# Lasers in dermatology

**Dermatological lasers offer significant benefits and their range of application continues to increase. GPs need to be able to advise patients as to what procedures are available and the limitations of current technology.**

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The use of lasers in dermatology is increasing as the range of problems amenable to treatment expands. This article describes the advantages and disadvantages associated with lasers that make use of four different mechanisms to interact with tissue: photothermolysis, photoacoustic effects, quasi selective ablation, and photosynthesis.

The term 'laser' is an acronym for 'Light Amplification by the Stimulated Emission of Radiation'. The box on page 66 provides some information about the principles underlying the use of lasers in dermatology.

## Photothermolysis

Photothermolysis, which is the most common mechanism employed by dermatological lasers, generates local heat to destroy its intended target. Specificity of wavelength means that only the intended target picks up the laser energy while the tissue around it is spared (see Figure 1). Pulsing ensures that the heat generated stays in the target zone, destroying this but not surrounding tissues.

Photothermolysis is the principal mechanism used by lasers treating blood vessels, some pigmented lesions, and photodamage (nonablative method). In addition, photothermolysis is the mechanism used to remove excess hair by laser treatment. This application is described in more detail in the box on page 69.

### The targets

The principal targets of lasers using photothermolysis include haemoglobin and deoxyhaemoglobin (in vascular lesions and blood transfer procedures), melanin (in superficial pigmented lesions and hair follicles) and water (in dermal lesions, with the epidermis protected by cooling).

### Vascular lasers

For the purpose of describing treatment by laser, vascular abnormalities may be usefully divided into:

- those with clearly visible individual vessels and basically normal-coloured background skin (e.g. some telangiectasia), and

**IN SUMMARY**

- **Vascular laser treatment is now the treatment of choice for a range of vascular disorders, such as telangiectasia, broad erythema, flushing and birthmarks.**
- **A range of benign pigmentary conditions can be treated successfully by laser.**
- **Tattoos are removable or at least may be lightened significantly by photoacoustic laser treatment, with only a small risk of scarring (less than 5%). Amateur tattoos are easier to remove than professional tattoos.**
- **Resurfacing lasers are capable of removing surface layers of the skin, leading to improvement in skin texture. They are useful for treating damage to the epidermis or dermis, such as scarring, sun damage or ageing changes.**
- **The best indication for laser hair removal is unwanted dark hair in both females and males.**
- **All lasers are capable of inducing complications such as scarring and changes in skin pigmentation. However, complications are uncommon and lasers are usually the safest technology currently available in most conditions for which they are used.**

## How do dermatological lasers work?

Laser beams have special characteristics that enable them to be used to treat a variety of dermatological problems. The applications of a particular laser will depend on how the beam interacts with biological tissue, which is in turn influenced by characteristics such as the beam's wavelength and pulse duration.

### Characteristics of laser beams

Laser light is different to ambient light in four major ways. It is spatially coherent, which means that the lightwaves are travelling in a synchronised fashion, and it is collimated, allowing it to retain its intensity over a long distance with low diffusion. Coherence and collimation allow a beam to be tightly focused to a point of maximum energy and used to cut tissue or interact with absorbing targets in the tissue (chromophores). The other important characteristic is that the light is monochromatic (i.e. single wavelength), which allows it to interact selectively with targets that are better able to absorb that wavelength.

Most dermatological lasers are used in a pulsed fashion that allows the beam to impact the target in tissue just long enough to damage it with relative sparing of surrounding structures. The duration of pulse required is proportional to the size of the target.

### Laser–tissue interactions

To interact with tissue, a laser beam must be absorbed by a target. Endogenous targets in the skin include DNA, subcellular organelles, haemoglobin (oxygenated and deoxygenated), melanin and water (Figure 1). Tattoo pigment is an example of an exogenous target. New targets may be added by applying, implanting or ingesting a sensitising material and then shining light or a laser on an area of skin (this is done with photodynamic therapy or blood transfer procedures).

A laser beam may interact with tissue in any of four ways:

- photothermolysis
- quasi selective ablation
- photoacoustic effects
- photosynthesis.

This article describes the way in which each of these laser–tissue interactions can be applied to problems in dermatology, and the types of effects that result.

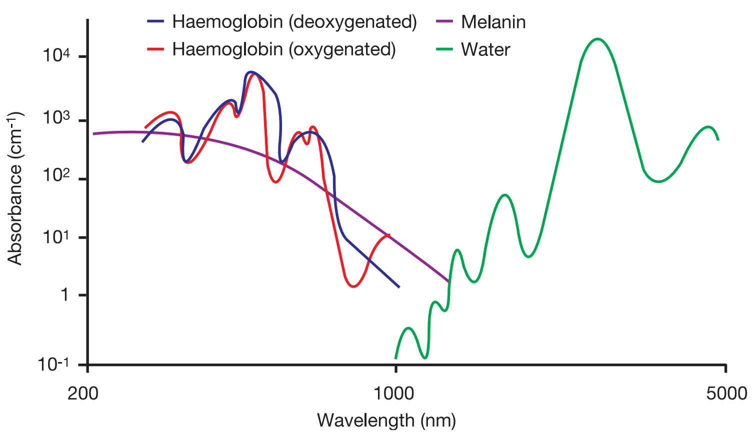



Figure 1. Absorption curves of light by major skin pigments.

- those with a more diffuse vascular abnormality (e.g. some port wine stains, haemangiomas, rosacea and other forms of densely packed telangiectasia).

For telangiectasia with normal background skin, almost all laser systems producing light between 500 and 600 nm are acceptable if used with a focused handpiece approximating the size of the vessel. However, when the vast majority of the tissue requires treatment, as with diffuse erythema, lasers must treat the entire area and it is essential to obey the rules regarding selective photothermolysis to avoid scarring and hypopigmentation.

### Applications

Vascular lasers are the treatment of choice for the following:

- telangiectasia (Figures 2a and b)
- paediatric and adult port wine stains (Figure 3)
- some haemangiomas
- postsurgical erythema
- erythematous scars and some hypertrophic scars.

In addition, vascular lasers possibly have a role in the treatment of warts and striae.

### 'Foibles': points to consider

- Fine diffuse vascular disease such as complexion changes and port wine stains require many treatments for success. Even given the relative safety of the systems now in use for treating broad disease, rarely scarring and pigmentary abnormalities will be seen (Figure 4).
- Perialar vessels are arteriolar and are difficult to treat, requiring several treatments for successful removal.
- Complications are rare with the more modern vascular lasers, but unintentional damage to the epidermis may occur causing temporary pigmentary changes (and, very rarely, scarring).

## Vascular laser therapy

Figures 2a and b. Telangiectasia before and after treatment.

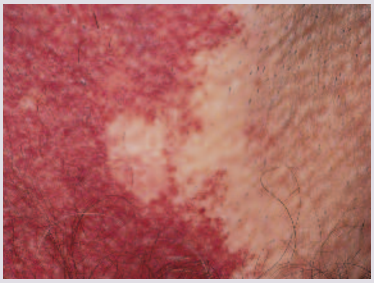


Figure 3. A port wine stain showing the effect of area treatment (see the hexagonal test patch).

Figure 4. Adverse effects of previous laser treatment to the anterior neck in which the pulse duration was too long, causing colour and texture change to a port wine stain. Posterior to this, an area treated with a shorter pulse has adequately cleared the stain.

## Vascular laser therapy

Figures 5a and b (above). Severe and widespread sun induced telangiectasia before and after treatment.

Figures 6a and b (above). Flushing before and after treatment.

Figures 7a and b (above). Poikiloderma of Civatte before and after treatment.

Figures 8a and b (right). A patient before and after combined treatment of vascular and pigmented lesions by widespread laser use.

### Recent improvements

Major changes have occurred in vascular lasers and light sources, entailing a combination of higher powered lasers able to generate large spot sizes with appropriate (and novel) wavelengths, appropriate pulse duration and use of epidermal cooling. Rosacea, keratosis pilaris rubra and rare forms of flushing are now amenable to treatment.

These changes mean that the ability to treat vascular lesions safely and effectively has improved (see Table 1). Vascular lasers can now be used to treat broad areas of telangiectasia, erythema (Figures 5a and b) and flushing (Figures 6a and b). In addition, they can be used to treat vascular diseases on any body site, such as poikiloderma (Figures 7a and b), a common disease occurring on the neck and chest that is thought to be due to combined effects of sun and perfume use.

Vascular and pigmented signs of ageing and photoageing can now be treated in the same session because many vascular lasers operate in wavelengths able to treat both vascular and epidermal pigmented lesions (Figures 8a and b). Many of the visible signs of photodamage involve the production of pigmented lesions (keratoses or lentigines) and telangiectasia. Removing these makes the patient appear a lot fresher and healthier.

continued

Most vascular diseases can be treated without the typical post-laser signs of bruising, scabbing or blistering. If these do occur at all they are likely to be mild and settle within a few days. The lack of short term sequelae has a lot to do with adequate epidermal cooling (Figure 9).

Vascular lasers are now also used with blood transfer procedures, which involves injecting a patient's own blood into the skin and then targeting and heating that blood. This is a method of inducing new collagen formation in diseases such as atrophic acne scarring.

Figure 9. Photograph of a static cooling device used to protect the epidermis.

## Photoacoustic effects

Photoacoustic effects utilise very high power and very short pulses to virtually shatter the target. They are at their best in the treatment of dermal and epidermal pigmentation and tattoos.

### The targets

Melanin is a common endogenous laser target. It is produced by melanocytes at the dermoepidermal junction and packaged in the form of small pigmented subcellular packages of pigment called melanosomes. Melanosomes are an epidermal component but may also appear in the dermis via pigmentary incontinence after inflammation and in deeper melanocytic lesions (such as naevi of Ota), and in intradermal, compound and congenital naevi.

Particles of tattoo pigment are approximately the same size as melanosomes – this means that most particles are too large to be removed effectively by the reticuloendothelial system. Some of the pigment will, however, be dealt with over time – this gives older tattoos a blurred appearance compared with recently acquired ones. Macrophages, perivascular fibroblasts and mast cells in the dermis phagocytose tattoo pigment.

### The lasers

Four Q-switched laser wavelengths are used in different situations – the frequency doubled Nd:YAG laser, the ruby, the alexandrite laser, and the Nd:YAG laser. These systems are probably equally effective in treating pigmented lesions and their ability to treat tattoos in general. However, they differ in their effectiveness for removing different tattoo pigments.

Typically, the Q-switching device stores up the power of the laser and then allows a sudden and short term release of this power, delivering pulses of laser light with high peak powers and extremely short (nanosecond) duration. Using wavelengths that are selectively absorbed by pigment granules (melanosomes or tattoos) they may break the pigment particles. The smaller sized granules of pigment are thought to be capable of removal by the reticuloendothelial system. As the duration of the pulse is very short, heat damage to adjacent tissues is minimised.

Longer pulse systems are only applicable for treating epidermal pigmented lesions if nonspecific destruction of the epidermis is permissible. For deeper melanocytic targets, Q-switched lasers must be considered the gold standard, but longer pulsed lasers can occasionally be used for large melanocytic lesions.

### Applications

Photoacoustic lasers are reasonably successful in removing tattoos and various benign pigmentary conditions. A summary is given in Table 2.

**Table 1. Applications of vascular lasers**

| Dermatological condition | Success of treatment |
|---|---|
| Telangiectasia | Excellent |
| Port wine stains, haemangiomas | Good to excellent |
| Spider naevi, angiofibromas | Good to excellent |
| Rosacea, photodamage and other flushing disorders | Good |
| Acne scarring (blood transfer techniques) | Fair |

**Table 2. Applications of photoacoustic lasers**

| Dermatological condition | Success of treatment |
|---|---|
| Tattoos | Excellent* |
| Naevi of Ota | Excellent |
| *Cafe au lait* macules | Excellent |
| Lentigines, freckles | Excellent |
| Benign junctional and compound naevi | Fair |
| Haemosiderin (post inflammatory pigmentation) | Fair |
| Melasma | Poor |

* But note that results are poor for aqua, cobalt blue and yellow and only fair for green.

## Laser hair removal

### The target

Laser hair removal usually depends on the ability to target melanin in the hair and hair follicle, so it is a treatment for darker hair only (i.e. not for red or blonde hair). The hair must be in the actively growing (anagen) phase and, because only a proportion of hairs are in this phase, a number of treatments must be performed before epilation is complete.

### The lasers and light sources

Q-switched Nd:YAG and ruby lasers were initially tried for hair removal without great long term success. Longer pulsed lasers have been much more successful – examples include ruby, alexandrite, diode and neodymium:yttrium–aluminium–garnet (Nd:YAG) systems. These lasers use wavelengths that are long enough to penetrate deeply and pulses sufficiently long to cook the hair follicles and possibly the hair bulge, which are large targets requiring relatively slow and low heating to succumb. Thermokinetic selectivity enables the melanin in the epidermis (a relatively small target) to be spared whereas the melanin in the hair follicle (a large target) is selectively destroyed.

Nonlaser systems such as filtered flashlamp pulsed intense light sources have been designed to produce epilation by the use of all longer wavelengths (between 600 and 1000 nm) to target melanin while filtering out short wavelengths (like a sunscreen).

### Applications

Unwanted dark hair in males or females is the best indication for laser hair removal. The best sites for treatment are the moustache area, chin, sides of face, areolae, back, axillae and bikini areas (Figures 10 and 11a and b). Larger areas such as the back, chest, arms and legs are treatable, but treatment takes a long time and thus becomes an expensive proposition.

### ‘Foibles’: points to consider

- Treating melanin in the hair while not affecting melanin in the skin is an ambitious feat of laser physics. A recent tan or heavily pigmented skin pigmentation may prove an obstacle to developing the relevant contrast and lead to scabbing, hypopigmentation or hyperpigmentation, and (rarely) scarring. The presence of competing chromophores presents less of a problem with longer wavelengths.
- It is not uncommon for three to six treatments to be required for a satisfactory outcome. To be successful, laser treatment must find the right target in the right stage of the hair cycle. In addition, most laser epilation will weaken the hair follicle but do not completely kill it, so the goal is to diminish the hair in terms of its colour, thickness and length with progressive treatments.

Figure 10. A test patch three months after epilation laser treatment.

Figures 11a and b. A patient with hirsutism before and after two treatments.

### Tattoo removal

Tattoos are removable or at least may be lightened significantly (Figures 12a and b) with only a small risk of scarring (less than 5%). Amateur tattoos are easier to remove than professional tattoos. After each treatment, the tattoo continues to slowly fade for up to three months or more.

The most common complication is nonremoval or incomplete removal of the tattoo. This is most often colour related: green, aqua, yellow and cobalt blue are particularly unresponsive to laser treatment. A deep deposit, acral location and dense pigment also contribute to nonremoval.

Q-switched lasers have a role in the removal and improvement of cosmetic facial tattooing (eyeliner and lip-liner). Cosmetic tattooing of the face is a popular but sometimes problematic technique. Malposition of the line, wrong colour, change of fashion or other reason may present a request for removal.

### Pigmented lesion removal

Epidermal pigmentation such as freckles, flat seborrhoeic warts and lentigines can be targeted by a number of different laser systems and nonlaser systems (Figures

13a and b, 14a and b, 15a and b). As the target is located high in the skin, its destruction will always end with the lesion forming into a scab – there is no other way for it to be eliminated but to be expelled from the skin surface as a crust or scab. Healing takes five to 10 days.

The same is not true, however, for dermal pigmented lesions such as deep melanocytic naevi, naevi of Ota or post-inflammatory pigmentation where the target is deep and the epidermis in many cases does not require destruction. In such cases, postoperative recovery can theoretically go on without obvious epidermal clues of scabbing, blistering or crusting. Cooling to protect the epidermis, used when treating vascular lesions, may be used when treating dermal pigmentation (see Figure 9).

### ‘Foibles’: points to consider

- Removing dermal pigmentation and tattoos is difficult. Many treatments may be required.
- Complications are rare with most lasers used for treating pigmented lesions. However, temporary pigmentary changes and (very rarely) scarring may occur.

## Quasi selective ablation

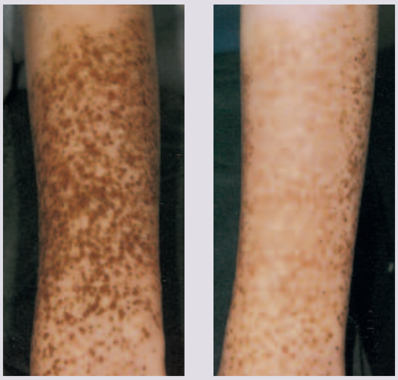
Quasi selective ablation involves heating tissues, but the mechanism is slightly different to that of selective uptake by skin targets such as melanin and haemoglobin. If water is the prime target of a laser, the beam becomes relatively nonselective because all skin contains this chromophore. However, the laser may be made capable of limiting the damage to the treated area by using short sharp pulses of extremely high energy – this makes it quasi selective. Examples include $CO_2$ and erbium:YAG resurfacing lasers. Quasi selective ablation causes tissue to be literally blown away in a puff of smoke.

The newer erbium:YAG laser has several perceived advantages over the $CO_2$ laser. It produces a cleaner ablation with

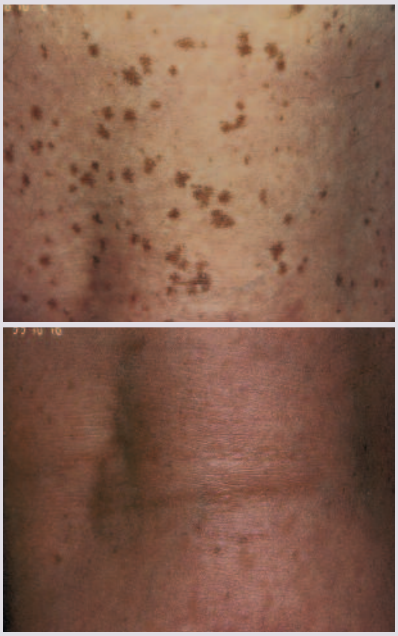
### Tattoo removal

Figures 12a and b. Tattoo before and midway through treatment.

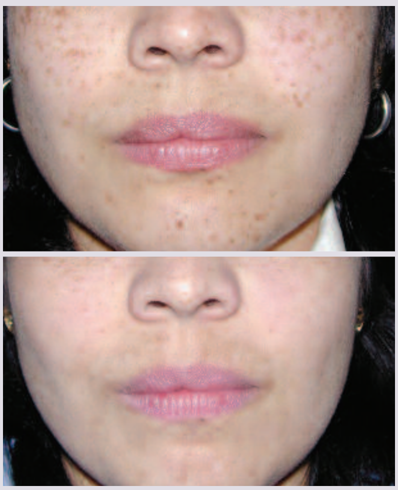
### Laser treatment for pigmented lesions



Figures 13a and b (above). Lentiginous naevi before and after treatment.



Figures 14a and b (above). Sunburn induced lentigines and freckles before and after treatment.



Figures 15a and b (left). Facial lentigines before and after treatment.

less healing time required and less chance of demarcation between treated and untreated areas (Figure 16). This allows facial regions or even small areas to be treated, rather than having to treat the entire face (as commonly required with the $CO_2$ laser).

## Applications

Resurfacing lasers remove surface layers of the skin – this results in healing and remodelling that leads to improvement in skin texture. They are useful for treating damage of the epidermis or dermis such as scarring (Figures 17a and b), sun damage or ageing changes (Figures 18a and b). The success of resurfacing lasers for different conditions is described in Table 3.

Infrared laser systems have largely replaced dermabrasion and stronger chemical peeling as the treatment of choice for sun-induced epidermal and dermal damage including epidermal keratoses, pigmented lesions, facial wrinkling and elastosis. Areas that were previously untreatable, such as the eyelids, can now be treated. Often the whole face is treated to minimise demarcation from treated to nontreated skin, but the so called cosmetic units (such as the areas around the mouth or eyes) may be well treated in isolation. With the erbium laser, in particular, these regional areas are treated under local anaesthesia. Premalignant disease such as actinic cheilitis where the lower lip is blotchy, scaly and discoloured is best treated with infrared lasers such as the $CO_2$ and erbium lasers.

Benign skin appendage lesions of sweat glands, sebaceous glands and hair follicles such as syringomas, trichoepitheliomas, sebaceous hyperplasia and adenoma sebaceum are relatively well treated. Often these lesions occur in such multitude or in such difficult locations that other treatment is awkward or unavailable. For some acne scarring, modern $CO_2$ lasers, often in combination with erbium lasers, offer the best currently available treatment.

Rhinophyma, the large bulbous nose developed as a complication of rosacea, is an efficiently treated disease by laser allowing a less bloody alternative to shaving and dermabrasion techniques and superior visualisation.

Sundry lesions such as warts, seborrhoeic keratoses and epidermal naevi may also be treated by infrared lasers.

## 'Foibles': points to remember

Resurfacing lasers can't do everything. For example:

- They are not a substitute for techniques such as face lifting, brow lifting or blepharoplasty where true tissue redundancy or structural loss is a problem.

## Resurfacing laser treatment

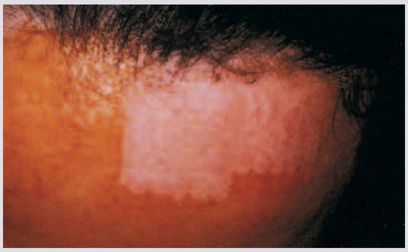


Figure 16. The erbium laser scan pattern on skin showing the clean ablative effect of the laser.

Figures 17a and b. A patient with acne scarring before and four months after treatment with $CO_2$ and erbium laser and fat transfer.

Figures 18a and b. A patient with photoageing before and three months after treatment with $CO_2$ and erbium lasers and fat transfer.

Figure 19. A demarcation line and relative hypopigmentation following $CO_2$ laser treatment.

- They are not particularly effective against expression lines or wrinkles that are dynamic in origin. Expression lines such as nasolabial lines are not well treated by lasers and should be addressed by other means such as by use of 'filling' materials. Muscle-induced or dynamic wrinkling is best treated by other means (such as botulinum toxin) rather than resurfacing.
- Laser resurfacing for acne scarring has its limitations. It is very useful for superficial scarring but is not the answer for deeper disease. In the latter situation, other procedures need to be used.

Complications do occur:

- Hyperpigmentation is a temporary but annoying complication in patients of olive skin type.
- Scarring is an uncommon complication, although distressing if it does occur.
- Hypopigmentation is a more common complication, possibly due to gradually increasing dermal fibrosis over the first two years after resurfacing together with a relative loss of melanocytes in the epidermis. Hypopigmentation is partially avoidable by decreasing the amount of energy supplied to the skin.
- It is important to appreciate the difference between sun damaged neck skin and newly resurfaced facial skin, which may produce a pseudo-hypopigmentation in which the face becomes the same colour as non-sun damaged skin elsewhere on the body but is quite different to its neighbouring tissues (Figure 19).

Morbidity is significant with resurfacing lasers, requiring one to two weeks of healing and many more weeks of erythema before normal skin is regained. There is continuing improvement for three to six months after resurfacing.

Maintenance of improvement is variable. There is much that is permanent about resurfacing results, but there is some deterioration over the course of the first two years. It is a reasonable conservative estimate that 50 to 60% of the best appearance post-resurfacing is maintained long term.

## Newer concepts in infrared laser resurfacing

The time of nonablative laser resurfacing is fast approaching. It is based on the concept of protecting the epidermis by cooling and then shooting the beam through this cooled epidermis to interact with targets such as water and blood vessels in the dermis.

It is important to keep in mind that these nonablative procedures – although reputed to be gentle – are significant. Swelling, temporary scabbing, dyschromia and scarring are possibilities.

## Photosynthesis

Photosynthesis is likely to become far more important with the growing interest in photodynamic therapy. Photodynamic therapy relies on a photosensitiser (e.g. topically applied 5-aminolevulinic acid) which acts to increase porphyrins within target cells (such as skin cancer cells). Once this porphyrin has accumulated sufficiently, exposing the skin to a measured dose of light or laser energy will generate singlet oxygen, a highly reactive molecule causing necrosis and apoptosis (programmed cell death) with antimicrobial properties. Typically, blue light is used for epidermal disease and red light for dermal effects.

Mostly this technology is being used for widespread but fairly superficial disease such as Bowen's disease, superficial basal cell carcinomas and solar keratoses

### Table 3. Applications for laser resurfacing

| Dermatological condition | Success of treatment |
|---|---|
| **Sun damage** | |
| Solar keratoses | Excellent |
| Wrinkling | Excellent |
| Actinic cheilitis | Excellent |
| Elastosis | Excellent |
| Dyschromia | Fair to good |
| Bowen's disease | Fair to good (with curettage) |
| Superficial basal cell carcinoma | Fair to good (with curettage) |
| **Acne scars** | |
| Atrophic dish like scars | Excellent |
| Ice pick scars | Poor |
| Hypertrophic scarring | Poor |
| **Complication of rosacea** | |
| Rhinophyma | Excellent |
| **Benign skin appendage tumours** | |
| Syringomas | Good |
| Trichoepitheliomas | Good |
| Xanthelasmas | Good |
| Sebaceous hyperplasia | Good |

## Photodynamic therapy

Figures 20a and b. Patient with multiple actinic keratoses before and after one session of photodynamic therapy.

(Figures 20a and b). It is also useful for cutaneous lymphoma and Kaposi's sarcoma. Unlike phototherapy, which uses ultraviolet light or radiotherapy, photodynamic therapy is noncarcinogenic. It also does not stimulate a collagen reaction and is thought to be a nonscarring technique rendering excellent cosmetic results. It probably has future applications for treating hirsutism, acne and psoriasis.

## Future and emerging applications

- **Treatment for hypertrophic scars.** Vascular lasers are possibly capable of decreasing thickened scars over a number of treatments. This will usually be in concert with other therapies such as intralesional corticosteroids and cytotoxic agents.
- **Excimer laser.** This recently introduced laser, which operates at a wavelength of 308 nm, is able to target diseases similar to those treated by photo - therapy – for example, psoriasis and vitiligo, and probably lichen planus and cutaneous T cell lymphoma. Early results suggest that this laser is able to induce remission much more quickly than conventional treatment and that remission tends to last a long time. The treatment delivers high energy, but is targeted to the lesions only and is ideal in patients with stable yet difficult to treat disease.
- **Leg vessel therapy.** A number of vascular lasers and light sources are beginning to lay claim to leg vessel treatment. It is unlikely that these devices will totally supplant sclerotherapy in the near future although a complementary role is likely.

## Conclusions

Lasers in dermatology have come a long way since Einstein's theorising in 1917 and Maiman's production of the first laser in 1960. They are now excellent tools for treating a bevy of conditions that were hitherto treated poorly or not at all. Port wine stains, haemangiomas, dermal pigmented birthmarks, diffuse telangiectasia, tattoos, excess hair, wrinkles, appendageal tumours and acne scarring are much better treated since the advent of this remarkable science.

Yet these applications are not all that lasers have to promise, and the rise of technology able to treat common cutaneous diseases such as acne, psoriasis, erythema and flushing, sun damage, vitiligo and skin cancers is exciting. It is fascinating to contemplate what may still await us. MT