Australasian Journal of Dermatology

Australasian Journal of Dermatology (2014) **55**, 1–14 doi: 10.1111/ajd.12111

REVIEW ARTICLE

Lasers and laser-like devices: Part two

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ABSTRACT

Part two of this review series evaluates the use of lasers and laser-like devices in dermatology based on published evidence and the collective experience of the senior authors. Dermatologists can laser-treat a wide range of dermatoses, including vascular, pigmentary, textural, benign proliferative and premalignant conditions. Some of these conditions include vascular malformation, haemangioma, facial telangiectases, café-au-lait macules, naevi of Ota, lentigines, acne scarring, rhytides, rhinophyma and miscellaneous skin lesions. Photodynamic therapy with lasers and intense pulsed light is addressed, with particular reference to actinic keratosis and actinic cheilitis. A treatment algorithm for acne scarring based on scar morphology and severity is comprehensively outlined. Following from part one, the various devices are matched to the corresponding dermatological conditions with representative pictorial case vignettes illustrating likely clinical outcomes as well as limitations and potential complications of the various laser and light therapies.

Key words: acne, CO_2 laser, Er:YAG laser, KTP laser, Nd:YAG laser, pigment, QS laser, rhytides, ruby laser, vascular.

INTRODUCTION

The broad principles of dermatological laser therapy have been covered in Part one of this review series.[1] Part two explores the use of lasers in procedural and cosmetic dermatology with a particular focus on conditions that are clinically relevant to dermatologists. We discuss likely clinical outcomes as well as the limitations of laser therapy, including its use in darker Fitzpatrick skin types, based on the literature review and the senior authors' collective experience.

Vascular conditions

Vascular malformation The most recent Cochrane Review[2] of laser treatments for capillary malformations (CM) (port-wine stains) included five randomised controlled trials (RCT) totalling 103 patients. A pulsed dye laser (PDL) (585 or 595 nm) was employed in all five trials and, depending on the regimen employed, resulted in a

Abbreviations:

AK	actinic keratosis
ALA	aminolevulinic acid
CM	capillary malformation
CMN	congenital melanocytic naevus
CO_2	carbon dioxide
DST	darker skin type
Er	erbium
EVLA	endovenous laser ablation
HHT	hereditary haemorrhagic telangiectasia
HQ	hydroquinone
HOI	haemangioma of infancy
IPL	intense pulsed light
KTP	potassium tritanyl phosphate
Nd:YAG	neodymium-doped yttrium aluminium garnet
PDL	pulsed dye laser
PIH	post-inflammatory hyperpigmentation
PDT	photodynamic therapy
QS	quality switched
RCT	randomised controlled trial
TCA	trichloracetic acid
TTT	triple topical therapy

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Conflict of interest: none

Submitted 28 June 2013; accepted 11 August 2013.

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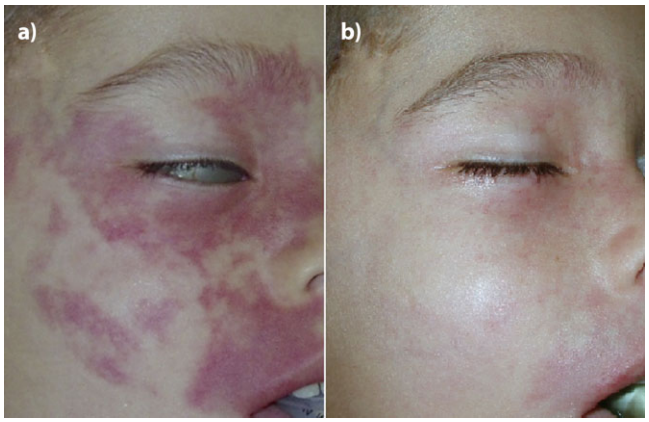

Figure 1 Caucasian male, 3-years old, Fitzpatrick phototype II with capillary malformation right cheek and upper lip treated with pulsed dye laser (Candela Vbeam; Candela, Irvine, CA, USA) (595 nm): 7 mm spot, 9 J/cm^2 fluence, 1.5 ms pulse duration (mild purpuric end-point), 30 ms spray 30 ms delay cryogen cooling, single pass with minimal overlap. Showing: (a) baseline and (b) 18 months after third treatment undertaken at 6–12 monthly intervals.

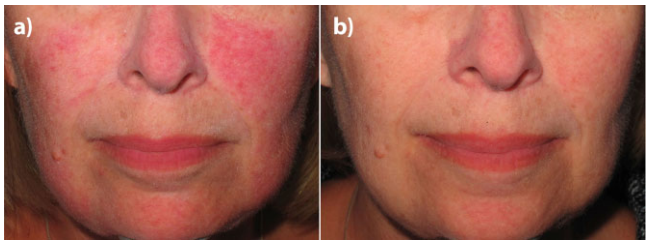

Figure 2 Caucasian woman, 57-years old, Fitzpatrick phototype I–II with rosacea erythema and telangiectases treated with pulsed dye laser (Candela Perfecta; Candela, Irvine, CA, USA) (595 nm): 3 × 10 mm spot, 13.5 J/cm^2 fluence, 20 ms pulse duration, 30 ms spray 20 ms delay cryogen cooling, 1–2 passes followed by intense pulsed light (Sciton BBL Palo Alto, CA, USA): 560 nm filter, 16 J/cm^2 fluence, 15–20 ms pulse duration, 15°C, single pass. Showing: (a) baseline and (b) 6 weeks after second treatment.

minimum of 25% reduction in redness. Both the pulsed neodymium-doped yttrium aluminium garnet (Nd:YAG) (1064 nm) laser and intense pulsed light (IPL) were effective, but the PDL results were superior and therefore, considered the laser of choice for CM (Fig. 1).[5]

Head and neck CM respond better than trunk and distal extremity lesions. Nodular, hypertrophic or recalcitrant CM may not respond to PDL and may be better suited to treatment with a pulsed Nd:YAG laser, a PDL and pulsed Nd:YAG laser combination, a pulsed alexandrite laser (755 nm) or IPL.[4] Children under the age of 1 year seem to have the best response and should be treated as early as possible.[4] It is important to inform patients or parents that gradual recurrence is likely but tends to be less cosmetically conspicuous. Recently topical rapamycin has been used as an adjuvant to vascular laser to accelerate the clearance of CM with PDL.[5]

Haemangioma of infancy Laser treatment of haemangioma of infancy (HOI) remains controversial. Early studies using obsolete, non-cooled lasers and employing excessive fluence and severe purpuric end-points have complicated the pursuit of an evidence-based approach to the management of HOI.[6] It has been our experience that the PDL at 6–7 J/cm^2, 10 mm spot, 1.5 ms pulse width, achieving a transient to minimally purpuric end-point will effectively treat early flat HOI present in the superficial dermis. This treatment protocol is often used for focal, facial and superficial haemangioma in conjunction with timolol; a topical beta-blocker. In general, lasers do not have a major role in raised or subcutaneous haemangiomas because PDL can penetrate to a depth of only 1.2 mm. PDL is useful in selected cases of involuting and ulcerated haemangiomas. Some centres use more deeply penetrating wavelengths (IPL and Nd:YAG) to treat thicker and deeper lesions. The role of lasers in patients with haemangiomas is set to diminish further with the advent of systemic beta-blockers as a dramatically effective medical treatment option.[7,8] However, many lesions treated with beta-blockers will leave a superficial telangiectatic component that is amenable to PDL.

Facial telangiectases The most commonly used devices for facial telangiectases are PDL, potassium tritanyl phosphate (KTP) (532 nm) lasers and IPL. The role of lasers in reducing telangiectases is well established, with several studies demonstrating their treatment efficacy with copper-bromide (578 nm), krypton (520, 530 or 568 nm), KTP and PDL (Fig. 2).[9] The 532 nm and 1064 nm tracing lasers are ideally suited for targeting discrete facial telangiectases; the latter being useful for larger calibre blood vessels and venules. PDL can be used on a range of vascular lesions with either purpuric (pulse duration < 3ms) or non-purpuric (pulse duration ≥ 3ms) end-points. It has been suggested that fine telangiectases can be adequately treated with non-purpuric parameters while purpuric parameters are more effective at clearing thicker telangiectases. However, thicker lesions can be effectively treated (without purpura) through pulse stacking and multiple passes using non-purpuric parameters. Perialar telangiectases can be recalcitrant to laser treatment, thus requiring more sessions, and are also more prone to recurrence.[10] IPL has also been shown to improve facial telangiectases. Although laser is considered to be superior,[11,12] a study comparing PDL and IPL showed no significant clinical difference between the two modalities.[15] Facial telangiectases frequently occur in the setting of rosacea. Anecdotally, it has been found that some patients will demonstrate a clinical amelioration of the rosacea itself but few studies have actually investigated this phenomenon.

Hereditary haemorrhagic telangiectasia Hereditary haemorrhagic telangiectasia (HHT) or Osler–Weber–Rendu syndrome is an autosomal dominant disorder characterised by cutaneous and visceral telangiectases that require systemic investigation. Smaller HHT vascular lesions respond to PDL and KTP lasers while larger and often bleeding lesions

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require treatment with a Nd:YAG laser. Use of the Nd:YAG laser within the oral cavity needs to be undertaken with care as the laser beam can damage natural dentition and dental crowns. Oral mucosal lesions may bleed profusely if the treatment power is inadequate and may require oversewing for adequate haemostasis.

Venous lakes and other vascular lesions Venous lakes are characterised by ectatic thin-walled venules in the superficial papillary dermis and, depending on size, can be effectively treated with a variety of vascular lasers: Nd:YAG or diode laser for larger lesions[14] and PDL for smaller lesions.[15] Nd:YAG laser is the laser of choice with a 94% clearance rate in one case series of 35 patients.[16] Other vascular lesions such as cherry angiomas, spider angiomas and angiokeratomas respond satisfactorily to any of the vascular lasers listed above if the laser is selected according to the lesion size and the laser's depth of penetration.

Leg veins Sclerotherapy remains the gold standard for small diameter vessels such as venules and capillaries. However, in the last decade, endovenous laser ablation (EVLA) has replaced surgical stripping as the preferred treatment option for varicose veins. EVLA consists of a fibre-optic thread inserted into the vein with wavelengths ranging from 810–1500 nm. A meta-analysis of 64 clinical studies evaluating 12 320 limbs concluded that EVLA of lower limb varicosities was superior to surgical intervention[17] and is often performed in conjunction with ultrasound-guided sclerotherapy. External beam lasers play a very limited role in lower limb vessels unless all the larger refluxing veins (both clinical and subclinical) have been adequately treated.[18] Nevertheless, external beam lasers may on occasion be useful for small vessels that are difficult to cannulate, telangiectatic matting not due to underlying venous reflux and for needle-phobic patients. Lasers with longer wavelengths offer deeper penetration and epidermal sparing, with the most commonly employed lasers being Nd:YAG, KTP, PDL, alexandrite, diode (810 nm) and IPL. The choice will again be determined by the size and depth of the vascular target.[19] Generalised essential telangiectasia is another cause of telangiectases on the legs and is responsive to low fluence vascular lasers (PDL and KTP) and IPL.

Pigment-related conditions

Epidermal lesions Lesions such as solar lentigines, lentigo simplex and ephelides consist of epidermal pigment originating from basal layer melanocytes. Any laser that selectively targets the melanin chromophore or ablates the epidermis can potentially ameliorate such lesions, typically in 1–2 sessions. The mainstay lasers include quality switched (QS) alexandrite, QS ruby (694 nm) and QS frequency doubled Nd:YAG (532 nm).[20] Long-pulsed counterparts are also effective, less likely to cause post-inflammatory hyperpigmentation (PIH) and generally preferred for patients of dark skin types (DST). IPL (filter 500–600 nm) can also be very effective for this indication, while concurrently improving telangiectases. Superficial and fractional resurfacing lasers (density > 50%) also treat epidermal pigmentation and ameliorate mild textural photodamage but have a recovery time of approximately 5–7 days.

Café-au-lait macule In our experience, QS lasers yield the best results with QS frequency doubled Nd:YAG, QS alexandrite and QS ruby as the modalities of choice. Recurrences are common and multiple treatment sessions may be required, but some patients will obtain excellent outcomes with a long-term significant reduction in colour of the macule if they sun-protect the area.

Becker's naevus Patients with Becker's naevus may ask for treatment for lesional hyperpigmentation and hypertrichosis. Recurrence and incomplete response are common and are believed to be due in part to the sparing of sanctuary sites of pigmented keratinocytes and melanocytes in the deeper hair follicle.[21] At this time there is no reliable treatment for Becker's naevus. Different approaches to treatment have been described in the literature but there is no consensus on their safety or effectiveness.[21,22] Until better outcomes are achieved these patients are usually best advised to avoid treatment.

Congenital melanocytic naevus Many different lasers have been employed in the management of congenital melanocytic naevus (CMN),[23] with the largest series of 52 patients with 314 lesions treated with combined ultrapulsed carbon dioxide (CO_2) laser and frequency doubled QS Nd:YAG (532 nm), with mean follow up of 8 years.[24] Approximately 95% of these lesions had a reduction in pigment, with five patients failing treatment, five experiencing recurrence and one developing melanoma. While there is some evidence for the role of lasers in the treatment of CMN, surgery remains the gold standard.

Acquired naevus Definitive surgical excision also remains the mainstay of treatment for acquired naevi. Shave excision of skin-coloured dermal nevi is accepted practice due to their low risk of malignant transformation, along with ablative laser re-contouring of these lesions. However, flat, pigmented naevi should be excised rather than treated with laser. Asian patients with a very low risk of melanoma are sometimes considered for QS laser treatment of benign naevi on the face.[25] Laser treatment of pigmented naevi may complicate an accurate diagnosis of subsequently re-pigmenting lesions and is not ideal in the setting of melanoma surveillance.

Naevus of Ota Pigment-selective lasers have largely superseded other treatments in the management of naevi of Ota. As the melanocytosis in the naevus of Ota is primarily dermal, longer wavelength QS lasers (694 nm, 755 nm and 1064 nm) are generally preferred (Fig. 3). Published case series support the use of QS ruby,[26] QS alexandrite[27,28] and

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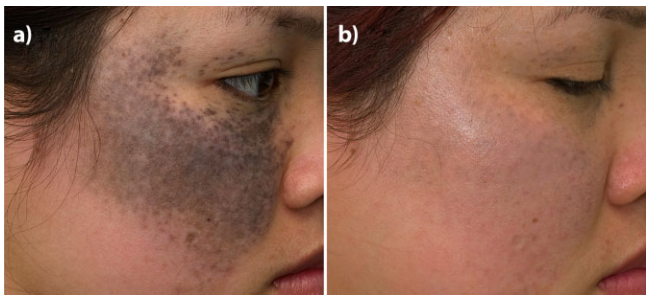

Figure 3 Asian woman, 33-years old, Fitzpatrick phototype IV with naevus of Ota, treated with quality switched neodymium-doped yttrium aluminium garnet laser (Revlite C3; Cynosure, Westford, MA, USA) (1064 nm): 4 mm spot, 6.5–7.5 J/cm^2 fluence at 10 Hz. Showing: (a) baseline and (b) after 12 treatments.

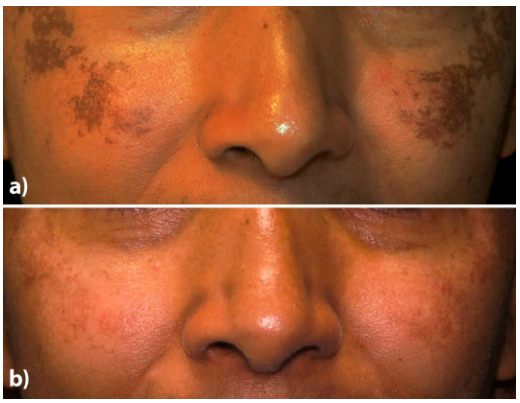

Figure 4 African woman, 45-years old, Fitzpatrick phototype V–VI with prominent periorbital melasma effectively controlled with first-line topical therapy with 4% hydroquinone, 4% kojic acid, 1% hydrocortisone and 0.05% tazarotene (prescribed separately). The pigmentation worsened with prior attempted low-fluence quality switched neodymium-doped yttrium aluminium garnet laser. Showing: (a) baseline and (b) after 12-months topical therapy.

QS Nd:YAG for this condition.[29] A study of 602 Chinese patients treated by QS alexandrite laser reported a cure rate of 92% after 9 treatments, with success significantly related to the number of treatment sessions ($P < 0.001$).[27]

Naevus of Hori Given the histopathological and clinical similarities between the naevus of Ota and Hori's naevus (bilateral mid-face macular pigmentation with ocular sparing), QS lasers have been used to treat the latter since it was first described in 1984. In a case series of 131 Thai female patients treated with QS ruby laser there was complete clearance of lesions after an average of 2.3 sessions at a mean follow-up period of 2.5 years.[30] In contrast, in a study of 66 patients treated by QS Nd:YAG only 26% of them demonstrated a 50% improvement after 1–2 treatments, although the authors noted that this may have improved with further sessions.[31]

Melasma Topical treatments such as superficial chemical peels, hydroquinone (HQ), kojic acid, tranexamic acid and triple topical therapy (TTT) (consisting of a mixture of HQ, retinoid and corticosteroid) remain first-line management, with mixed evidence for the effectiveness of lasers (Fig. 4). A RCT of 20 patients with predominantly epidermal melasma compared TTT with fractional erbium:glass (Er:glass) non-ablative laser (1,550 nm) and demonstrated similar efficacy and safety,[32] but at 6 month follow up most of the patients had recurrence. In contrast, a split-face RCT of 29 patients comparing combined TTT and fractional Er:glass non-ablative laser with TTT monotherapy demonstrated poorer outcomes with laser due to a high frequency of PIH.[33]

Topical agents remain the mainstay of treatment for melasma with the benefits offered by laser seemingly reduced by the risk of PIH and rebound hyperpigmentation. At best, lasers play an adjuvant and supporting role to topical therapy for melasma. Trials comparing TTT monotherapy with combination TTT and fractional CO_2 laser[34] and combination TTT and PDL (to treat fine telangiectases commonly accompanying melasma)[35] have demonstrated a beneficial synergistic effect of combining topical and laser modalities. This finding was also observed in a RCT comparing HQ monotherapy with low fluence QS Nd:YAG plus HQ.[36] The fractionated thulium (1927 nm) laser, a relative newcomer, has shown early promise in this setting.[37] Ablative lasers may facilitate the delivery of drugs through the skin, such as HQ, with a multimodal approach potentially improving patient outcomes. Laser-assisted drug delivery may have a role in melasma management as well as in the broader dermatological arena.[38]

Post-inflammatory hyperpigmentation As with melasma, PIH can be disappointing to treat and general measures along with realistic patient expectations are paramount. There is a paucity of clinical trials investigating the role of lasers in the management of PIH and accordingly it is difficult to provide an evidence-based evaluation of their efficacy in this setting. Selected cases of persistent PIH (> 12 months) may respond to QS lasers[39] but this is fraught with potential problems and is not routinely recommended. Variable responses of PIH to laser therapy have been observed and generally there is incomplete clearance of pigmentation, along with a risk of the PIH worsening.

Hair removal Permanent hair reduction refers to stable, long-term decreased hair regrowth following laser treatment rather than the total elimination of all hairs in the treatment area.[40] A systematic review concluded that epilation with lasers resulted in partial short-term hair reduction beyond 6 months following treatment with alexandrite and diode lasers, and probably after ruby and Nd:YAG laser treatment.[41] Efficacy was improved with repeated treatment, superior to conventional epilation treatments and IPL, with a low frequency of adverse effects being observed across all laser types. More recent studies have further validated the utility of the diode[42–44] alexandrite[45,46] and Nd:YAG[47] lasers, with hair reduction achieved beyond 12 months in

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some studies,[48–50] and this is preferred over the ruby laser. IPL produced a comparable degree of hair reduction to lasers, especially in fair-skinned individuals, but was less effective and more likely to cause burns in tanned or dark skin types.[41] There is increasing awareness of the problem of paradoxical hypertrichosis (especially in women with polycystic ovarian syndrome) that can compromise the treatment of fine facial hair.

Tattoo removal QS lasers are the treatment of choice for tattoo removal and the most commonly employed are the QS ruby, QS Nd:YAG and QS alexandrite.[51] The QS Nd:YAG can treat most colours but blue or green responds best to QS alexandrite, purple or violet responds best to QS ruby and red responds best to QS 532 nm. All lasers perform equally well at removing black tattoo pigment[52] and amateur black tattoos are the easiest to remove. A recent report advocated undertaking four treatment sessions in the same day separated by a 20-min interval for accelerated tattoo clearance.[53] However, we have not been able to replicate these impressive results with this method of tattoo removal.

Important adverse effects observed with laser treatment include pigmentary changes and irreversible darkening of cosmetic (e.g., skin-coloured) tattoos. Accordingly, test spots are an important consideration when using lasers for this indication. Multiple treatments (often > 5 sessions and sometimes between 10–20 sessions) are required to achieve the greatest clearance. However, if a particular laser fails to adequately remove a tattoo, another device can be employed as multi-modal and multi-wavelength treatment often has a synergistic effect on clearance.

Lasers in Darker Skin Types (DST)

Patients with Fitzpatrick phototypes III–VI have greater quantities of melanin in the stratum basale and thus have an increased risk of non-specific light absorption, leading to a higher risk of adverse effects including burns, dyspigmentation, textural changes, atrophy and scarring. Concomitantly, competitive absorption by melanin decreases the total amount of energy reaching target tissues, rendering it more of a challenge to obtain desired clinical outcomes.[54] Given the predilection for absorption of energy by the epidermal melanin, it is essential to use conservative power settings and employ effective cooling devices to counteract the effects of accumulated thermal energy within the stratum basale in DST patients.

Despite these challenges, patients with DST can be successfully treated with a variety of lasers using appropriate modification of laser parameters. The peak absorption of melanin lies within the UV range and decreases as wavelength increases. Accordingly, lasers generating longer wavelengths, which are less avidly absorbed by endogenous melanin, provide improved safety profiles and clinical efficacy for DST patients such as the diode, Nd:YAG or IPL with filter cut-offs at longer wavelengths.[55] Devices with longer infrared wavelengths become colour blind as they have a low affinity to melanin but a high affinity to water, and are characterised by resurfacing lasers (1550 nm and beyond). Resurfacing lasers (ablative or non-ablative) in DST patients have increased potential for PIH and thus periprocedural bleaching and sun protection is important.

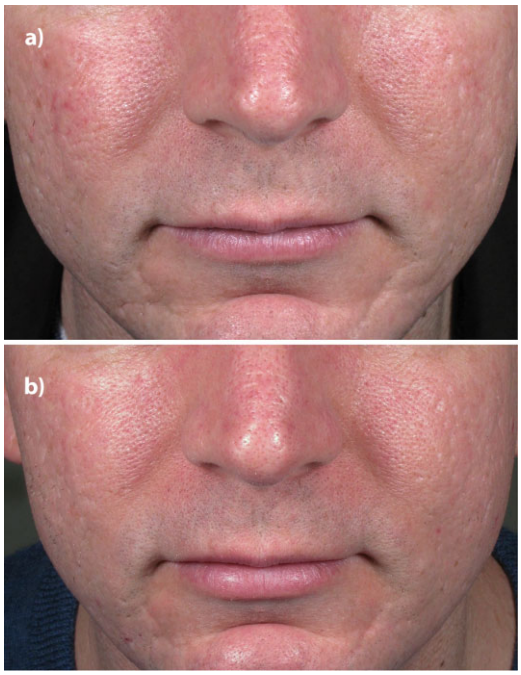

Figure 5 Caucasian man, 39-years old, Fitzpatrick phototype III with Grade 3 acne scarring. The patient received treatment with fractionated CO_2 laser (Deka Smartxide; Deka, Via Baldanzese, Italy) and fractionated non-ablative erbium: glass laser (1550 nm) (Fraxel Restore; Fraxel, Hayward, CA, USA), as well as hyaluronic acid injections, punch grafting and scar excision. Showing: (a) baseline and (b) after combination treatment.

Textural or benign proliferative conditions

Acne scarring Fractional non-ablative Er:glass (1540 nm,[56] 1550 nm), fractional ablative CO_2 laser[57] and ablative Er:YAG[58] have all been shown to ameliorate the appearance of acne scars. Based on qualitative findings from a RCT of 20 patients with DST, combination treatment with fractional ablative CO_2 plus non-ablative Nd:YAG laser treatment yielded superior cosmetic results compared with a fractional CO_2 laser alone.[59] While the outcome measures employed in the various studies have been diverse, a systematic review of fractional laser for acne scars concluded that ablative fractional lasers offered an improvement range of 26–83% compared to 26–50% with non-ablative fractional resurfacing.[60] It is reasonable to say that of all the conditions that fractional lasers can improve, it is acne scarring that shows the most consistent and remarkable benefits and the procedure is not only safer than fully ablative lasers but appear to be at least as effective (Fig. 5).

A treatment algorithm has been developed by a senior author stratifying patients according to the grade of acne

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Table 1 Grading algorithm for acne scarring according to lesion morphology

Grade	Description
1	Abnormally coloured macular disease: erythematous, hyperpigmented or hypopigmented flat marks visible at any distance.
2	Mild but abnormally contoured scarring: mild atrophy or hypertrophy that may not be obvious at social distances of 50 cm or greater and may be adequately camouflaged with makeup, the normal shadow of a shaved beard in men or normal body hair if extra-facial.
3	Moderately abnormally contoured disease: moderate atrophic or hypertrophic scarring that is obvious at social distances of 50 cm or greater and is not covered easily but flattens substantially by manual stretching of the skin.
4	Severely abnormally contoured disease: severe atrophic or hypertrophic scarring that is obvious at social distances greater than 50 cm, is not covered easily. Manual skin stretching cannot flatten it.

scarring and burden of disease, which has been reported previously.[61] Briefly, the scarring is first graded according to the morphology of the lesions (Table 1), with treatment determined accordingly (Tables 2–5). In grade 1 scarring, where pathology is mainly flat but dyschromic the emphasis is to even out these discolourations. As the severity of contour abnormality increases, preparatory (pre-laser) work is necessary for contour correction before laser therapy, whose role is to treat the more superficial contour and texture issues. For hypertrophic scarring, lasers may have a minor ancillary role in settling the contour but again only after a preparatory injection and medical therapy. Quite often the preparatory medical and procedural treatment will make laser treatment unnecessary. Our management algorithm is outlined in Tables 2–5.

Rhytides The role of lasers in facial rejuvenation is well established and a range of lasers has been utilised in the treatment of rhytides. For the past 20 years fully ablative laser resurfacing with the continuous wave CO_2 laser or Er:YAG has been the mainstay of therapy. The popularity of these methods of full ablation has waned, in view of long healing times and the very high incidence of CO_2-induced hypopigmentation. However, advances such as fractionated lasers and novel technologies (erbium: yttrium scandium gallium garnet [2790 nm] and plasma skin resurfacing) have further expanded our therapeutic armamentarium.[62] Three RCT comparing CO_2 lasers with Er:YAG lasers have demonstrated comparable clinical results.[63–65] It has been proposed that Er:YAG laser is best employed for fine to medium rhytides and due to its superior safety profile it is better suited to DST patients. In comparison CO_2 laser is superior for deep lines and more intensive tissue tightening. In terms of combination therapy, the administration of botulinum toxin enhanced cosmetic outcomes in patients undergoing laser resurfacing,[66,67] the application of topical retinaldehyde increased dermal thickness in patients treated with the Er:glass laser[68] and adjunctive CO_2 laser resurfacing improved the overall cosmetic effect for patients undergoing surgical blepharoplasty.[69] Fractional ablative lasers (CO_2 and erbium) have an established role in the management of rhytides and can complement other modalities ranging from non-ablative IPL to full resurfacing (Fig. 6).[70,71]

Rhinophyma Ablative resurfacing lasers can effectively re-contour the rhinophymatous nose.[72] CO_2 is preferred over erbium lasers because of the bloodless field that accompanies the coagulation of blood vessels from residual thermal energy (Fig. 7). There have been several small case series comparing laser resurfacing to electrosurgery or scalpel excision, all yielding similar patient outcomes.[9] Rhinophyma can also be de-bulked and sculpted with a radiofrequency electrosurgery wire loop. It has been recommended that isotretinoin be discontinued 6 –12 months prior to resurfacing of rhinophyma to mitigate the risk of delayed wound healing or keloid formation.[9] There is also an increasing trend to employ high-density fractional ablative lasers for mild rhinophyma followed by a second touch-up treatment if required.

Epidermal naevus Pigmented epidermal naevi can be targeted by long pulsed 532 nm lasers. Verrucal epidermal naevi and related benign proliferative skin disorders can be effectively controlled with ablative lasers. Depending upon the type of epidermal naevus, long-term remission can be achieved with a single treatment session. In general, superficial seborrhoeic keratosis and acrochordon-like lesions do best whereas lesions with deep appendageal involvement will tend to recur unless deep ablative procedures are performed, which carry the risk of incomplete ablation, scarring and dyspigmentation. Although there are more published data on CO_2 ablation of epidermal naevi than on ablative erbium, the latter is also effective.[75] Debulking curettage of the lesion immediately prior to ablative laser hastens the procedure and provides a specimen for a histopathological review.

Other benign skin pathologies Seborrhoeic keratosis and its related variant – dermatosis papulosa nigra – commonly present for cosmetic treatment. Many of these are amenable to cryotherapy, shave excision, curettage and cautery; all of which are reasonable first-line therapies. However, for cosmetically sensitive locations such as the eyelids, nose and lips, lasers offer superior control and finesse. These growths can be treated with 2–3 mm spot ablative lasers, as well as long pulsed 532nm lasers (Table 6). Common skin-derived tumours such as dermal naevi, fibrous papules angiofibromas and sebaceous hyperplasia are amenable to ablative laser removal, as are appendageal tumours such as syringomas and deposits such as xanthelasma. However, many of these tumours, particularly syringomas and angiofibromas, will recur over

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Table 2 Treatment algorithm for acne scarring grade 1: macular coloured marks

Scar type	Pre-laser treatment plan	Appropriate laser treatment
Erythematous flat marks	**Surface** Skin care†	**Surface** Vascular lasers (long-pulsed 532 nm or 595 nm) Fractional non-ablative lasers
Hyper-pigmented flat marks (post-inflammatory marks)	Skin care† Optimised home care (bleaching agents, sun protection etc.) and light-strength peels ± microdermabrasion	Possibly fractional 1927 nm laser Pigment lasers or intense pulsed light if required
Hypo-pigmented macular scars	Skin care,† sunscreens and occasionally bleaching preparations to limit contrast Occasionally melanocyte transfer procedures	Fractional non-ablative resurfacing

†Retinoids, topical anti-inflammatories and silicon dressings.

Table 3 Treatment algorithm for acne scarring grade 2: minor atrophic or hypertrophic disease

Scar type	Pre-laser treatment plan	Appropriate laser treatment
Mild rolling atrophic scars	**Surface** Multiple treatments of one or more of the following: Skin needling or rolling Microdermabrasion **Volume (to increase)** Dermal fillers and superficial dermal fillers	**Surface** Non-ablative fractional resurfacing Mid-infrared, non-ablative non-fractional resurfacing (not as effective as fractional lasers)
Small soft papular scars and mild hypertrophic disease	**Volume (to decrease)** Fine wire diathermy Intralesional fluorouracil, intralesional corticosteroids	**Volume (to decrease)** Fractional ablative lasers

Table 4 Treatment algorithm for acne scarring grade 3: moderately abnormally contoured disease – moderate atrophic or hypertrophic scarring

Scar type	Pre-laser treatment plan	Appropriate laser treatment
Moderate rolling, shallow boxcar	**Surface** Medical skin rolling, dermabrasion, chemical peeling, plasma skin resurfacing These may be replacement for lasers rather than preparatory treatment (medical skin rolling is the only currently popular alternative technique) **Volume (to increase)** Focal dermal fillers if localised Consider volumetric, deeply placed hyaluronic acid, calcium hydroxylapatite or other stimulatory agents such as poly-L-lactic acid if more generalised **Volume (to decrease)** Intralesional corticosteroids or intralesional fluorouracil **Movement** Botulinum toxin to muscles in lower face in affected areas (chin, marionettes) or in sites (glabella, forehead) of maximal muscle movement **Surgery** Subcision	**Surface** Fractional resurfacing (ablative or non-ablative); ablative lasers (CO_2 or erbium). All are excellent for this scar type after appropriate preparation **Volume (to decrease)** Fractional ablative and non-ablative occasionally useful Pulsed dye laser for residual erythema

time due to their deep location in the skin. Laser (Er:YAG) is also better suited for patients of DST where excessive tissue injury from non-laser methods can increase the risk of PIH. It is important to acknowledge that the use of topical rapamycin is a major breakthrough in the management of angiofibromas associated with tuberous sclerosis. Rapamycin has the potential to significantly reduce the role of laser in this condition.[74]

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Table 5 Treatment algorithm for acne scarring grade 4: severely abnormally contoured disease – severe atrophic or hypertrophic scarring

Scar type	Pre-laser treatment plan	Appropriate laser treatment
Punched out atrophic (deep boxcar), ice pick	**Surface** Trichloroacetic acid (Chemical Reconstruction of Skin Scars [CROSS] technique if numerous, deep and small) Fractional resurfacing may be combined with CROSS If few and broad but still < 4 mm in diameter, consider punch techniques (float, elevation, excision or grafting) – see surgery, with or without subsequent fractional or ablative resurfacing techniques	**Surface** Fractional resurfacing (ablative or non-ablative) All are good for this atrophic scar type but only after preparatory treatment Ablative lasers (CO_2 or erbium) is generally not as useful as fractional lasers
Marked atrophy	**Volume (to increase)** Fat transfer Volumetric filling with hyaluronic acid or calcium hydroxylapatite or stimulatory fillers such as diluted poly-L-lactic acid	**Volume (to increase)** Fractional resurfacing (ablative or non-ablative) All are good for this atrophic scar type but only after preparatory treatment Ablative lasers (CO_2 or erbium) is generally not as useful as fractional lasers but is better than it is with punched out scars due to its tightening effect on the skin surface
Significant hypertrophy or keloid	Intralesional corticosteroids or fluorouracil maybe supplemented with vascular laser	Fractional lasers and vascular lasers may be useful but again, preparation must be undertaken for useful results
Atrophic or hypertrophic disease	**Movement** Botulinum toxin often combined with fillers especially in lower face for atrophic disease As supplement to excision of atrophic or hypertrophic scars	Fractional lasers are more useful if movement and tension on scars are settled prior to laser therapy even if only in the few months following treatment
Bridges and tunnels, dystrophic scars	**Surgery** Excision	Fractional ablative and non-ablative and non-fractional full ablative lasers are all useful to disguise scars after excision
Punched out scars (deep boxcar)	Punch elevation if scar base suitable Punch excision, punch grafting if scar base poor	Laser use is the same as for bridges and tunnels
Marked sagging and apparent redundancy	Occasionally rhytidectomy	Lasers have limited role

CO_2, carbon dioxide.

Premalignant conditions

Solar radiation is implicated in the pathophysiology of photoaging, actinic dysplasia and cutaneous malignancy. In Australia these conditions commonly overlap and lasers are well placed to treat these conditions synchronously.

Actinic keratosis Historically, ablative lasers such as full CO_2 and erbium resurfacing have been used to treat actinic keratosis (AK) and compare favourably with field fluorouracil (5-FU) and trichloroacetic acid (TCA) (30%) peels.[75,76] Fractional resurfacing lasers are currently being evaluated for their efficacy in treating AK, with thulium (1927 nm) showing the most promise.[77] Amelioration of photoaging was noted in a RCT comparing photodynamic therapy (PDT) monotherapy with combination fractional CO_2 laser and PDT treatment. Combination treatment also resulted in a lower rate of AK recurrence.[78] PDT using aminolevulinic acid (ALA) in combination with either PDL (575–595 nm) or IPL can significantly clear AK.[79,80] Pretreating the skin with short contact (1 h) ALA prior to vascular laser or IPL therapy is a useful strategy to reduce any dysplastic lesions that may accompany the pigmentary and vascular photodamage (Fig. 8). For patients seeking treatment of premalignant skin lesions as well as photorejuvenation, either PDT with non-ablative laser or light devices or fractional resurfacing lasers (thulium or CO_2) may offer a practical therapeutic solution.

Actinic cheilitis Ablative laser therapy of actinic cheilitis is an important tool in the dermatologist's armamentarium, which includes topical therapy, PDT, cryotherapy, curettage and cautery, and surgical vermillionectomy. A prospective cohort study of 40 patients compared CO_2 laser with vermillionectomy, 5-FU or TCA peels in the management of actinic cheilitis, followed up for 4 years.[81] None of the patients treated with laser or surgical vermillionectomy developed clinical recurrence, compared with ≥ 50% recurrence rates with the other modalities. ALA PDT activated by PDL has also shown promise as an effective intervention for patients with actinic cheilitis recalcitrant to conventional therapies,[82] as has fractional thulium laser.[83] An important

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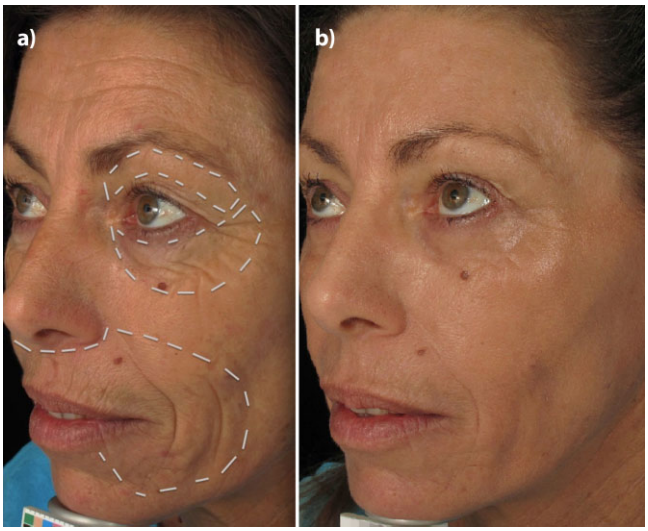

Figure 6 Caucasian woman, 50-years old, Fitzpatrick phototype III with photodamage and periorificial rhytides. Resurfacing parameters for: (i) upper eyelids: superficial fractional CO_2 (Lumenis Acupulse, San Jose, CA, USA) – 100 mJ, 60% density, single pass, (ii) perioral region: deep fractional CO_2 – 25 mJ 15%, two passes with third pass superficial CO_2 100 mJ 60% (Lumenis Acupulse), (iii) rest of face: superficial erbium peel 30 microns with 30 microns coagulation (Sciton Profile, Palo Alto, CA, USA) with onabotulinumtoxinA (Botox; Allergan, Irvine, CA, USA) injections to frontalis, corrugator supercilii, procerus and lateral orbicularis oculi (30 units in total). Showing: (a) baseline and (b) 2 months after treatment.

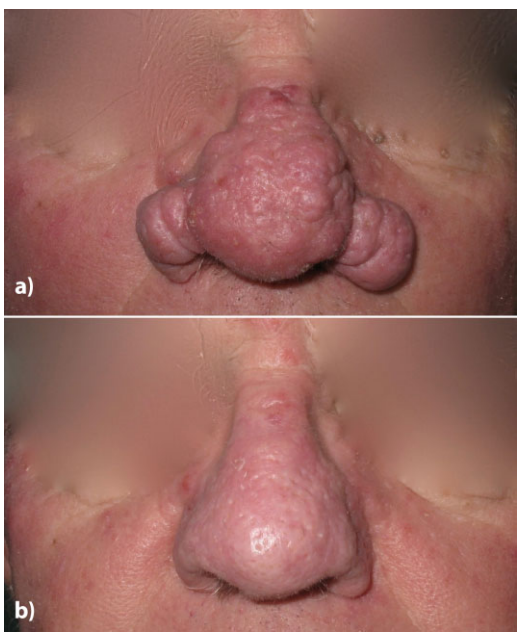

Figure 7 Caucasian man, 72-years old, Fitzpatrick phototype II with severe rhinophyma. Treated with the Sharplan CO_2 (now Lumenis Acupulse; Lumenis, San Jose, CA, USA) laser with computerised flash-scanner at 30 w, 3 mm spot, on continuous setting in feather mode. Treatment carried out under nerve block local anaesthesia. Showing: (a) baseline and (b) after treatment.

consideration in treating actinic cheilitis with laser, as with any other ablative modality, is that no tissue specimen is obtained, precluding a histopathological review. In an anecdotal report on approximately 100 patients with actinic cheilitis treated with CO_2 ablation only one case developed a squamous cell carcinoma in the treatment field,[84] although rates of up to 5% have been reported. Ongoing surveillance in this group is essential.

Inflammatory dermatoses

Lasers have been used as a non–first-line therapy for various common dermatological conditions such as acne and psoriasis (Table 6). The generic mechanism of action is most likely related to laser effects on lesion vasculature and the modulation of underlying cytokines and inflammatory mediators. Due to community concern over the systemic therapy of active acne, laser and light-based treatment alternatives have gained popularity in recent years. These therapies are thought to ameliorate acne through the inhibition of sebum production, the modulation of inflammation and keratinisation, and the conversion of porphyrins naturally synthesised by *Propionibacterium acnes* to bactericidal reactive oxygen species.[85] PDL has been shown to reduce acne severity, with the most rapid improvements observed within 4 weeks of commencing treatment.[86] PDL has been shown to be as effective as IPL and light-emitting diode phototherapy in the treatment of acne.[87] PDL effects were enhanced in the setting of methyl-aminolevulinate-PDT,[88] but conferred no additional benefit when combined with clindamycin-benzoyl peroxide topical therapy.[89] The results for Nd:YAG, KTP and diode (1450 nm) were less conclusive.[90–94] The studies described have employed a wide range of outcome measures, using pooled results for meta-analysis. However, a protocol recently submitted for a Cochrane Review on light therapies for acne may yield an evidence-based approach for the use of lasers in this setting.[95] Nevertheless, given that well-established, effective and less costly medications are available, consideration for laser therapy should be reserved for those who fail or have contraindications to medical therapies.

LASER COMPLICATIONS

The safety of laser therapy is well established although, as with any intervention, adverse effects are possible. A preoperative clinical review should include an evaluation of Fitzpatrick phototype, recent or planned sun exposure, recent artificial tan application, immunological or inflammatory comorbidities, history of herpes simplex, allergy, scarring, previous cosmetic or surgical procedures and a medication history for risk stratification. Pre-procedure and post-procedure photo-documentation should be mandatory. Common transient side effects include pain, pruritus, erythema, purpura, oedema, acne, vesiculation, crusting and pigmentary change. Bacterial, viral and candidal infections can complicate resurfacing procedures and prophylactic antimicrobials are often considered. Depending on the laser employed, potential long-term sequelae include permanent

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Table 6 Common dermatological conditions amenable to laser therapy

Dermatological condition	Pathology	Non-laser therapy	Laser therapy	Comment
Acne vulgaris	Comedones, papules, pustules from increased sebum and *Propionibacterium acnes* activity	• Topicals (benzoyl peroxide, antibiotics, retinoids) • Chemical peels • Systemic (antibiotics, retinoids, anti-androgens)	• LED (blue, red) • PDL/IPL • ± PDT with above	Conventional therapy less costly than laser
Angiofibroma	Papules with increased vasculature and fibrous tissue	• Electrosurgery (cautery or hyfrecation) shave excision	• Ablative laser (spot CO_2 or erbium) • Hot KTP	Potential tuberous sclerosis link (consider topical rapamycin) PDL useful only for lesion erythema
Dermal nevus	Smooth skin-coloured dome-shaped nests of naevomelanocytic cells	• Shave excision; electrosurgery; curette • Excision	• Ablative laser (spot)	Laser useful for facial lesions
Seborrhoeic keratosis or dermatosis papulosa nigra	Benign epidermal hyperkeratosis and acanthosis	• Cyrotherapy • Shave excision or electrosurgery or curette	• Ablative laser (spot) • KTP (532 nm)	Solar lentigines may be precursor lesion (treat with non-ablative devices) Flat lesions may respond to pigment lasers or IPL
Keratosis pilaris rubra	Follicular keratosis with perifollicular erythema on face, lateral arms and thighs	• Topical keratolytics • Gentle mechanical exfoliation	• PDL or IPL • Laser hair removal	Erythema responds better than texture roughness
Pseudofolliculitis	Inflammatory follicular papules, and pustules from curly hair re-entering the skin	• Topical (benzoyl peroxide, antibiotics, eflornithine) • Stop shaving	• Laser hair removal	Long pulsed Nd:YAG preferred for patients with dark skin phototypes
Psoriasis	T-cell driven hyperproliferative skin disorder	• Topical • Phototherapy • Systemic or biologics	• 308 nm excimer laser • PDL	Laser option not been widely adopted
Sebaceous hyperplasia	Visible yellow enlargement of sebaceous glands	• Electrosurgery	• PDL (± PDT) • Diode (1450 nm) • Ablative laser (spot) • KTP (532 nm)	Recurrence common
Syringoma	Benign proliferation of sweat ducts presenting as periocular papules	• Electrosurgery • Snip excision (few)	• Ablative laser (spot) • Fractional ablative laser • Occasionally KTP laser	Recurrence expected
Vitiligo	Focal or generalised loss of skin melanocytes and pigment	• Topical immunosuppression • Phototherapy • Autologous grafts	• 308 nm excimer laser • Ablative with pigment transfer techniques	Laser option not been widely adopted
Wart (verrucae)	Human papilloma virus induced epidermal hyperkeratosis	• Cryotherapy • Electrosurgery • Topical chemocautery • Immunotherapy	• PDL (± PDT) • Long-pulse Nd:YAG (1064 nm) • Ablative laser (spot CO_2)	Non-scarring methods preferred
Xanthelasma	Cholesterol deposition around the medial canthus	• Trichloroacetic acid (30–50%) • Electrosurgery • Excision	• Ablative laser (spot) • Fractional ablative laser	Check serum lipids

CO_2, carbon dioxide; IPL, intense pulsed light; KTP, potassium tritanyl phosphate; LED, light-emitting diode; Nd:YAG, neodymium-doped yttrium aluminium garnet; PDL, pulsed dye laser; PDT, photodynamic therapy.

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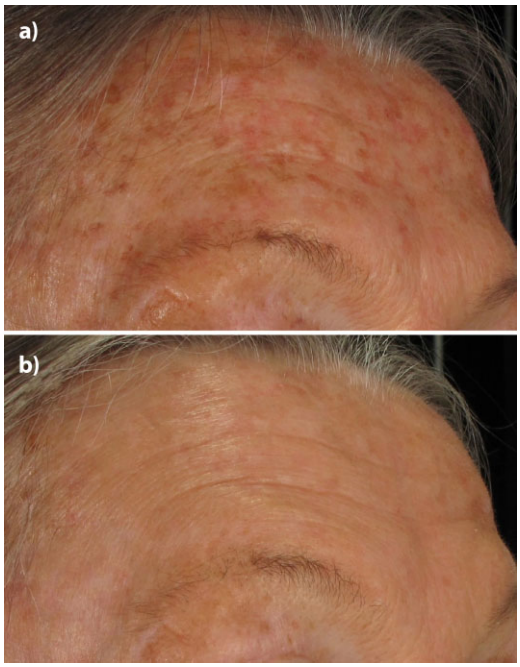

Figure 8 Caucasian woman, 65-years old, Fitzpatrick phototype II with severe solar lentigines and actinic keratoses. Face pretreated with 20% aminolevulinic acid for 90 min prior to pulsed dye laser (Candela Perfecta, Irvine, CA, USA) (595 nm): 12 mm spot, 5.5 J/cm^2 fluence, 40 ms pulse duration, medium cryogen cooling, followed by intense pulsed light (Sciton BBL, Palo Alto, CA, USA): 515 nm filter, 14 J/cm^2 fluence, 10ms pulse duration, 15°C (first pass) and 590 nm filter, 20 J/cm^2 fluence, 50 ms pulse duration, 15°C. Showing: (a) baseline and (b) 6 weeks after second treatment.

hypopigmentation or hyperpigmentation, paradoxical hypertrichosis (from laser hair removal) and scarring.[96]

WHAT'S NEW AND WHAT'S IMPORTANT?

Over the past 50 years technological advances have led to the development of light-based modalities, such that laser now offers a valuable therapeutic option for a wide range of dermatoses. As this technology evolves it is likely that the range of conditions amenable to light treatment will continue to expand. Confocal microscopy, optical coherence tomography and spectral approaches are all poised to bolster the impact of lasers in dermatology.[97] Newer lasers are being developed with pulse durations in femtoseconds, with some already finding clinical applications such as the femtosecond infrared titanium sapphire laser for onychomycosis.[98] Recent work on platelet-rich plasma,[99] neonatal cell suspensions[100] and cultured epithelial autografts[101] in concert with laser show promising results in improving postoperative healing. Adjuvant photosensitisers such as the use of intravenous indocyanine green to augment laser–tissue interaction when treating vascular lesions are currently being trialled.[102] Combination therapy is another important consideration, with research now directed at multimodal treatments utilising different lasers, or lasers in combination with medical therapies.

As more lasers and laser-like devices enter the market, patients and doctors may feel overwhelmed by the information and hype surrounding these devices; information that may be unsubstantiated, misleading or at times erroneous. Even published studies relating to a particular device or procedure may be subject to various biases and methodological flaws, such as insufficient power calculation, inadequate follow up and the misrepresentation of statistical significance as clinical significance. It is only with the benefit of time and shared experience that a particular device or treatment algorithm can be adequately assessed. The practitioner's experience and familiarity with their device(s) has a bearing on treatment outcomes. This is particularly relevant for multimodal or combination therapy favoured by some experienced practitioners – a treatment paradigm that is not well represented in conventional RCT. Furthermore, there is a significant learning curve in using many devices prior to gaining competency. In the rush to embrace the new, one should not lose sight of the fact that it is the practitioner, not the device, that is driving the treatment and ultimately, the end results.

CONCLUSION

Since the first applications of lasers in dermatology 50 years ago, we are now able to treat a myriad of conditions including vascular, pigmentary, inflammatory and cosmetic concerns. With ongoing research and clinical application, existing laser and laser-like therapies will continue to evolve and serve us well. We can expect a steady introduction of new technologies – the good, the bad, and the mediocre – that will be subjected to ongoing evaluation. To get the most out of each new wave of technology, the practitioner should take time to evaluate the available clinical evidence, strive to develop personal experience with worthwhile devices in order to find new ways to assist our patients. Practitioner experience in turn should be matched with sound clinical judgement to ensure that useful devices are used appropriately and ethically for optimum patient care.

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