrin IX [52,53]. PpIX is particularly suitable for the activation with broadband IPL because the major absorption bands include 410, 504, 538, 576, and 630 nm. Both ALA andMAL are used for PDT in combination with IPL, for example, for the treatment of non-melanoma skin cancers [54].
Major side effects of PDT are phototoxic reactions (erythema, edema, hyperpigmentation) and pain during the treatment—which is dependent on the type of photosensitizer (PS) used, the treatment area, and the type of lesion treated [55].

Group compared the efficacy and painfulness of an IPL device (Swansea, UK; 610–950 nm, 2 pulse trains, each 15 pulses of 5 milliseconds, delay: 20 milliseconds, fluence: 40 J/cm2 per pulse train) to a standard light source for PDT, a light-emitting diode (LED)-system (6353 nm, 50mW/cm2; 37 J/cm2), in a prospective randomized controlled split-face study [56]. In 25 patients with AKs (n¼238), topical PDT was applied followed by a re-evaluation of up to 3 months. According to our results, IPL use for PDT is an efficient alternative for the treatment of AKs, resulting in complete remission and cosmesis equivalent to LED irradiation but with significantly less pain (VAS: 4.3 (IPL) vs. 6.4 (LED); P<0.001).

Kim et al. [57] conducted a clinical and histopathological trial (seven patients) to confirm the effectiveness of topical ALA–PDT using an IPL device (Danish Dermatologic Development; lem¼555–950 nm; spot size:10mm————————————48mm; pulse duration: 20–30 milliseconds; fluence:12–16 J/cm2, two passes) as a light source in the resolution of AKs (n¼12). Eight or 12 weeks after treatment, the clinical response was assessed and histopathologic examinations were conducted on clinically resolved lesions. Six out of 12 (50%) lesions showed clinical clearance after one single treatment, but histologic examinations showed that only 5 of the 12 (42%) lesions had been removed. Complications, such as pigmentary changes or scarring, were not observed. According to these results, determining complete remission in AKs requires caution, and long-term follow-up or histologic confirmation may be required.

Gold et al. [58] focused on the treatment of AKs and associated photodamaged skin. In a split-face study involving 16 patients (three treatments; 1-month intervals), Gold et al. evaluated short-contact (30–60 min) ALA–PDT with IPL (Yokneam, Israel; 550 or 570nm filter, fluence: 34 J/cm2; double pulsing, delay: 20 milliseconds, spot size: 8mm————————————16mm) as light source in

comparison to IPL alone. Three months after the final treatment, ALA–PDT–IPL showed significantly better improvement as compared to IPL alone in the assessed facets of photodamage (crow's feet appearance 55.0% vs. 29.5%, tactile skin roughness 55% vs. 29.5%, mottled hyperpigmentation 60.3% vs. 37.2%, and telangectasias 84.6% vs. 53.8%) and in the clearance rate of AK lesions (78% vs. 53.6%). Thus, this study further proves the usefulness of ALA–PDT–IPL in the successful treatment of AKs and signs of photodamage. Whether a short contact incubation is able to induce significant amounts of PpIX in the skin has to be proven in additional experiments.

However, the fact that telangiectasias respond better to ALA is remarkable, as the creation of PpIX by endothelial cells cannot be expected after such short contact incubation. Skin rubbing which was only done in the ALA–PDT site (methodical mistake) or light coupling effects might have contributed to the clearance of telangiectasias. A level of evidence IIB supports the use of IPL as a light source for PDT of AKs.

## ACNE

Targeting acne by laser or light devices is widely accepted in the literature. Two mechanisms of action target acne lesions: A photodynamic effect is evoked by the use of both UV light and visible light that is absorbed by porphyrins (PpIX, Coproporphyrin III) (absorption peaks: 400, 510, 542, 578, 630, 665 nm) that are produced by Propionibacterium acnes. This absorption leads to the generation of reactive oxygen species (ROS) with subsequent bactericidal effects.

Another pathway is based on the selective photothermolysis of blood vessels that supply sebaceous glands, which reduces the sebum secretion rate. A third mechanism of action requires an exogenous PS which is applied to the skin surface. The PS accumulates in the sebaceous glands and leads to the destruction of sebaceous glands after light activation [59,60]. The use of IPL offers the possibility to cover the absorption peeks of the porphyrins and the hemoglobin and may be therefore a suitable tool for acne treatment.

In a randomized split-face trial, Yeung et al. [61] evaluated the effect of IPL therapy alone versus MAL– PDT–IPL versus control on moderate acne vulgaris in Asian patients (n¼30) with skin type IV or V. Incubation time was 30 minutes in the PDT group. IPL treatment (Danish Dermatologic Development; lem¼530–750 nm; spot size: 10mm-48mm; pulse 100 BABILAS ET AL.duration: 2.5 milliseconds, delay: 10 milliseconds; fluence: 7–9 J/cm2) was applied four times at 3-week intervals. The response was evaluated by two blinded investigators based on photographs 4 and 12 weeks after the final treatment. In this study, a significant reduction of non-inflammatory lesions was observed in the MAL–PDT group (38%, P

0.05) and IPL groups (43%, P 0.01), whereas the control group showed an increase of 15% of non-inflammatory lesions 12 weeks after treatment. No statistically significant differences existed between the intervention groups (PDT: 65%; IPL: 23%) and the control group (88%) in the mean reduction of inflammatory lesions. However, 25% of patients treated with PDT withdrew because of treatment-associated discomfort. Sami et al. [62] compared the effectiveness of PDL, LED, and IPL (lem¼550–1,200 nm, fluence: 22 J/cm2, pulse duration: 30 milliseconds) treatment in a controlled randomized clinical trial. Patients (n¼45) with moderate to severe acne were randomly divided into three equal groups (PDL vs. IPL vs. blue-red combination LED). Clearance of 90% of lesions was achieved after 4.11.4 (PDL) versus 62.1 (IPL) versus 103.3 (LED) sessions (one treatment per week). At mid-point evaluation, the percent reduction in acne lesions was90.0% (PDL) versus 41.7% (IPL) versus 35.3% (LED). All treatments were well tolerated.

Taub [63] compared the effectiveness of three different light sources for ALA–PDT in treating moderate to severe acne vulgaris. Patients (n¼22) were randomly assigned to IPL (lem¼600–850 nm), a combination of IPL (lem¼580–980 nm) and bipolar RF energies, or blue light (417 nm). Each patient received three ALA–PDT sessions at 2-week intervals. Follow-up evaluations were conducted 1 and 3 months after the final treatment. The author reported that ALA–PDT with activation by IPL provided better, longer-lasting, and more consistent improvement than RF–IPL or blue light activation. Chang et al. [64] evaluated an IPL device (Danish Dermatologic Development; lem¼530–750 nm; spot size: 10mm48mm; pulse duration:2- 2.5 milliseconds, delay: 10 milliseconds; fluence: 7.5–8 J/cm2) in female patients (n¼30) with mild to moderate acne. One side of the face was treated with benzoyl peroxide gel alone; on the other side, IPL treatment was applied in addition. After three sessions in 3 weeks, no significant difference could be detected with regard to a possible reduction of inflammatory lesions in either side of the face. However, red macules, irregular pigmentation, and skin tone improved in 63% of the laser-treated sides versus 33% on the control side.

The heterogeneous results in current clinical trials show that acne treatment with IPL is far from being a standard treatment. Most studies lack sufficient treatment durations and follow-up periods. This is highly relevant, particularly with regard to the treatment impact against P. acnes and inflammatory acne lesions. P. acnes levels only remain reduced if light treatments are applied over a longer period of time, similar to the need of prolonged courses of antibiotics.

## SKIN/PHOTOREJUVENATION

Skin aging, which consists of photoaging and intrinsic aging, is characterized clinically not only by wrinkles but also by pigmentary alterations, skin thinning, and telangiectasias. Currently, various non-ablative skin-resurfacing techniques are

available to rejuvenate facial skin, including lasers and IPL. Thus, interest in the efficacy of IPL devices remains high. To further define the mechanism of action of IPL application in skin rejuvenation, biopsies taken before and after IPL treatment were histologically examined [17]. Analysis showed that both type 1 and type 3 collagens increased after treatment, whereas the elastin content decreased but elastin fibers were more neatly arranged. According to transmission electron microscope investigations, the amount of fibroblast activity increased, the fibroblasts were more active, and more collagen fibers were neatly rearranged within the stroma [17].

Thus, morphological evidence exists for clinical improvement of the skin texture. In a randomized controlled split-face trial, Jorgensen et al. [65] evaluated the efficacy and adverse effects of LPDL versus IPL therapy (Danish Dermatologic Development; lem¼530–750nm or 555–950 nm; spot size: 10mm-48mm; pulse duration: 2-2.5 milliseconds, delay: 10 or 8–20 milliseconds; fluence: 6–20 J/cm2) in the treatment (three treatments; 3-week intervals) of photodamaged skin in women (n¼20) with Fitzpatrick skin types I–III. One, 3, and 6 months after therapy, patients as well as blinded investigators assessed the impact on telangiectasias, pigmentation, skin texture, rhytids, treatment- related pain, adverse events, and the preferred treatment by means of photographs. LPDL rejuvenation showed advantages over IPL rejuvenation because of considerably better vessel clearance and less pain. Irregular pigmentation and skin texture improved with both treatments without significant side-to-side differences. No reduction of rhytides was seen in either treatment side.

Using the same IPL device (Danish Dermatologic Development; lem¼530–750nm or 555–950 nm; spot size: 10mm-48mm; pulse duration:2-2.5 milliseconds, delay: 10 or 8–20 milliseconds; fluence: 6–20 J/cm2), Bjerring et al. [66] compared the clinical efficacy and safety of two different filter sets (555–950nm (VL) vs. 530–750nm (PR)) in the treatment of photodamaged skin in 35 patients. In this study, the use of the VL filter resulted in better clearance of irregular pigmentation, whereas the PR filter achieved better clearance of telangiectasias and diffuse erythema. Either fair, good, or excellent results were reported by 66.7% (PR) versus 76.2% (VL) of patients. No skin atrophy, scarring, or pigment disturbances were noted, but swelling and erythema occurred in 66% (PR) versus 33% (VL) of patients.

Hedelund et al. [67] evaluated the efficacy and adverse effects of the same IPL device (Danish Dermatologic Development; lem¼530–750 nm; spot size: 10mm-48mm; pulse duration: 2-2.5milliseconds, delay: 10 milliseconds; fluence: 7.5–8.5 J/cm2) in a randomized controlled split-face trial on skin rejuvenation (three treatments; 1-month interval) in women (n¼32, class I or II rhytids). Nine months after the final treatment, blinded investigators and patients assessed significant improvement in telangiectasia (P<0.001) and in irregular pigmentation (P<0.03) between treated and untreated sides but no significant difference in rhytids.

Li et al. [68] evaluated the efficacy and safety of an IPL device (Santa Clara, CA; 515–1,200 nm, fluence: 11–20 J/cm2, double or triple pulse mode, pulse duration:

# CLINICAL STUDIES

2.5–4 milliseconds, delay: 20–40 milliseconds) in the treatment (four treatments; 3- to 4-week intervals) of photoaged skin in Asian patients (n¼152). In this study, assessment showed a score decrease of three or two grades in 91.4% of patients. 89.5% of patients rated their overall improvement as excellent or good. Adverse effects were limited to mild pain and transient erythema.

Kono et al. [69] compared—in a split-face study—the effectiveness of an IPL device (Burlington, MA; 470–1,400 nm, fluence: 27–40 J/cm2, pulse duration: 20 milliseconds) to a LPDL (595 nm, spot size: 7mm) in the treatment (six treatment sessions) of facial skin rejuvenation in Asian patients (n¼10). Three months after the last treatment, lentigines had improved by 62.3% (IPL) versus 81.1% (LPDL). No significant difference was evident between IPL and LPDL in wrinkle reduction, and no scarring or pigmentary change were seen with either device.

Sequential Er:YAG laser treatment versus IPL treatment (Palomar Medical Technologies; 560nm filter, 30 J/cm2, pulse duration: 2.4 and 4.0 milliseconds, delay: 10 milliseconds) for mild to moderate facial photodamage was compared by Hantash et al. [70] in a split-face randomized prospective trial in patients (n¼10) with facial dyschromia and rhytids. Assessment 3 months after the final treatment (three treatments; 1 month apart) showed that IPL and Er:YAG treatments did not significantly improve rhytid scores. However, dyschromia scores improved by 26–38% (IPL) versus 7–29% (Er:YAG). Global facial appearance scores improved by 20–28% (IPL) versus 16% (Er:YAG). Adverse events occurred more frequently after Er:YAG than after IPL treatment (hyperpigmentation: 10% vs. 0%; exfoliation: 30% vs. 10%; blistering: 10% vs. 0%; discomfort: 50% vs. 10%). In most studies, data on the effectiveness of IPL in skin rejuvenation is inhomogeneous.

Obviously, IPL treatment is a good alternative to laser therapy in terms of vascular and pigment disturbances rather than wrinkle reduction.
Advantageous is the relatively low incidence of complications as compared to ablative laser devices.

## CONCLUSION

Numerous trials show the effectiveness and compatibility of IPL devices in a variety of skin conditions. Most comparative trials attest IPLs similar effectiveness to lasers; in some studies, IPL devices seem to be even more effective in the treatment of vascular malformations or hypertrichiosis. However, large controlled and blinded comparative trials with an extended follow-up period are necessary. The strongest advantage of IPLs is their versatility and economy. When treating large areas, IPLs are advantageous because of their high skin coverage rate.

The wide range of selectable treatment settings are of great advantage for skilled

# CLINICAL STUDIES

and experienced dermatologists but are a fatal source of error for untrained physicians and even more for non-medical staff. This point is of high importance because more and more users are not qualified dermatologists or even physicians, particularly users in beauty institutions and spas. As a matter of fact, IPL devices are widely unregulated and not subject to governmental control such as lasers. In most countries, the sale of IPLs is generally unrestricted. This issue needs to be addressed in the near future to achieve successful as well as safe treatments.

## ACKNOWLEDGMENTS

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