

Nonvascular uses of pulsed dye laser in clinical dermatology

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Abstract

Lasers are fast becoming the vogue of dermatology ranging from ablative, nonablative, fractional photothermolysis to vascular lasers. There are a range of vascular lasers including potassium titanyl phosphate (KTP 532 nm), pulsed dye laser (PDL –595 nm), diode (810 nm), and Nd:YAG (1064 nm). PDL is a laser that emits yellow light using Rhodamine dye as its lasing medium. Typical vascular lesions which are treated by PDL include port wine stain, hemangioma, telangiectasia, spider angioma, and rosacea. This article focuses on the use of PDL beyond primary vascular conditions. We review the evidence, or lack thereof, of the use of PDL in acne vulgaris, scars, striae, warts, molluscum, psoriasis, rejuvenation, basal cell carcinoma (BCC), and miscellaneous dermatological sequelae.

KEYWORDS

acne, laser, nonvascular, psoriasis, pulsed dye, scar

1 | INTRODUCTION

Lasers are fast becoming the vogue of dermatology ranging from ablative, nonablative, fractional photothermolysis to vascular lasers. There are a range of vascular lasers including potassium titanyl phosphate (KTP 532 nm), pulsed dye laser (PDL 595 nm), diode (810 nm), Nd:YAG (1064 nm), and intense pulsed light (IPL [vascular filter]). PDL is a laser that emits light from a rhodamine dye solution and was initially introduced in the 1980s for vascular malformations and now represents the Gold standard vascular laser with a wealth of published evidence. The 595-nm wavelength targets oxyhemoglobin found in erythrocytes. The main modes of actions are photothermal, including coagulation of the blood and endothelial damage in conjunction with photochemical effects. Typical vascular lesions which are treated by PDL include port wine stain, hemangioma, telangiectasia, spider angioma, and rosacea. This article focuses on the use of PDL beyond vascular malformations. We review the evidence, or lack thereof, of the use of PDL in acne vulgaris, scars, striae, warts, molluscum, psoriasis, rejuvenation, basal cell carcinoma (BCC), and miscellaneous dermatological sequelae. Please refer to Table 1 for details.

2 | ACNE VULGARIS

Acne vulgaris is one of the most common skin ailments in adolescents, with a prevalence nearing 90%.¹ The mechanism of acne is well known to be a multifactorial process and its physical and psychological sequelae have a huge impact on the quality of life (QOL) of its sufferers. Although conventional treatment is known to be beneficial in most patients, there are always recalcitrant cases or patients who cannot tolerate traditional antibiotics or isotretinoin due to their side effects. PDL's mechanism of treatment in acne is both photochemical, by killing *Cutibacterium acnes* (one of the known contributory mechanisms) through the oxidative reaction as a result of porphyrin absorption² in addition to photothermal effects on the sebaceous glands and microvasculature.³

We have reviewed 12 studies, consisting of a total of 359 patients between 2003 and 2017 reviewing the use of PDL in acne. Split-face studies comparing PDL to either no treatment,^{4,5} combined PDL and clindamycin 1%, benzoyl peroxide 5%,⁶ 1064 nm Nd:YAG,⁷ combined PDL and 1064 nm Nd:YAG⁸ showed no significant difference between treatment arms. However, Choi et al found in a randomized split-face trial of 20 patients comparing IPL to PDL

TABLE 1 Summary of literature on the nonvascular uses of PDL in dermatology

Study	Indication	Patients	Findings
Acne Vulgaris			
Lekwuttikarn et al (2017) ⁴	Randomized, controlled trial split-faced study of 595-nm PDL in the treatment of acne vulgaris and acne erythema in adolescents and early adulthood	N = 30	Split-faced 595-nm PDL (fluence 8 J/cm ³ pulse duration 10 ms, spot size 7 mm 2 sessions 2 weekly vs no treatment Results: no significant improvement in acne between treated and untreated side
Salah at al (2017) ⁸⁴	Comparison of PDL vs combined pulsed dye laser and Nd: YAG laser in the treatment of inflammatory acne vulgaris	N = 30	Split-face study of PDL vs combined 585/1064-nm laser Results: Significant improvement in both side but no difference between treatment arms
Voravutinon et al (2016) ¹³	A comparative split-face study using different mild purpuric and subpurpuric fluence level of 595-nm PDL for treatment of moderate to severe Acne vulgaris	N = 55	Results: Overall significant decreases in lesions in comparison with baseline—but no difference between fluences SE: temporary hyperpigmentation
Lekakh et al (2015) ⁸⁵	Treatment of acne vulgaris with salicylic acid chemical peel and PDL: a split-face, rater-blinded, randomized controlled trial	N = 18	3 treatments at 3 weekly intervals. Week 0, 3, and 6: half of face treated with PDL then 30% salicylic acid peel Results: Overall both groups had significant improvement but global acne severity (GEA) scale scoring showed statically greater improvement with PDL combination treatment group ($P = 0.003$)
Choi et al (2010) ⁹	Intense pulsed light vs PDL in the treatment of facial acne: a randomized split-face trial	N = 20	IPL on one side of face and then PDL on the other 4 treatments, 2 weekly Results: both effective-PDL, more sustained effect
Karsai, Schmitt and Raulin (2010) ⁶	PDL as an adjuvant treatment modality in acne vulgaris: a randomized controlled single-blinded trial	N = 88	Medical treatment with clindamycin 1%-benzoyl peroxide 5% hydrating gel alone vs medical treatment in conjunction with PDL (wavelength 585-nm, energy fluence 3 J/cm ² , pulse duration 0.35 ms, spot size 7 mm) Results: improvement in both treatment arms but no significant difference between treatments
Passeron, Khemis, Ortonne (2009) ⁵	PDL-mediated photodynamic therapy for acne inversa is not successful: a pilot study on four cases	N = 4	Result: no improvement when comparing to control SE: intense pain
Lee et al (2009) ⁷	Comparison of a 585-nm PDL and a 1064-nm Nd: YAG laser for the treatment of acne scars: A randomized split-face clinical study	N = 18	Results: Both lasers showed improvement in acne. PDL-treated ice-pick scars better than ND: YAG
Jung et al (2009) ⁸	Comparison of a PDL and a combined 585/1064-nm laser in the treatment of acne vulgaris	N = 16	Single pass of a combined 585/1064-nm laser on half of the face and PDL on the other half for 3 sessions 2 weekly Results: inflammatory acne lesions were reduced by 86% on the PDL sides and by 89% on the 585/1064-nm laser sides
Yoon et al (2008) ¹⁰	Acne erythema improvement by long-pulsed 595-nm PDL treatment: a pilot study	N = 20	595-nm PDL 2 sessions 4 weekly Results: 90% clinical improvement with reduced lesion count from baseline SE: transient erythema and edema
Alexiades-Armenakas (2006) ¹¹	Long PDL-mediated photodynamic therapy (PDT) combined with topical therapy for mild to severe comedonal, inflammatory, or cystic acne	N = 19	Results: Complete clearance in 100% patients in the LP PDL-PDT-treated group

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TABLE 1 (Continued)

Study	Indication	Patients	Findings
Seaton et al (2003) ¹²	PDL treatment for inflammatory acne vulgaris: randomized controlled trial. PDL vs placebo treatment—one treatment only	N = 41	Results: At 12 wk, acne severity reduced from 3.8 to 1.9 in the PDL group and 3.6 to 3.5 in the placebo group ($P = 0.007$)
Scars/cosmetic			
Tao et al (2018) ¹⁷	Treatment of burn scars in Fitzpatrick phototype III patients with a combination of PDL and nonablative fractional resurfacing 1550-nm erbium: glass/1927-nm thulium laser devices	N = 2	Patient one: 3× 595 nm PDL (7 mm, 8 J, 6 ms), 6× 1550 nm erbium: glass laser (30 mJ, 14% density, 4-8 passes) and 5× 1927 nm thulium laser (10 mJ, 30% density, 4-8 passes) Results: significant improvement in thickness, texture, and color Patient two: 2× 595 nm PDL (5 mm, 7.5 J, 6 ms), 4× 1550 nm erbium: glass laser (30 mJ, 14% density, 4-8 passes) 2× 1927 nm thulium laser (10 mJ, 30% density, 4-8 passes) Results: thinner, smoother and more normal in pigmentation of scars
Ouyang et al (2018) ¹⁹	Comparison of the effectiveness of PDL vs PDL combined with ultra pulse fractional CO ₂ laser in the treatment of immature red hypertrophic scars	N = 56	Control group: 595-nm PDL at a fluence of 7-15 J/cm ² , pulse widths of 1.5-3 ms, 7-mm spot size Treatment group: fractional CO ₂ laser (Ultra Pulse CO ₂ : Deep FX, Energy: 30~50 mJ, Frequency: 300 Hz, Density 5% post-PDL treatment (as above) Results: Control group outcome better than the treatment group ($P < 0.05$) in VSS score, melanin, height, and vascularity
Park et al (2016) ¹⁸	Combined treatment with 595-nm PDL and 1550-nm erbium-glass fractional laser for traumatic scars	N = 2	Results: Combined consecutive treatment with PDL and 1550-nm erbium-glass fractional laser demonstrated clinical improvement after a course of treatment
Al- Mohamady, Ibrahim, Muhammad (2016) ²²	PDL vs long-pulsed Nd: YAG laser in the treatment of hypertrophic scars and keloid: A comparative randomized split-scar trial	N = 20	Split scar 6 treatments 1 mo of either PDL or long-pulse Nd: YAG Results: Vancouver scar scale (VSS) analysis showed significant improvement in both ($P < 0.001$) but no difference between the two treatments
Lee et al (2015) ²⁵	Combined treatment with botulinum toxin and 595-nm PDL for traumatic scarring	N = 2	Patient one—4 treatments 2 weekly Patient 2—2 treatments 3 weekly Results: Good cosmetic result SE: mild pain
Keaney et al (2016) ²⁶	Comparison of 532-nm potassium titanyl phosphate laser and 595-nm PDL in the treatment of erythematous surgical scars: a randomized, controlled, open-label study	N = 20	Scars divided into two halves Each half randomized to receive 3× 6 weekly treatment with either a 532-nm KTP laser or a 595-nm PDL Result: Overall significant clinical improvement in both with no statistically significant difference between the treatment arms
Vranova et al (2015) ²⁷	Comparison of quality of facial scars after single low-level laser therapy and combined low-level with high-level (PDL 595 nm) laser therapy	N = 41	14 patients: single low-level laser therapy (670 nm, fluence 3-5 J/cm ²) 17 patients: combined PDL 595 nm (spot size 7 mm, delay 0.45 ms or 1.5 ms, fluence 9-11 J/cm ²) and low-level laser therapy 10 patients (control group): untreated Result: significant improvement in both treatment groups ($P < 0.0001$) using POSAS questionnaire

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TABLE 1 (Continued)

Study	Indication	Patients	Findings
Kim et al (2014) ²⁰	A comparison of the scar prevention effect between CO ₂ fractional laser and PDL in surgical scars	N = 14	Scars divided into two halves Half treated with 10 600-nm AFL and another half with the 595-nm PDL Results: PDL and AFL treatments for surgical scar provide significant improvement. PDL was more effective in color of scar compared with AFL
Gladsjo and Jiang (2014) ²⁸	Treatment of surgical scars using a 595-nm PDL using purpuric and nonpurpuric parameters: a comparative study	N = 26	Scars divided into three sections Treatment randomized to: (a) 595-nm PDL with purpuric (1.5 ms) or (b) nonpurpuric (10 ms) settings or (c) no treatment Result: Nonpurpuric PDL showed significant improvement
Stephanides et al (2011) ³⁴	Treatment of refractory keloids with PDL alone and with rotational PDL and intralesional corticosteroids: a retrospective case series	N = 99 (755 keloids)	Results: PDL with or without intralesional triamcinolone moderately effective treatment of keloids from review of case notes
Nouri et al (2010) ³⁰	Comparison of the effects of short- and long-pulse durations when using a 585-nm PDL in the treatment of new surgical scars	N = 20	Scar divided into 3 sections One control One 585-nm PDL, 7 mm spot size, 4.0 J at 450 μ s One as above but at 1.5-ms pulse Total of 4 treatments Results: Overall significant improvement in PDL-treated sections ($P < 0.05$) but no difference between short and long pulses
Nouri et al (2009) ²⁹	Comparison of the effectiveness of the PDL 585 nm vs 595 nm in the treatment of new surgical scars. A prospective, nonrandomized, double-blind, controlled	N = 14 (19 postoperative scars)	Scars divided into 3 sections 1. PDL at 585 nm or 2. PDL at 595 nm (3.5 J/cm ² , 450 micros, 10 mm spot size) 3. Untreated control Results: According to VSS, pigmentation, vascularity, and pliability: Both PDL wavelengths improvement scar appearance compared control. 585 nm preferential in wavelength (better improvement in height, vascularity, and pliability of scars)
Tierney et al (2009) ²³	Treatment of surgical scars with nonablative fractional laser vs PDL: a randomized controlled trial	N = 12 (15 scars)	Scar divided into two and treated with either 1550-nm NAFL or 595-nm PDL 4 treatments, 2 weekly Result: NAFL better outcome in scar appearance than PDL
Martins, Trindade, Leite (2008) ²⁴	Facial scars after a road accident--combined treatment with PDL and Q-switched Nd: YAG laser	N = 1	Combined laser treatment with PDL and Q-switched Nd: YAG laser for erythematous, atrophic, and hypertrophic scars on face Results: very good cosmetic outcome
Manuskiatti, Wanitphakdeedecha, Fitzpatrick (2007) ³¹	Effect of pulse width of a 595-nm flash lamp-pumped PDL on the treatment response of keloidal and hypertrophic sternotomy scars	N = 19	Scar divided into 2 segments and treated with 595-nm PDL at a fluence of 7 J/cm ² either pulse width of 0.45 or 40 ms 4 weekly three times Results: segments treated with 0.45 ms significantly greater improvement than if treated with 40-ms pulse length

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TABLE 1 (Continued)

Study	Indication	Patients	Findings
Asilian, Darougheh, Shariati (2006) ³²	New combination of triamcinolone, 5-FU, and PDL for treatment of keloid and hypertrophic scars	N = 60	Group 1: Intralesional triamcinolone acetone (TAC, 10 mg/mL) weekly for 8 wk Group 2: TAC+ 5-FU weekly for 8 wk Group 3: as per group 2+ PDL 585 nm (5-7.5 J/cm ²) at 1, 4, and 8 wk Results: All groups improvement Statistically more significant in group 2 and 3 ($P < 0.5$). Group 3 thought to be best approach
Bellew, Weiss & Weiss (2005) ³⁵	Comparison of intense pulsed light (IPL) to 595-nm long-pulsed pulsed dye laser (LPDL) for treatment of hypertrophic surgical scars: a pilot study	N = 15 (scars)	2 treatments 2 monthly Half scar treated with IPL other half with LPDL Results: LPDL and IPL equally effective in improving hypertrophic surgical scars
Kono et al (2003) ¹⁵	The flash lamp-pumped PDL (585 nm) treatment of hypertrophic scars in Asians	N = 13 (19 scars)	PDL 585 nm (pulse duration of 450 μ s, energy fluence of 6 J/cm ² , and spot diameter of 7 mm) 4-8 weekly Results: 84% showed clinical improvement
Nouri et al (2003) ¹⁶	585-nm PDL in the treatment of surgical scars starting on the suture removal day	N = 11 (12 scars)	585-nm PDL (450 ms, 10 mm spot size, 3.5 J/cm ² with 10% overlap) on one scar half, other half-no treatment 3 treatments, monthly Results: VSS score 54% improvement vs 10% improvement in controls ($P = 0.0002$)
Manuskiatti & Fitzpatrick (2002) ³³	Treatment response of keloidal and hypertrophic sternotomy scars: comparison among intralesional corticosteroid, 5-FU, and 585-nm PDL treatments	N = 10	Scar divided into 5 sections and treated with 1. 585-nm PDL (5 J/cm) 2. iTAC 3. i5-FU 4. iTAC and i5-FU 5. no treatment Results: statistical clinical improvement in all treated segments, comparable outcomes between treatment groups (1-4) except more SE in group 2
Alster, Lewis and Rosenbach (1998) ²¹	Laser scar revision: comparison of CO ₂ laser vaporization with and without simultaneous pulsed dye laser treatment	N = 20	Scar divided into 2 sections. Half with CO ₂ laser, half with CO ₂ laser, and PDL Results: dual laser found to be the superior treatment
Ghaninejadi et al (2013) ⁸¹	Solar lentigines: evaluating PDL as an effective treatment option	N = 21	PDL 595 nm 10 joules, without dynamic cooling device using extra compress lens Results: 57% of patient had >75% improvement-as per dermoscopy photographs. Mean pigment analysis score was respectively 8 and 2 pre- and post-PDL therapy SE: mild erythema and localized irritation, transient PIH
Defatta et al (2009) ³⁶	PDL for treating ecchymoses after facial cosmetic procedures	N = 20	PDL 10 mm spot size, pulse duration of 6 ms, fluence of 6 J/cm ² Results: 73% mean improvement in ecchymoses scores within 48-72 h SE: mild edema and pain
Striae			
Naeini et al (2014) ⁸⁶	Comparison of the fractional CO ₂ laser and the combined use of a PDL with fractional CO ₂ laser in striae alba treatment	N = 3 (88 lesions)	Lesions on each half of the body were split randomly into 2 groups Group 1: Fractional CO ₂ laser resurfacing Group 2: combination of PDL and Fractional CO ₂ laser Result: Mean VAS and dermatologist assessed improvement scale in group 2 significantly higher than group 1 ($P < 0.001$ and 0.04, respectively)

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TABLE 1 (Continued)

Study	Indication	Patients	Findings
Shokeir et al (2014) ⁸⁷	Efficacy of PDL vs IPL in the treatment of striae distensae	N = 20	One side of body treated with PDL, the other with IPL 5 times, 4 weekly Results: Striae improved after both treatments. Striae rubra better result to both than striae alba PDL significantly increased collagen 1 expression compared with IPL, ($P < 0.001$ and $P = 0.193$, respectively)
Nehal et al (1999) ⁴⁰	Treatment of mature striae with PDL	N = 5	Abdominal striae treated with PDL 585 nm 2 monthly for 1-2 y Results: slight overall subjective improvement
Warts			
Shin et al (2017) ⁴⁴	A comparative study of PDL vs long-pulsed Nd: YAG laser treatment in recalcitrant viral warts	N = 72	A total of 39 patients treated with PDL (spot size, 7 mm; pulse duration, 1.5 ms; and fluence, 10-14 J/cm ²) and 39 with LPNY (spot size, 5 mm; pulse duration, 20 ms; and fluence, 240-300 J/cm ²) Results: complete clearance in 5.1% of PDL group and 9.1% of LPNY group. At least 50% improvement in 51.3% of PDL and 66.7% of LPNY group
Dobson & Harland (2014) ⁴⁶	PDL and intralesional bleomycin for the treatment of recalcitrant cutaneous warts	N = 20	2 treatments given Results: 60% complete response, 15% partial and 25% no response
El-Mohamady et al (2014) ⁴⁵	PDL vs Nd: YAG laser in the treatment of plantar warts: a comparative study	N = 46	Lesions divided into two 6 sessions, 2 weekly Group 1: Nd: YAG (spot size, 7 mm; energy, 100 J/cm ² ; and pulse duration, 20 ms) Group 2: PDL (spot size, 7 mm; energy, 8 J/cm ² ; and pulse duration, 0.5 ms) Results: PDL and Nd: YAG effective treatment but PDL safer but longer treatment required Nd: YAG more SE (hematoma most common)
Grillo et al (2014) ⁴¹	PDL to treat facial flat warts	N = 32	PDL 595 nm, a laser energy density of 9 or 14 J/cm ² with a spot size of 7 or 5 mm Results: Complete response in 14 (44%), excellent response in 18 (56%). FU 1 y. Total of 4 recurrences No SE
Fernandez-Guarino et al (2011) ⁴⁷	Treatment of recalcitrant viral warts with PDL MAL-PDT	N = 19	MAL applied for 3 h + PDL 595 nm (Vbeam; Candela) with subpurpuric parameters as the light source (7 mm, 6 ms, 9 J/cm ² , overlap 50%) until clearance or for maximum of 6 sessions Results: Warts cleared in 53% No SE reported
Sethuraman et al (2010) ⁴²	Effectiveness of PDL in the treatment of recalcitrant warts in children-a retrospective survey	N = 61	On average 3.1 treatment sessions Results: 75% total clearance SE: mild scarring in 2%
Akarsu et al (2006) ⁴⁸	Verruca vulgaris: PDL therapy (group 1) compared with salicylic acid + PDL (group 2)	N = 19 (66 lesions)	Results: both groups size of lesions reduces. NO statistical difference between groups but I group 2 less sessions required to clear lesions

(Continues)

TABLE 1 (Continued)

Study	Indication	Patients	Findings
Passeron et al (2007) ⁴³	595-nm PDL for viral warts: a single-blind randomized comparative study vs placebo	N = 35	PDL 595-nm (spot diameter 5 mm, pulse duration 0.45 ms, fluence 9 J/cm ² with 5 passes at a frequency of 1 Hz) 3 sessions, 3 weekly Group 1 (PDL-n = 19) Group 2 placebo-n = 16) Results: No significant difference in number of warts between group 1 and 2
Smucler & Jatsovea (2005) ⁴⁹	Comparative study of aminolevulinic acid photodynamic therapy plus PDL vs PDL alone in treatment of viral warts	N = 24 (86 lesions)	Results: 100% cure rate after 1.96 sessions in combined group, PDL solo treatment failed in 4% even after average of 2.54 sessions
Robson et al (2000) ⁵⁰	PDL vs conventional therapy in the treatment of warts: a prospective randomized trial	N = 40 (194 lesions)	Group 1: PDL 584 nm (4 treatments 1 mo) Group 2: conventional treatment Results: PDL useful form of treatment but no difference to conventional therapy
Molluscum contagiosum			
Hancox, Jackson and McCagh (2003) ⁵⁴	Treatment of molluscum contagiosum with the PDL over a 28-mo period- A retrospective review	N = 43 (1250 lesions)	Results: All treated lesions resolved, 35% of patients had no new lesions after 2 treatments
Yoshinaga et al (2000) ⁵⁵	Recalcitrant facial molluscum contagiosum in a patient with AIDS: combined treatment with CO ₂ laser, trichloroacetic acid (TCA), and PDL	N = 1	Results: The CO ₂ laser-treated lesions healed within 2 wk The PDL-treated lesions and the TCA-treated lesions resolved completely after one treatment
Hughes (1998) ⁵⁶	Molluscum treated with PDL	N = 1 (lesions = 88)	Double-pulse 585-nm PDL 1 Hz (one pulse per second) with a 3 mm spot size (fluence, 7.0-8.0 J/cm ²) or 5 mm spot size (fluence, 6.8-7.2 J/cm ²) Results: 87/88 lesions complete resolution
Psoriasis			
Arango-Duque (2017) ⁵⁷	Treatment of nail psoriasis with results: plus, calcipotriol betamethasone gel vs Nd: YAG plus calcipotriol betamethasone gel: An inpatient left-to-right controlled study		Right hand-treated with PDL, Left hand with Nd: YAG Results: All patients improvement in nails as per NAPS score. No statistical clinical difference between PDL and Nd: YAG except more SE with Nd: YAG, for example, pain
Peruzzo et al (2017) ⁵⁸	Nail psoriasis treated with PDL	N = 14	Monthly sessions, for a total of 3 mo PDL 585 nm, spot size 7 mm, pulse duration 0.45 ms, fluence 6 J/cm ² Results: Median overall improvement in NAPS score 44% (P = 0.002), nail bed NAPS 50% (P = 0.033), nail matrix NAPS 65.1% (P = 0.024)
Youssef et al (2017) ⁵⁹	PDL to treat nail psoriasis: a controlled study	N = 20	Once monthly PDL sessions were applied to nails for 6 mo, with fluence 8 J/cm ² ; pulse duration 1.5 ms; and spot size 7 mm, applied to the nail plate and proximal nail fold vs no treatment Results: decrease in matrix, nail bed and total NAPS scores in treated nails at month 3 and 7 (P < 0.001) compared to pretreatment scores, and to control nails' scores
Al-Mutairi, Noor and Al-haddad (2014) ⁶¹	Single-blinded left-to-right comparison study of excimer laser vs PDL for the treatment of nail psoriasis	N = 42	Excimer laser vs PDL Group 1: right hand excimer laser 2 weekly Group 2: PDL 4 weekly for 3 mo Results: NAPS improvement > in PDL than Excimer group

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TABLE 1 (Continued)

Study	Indication	Patients	Findings
Goldust and Raghifar (2013) ⁶⁰	Clinical trial study in the treatment of nail psoriasis with PDL	N = 40	80 nails were treated with either 6-millisecond pulse duration and 9 J/cm ² or 0.45-millisecond pulse duration and 6 J/cm ² for 6 mo Results: Significant reduction in NAPS in both groups but no difference between pulse duration SE: transient petechiae and hyperpigmentation
Huang, Chou, Chiang (2013) ⁸⁸	Efficacy of PDL plus topical tazarotene vs topical tazarotene alone in psoriatic nail disease: a single-blind, inpatient left-to-right controlled study	N = 19	One hand (PDL monthly for 6 mo and tazarotene 0.1% cream) Other hand (tazarotene 0.1% cream) Results: Significantly higher percentage of patients had ≥75% improvement at 6 mo in the experimental group than the control group (31.6% vs 5.3%, <i>P</i> = 0.045) PDL and topical tazarotene 0.1% cream effective and safe to treat nail psoriasis
Treewittayapoom et al (2012) ⁵³	The effect of different pulse durations in the treatment of nail psoriasis with 595-nm PDL: a randomized, double-blind, inpatient left-to-right study	N = 20	Group one: 40 nails were treated with PDL 595 nm 6-millisecond pulse duration and 9 J/cm ² Group 2: 39 nails were treated with PDL 595 nm 0.45-millisecond pulse duration and 6 J/cm Results: PDL effective treatment, but no difference between longer and shorter pulse duration
Fernández-Guarino et al (2009) ⁸⁹	PDL vs photodynamic therapy (PDT) in the treatment of refractory nail psoriasis: a comparative pilot study	N = 14 (nails:121)	One hand: monthly PDT Other hand: monthly PDL Results: No significant difference between PDT and PDL hand Both treatments reduced NAPS score and effective in treat nail psoriasis
De Leeuw et al (2009) ⁹⁰	PDL vs UVB-TL01 in Plaque Psoriasis- A single-center, single-blind, prospective, paired randomized controlled study	N = 27	PDL 585-nm wavelength 585 nm, pulse duration 0.450 ms, spot diameter 7 mm, spots overlapping 720%, and fluences between 5.5 and 6.5 J/cm ² vs UVB-TL01 S Half sides of plaques (n = 4) treated with PDL, UVB, a combination of UVB/PDL or no treatment Outcome: Overall improvement in plaque psoriasis with treatment at week 13 (<i>P</i> < 0.001). No statically significant difference between PDL and UVB SE: transient purpura, moderate discomfort, PIH
Erceg et al (2006) ⁶⁴	Efficacy of PDL in the treatment of localized recalcitrant plaque psoriasis: a comparative study	N = 8	PDL (585 nm) and calcipotriol/betamethasone dipropionate treatment given in an open, inpatient, left-right comparison Results: PDL more significant reduction in plaque (62% vs 19% in topical therapy group) SE: post-PDL pain
De Leeuw et al (2006) ⁹¹	Concomitant treatment of psoriasis of the hands and feet with pulsed dye laser and topical calcipotriol, salicylic acid, or both: a prospective open study in 41 patients	N = 41	PDL 585-nm (450-microsecond pulse duration, 7 mm spot diameter, and 5- to 6.5-J/cm ² fluence) 4-6 weekly In conjunction with calcipotriol ointment and salicylic acid 5%-10% ointment were used as keratolytic agents Results: 76% had good to very good improvement in lesions SE: transient purpura and discomfort

(Continues)

TABLE 1 (Continued)

Study	Indication	Patients	Findings
Ilknur et al (2006) ⁶³	Comparison of the effects of PDL, PDL + salicylic acid, and Clobetasol propionate + salicylic acid on psoriatic plaques	N = 19	Plaque 1: PDL alone Plaque 2: PDL postsalicylic acid Plaque 3: Clobetasol propionate ointment and salicylic acid Results: Statistically significant reduction in all treatment groups ($P < 0.003$) but Clobetasol propionate ointment and salicylic acid treatment more effective than treatment on plaque 1 and 2
Taibjee et al (2005) ⁶²	Controlled study of excimer and PDL in the treatment of psoriasis	N = 15	Two selected plaques were treated 1. excimer twice weekly or V Beam PDL, pretreated with salicylic acid (SA), every 4 wk, respectively 2. SA alone 3. No treatment Results: PASI score improvement greater in excimer than PDL ($P = 0.003$) or control ($P < 0.001$) Authors postulated PDL may be better in subset of patients
Lanigan & Katagimupola (1997) ⁹²	Letter on treatment of psoriasis with PDL	N = 8	Results: About 62.5% of patients had at least 50% reduction in their treated plaque and complete clearing in one patient
Basal cell carcinoma			
Carija et al (2016) ⁶⁹	Single treatment of low-risk basal cell carcinomas with pulsed dye laser-mediated photodynamic therapy (PDL-PDT) compared with photodynamic therapy (PDT): A controlled, investigator-blinded, intra-individual prospective study	N = 15 (62 BCC)	BBC treated half with PDT (630 nm LED light source, fluence rate = 30 mW/cm ² , total dose of 150 J/cm ²) and other half with 585-nm PDL-PDT (spot size = 7 mm, fluence = 10 J/cm ² , pulse duration = 10 ms, 10% overlap, three passes, and cooling) Results: No significant difference between treatments Complete regression of BCCs in 79% of the PDT-treated area and 74% of the PDL-PDT Note recurrence rate of PDL-PDT higher than PDT alone
Karsai et al (2015) ⁷⁰	595-nm PDL to treat superficial BCC: a double-blind randomized placebo-controlled trial	N = 39	Randomized to receive PDL treatment (wavelength 595 nm; fluence 8 J/cm ² ; pulse duration 0.5 ms; spot size 10 mm) or placebo Results: At 6 mo remission of BCC, significant superiority found in the laser group vs placebo ($P < 0.0001$) 78.6% complete remission in PDL group SE: dyspigmentation/purpura
Alonso-Castro et al (2015) ⁹³	Effect of PDL on high-risk BCC with response control by Mohs surgery	N = 7	3 sessions of 595-nm PDL, at 4 weekly intervals Tumor + 4 mm of peripheral skin were treated with two stacked pulses (1-s delay), a fluence of 15 J/cm ² , a pulse duration 2 ms, spot size of 7 mm Mohs 1-mo after last PDL Results: complete clinical response in 5/7 patients. nb patient who did not have Mohs had recurrence at 14 mo
Jalian et al (2014) ⁹⁴	Combined 585-nm PDL and 1064-nm Nd:YAG lasers for the treatment of basal cell carcinoma	N = 10	4 combined PDL and Nd:YAG at treatments 2-4 weekly Results: 58% complete response PDL & Nd:YAG effective at reduce tumor burden

(Continues)

TABLE 1 (Continued)

Study	Indication	Patients	Findings
Minars and Blyumin-Karasik (2012) ⁶⁸	BCC treated with PDL	N = 29	PDL 595 nm 15 J/cm ² , 3 millisecond pulse length, 7 mm spot size 1-4 therapies, 2-4-wk intervals Results: 24/32 (75%) tumors with complete resolution; 5/32 (16%) tumors recurred; 3/32 (9%) tumors with incomplete responses
Konnikov et al (2011) ⁶⁷	PDL as a nonsurgical treatment for basal cell carcinomas: response and follow-up 12-21 mo after treatment	N = 14 (20 BCC's)	Each BCC treated with 4 PDL, 3-4 weekly Results: Complete response in 95% treated BCC Of these, only one BCC recurred at 17-mo follow-up
Shah et al (2009) ⁶⁶	The effect of 595-nm PDL on superficial and nodular basal cell carcinomas	N = 20	4 2 weekly 595-nm PDL treatments (one pass, 15 J/cm ² energy, 3 ms pulse length, no cooling, and 7 mm spot size with 10% overlap) Results: BCCs <1.5 cm: 91.7% complete response to four PDL treatments vs 16.7% of controls (n = 2/12, P-value = 0.0003) BCCs ≥1.5: 25% complete response rate vs 0% of controls (n = 0/8, P-value = 0.2)
Sarcoid			
Cliff et al (1999) ⁷¹	The successful treatment of lupus pernio with the flash lamp PDL	N = 1	Results: Improvement of lupus pernio of nose post-PDL treatment, however, biopsy showed no change in histology
Lupus			
Rerknimitr et al (2018) ⁷³	PDL as adjuvant for DLE, an RCT	N = 9 (lesions = 48)	PDL (595 nm) every 4 wk for 4 mo Results: PDL-treated lesions significant decrease in erythema and texture
Yelamos et al (2014) ⁷²	Pediatric cutaneous lupus erythematosus treated with PDL	N = 1	Failed treatment with hydroxychloroquine 200 mg OD for 10 wk, still continues in conjunction with PDL 585-nm PDL 10 mm spot size at a 0.5-ms pulse width, a fluence of 5.5 J/cm ² on both cheeks, and 7 J/cm ² on the dorsum of the hands Results: Dorsum lesions resolved 1-mo postprocedure Facial-transient PIH resolved 6 mo post-treatment FU: no lesions 2 y post-PDL
Truchuelo et al (2012) ⁷⁴	PDL to treat lupus timidus	N = 10	595-nm PDL using the 10 mm spot size at 0.5 ms pulse width and a fluence of 8 J/cm ² Results: Post-PDL histology demonstrated reduction in dermal lymphocytic infiltrate in 90% patients. No epidermal changes. Possibly beneficial for acute flares of lupus timidus
Erceg et al (2009) ⁷⁵	Efficacy and safety of PDL treatment for cutaneous discoid lupus erythematosus	N = 12	Active CDLE lesions were treated with PDL (585 nm, fluence 5.5 J/cm ² , spot size 7 mm) 3 times 6 weekly Results: Significant reduction in active CLASI suggesting PDL effective treatment (note small sample size) SE: minimal pain
Miscellaneous			
Sapra et al (2013) ⁷⁹	PDL to treat pearly penile papules	N = 4	Pretreatment topical local anesthetic, PDL, 5 mm spot size and 0.50-ms pulse duration, with fluence ranging from 6 to 10 J/cm ² 1-3 treatments Results: significant reduction or complete clearance

(Continues)

TABLE 1 (Continued)

Study	Indication	Patients	Findings
Funayama et al (2012) ⁸²	Effectiveness of combined PDL and Q-switched ruby laser treatment for large to giant congenital melanocytic naevi	N = 6	One pass of PDL treatment followed by one pass of QsRL treatment on average 7× to lighten skin Results: histology showed reduction in melanocytic nevus cells SE: minimal scarring
Macarenco et al (2006) ⁷⁷	Angiolymphoid hyperplasia with eosinophilia treated with PDL	N = 3	PDL at 595-nm or with a combined sequential application of 595-nm PDL and 1064-nm Nd: YAG wavelengths Results: complete resolution in 75% and partial response in 25% SE: nil significant reported
Eisen and Alster (2002) ⁸⁰	Use of a 585-nm PDL for the treatment of morphea	N = 1	585-nm PDL (fluence of 5.0 J/cm ²) 2 monthly Results: clinical improvement (improved skin color and pliability) Mechanism unknown

CLASI, Cutaneous Lupus Erythematosus Disease Area and Severity Index; I 5-FU, intralesional 5-fluorouracil; iTAC, intralesional triamcinolone acetate; NAPSI, Nail Psoriasis Severity Index; PASI, Psoriasis Activity and Severity Index; PDT, photodynamic therapy; PIH, postinflammatory hyperpigmentation; SE, side effects.

that although both had effective results, the PDL arm had better results at longer term follow-up.⁹ PDL alone¹⁰ and in combination with topical therapy¹¹ has been demonstrated to be beneficial in other studies. Seaton et al also found that PDL vs placebo in 41 patients with inflammatory acne demonstrated a significantly better improvement in acne severity in the treatment arm vs the placebo arm at 12-week follow-up ($P = 0.007$).¹² Salah et al carried out a split-face study comparing PDL alone vs PDL and Nd:YAG in the treatment of acne and although there was no significant difference between the two treatment arms, both were found to be efficacious. When comparing fluence levels of PDL in the treatment of moderate to severe acne in 55 patients, again there was no difference between various fluences used but there was an overall reduction in total number of lesions found post-PDL vs baseline.¹³

3 | SCARS

Scars have a multitude of causes, including burns, acne, trauma, surgery and are a very common reason for dermatological consultation. The authors surmise the use of PDL lasers in keloid scars, demonstrating PDL and ablative lasers (such as the CO₂ laser) are the most widely trialed lasers for keloid scars.¹⁴ We reviewed 22 studies over the last 20 years for the use of PDL independently^{15,16} or in comparison or conjunction/comparison to Erbium-glass laser,^{17,18} fractional CO₂ laser,¹⁹⁻²¹ Nd:YAG,²²⁻²⁴ botulinum toxin,²⁵ KTP,²⁶ low-level laser,²⁷ different parameters and wavelengths of PDL,²⁸⁻³¹ triamcinolone/5-FU,³²⁻³⁴ IPL³⁵ in 477 scars including: hypertrophic, keloidal, burns, and traumatic.

All treatment modalities demonstrated improvement in scar outcome, however, when comparing PDL to the alternative modalities stated above the majority showed no significant improvement between treatment arms. Ouyang et al demonstrated that 595-nm

PDL alone to treat immature red hypertrophic scars had better outcome than combination of PDL with CO₂ (ablative) laser ($P < 0.05$)¹⁹ in comparison with Park et al who found combination treatment with PDL and 1550-nm erbium-glass fractional laser showed a clinical improvement.¹⁸ Kim et al compared scar prevention between CO₂ laser and PDL using split-scar analysis. Both were found to be efficacious but PDL was better in improving the color of the scar.²⁰ When comparing short- and long-pulse durations of 585-nm PDL vs control in split-scar study of 20 patients Nouri et al found PDL to be more efficacious than the control, however, there was no difference between the different pulse durations,³⁰ whereas Manuskiatti et al found 0.45 ms pulse width more effective than 40 ms in scar improvement.

One RCT of 15 scars found nonablative fractional laser (NAFL) to have preferable outcomes than PDL.²³ Asilian et al compared triamcinolone alone, triamcinolone in combination with 5-Fluorouracil (5-FU) and triamcinolone in combination with 5-FU and PDL in keloids and hypertrophic scars. All groups showed an improvement; however, interestingly the triple therapy group had the best outcome.³² Another efficacious combination treatment was found in using CO₂ laser in conjunction with PDL.²¹

Tao et al found that PDL in conjunction with erbium-glass lasers improved thickness, texture, and color in patients with burns,¹⁷ and Lee et al found that Botulinum toxin in conjunction with PDL for traumatic scarring on the face also demonstrated improvements.²⁵

Erythematous surgical scars are a common phenomenon and a usual reason for seeking consultation in dermatology. Keaney et al carried out a randomized controlled open-label study in surgical scars. Half were treated with KTP laser and the other half with PDL. Both arm outcomes were found to be efficacious as measured by blinded photography assessments with no statistical difference found between both arms.²⁶ Scarring in children creates huge psychological sequelae which are often carried forward into adulthood. Vranova et al used the Patient and Observer Scar

Assessment Scale (POSAS) to demonstrate the effectiveness of single low-level laser therapy and combination low-level laser therapy with PDL vs the control (untreated group). The treated arm of the study demonstrated a significant improvement ($P < 0.001$) in the facial scars.²⁷ Nouri et al assessed the value of early laser intervention by using PDL to treat surgical scars commencing on the day of suture removal. A split-scar study demonstrated a 44% benefit in Vancouver Scar Scale (VSS) score with PDL as opposed to without it ($P = 0.0002$).¹⁶

4 | ECCHYMOSES

PDL has also shown to be effective in treating postprocedural ecchymoses with only mild edema and pain reported as side effects.³⁶ Alegre-Sanchez et al 2016 reviewed ecchymoses treated by PDL. They reviewed the use of PDL 595 nm (pulse duration 0.5–0.6 ms) on ecchymoses of varying sites and treated either half of the lesion or half of the affected surface in 34 patients and found a mean improvement of 75% which was statistically significant.³⁷ PDL works via the chromophore of oxyhemoglobin which theoretically ensures that the absorbed energy is transferred to the cell membrane leading to destruction and rapid clearance.³⁷ Alegre-Sanchez et al nicely summarize other studies which have used PDL to treat ecchymoses postcosmetic procedures by DeFatta³⁶ and Karen et al³⁸ In comparison with their study, they found these authors were using longer pulse durations which they deemed to be less effective suggesting that pulse durations equal to or lower than 6 ms appear to be more effective.³⁷

5 | STRIAE

Striae are a common presenting complaint and can either be physiological or iatrogenic. Striae rubra (SR) progress to striae alba (SA) and both are often refractory to treatment.³⁹ SR present as linear red plaques—which evolve into linear atrophic plaques—SA.³⁹ Forbat & Al-Niaimi's literature review on the treatment options available for Striae distensae systematically appraises the evidence of energy-based treatment for striae available to date. They found that SA is more difficult to treat than SR and side effects of laser treatment such as postinflammatory hyperpigmentation were more common in higher Fitzpatrick skin types.³⁹ The outcome of treating striae with PDL is variable. Nehal et al only found a slight improvement in treating mature striae with PDL 2 monthly for 1–2 years.⁴⁰ Shokeir et al compared the efficacy of PDL with IPL and found both improved the appearance of striae, but early striae (SR) had a better outcome with both. Of note, PDL was found to significantly increase collagen 1 expression compared with IPL ($P < 0.001$ and $P = 0.193$, respectively) which could suggest it may be preferential if larger studies were to be carried out. It is currently largely accepted that PDL works in the reduction in erythema in SR with a possible improvement in the overall texture and appearance.

6 | WARTS

Warts are common and present as papillomatous or hyperkeratotic papules. We reviewed 10 studies looking at the use of PDL as a monotherapy for warts,^{41–43} in comparison with Nd:YAG laser,^{44,45} in conjunction with intralesional bleomycin,⁴⁶ in conjunction with MAL-PDT,⁴⁷ alone & in comparison to & in combination with salicylic acid,⁴⁸ alone or in conjunction with aminolevulinic acid PDT,⁴⁹ and finally vs conventional therapy.⁵⁰ Further detail of the aforementioned can be found in Table 1.

Shin et al carried out a comparative study of PDL vs Nd:YAG in 72 recalcitrant viral warts. Although only a small percentage had complete clearance, 5.1% and 9.1% in the PDL and Nd:YAG group, respectively, at least half of the treated patients had a 51.3% improvement and 66.7% improvement when treated with PDL and Nd:YAG, respectively.⁴⁴ Intralesional bleomycin's mechanism of action in warts is thought to be via blocking DNA synthesis. Assessment of combination treatment of intralesional bleomycin and PDL for recalcitrant viral warts demonstrated a 60% complete response rate suggesting this combination to be more beneficial than alternative combination therapies.⁴⁶ Most impressively Smucleat & Jatsoeva demonstrated a 100% cure rate in warts treated with combination photodynamic therapy and PDL with an average of two sessions.⁴⁹

El-Mohamady et al found PDL to be safer than Nd:YAG but longer treatment was required,⁴⁵ and PDL was found to be an effective monotherapy in 2 out of the three studies reviewed^{41,42} but the third study, a small randomized comparative study of 35 lesions found no significant difference between PDL and placebo.⁴³ Conversely, Robson et al found no difference between PDL and conventional therapy of warts in the prospective review on 194 lesions.⁵⁰

Al-Niaimi et al reviewed the literature on the use of PDL in the treatment of warts. Short pulse duration and high fluences were found to be more effective modalities in the treatment of warts, and simple warts demonstrated the best outcomes whereas recalcitrant warts had more variable outcomes.⁵¹

7 | MOLLUSCUM CONTAGIOSUM

Molluscum contagiosum (MC) is a common infectious dermatosis that typically affects children or the immunocompromised.⁵² Forbat et al systemically reviewed the treatment options available to date for MC. Included in this review are 6 studies on the efficacy of PDL to treat MC, demonstrating it is an efficacious and safe laser therapy, with minimal treatments required.⁵²

Hancox et al carried out a retrospective review of MC treated with PDL in 1250 lesions. They found that all treated lesions resolved and over a third of patients had no new lesions after just two treatments.⁵⁴ It is well known that MC is more recalcitrant in the immunosuppressed. One case study compared CO₂ laser with PDL and Trichloroacetic acid in MC of an AIDS patient. Only one treatment was required to clear PDL- and TCA-treated molluscum, vs 2 weeks to heal CO₂ laser-treated lesions.⁵⁵ Monotherapy with PDL to treat

88 lesions resolved 87 of 88 lesions in a study, demonstrating that PDL is an excellent treatment for this condition.⁵⁶

8 | PSORIASIS

From this systematic review, it is evident that the most research has been carried out on the efficacy of psoriasis and PDL. We reviewed 15 papers from the literature between 1997 and 2017 of which the majority focus on nail psoriasis. Nail psoriasis is often recalcitrant and conservative treatments including calcipotriol and topical corticosteroids are often ineffective. Nail psoriasis is graded with the Nail Psoriasis Severity Index, otherwise known as NAPS I score. NAPS I scores improved in nail psoriasis treated with PDL monotherapy⁵⁷⁻⁵⁹ but no significant difference was found between varying pulse durations of PDL and NAPS I scores, although both durations (6 and 0.45ms, respectively) were found to be efficacious.^{53,60} PDL was found to be more effective in treating nail psoriasis than excimer laser⁶¹ but interestingly less effective in plaque psoriasis.⁶² Conventional treatment of plaque psoriasis with salicylic acid and dermivate was also found to be more efficacious than PDL in one study which compared PDL treatment alone, with PDL treatment in conjunction with salicylic acid vs dermivate and salicylic acid.⁶³ Interestingly, Erceg et al found PDL to show a 62% reduction in plaque with PDL treatment vs only a 19% plaque reduction with topical calcipotriol and betamethasone dipropionate treatment.⁶⁴ At present, most of the evidence of PDL relates to the effective treatment in nail psoriasis and can be considered in stable plaque psoriasis in small areas unresponsive to topical therapy when systemic therapy may not be considered.

9 | BASAL CELL CARCINOMA

Basal cell carcinoma is the most common type of nonmelanoma skin cancer, with a reported incidence of 343 per 100 000 persons per year in the USA.⁶⁵ Conventional therapies including excision, Mohs surgery, photodynamic therapy, cryosurgery, and topical chemotherapy including imiquimod and 5-FU. The treatment choice is dependent on the subset of the disease, that is, nodular vs superficial BCC. Shah et al demonstrated that superficial or nodular BCC less than 1.5cm had a 91.7% complete response rate to 595-nm PDL vs only a 25% complete response rate in BCCs greater than or equal to 1.5cm.⁶⁶ Konnikov et al found only one recurrence of BCC at 17-month follow-up post-PDL treatment 3-4 weekly for 4 sessions.⁶⁷ Contrastingly, another study found that 16% of 29 BCC tumors recurred and 9% had incomplete response with PDL treatment at 2-4 weekly.⁶⁸ When comparing recurrence of low-risk BCC post-treatment with either PDL-PDT or PDT alone, Carija et al found a higher recurrence rate in the combination arm which they postulated could be secondary to a reduction in photobleaching in PDL-treated skin.⁶⁹ A double-blind randomized placebo-controlled trial comparing PDL to placebo found a 78.6% complete remission in the PDL group, with

a significant superiority demonstrated against placebo ($P < 0.0001$). They did however note that pigmentary scarring was noted to be a limitation of this treatment.⁷⁰ While there is evidence of PDL in some BCCs; current practice relates largely to small well-defined superficial and/or nodular BCCs in low-risk areas.

10 | SARCOID AND CUTANEOUS LUPUS

Sarcoid is a granulomatous systemic disease which can present cutaneously as dusky purple nodules or plaques which can be disfiguring to the patient. We found one case study which demonstrated PDL to improve the appearance of lupus pernio on the nose.⁷¹ Lupus is an autoimmune connective tissue disease which can present cutaneously as a butterfly rash on the face or erythematous plaques and eruptions on photosensitive sites. Treatment depends on the subtype, and again can be refractory to conventional treatment of topical steroids or systemics such as hydroxychloroquine. Yelamos et al found that using PDL in conjunction with hydroxychloroquine (which had not resolved the lesions as a monotherapy) in fact cured one child's cutaneous lupus on the dorsi of their hands with no recurrence at 2 years.⁷² Several other studies have also shown PDL to be effective both as an adjuvant therapy⁷³ and monotherapy^{74,75} in cutaneous lupus.

Rerknimitr et al carried out a double-blind RCT in 48 discoid lupus lesions which were randomized to either receive 595-nm PDL or no treatment 4 weekly for 4 months. Lesions treated with PDL improved and post-PDL histology showed molecular changes found in disease remission pointing to the molecular effects of PDL on the disease.⁷³ Al-Niaimi et al found that individual telangiectasia in sarcoid can be safely and effectively treated with some improvement in lupus pernio and plaques with a vascular component.⁷⁶

11 | MISCELLANEOUS

Angiolymphoid hyperplasia with eosinophilia otherwise known as Histiocytoid hemangioma is a rare lesion involving as the name suggests: blood vessels, lymphocytes, and eosinophils. PDL monotherapy or PDL in conjunction with NdYAG laser demonstrated an overall 75% response in 3 patients with this condition.⁷⁷ Another study showed that both surgical excision and PDL were associated with low treatment failure and recurrence which would make PDL an attractive choice over surgical excision, particularly in large areas.⁷⁸ Small studies on penile pearly papules and morphea have also reported to show clinical improvement post-treatment with PDL.^{79,80} Ghaninejadi et al reviewed the use of PDL in solar lentigines in 21 patients via dermoscopy photographs and found that more than half of the patients had a greater than 75% improvement in the appearance of the above.⁸¹

Finally, combination of Q-switched ruby laser and PDL in congenital melanocytic naevi has histologically shown a reduction in melanocytic nevus cells and clinically demonstrated improvement in their appearance, with reduced lesional color and minimal side effects.⁸²

12 | DISCUSSION

This systematic review has evaluated the efficacy of PDL for a multitude of nonvascular lesions in dermatology. A total of 84 studies have been reviewed for the use of PDL in acne vulgaris, scars, striae, warts, molluscum, psoriasis, rejuvenation, BCC, and miscellaneous dermatological sequelae. PDL has shown to be efficacious in acne, with both a photothermal and photochemical effects with variable fluences used and can safely be combined with other treatment modalities. PDL exhibits scar remodeling and prevention, particularly when used in the early remodeling phase of scar prevention and has shown to have a synergistic response with fractional lasers. In one study, PDL was as effective as fractional nonablative laser in post-thyroidectomy prevention scars highlighting the efficacy of its use in early scar remodeling and prevention.⁸³ Treatment of postfiller ecchymoses has become popular with PDL with excellent efficacy with pulse duration of 6 ms or shorter showing superior results. Similarly, in treatment of warts with PDL, short pulse duration and high fluence were found to be more effective modalities compared to longer pulse durations. The absence of cooling further enhances the success rate when using PDL in warts treatment. Variable results have been shown when comparing PDL vs more conventional treatments for psoriasis but in particular nail psoriasis appears to respond well to PDL with no difference in short vs long-pulse durations used. In BCCs, PDL has shown some improvement and can be considered in low-risk well-defined small superficial or nodular BCCs smaller than 1.5 cm. PDL has also demonstrated to be effective in a small set of lupus case studies explore the molecular changes in lupus and PDL. The use of PDL in dermatology has progressed from its inception in early 80s when it was designed for capillary malformations to its current state with a broad range of uses in nonprimary vascular conditions as highlighted in this article.

CONFLICT OF INTEREST

None.

CONSENT FOR PUBLICATION

All authors have approved this final submitted version of the manuscript and consent to its submission for consideration of publication.

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