Review

Use of intense pulsed light sources in dermatology: Update 2012

Der Einsatz der IPL-Technologie in der Dermatologie: Update 2012

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Abstract

Intense pulsed light sources (IPLs) consist of flash lamps with bandpass filters and emit incoherent polychromatic pulsed light of a high intensity and determined wavelength spectrum, fluence, and pulse duration. The combination of prescribed wavelengths, fluencies, pulse durations, and pulse intervals facilitates the treatment of a wide spectrum of skin conditions. Hereby, IPLs follow the basic principle of a more or less selective thermal damage of the target. This review discusses the current literature on IPLs with regard to the treatment of unwanted hair growth, vascular lesions, pigmented lesions, and as a light source for photodynamic therapy and skin rejuvenation. It also summarizes the physics of IPLs and provides guidance for the practical use of IPLs.

Keywords: laser; dermatology; vascular lesions; pigmented lesions; hair removal; skin.

1. Introduction

1.1. Technical aspects

After the introduction of polychromatic infrared light in 1976 by Mühlbauer et al. [1], Goldman and Eckhouse [2] described in 1996 a new high-intensity flash lamp as a suitable tool for treating vascular lesions. The basic principle was a rather selective photothermolysis of pigmented structures, cells, and organelles by selective absorption of pulsed radiation as described in 1983 [3]. With the aid of flash lamps and computer-controlled capacitor banks, intense pulsed light sources (IPLs) generate pulsed polychromatic high-intensity light. The emission spectrum of IPLs ranges from 500 to 1300 nm. Convertible cut-off filters adapt the polychromatic emission spectrum to the desired wavelength to allow versatility. In the new generation of IPLs, water filters suppress the infrared light, thereby reducing the risk of side effects. The patient’s skin type and the focused indication determine the cut-off filters used and thus the spectrum of emitted wavelengths as well as the pulse duration. Similar to laser devices, the pulse duration should be lower than the thermal relaxation time of the target structure to prevent unselective damage to the surrounding tissue. Owing to a high degree of freedom in terms of combining wavelengths, pulse durations, pulse intervals, and fluencies, IPLs enable a successful treatment of a wide spectrum of skin conditions, such as acne vulgaris, pigmented lesions, vascular lesions, unwanted hair growth, photodamaged skin, scars [4], and angiokeratomas [5]. It is worth mentioning that the versatility of IPLs means that the risk of side effects due to unspecific thermal damage is increased, especially if the devices are used by untrained physicians. Also, the IPLs have a rather heavy handpiece and a large spot size, which accounts for a certain limitation in maneuverability. On the other hand, the large spot size enables a high skin coverage rate, which can be an advantage. Further advantages are the low purchase price and a more robust technology as compared with lasers. However, the fact that the emitted spectrum and fluence can be inconsistent from pulse to pulse, in particular, in IPLs containing a small capacitor bank [6], can be considered disadvantageous. This point accounts for the fact that different types of IPLs are hardly comparable. A serious comparison should account for the fluence per area for every emitted wavelength and for every possible pulse duration and pulse shape against the background of the real on-off time, fluence, and spectral jitter during an impulse. This has
been impressively shown in the article by Maisch et al. [7], who analyzed the emission spectrum of five different IPLs all equipped with comparable cut-off filters. It was found that the emission spectra of the IPLs showed a high degree of divergence and that the induced photothermal effect was not predictable [7].

1.2. Practical aspects

Patient handling, pretreatment, and posttreatment are of great importance using intense pulsed light (IPL) and are extensively discussed in a previous review on IPLs in the preceding DGLM journal Medical Laser Application [8] or in Babilas et al. [9].

The following sections discuss the current literature on IPLs for the treatment of unwanted hair growth, vascular lesions, pigmented lesions, acne vulgaris, and photodamaged skin as well as light sources for photodynamic therapy (PDT) and skin rejuvenation. Where available, we focus on controlled studies comparing IPLs to the respective standard treatment.

2. Hair removal

Hair removal has become a key indication for IPLs. In a recently published article, Alijanpoor et al. [10] report on a randomized clinical trial on 62 hirsute patients with excessive white facial hair on the chin and cheeks. The patients randomly colored their white hair with either black eyeliner or black hair dye before IPL treatment (six times, at 4-week intervals). In both groups, approximately 50% of patients showed a good response of >60% with no significant difference between both groups (p=0.895). The authors concluded that hair coloring might be an efficient and feasible technique that can be combined with IPL treatment to eliminate white facial hair. Haak et al. [11] compared the efficacy and safety of an IPL device (525–1200 nm; StarLux IPL system; Palomar Medical Technologies, Burlington, MA, USA) vs. a long-pulsed diode laser (LPDL, 810 nm; Asclepion MeDiostar XT diode laser) in 31 hirsute women with normal testosterone levels in a split-face study. According to their results, IPL and LPDL treatment significantly reduced hair counts (77%, 53%, and 40% for IPL treatment vs. 68%, 60%, and 34% for LPDL treatment) at 1, 3, and 6 months follow-up. Although there was no significant difference between treatments in terms of hair reduction (p=0.427) and patient satisfaction (p=0.125), pain scores were higher for IPL treatment (median, 6; interquartile range, 4–7) than LPDL (median, 3; interquartile range, 2–5) (p<0.001).

Holzer et al. [12] used an IPL device (610–950 nm; Energist VPL system) for the removal of unwanted nonfacial, dark-pigmented, body hair in an uncontrolled study in 42 volunteers. They documented a very good (>75% hair reduction) or good efficacy (51%–75% hair reduction) in 42.9% (n=18) and 33.3% (n=14) of patients, respectively. Side effects were a seldom occurrence.

In a split-face study with 9 female participants, Cameron et al. [13] compared a diode laser (Lightsheer EC; Lumenis, Santa Clara, CA, USA; 810 nm; fluence, 20–45 J/cm²; pulse duration, 30 ms) with an IPL device (Luminate; Lynton Lasers, UK; 625–1100 nm; fluence, 32 J/cm²; pulse train, 8×4 ms; total train time, 95 ms) for the removal of facial hair. Six weeks after the treatments (three times, at 6-week intervals), laser and IPL therapy had substantially reduced the average hair counts in a 16-cm² area, which were 42.4 and 10.4 (laser), 38.1 and 20.4 (IPL), and 45.3 and 44.7 (control) before and after treatment, respectively.

Despite higher pain scores and more inflammation, laser treatment was preferred by five patients; two patients preferred IPL treatment and one had no preference.

McGill et al. [14] conducted a randomized split-face comparison of facial hair removal with an alexandrite laser (GentleLASE®; Candela Laser Corp., Wayland, MA, USA; 755 nm; spot size, 15 mm; fluence, 10–30 J/cm²; pulse duration, 3 ms) and an IPL device (Lumina; Lynton Lasers; 650–1100 nm; fluence, 16–42 J/cm²; three pulses of 55 ms; delay, 20 ms) in 38 women with polycystic ovary syndrome. 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). The 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 are responsible for higher follicular destruction. Unfortunately, no histological investigations were carried out at the time, and the treatment duration was not documented.

Toosi et al. [15] compared the clinical efficacy and side effects of an alexandrite laser (Cynosure, Langen, Germany; 755 nm; fluence, 16–20 J/cm²; spot size, 10 mm; pulse length, 2 ms), a diode laser (810 nm; Palomar diode laser), and an IPL device (Medical Photo Bio Care, Sweden; filter, 650 nm; fluence, 22–34 J/cm²; double pulse; pulse duration, 20 ms; delay, 10–40 ms) for hair removal in 232 patients. Six months after treatment (three to seven sessions), no significant difference could be seen among the average hair reduction by means of IPL device (66.9±17.7%), alexandrite (68.8±16.9%), and diode laser (71.7±18.1%) (p=0.194). The incidence of side effects was significantly higher after diode laser treatment (p=0.0001).

In a prospective comparison study, Amin et al. [16] evaluated the efficacy of an IPL device with red filter, an IPL device with yellow filter, an 810-nm diode laser, and a 755-nm alexandrite laser in 10 patients with unwanted hair on the back or thigh. Evaluation with a camera system at 1, 3, and 6 months after the second treatment showed a significant decrease in hair counts (approx. 50%) for all light devices (no statistical difference).

An evidence-based review published by Haedersdal and Wulf in 2006 [17] summarizes 9 randomized controlled (RCTs) and 21 controlled trials (CTs) on the efficacy and safety of hair removal by means of ruby, alexandrite, diode, or Nd:YAG lasers and IPLs, whereas for IPLs, only limited evidence was available (only 1 RCT and 1 CT). Based on these data, the authors concluded that no sufficient evidence exists for long-term hair removal after IPL treatment. Bjerring et al.
[18], in a split-face study, compared the effectiveness of an IPL device (Ellipse Relax Light 1000; Danish Dermatologic Development, Hoersholm, Denmark; 600–950 nm; fluence, 18.5 J/cm²; spot size, 10×48 mm) to a normal mode ruby laser (EpiTouch, ESC Sharpplan, Tel Aviv, Israel; 694 nm; spot size, 5 mm; pulse duration, 0.9 ms) for hair removal in 31 patients (three treatments). The authors reported an average hair count reduction of 49.3% (IPL) vs. 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 papers have focused on the safety of IPLs in hair removal. According to these articles, burning, postinflammatory hyperpigmentation, bullae and erosion, leukotrichia, folliculitis, postinflammatory hypopigmentation, very seldom scar formation, and paradoxical hypertrichosis (1–10%) can be registered as side effects [19–22].

The market for portable devices for home use is increasing. Even some works assess efficacy and safety [23, 24], and 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 size minimization of the apparatus, a smaller capacitor bank has to be used, which evokes fluence and spectral jitter within each pulse.

In conclusion, a number of medical papers document the effectiveness of IPL treatment for hair removal, yet only a few provide data from RCTs or CTs. Level of evidence IIB is reached.

3. Pigmented lesions

Several reports indicate the effectiveness of IPLs in the treatment of pigmented lesions. Li et al. [25] published recently a work on the efficacy and safety of an IPL device (Lumenis One; Lumenis, Santa Clara, CA, USA; 590-/590-nm cut-off filters; fluence, 11–17 J/cm², with triple-pulse mode; pulse width, 2–6 ms; delay time, 35–40 ms) in the treatment of Riehl melanosis in a split-face study of six patients ( Fitzpatrick skin type IV). In terms of histological analysis, the authors reported significantly fewer melanin granules and melanophages in the treated side as compared with the control side after 10 IPL sessions. According to a professional assessment, five patients exhibited good improvements, whereas one patient showed excellent improvement, whereby therapeutic efficacy was correlated to the number of treatment sessions and anatomical sites. In another study, Li et al. [26] reported on the efficacy and safety of the same IPL device (fluence, 13–17 J/cm²; 560-/590-nm filters and double pulse or 590-/640-/695-nm filters and triple pulse; pulse duration, 3–4 ms; delay time, 25–40 ms) in the treatment of melasma in 89 Chinese patients. Patients received a total of four IPL treatments at 3-week intervals. As a result, 69 (77.5%) of 89 patients showed an improvement of 51–100% according to the overall evaluation by dermatologists. Self-assessment by the patients indicated that 63 (70.8%) of 89 patients considered that there was a 50% or more improvement. Melasma area and severity index decreased substantially from 15.2 to 4.5.

Park et al. [27] determined the effectiveness of a combined IPL and Q-switched ruby laser (QSRL) therapy for targeting pigment dissolution and global photorejuvenation in 25 Korean women with more than two types of facial pigmentation disorders. Initial treatment was conducted with the IPL device (560-/590-nm cut-off filter; fluence, 20–25 J/cm² with double pulse mode; pulse duration, 2.4–4 or 4.5–8 ms; delay time, 15 ms) and followed by repeated treatments every 3 to 4 weeks as required. QSRL treatments (Lambda Photometrics, Hertfordshire, UK; 694 nm; fluence, 4.5–6 J/cm²; spot size, 3–4 mm; pulse duration, 25 ns) were added either during the same session or within 1 week after the IPL treatment. According to their results, 19 (76%) of 25 patients reported a good to excellent response. Two independent physicians assessed that 15 (60%) of 25 patients showed a 76–100% improvement, whereas 19 (76%) of 25 patients showed at least an improvement of 50%. Side effects were minimal; 3 (12%) of 25 patients showed transient postinflammatory hyperpigmentation and 1 (4%) of 25 patients had linear hypopigmentation.

Galeckas et al. [28] conducted a multiple-treatment split-face comparison using a pulsed dye laser (PDL) (Perfecta; Candela Laser Corp.; spot size, 10 mm; mean light dose, 9.36 J/cm²) with a compression handpiece vs. an IPL device (StarLux; Palomar Medical Technologies; fluence, 35.6 J/cm²; pulse duration, 10 ms). In total, 10 patients 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% vs. 82.0% for PDL vs. IPL treatment for dark lentigines, 65.0% vs. 62.5% for light lentigines, 85.0% vs. 78.5% for vessels <0.6 mm, 38.0% vs. 32.5% for vessels >0.6 mm, and 40.0% vs. 32.0% for texture. Mean third treatment times were 7.7 min for PDL vs. 4.6 min for the IPL device (p=0.005). Mean pain ratings were 5.8 for PDL vs. 3.1 for the IPL device (p=0.007). The rate of side effects was lower using the IPL device (infraorbital edema: 0% vs. 50% for PDL, posttreatment purpura 0% vs. 10% for PDL).

Bjerring et al. [29] evaluated the effectiveness of an IPL device (Ellipse Flex; Danish Dermatologic Development, Hoersholm, Denmark; 400–720 nm; fluence, 10–20 J/cm²; spot size, 10×48 mm; pulse duration, 2×7 ms; delay, 25 ms) in the treatment of lentigo solaris (18 patients) and benign melanocytic nevi (8 patients). Two months after a single treatment, evaluation by means of close-up photographs showed a pigment reduction in 96% of the patients. The average clearance was 74.2% for lentigo solaris and 66.3% for melanocytic nevi.

In a case report by Pimentel and Rodriguez-Salido [30], an IPL device (Harmony System; Alma Lasers Ltd., Caesarea, Israel; filter, 570 nm; fluence, 10–12 J/cm²; pulse duration, 15 ms) was successfully used to treat pigmentary ochre dermatitis secondary to chronic venous insufficiency. The normal skin color was restored, no repigmentation was observed within the 6-month follow-up period, and no side effects occurred.

In contrast, dyschromasia of both upper eyelids was reported as a noteworthy side effect after an IPL treatment
by Pang and Wells [31]. Both eyelids were treated with an IPL device (Quantum SR; Lumenis, Santa Clara, CA, USA; 560–1200 nm; fluence, 24 J/cm²) at a beauty salon without the application of eye shields. The iris has 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.

In another report by Shin et al. [32] published in 2010, vitiligo was introduced as an acquired depigmenting disorder due to IPL treatment for lentigines and dyspigmentation.

It should be emphasized that the first and foremost step in the treatment of pigmented lesions is a doubtless diagnosis and the exclusion of a malignant process. Besides, it has to be emphasized that nevomelanocytic lesions are not a routine indication for laser treatment. For the treatment of benign pigmented, nonnevomelanocytic lesions, Q-switched laser systems are currently the method of choice.

4. Tattoos

Tattoo removal requires very short pulse duration and high light intensities. Only Q-switched lasers fulfil these requirements. IPLs are not suitable for tattoo removal, as Q-switching is not possible in incoherent light sources. IPLs emit pulse durations in the millisecond range, resulting in a prolonged heating of the pigment particles and subsequently in heating of the surrounding tissue. This fact needs to be considered if IPLs are used for hair removal on tattooed skin areas [33] or for facial treatments in areas with permanent makeup.

5. Vascular lesions

There is evidence in the literature for successful treatment of essential telangiectasias [34], rosacea [35, 36], port-wine stains (PWS) [37–41], spider nevi [42], angiomata [43–45], and erythrosis [34]. For the treatment of essential telangiectasias, PWS, and rosacea level of evidence IIB is reached. In 2007, the European Society for Laser Dermatology published guidelines for the use of IPLs in the treatment of vascular malformations [46].

5.1. Port-wine stains

In a controlled comparative split-face study, our research group evaluated the efficacy and the side effects of IPL treatment (Ellipse Flex; Danish Dermatologic Development, Hoersholm, Denmark; 555–950 nm; fluence, 11.0–16.9 J/cm²; spot size, 10×48 mm; pulse duration, 8 or 10 ms) of PWS in a direct comparison to a short-pulsed dye laser (SPDL) (C-Beam™; Candela Laser Corp.; 585 nm; fluence, 6 J/cm²; spot diameter, 7 mm; pulse duration, 450 ms) and a long-pulsed dye laser (LPDL) (Sclero; Candela Laser Corp.; wavelengths, 585, 590, 595, and 600 nm; fluence depending on the respective wavelength, 12 J/cm² at 585 nm, 14 J/cm² at 590 nm, 16 J/cm² at 595 nm, and 18 J/cm² at 600 nm; circular foot print (diameter), 5 mm; pulse duration, 1500 ms) in untreated (n=11) and previously treated (n=14) patients with PWS [47]. In previously untreated PWS as well as in pretreated PWS, IPL treatments were rated significantly (p<0.05) better than treatments with the SPDL (585 nm; fluence, 6 J/cm²; pulse duration, 0.45 ms). In both groups, IPL and LPDL (585-/590-/595-/600-nm cut-off filters; fluencies, 12/14/16/18 J/cm²; pulse duration, 1.5 ms), treatments did not differ significantly. There were few side effects at all settings.

Besides multiple uncontrolled trials, two other works provide data from controlled side-by-side comparisons of IPLs and the standard therapy, the PDL [48, 49]. Faurschou et al. [48] treated 20 patients with PWS in a side-by-side trial with a PDL (V-beam Perfecta; Candela Laser Corp.; 595 nm; pulse duration, 0.45–1.5 ms) and an IPL device (StarLux; Palomar Medical Technologies; 500–670 and 870–1400 nm; fluence, 7–14 J/cm²; pulse duration, 5–10 ms). The researchers found that both PDL and IPL treatment significantly lightened PWS, whereas median clinical improvements were significantly better with the PDL (65%) than with the IPL device (30%). McGill et al. [49] compared a PDL, an alexandrite, a KTP, and an Nd:YAG laser as well as an IPL device (Lumina; Lynton Lasers, Cheshire, UK; 550–1100 nm; fluence, 28–34 J/cm²; spot size, 10×10 mm; double pulse; delay time, 10 ms) in a split-lesion modus in 18 patients with PWS. In this study, the alexandrite laser was most effective and resulted in fading PWS in 10 patients, but hyperpigmentation (n=4) and scarring (n=1) were frequent. IPL treatment 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 double-passed PDL treatment.

5.2. Rosacea and erythrosis

In 2011, Kassir et al. [50] evaluated an IPL device (NaturaLight IPL System; Focus Medical, Bethel, CT, USA; filter, 420 or 530 nm; fluencies, 10–20 or 10–30 J/cm²; 2.5/5 ms, double, triple, or quadruple pulse; delay time, 20–30 ms) in 102 patients with mild to severe rosacea. A mean of 7.2 treatments were applied in 1- to 3-week intervals. A reduction in redness was documented in 80% of patients, reduced flushing and improved skin texture in 78%, and fewer acneiform were achieved in 72% of patients. There were no complications or adverse effects.

Papaioannou et al. [36] assessed the efficacy of an IPL device (Quantum SR; Lumenis, London, UK; 560–1200 nm; fluence, 24–32 J/cm²; spot size, 34×8 mm, double pulses of 2.4/4.0/5.0/6.0 ms depending on the skin type) for the treatment (four treatments, 3-week 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 visual analogue scale (VAS). The results were sustained at 6 months. Side effects were minimal and self-limiting.

Schroeter et al. [35] approved these positive results in the treatment of rosacea, testing the effectiveness of IPL devices...
hyperpigmentation.

transient hypopigmentation; another patient showed transient 76 – 90 % in six of nine patients, 51 – 75 % in two patients, 14 – 18 ms). According to their results, clearance rates were assessed the efficacy and safety up to 12 months after treatment. In total, 51 patients showed a marked improvement, 10 a moderate improvement, and 2 a slight improvement. Side effects were rare (moderate erythema persisted in five patients after the end of treatment.

Campolmi et al. [52] used an IPL device (Minisilk FT; DEKA Medical Inc., USA; 500–520/550 nm cut-off filters dependent on the types of lesion and the patient’s skin types; fluence, 16–23 J/cm²; pulse time, 3–8 ms; double pulse; pulse delay, 10 ms) in patients with poikiloderma of Civatte (n=28) and rosacea (n=35) repeatedly over a period of 2 years. They assessed the efficacy and safety up to 12 months after treatment. In total, 51 patients showed a marked improvement, 10 a moderate improvement, and 2 a slight improvement. Side effects were seldom.

Madonna Terracina et al. [53] used an IPL device (IPL Quantum; Lumenis, Santa Clara, CA, USA; 560-nm filter; fluence, 25 J/cm²; pulse train, 2.4 and 6.0 ms; delay time, 15 ms) in the treatment of facial erythematotelangiectatic rosacea. In total, 29 patients underwent 3-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.

Wenzel et al. [34] reported about the successful treatment of patients with progressive disseminated essential telangiectasia (n=4) and erythrosis interfollicularis colli (n=5) by means of an IPL device (Ellipse Flex; Danish Dermatologic Development, Hoersholm, Denmark; 555–950 nm; fluence, 11.7–17 J/cm²; spot size, 10×48 mm; pulse duration, 14–18 ms). According to their results, clearance rates were 76–90% in six 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 had transient crusts and blisters, which resulted in transient hypopigmentation; another patient showed transient hyperpigmentation.

5.3. Telangiectasias

Nymann et al. [54] compared an LPDL (V-beam; Candela Laser Corp.; 395 nm) to an IPL device (Ellipse Flex; Danish Dermatologic Development, Hoersholm, Denmark; 530–750 or 555–950 nm; fluence, 8–20 J/cm²; spot size, 10×48 mm; pulse duration, 10–20 ms) in a randomized, controlled split-face trial (three settings; 3-month follow-up) in 49 patients with symmetrically located facial telangiectasias. According to the blinded assessment, both treatments showed good or excellent response in 30 of 39 patients. A 75–100% vessel clearance rate was found in 18 (LPDL) vs. 11 (IPL) patients (p<0.01). LPDL was classified as less painful. No adverse effects occurred. In another randomized split-lesion trial [55], the same authors compared both devices in 13 patients 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) vs. 50% (IPL) (p<0.01) 3 months after treatment. LPDL treatments were associated with lower pain scores than IPL treatments. Even if the patients’ satisfaction did not differ significantly, more patients preferred the LPDL (n=9) to IPL treatment (n=2) (p<0.01).

Bjerring et al. [56] evaluated the effectiveness and side effects of the same IPL device (Ellipse Flex; Danish Dermatologic Development, Hoersholm, Denmark; 555–950 nm; fluence: 10–26 J/cm², spot size: 10×48 mm, pulse duration: 10–30 ms) in 24 patients with facial telangiectasias. On average, 2.5±0.96 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. [57] compared an IPL device (Vasculight; Lumenis, London, UK; filter: 515, 550, or 570 nm; fluence, 15–38 J/cm²; pulse duration, not stated) to an Nd:YAG (Vasculight; Lumenis, London, UK; 1064 nm; fluence, 120–140 J/cm²) laser in 25 patients with telangiectasias, leg veins, or cherry angiomas. Patients with telangiectasias, cherry angiomas, or leg veins <1 mm were more satisfied after IPL treatment, whereas patients with leg veins >1 mm were more satisfied after Nd:YAG treatment. Overall, satisfaction with treatment of vascular lesions was greater with Nd:YAG laser, although this method was reported to be more painful.

Retamar et al. [58] investigated the effectiveness and safety of an IPL device (type unknown; 515–1200 nm) in the treatment of linear and spider facial telangiectasias in 140 patients. In this study, 94 (67.1%) patients showed excellent (clearance of 80–100%), 43 (30.7%) good (clearance of 40–80%), and 3 (2.1%) poor (clearance <40%) results. Posttreatment side effects were minimal and transient.

6. PDT of nonmelanoma skin cancer

A key indication for PDT is the treatment of nonmelanoma skin cancer such as actinic keratoses (AK) or superficial basal cell carcinomas [59]. Aminolevulinic acid (ALA) or its methyl ester (MAL) are prodrugs that have to be converted into their active form, i.e., protoporphyrin IX (PpIX) [60, 61].
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 and MAL are used for PDT in combination with IPL for the treatment of non-melanoma skin cancer [62]. Major side effects of PDT are phototoxic reactions (erythema, edema, hyperpigmentation) and pain during the treatment, which is dependent on the type of photosensitizer used, the treatment area, and the type of lesion treated [63].

Haddad et al. [64] evaluated the effect of increasing the fluence (20, 25, 40, and 50 J/cm²) of an IPL device on the outcome of ALA-PDT (single treatment, 2-h incubation) in 24 patients with AK and photodamaged skin. The assessment 8 weeks after treatment indicated that AK clearance improved with increasing fluence. The mean posttreatment AK grade was 56% lower in the 50-J/cm² treatment group, 50% lower in the 40-J/cm² group, 32% lower in the 25-J/cm² group, 20% lower in the 20-J/cm² group, and 7% lower in the control group as compared with the mean pretreatment AK grades. Erythema, edema, crusts and erosion, and pain did not cause any patient to discontinue the study.

Our group compared the efficacy and painfulness of an IPL device (Energist Ultra VPL; Energist Ltd., Swansea, UK; 610–950 nm; two pulse trains, each 15 pulses of 5 ms; delay, 20 ms; fluence, 40 J/cm² per pulse train) to a standard light source in comparison to IPL alone was evaluated. Three irradiation but with significantly less pain [V AS, 4.3 (IPL) vs. 6.4 (LED); \( ^{<}0.001 \)].

Kim et al. [66] conducted a clinical and histopathological trial to confirm the effectiveness of topical ALA-PDT using an IPL device (Ellipse Flex; Danish Dermatologic Development, Hoersholm, Denmark; 555–950 nm; fluence, 12–16 J/cm²; spot size, 10×48 mm; pulse duration, 20–30 ms; two pulses) as light source. In total, 12 AK lesions in 7 patients were treated. Eight or 12 weeks after treatment, the clinical response was assessed, and histopathological examinations were conducted on clinically resolved lesions. As a result, 6 (50%) of 12 lesions showed clinical clearance after a single treatment, but histological examinations showed that only 5 (42%) of 12 lesions had been removed. Complications, such as pigmentedary changes or scarring, were not observed. According to these results, determining complete remission in AK requires caution, and long-term follow-up or histological confirmation may be required.

Gold et al. [67] focused on the treatment of AK and associated photodamaged skin. In a split-face study involving 16 patients (three treatments, 1-month intervals), short-contact (30–60 min) ALA-PDT with an IPL device (vasculight; Lumenis, Yokneam, Israel; 550- or 570-nm filter; fluence, 34 J/cm²; spot size, 8×16 mm; double pulsing; delay, 20 ms) as light source in comparison to IPL alone was evaluated. Three months after the final treatment, ALA-PDT-IPL showed a significantly better improvement, compared with IPL alone, in the clearance rate of AK lesions (78% vs. 53.6%) as well as 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%; telangiectasias, 84.6% vs. 53.8%). Thus, this study further proves the usefulness of ALA-PDT-IPL in the successful treatment of AK and signs of photodamage. As to whether 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 noteworthy, 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 AK.

7. Photorejuvenation/photodynamic photorejuvenation

Photorejuvenation is the use of light devices to remove clinical signs arising from photoaging. If the process is combined with a photosensitizer so that a photodynamic reaction takes place, it is called photodynamic photorejuvenation. Clinical hallmark features of photoaging are skin roughness, epidermal neoplasias, mottled pigmentation, telangiectasias, erythema, thin wrinkles, lax skin texture, and sebaceous gland hypertrophy [68].

To define the mechanism of action of IPL application in photorejuvenation, biopsies taken before and after IPL treatment were examined histologically [19]. 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 [19]. Wong et al. [69] examined the effects of IPL irradiation (triple pulses, 7 ms; pulse interval, 70 ms; fluences, 20, 50, and 75 J/cm²) on normal human dermal fibroblasts grown in contracted collagen lattices. Twenty-four hours after IPL irradiation, a dose-dependent increase in viable cells as well as an up-regulated expression of collagen III and TGF-β1 in dermal fibroblasts could be observed. No significant change in mRNA levels of collagen I and fibronectin was reported. Cao et al. [70] evaluated the effects of IPL irradiation (double pulses, 4/6 ms; pulse interval, 20 ms; fluences, 18, 23, 28, and 33 J/cm²). They were able to show that 24 h after irradiation, cell viability of skin fibroblasts improved in a dose-dependent manner (increase of percentage of fibroblasts at the S and G/M stage of the cell cycle). IPL irradiation increased the expression of collagen (types I and III) at the mRNA and protein level. Thus, cytological and morphological evidence exists for clinical improvement of the skin texture after IPL irradiation. Regarding photodynamic photorejuvenation, Park...
et al. [71] performed a study on 14 patients with photodamaged skin. Skin biopsies taken before and 1 month after PDT revealed an increase in mean epidermal thickness, expression of types I and III procollagen, and dermal collagen volume and a decrease in dermal elastotic material, expression of matrix metalloproteinases 1, 3, and 12, and inflammatory infiltrate.

Besides these histomorphological investigations, there have been a couple of controlled clinical trials published so far. Palm and Goldman [72] compared the effectiveness of MAL-PDT with red vs. blue light for photodynamic photorejuvenation in 18 patients with moderate to severe facial photodamage. The authors did not find a statistically significant difference between blue and red light in terms of efficacy and side effects. The greatest improvement was achieved in pigmentation, AK, and erythema. Kosaka et al. [73] conducted a comparative study with 16 Asian patients with facial photodamage to compare the effectiveness of photodynamic photorejuvenation (5% ALA; 2-h incubation; IPL irradiation, 500–670 and 870–1400 nm; 23–30 J/cm²) and photorejuvenation under the use of IPL light only. Three treatments (4-week intervals) were applied in a split-face modus. Although the treatment results did not differ significantly between the two sides in all subjects, 75% of the patients considered the ALA-PDT-IPL treated side as better than the IPL-only treated side. However, all ALA-PDT-IPL treated sides showed adverse effects such as erythema and pain.

Shin et al. [74] treated 26 Korean women with wrinkles and facial dyschromias at 4-week intervals using an IPL device (Powerlite 600⁰EX, Scandinavia Corp., Japan; 530-nm cutoff filter; fluence, 15.5–17.5 J/cm²; pulse duration, 5×2 ms; delay, 5×2 ms). The authors reported that pigmented lesions (p<0.05), skin elasticity, and wrinkles improved while sebum secretion and water content of skin remained unchanged. Butler et al. [75] performed a split-face comparison of IPL vs. KTP laser treatment in 17 patients, of skin types I–IV, with dyschromias and telangiectasias. The mean improvement 1 month after the treatment vascular/pigment lesions was 38% and 35% for the IPL side vs. 42% and 30% for the KTP side. The patients’ assessment revealed a mean global improvement of 66% (IPL) vs. 61% (KTP) and a higher rate of side effects due to KTP treatment (pain, postprocedure swelling).

In a randomized controlled split-face trial, Jørgensen et al. [76] evaluated the efficacy and adverse effects of an LPDL (V-beam Perfecta; Candela Laser Corp.; 595 nm) and an IPL device (Ellipse Flex; Danish Dermatologic Development, Hoersholm, Denmark; 530–750 or 555–950 nm; fluence, 6–20 J/cm²; spot size, 10×48 mm; pulse duration, 2×2.5 ms; delay, 10 or 8–20 ms) in the treatment (three treatments; 3-week intervals) of photodamaged skin in 20 women with Fitzpatrick skin types I–III. One, three, and six months after therapy, patients as well as blinded investigators assessed the impact on telangiectasias, pigmentation, skin texture, rhytides, 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 with the same specifications, Bjerring et al. [77] compared the clinical efficacy and safety of two different filter sets of 555–950 nm (VL) and 530–750 nm (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 a lower rate of side effects. The greatest improvement was seen in pigmentation, AK, and erythema. Kosaka et al. [78] conducted in a split-face randomized prospective trial in 32 women (Fitzpatrick skin type I–III) with class I or II rhytides. Nine months after the final treatment, blinded investigators and patients assessed significant improvement in telangiectasias (p<0.001) and in irregular pigmentation (p<0.03) between treated and untreated sides but no significant difference in rhytides.

Li et al. [79] evaluated the efficacy and safety of an IPL device (Lumenis One; Lumenis, Santa Clara, CA, USA; 515–1200 nm; fluence, 11–20 J/cm²; double- or triple-pulse mode; pulse duration, 2.5–4 ms; delay time, 20–40 ms) in the treatment (four treatments, 3- to 4-week intervals) of photoaged skin in 152 Asian patients. In this study, assessment showed a score decrease of three or two grades in 91.4% of patients. In total, 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. [80] compared in a split-face study the effectiveness of an IPL device (Smooth Pulsed Light; Palomar Medical Technologies; 470–1400 nm; fluence, 27–40 J/cm²; pulse duration, 20 ms) to an LPDL (V-beam; Candela Laser Corp.; 595 nm; fluence, 9–12 J/cm²; spot size, 7 mm; pulse duration, 1.5 ms) in the treatment (six treatment sessions) of facial skin rejuvenation in 10 Asian patients (Fitzpatrick skin types III–IV). Three months after the last treatment, lentigines had improved by 62.3% (IPL) vs. 81.1% (LPDL). No significant difference was evident between IPL and LPDL treatment in wrinkle reduction, and no scarring or pigmentary change were seen with either device.

Sequential Er:YAG laser treatment vs. IPL treatment (StarLux; Palomar Medical Technologies; 560-nm filter; fluence, 30 J/cm²; pulse duration, 2.4 and 4.0 ms; delay, 10 ms) for mild to moderate facial photodamage was compared by Hantash et al. [81] in a split-face randomized prospective trial in 10 patients with facial dyschromia and rhytides. Assessment 3 months after the final treatment (three treatments, 1-month intervals) showed that IPL and Er:YAG treatments did not significantly improve rhytid scores. However, subjective and blinded physician dyschromia scores improved by 26%
and 38% (IPL) vs. 7% and 29% (Er:YAG). Subjective global facial appearance scores worsened by 5% (Er:YAG) vs. 28% (IPL), whereas blinded physician scores improved by 16% (Er:YAG) vs. 20% (IPL). 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 are heterogeneous. Obviously, IPL treatment is a good alternative to laser therapy in terms of vascular and pigment disturbances rather than wrinkle reduction. The relatively low incidence of complications is advantageous when compared with laser devices. The combination of IPL with a suitable photosensitizer (ALA, MAL) seems to enhance the impact on photodamaged skin. However, there is still no standardized protocol for photodynamic photorejuvenation.

8. Conclusions

Based on a large body of works, IPL devices can be considered as safe and effective in the treatment of a variety of skin conditions (Table 1). Hereby, the effectiveness of IPLs seems to be comparable to lasers, especially if treating vascular malformations or hypertrichiosis. However, there is still a need for large, controlled and blinded, comparative trials with an extended follow-up period. Most users of IPL devices are impressed by the versatility and low cost of IPLs. If treating large areas, IPLs may be advantageous because of their high skin coverage rate.

References


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