



PERSPECTIVE

## Facial laser surgery

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**Abstract:** Lasers have a number of clinical applications on the face, ranging from aesthetic uses such as the rejuvenation of ageing face to functional ones such as the correction of bleeding vascular malformations. The vast growing uses of lasers on the face emphasises the need to have knowledge of the subject. Though the vast spectrum of lasers is very difficult to compile in an article, the authors give an overview of the application of lasers in the facial region and discuss the most defining treatment of the individual disease processes.

**Keywords:** face; laser; surgery

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## Introduction

### Background and history

Laser is an abbreviation for “light amplification by stimulated emission of radiation”. It generates light energy in the photon beam form. The concepts to build laser was postulated in 1917 by Albert Einstein, which was published in *The Quantum Theory of Radiation*. Maser, an acronym for microwave amplification by stimulated emission of radiation, was devised by Charles H Townes and Arthur L Schawlow in 1958. Townes along with Aleksandr Mikhailovich Prokhorov and Nikolay G Basov were awarded Nobel Prize in 1964 for their contribution in quantum electronics which helped in the discovery of Laser and Maser<sup>[1]</sup>.

Helium-neon laser, the first gas laser which produced a continuous beam, was developed by physicists William Bennett and Ali Javan in 1961. Argon laser was thereafter discovered, followed by 10,600-nm carbon dioxide (CO<sub>2</sub>) laser by engineers Kumar Patel *et al.* in 1964<sup>[2]</sup>. Neodymium-doped yttrium aluminium garnet (Nd:YAG) was developed by scientists JE Geusic, HW Marcos and LG Van Uitert in 1964 and was used first for the control of gastrointestinal bleed. Dye lasers were discovered by physicists PP Sorokin and JR Lankard as well as FP Schafer *et al.*, in 1966<sup>[3]</sup>.

Later, excimer lasers, copper vapour lasers and other lasers were discovered and continued to be added to the armamentarium of the treating doctors. The principle of selective photothermolysis was proposed in 1983 by Anderson and Parrish where they explained the process of selective destruction of certain tissues by absorption of a particular wavelength by a chromophore<sup>[4]</sup>. To standardise the practice of laser, many societies were established such as The Laser Institute of America, International Society for Laser Medicine and Surgery, American Society for Laser Medicine and Surgery, and The American National Standard Institute for the organisation and evolution of lasers.

### Facial laser surgery

The use of lasers on the face has a very wide spectrum. They are amongst the most popular options in aesthetic practice for facial rejuvenation. They can also be used for the treatment of vascular and pigmented lesions, removing unwanted hair, treatment of facial scar and for the treatment of some dermatological disorders. We will discuss them in the article.

### Safety in laser surgery

Safety in laser surgery is of paramount importance. It comes in the top priorities for any clinician. The Federal Laser Product Performance Standard classifies med-

ical lasers on the basis of the ability to cause damage to ocular and cutaneous structures (Table 1). Class I laser does not cause damage. Class II lasers can cause ocular damage only if someone overcomes the natural aversion response towards bright light. Class III (mainly IIIb) lasers can cause ocular damage, and class IV lasers can be harmful to eyes and skin and has potential fire hazard.

Ocular hazard by long wavelength lasers (CO<sub>2</sub> and Erbium-doped yttrium aluminium garnet (Er:YAG)) can cause corneal burns. Holmium: YAG (Ho:YAG) laser can cause injury to the lens and cornea. It spares the retina. Short wavelength lasers can cause retinal damage<sup>[5]</sup>. Appropriate safety eyewear should be used for the protection of the eyes of all members who are inside the chamber where the session is going on. Fire hazard is associated mostly with the use of high power systems. Fire safety should be a priority inside the chamber. Fire extinguisher should be available near the laser room. The chamber should have restricted entry at the time of the procedure to avoid any accidental exposure.

Evacuation systems and ultra-low particulate air filter should be used to evacuate the plume and protective devices should be used by all members of the team.

International standards can be followed by observing the guidelines laid by the International Electrotechnical Commission for manufacturers, clinicians and administrators.

## Ethics statement

The figures of the patients exhibiting various conditions are from the Department of Plastic and Maxillofacial Surgery, Government Medical College and Hospital, Nagpur, India. Informed consent was taken from the patients (or their parents, in the case of minor patients).

**Table 1.** Laser safety

Class of Laser	Safety profile
I	Safe
II	Safe but harmful if natural aversion response to light averted
III	Harmful to eyes
IV	Harmful to eyes, skin.

## Discussion

### Laser for rejuvenation of the face

The features of the aging face appear due to a combination of intrinsic and extrinsic factors<sup>[6]</sup>. These include wrinkles, malar depression, actinic changes, excess of skin, furrows, accumulation of submental fat and the showing of mandibular teeth. Sagging occurs due to the loss of skin elasticity, which decreases from an early age<sup>[7]</sup>. Wrinkles (Figures 1 and 2) appear due to the decrease of procollagens I and III and collagen VII<sup>[8]</sup>. Fitzpatrick skin phototypes<sup>[9]</sup> are used to classify the responses to sun exposure by the skin (Table 2). There are many lasers available for skin resurfacing. They can be used in the treatment of skin wrinkles, acne scars, actinic and seborrheic keratosis, photo-aging and lentigines. Table 3 summarises the different types of lasers.









**Figure 1.** Aging face with wrinkles



**Figure 2.** Aging face with wrinkles and lentigines

**Table 2.** Fitzpatrick skin types

Type	Scores	Skin colour	Effect to UVA	Reaction to sun	Skin tone	
I	0–6	Caucasian, blond/red hair, freckles, fair skin , blue eyes	Very sensitive	Always burns, never tans	Very fair	
II	7–13	Caucasian	Very sensitive	Usually burns, tans minimally	Fair	
III	14–20	Darker Caucasian, light Asian	Sensitive	Burns moderately, tans uniformly	Fair to medium	
IV	21–27	Mediterranean, Asian, Hispanic	Moderately sensitive	Rarely burns, always tans well	Medium	
V	28–34	Middle Eastern, Latin, light-skinned black, Indian	Minimally sensitive	Very rarely burns, tans very easily	Olive or dark	
VI	35–36	Dark-skinned black	Least sensitive	Never burn, always tans	Very dark	

**Table 3.** Summary of lasers

Laser type	Wavelength (nm)	Indications	Pulse duration (ms)	Complications
CO <sub>2</sub>	10,600	Skin resurfacing, wrinkles	50	Edema, erythema, pruritus, contact dermatitis, hyperpigmentation
Erbium:YAG	2940	Mild-to-moderate rhytids, scars, pigmentation	.25	Minimal burning
Nd:YAG	1064, 1320,1440	Wrinkles, pigmentation	50	Pain, redness, itching, swelling
IPL	500–1200	Dyspigmentation, wrinkling, telangiectasia, hair removal	1–300	Erythema, discomfort, blisters, pain, hyperpigmentation, crusting, purpura
PDL	585, 595	Vascular lesions, wrinkling, dyspigmentation	45	Pain, purpura, swelling
KTP	532	Photo-damaged red-brown discoloration	20–50	Edema, pain, crusting, erythema, telangiectasia
Alexandrite	755	Tattoo, hair removal	3	Pain, redness, swelling, itching
Diode	600–1020	Facial rhytids, telangiectasia, hair removal	30	Hyperpigmentation, erythema, edema

**Ablative techniques**

This is more aggressive as compared to non-ablative lasers. CO<sub>2</sub> laser (10,600 nm) vaporises the epidermis and dermis layer by layer. It rejuvenates the skin by epidermal regeneration and reorganisation, and by the strengthening of collagen bundles. It is more useful in severe facial wrinkles, challenging skin textures, and dyspigmentation<sup>[10]</sup>. Fractional ablative lasers provide adequate skin resurfacing safely as compared to the unfractionated models used earlier. Non-ablative laser spares the epidermis, decreases fine wrinkles, chang-

es the texture and tone of skin and treats dyspigmentation.

The scarring produced in continuous wave (CW) laser is more when compared to the short-pulsed CO<sub>2</sub> laser. Currently, high power pulse (ultrapulse) and CW CO<sub>2</sub> laser (acupulse) are used. The outermost layer of the epidermis and some part of superficial dermis are removed. Activated fibroblasts help in the deposition of collagen and elastin tissue<sup>[11]</sup>. The papillary dermis is affected to a minimum in newer lasers. The superpulsed lasers based on selective photothermolysis result in pure steam vaporisation and the adjacent tissue is affected

minimally<sup>[12]</sup>

Ultrapulse CO<sub>2</sub> lasers for midfacial region are treated with 90 mJ/45W with first-pass density setting of 7, and less for the upper and lower eyelids and even lesser for hairline and jawline. In the second pass, lesser density is required as compared to the first. Some wrinkles may require a third pass.

Postoperative period may be complicated with swelling (which subsides in a week), erythema, pruritus and contact dermatitis. Post-inflammatory hyperpigmentation, which occurs 2–3 weeks post-therapy, may be decreased with prior treatment of retinoic acid and hydroquinone<sup>[13]</sup>.

#### Er:YAG lasers

It has a wavelength of 2,940 nm with water as its chromophore. It is used for superficial rhytids, actinic keratosis, dyschromia and Favre-Racouchot disease<sup>[14]</sup>. The penetration and ablation is more superficial compared to CO<sub>2</sub>. About 10–20 μm of thermal damage is caused by 10–40 μm of skin impact. Skin tightening is achieved by the second and third pass. Wrinkles are reduced up to 50% in 2–3 passes<sup>[14]</sup>. Er:YAG has less crusting and erythema compared to CO<sub>2</sub> laser<sup>[15]</sup>. Erbium can be combined with CO<sub>2</sub> to give uniformity in the treatment of different areas of the face.

#### Fractional photothermolysis

It was developed by Relent technologies. The wavelength is 1,550 nm. It is among the recent options for skin rejuvenation<sup>[16]</sup>. It treats only a fraction of skin. The thermal side effects are decreased.

#### Non-ablative techniques

These include plasma skin regeneration, pulse dye laser, Nd:YAG, intense pulsed light (IPL), light-emitting diode(LED) devices and photodynamic therapy. It involves the sparing of epidermis, and affects the dermis directly, which helps in early recovery. The mechanism is by targeting chromophores such as melanin, haemoglobin and collagen. The wavelength is in the visible to infrared region, targeting the upper and middle part of the dermis. There is the activation of dermal fibroblasts, which helps in healing.

#### Plasma skin regeneration

Nitrogen plasma delivers energy to the skin. There is no chromophore mediator and the energy is delivered in a uniform and smooth way to the dermis by pulses of plasma. It is a non-ablative method used to treat facial rhytids, benign facial skin lesions and actinic keratosis.

#### Pulse dye laser

Long pulse dye laser is used for the treatment of facial

lentiginos and wrinkles. There is no scarring or changes in skin pigmentation post-operatively<sup>[17]</sup>. There is an increase in dermal collagen with the use of 585-nm pulsed dye laser (PDL) between days 0–90 with maximum increase in the periorbital region<sup>[18]</sup>.

#### Intense pulse light

Dyschromia, ephelides, senile and solar lentiginos can be treated with intense pulsed light (IPL)<sup>[19]</sup>. It is a non-coherent light with a wavelength between 500–1,200 nm. It works on the basis of selective photothermolysis targeting haemoglobin, melanin and water. Skin tightening in IPL occurs due to the contracture of the heated collagen fibers. Photoaging due to telangiectasia and pigmentation shows significant improvement within three treatments<sup>[20]</sup>. Side effects include mild crusting, blistering, erythema and purpura, all of which are transient and self-limiting.

#### Potassium titanyl phosphate

The 532-nm lasers produce energy pulses with small spots. They target oxyhemoglobin and melanin. Patients with Fitzpatrick types I to III are good candidates for these lasers<sup>[21]</sup>. They are effective in treating photo-damaged red and brown discolourations. Side effects of the therapy include erythema and edema.

#### Light-emitting diode

Light-emitting diode (LED) was invented in 1962. It stimulates collagen synthesis and accelerates fibroblast-myofibroblast transformation. The wavelengths are 590, 633 and 830 nm. For fine wrinkles, the periorbital area show more improvement than nasolabial area<sup>[22]</sup>. LED has shown to decrease erythema, edema, pain and bruising following blepharoplasty and periocular resurfacing by Er:YAG/CO<sub>2</sub> laser<sup>[23]</sup>.

#### Near-infrared laser

Rejuvenation with this laser is produced by long-lasting elastin stimulation. Significant improvement in the skin texture and wrinkles has been observed<sup>[24]</sup>. The increase in collagen and elastin improves skin texture, although without significant improvement in hyperpigmented lesions<sup>[25]</sup>.

#### Photodynamic therapy

It involves use of light with photosensitising substance (δ-amino levulonic acid). It has an additional advantage of destroying precancerous cells, in addition to the treatment of sun-damaged fine lines and pigmentation.

The more ablative the laser is, the better results it gives. This, however, comes at a cost of longer time of

recovery for these patients. The fractional lasers provide the best combination to give optimal results.

## Treatment of pigmentation

### Solar lentigines

Though there are many topical therapies available, the treatment of solar lentigines by laser provides almost complete clearance. The options include Q-switched lasers, long-pulsed lasers and HGM K1 krypton lasers. Long-pulsed dye laser have shown near complete clearance of the lesion and reduced machine-produced index factor<sup>[26]</sup>. Q-switched Nd:YAG with 532-nm wavelength is a good option for light-skinned patients with lentigines, and 1064nm for darker-skinned patients. Q-switched Nd:YAG is better than fractional CO<sub>2</sub> laser for treating solar lentigines<sup>[27]</sup>.

### Solar elastosis

CO<sub>2</sub>, Nd:YAG, diode, IPL and Er:YAG can be used for solar elastosis. Diode laser has the advantage of preserving the epithelial layer with resurfacing effects, same as that of CO<sub>2</sub> laser<sup>[28]</sup>.

### Melasma

Treatment options for melasma include:

1. Q-switched ruby laser
2. Erbium:YAG – refractory melasma
3. PDL – recurrent melasma
4. Fractional laser
5. IPL

Lasers should be used in patients of melasma who are refractory to topical therapies.

### Use of lasers in facial acne

Potassium titanyl phosphate (KTP) laser may act through selective photothermolysis of the blood vessels or by a photodynamic effect on *Propionibacterium acnes*<sup>[29]</sup>. The 585-nm PDL has been used in treatment of acne scar<sup>[30]</sup>. It also decreases post-acne erythema. 1450-nm diode laser and 1540-nm Erbium glass laser are also used for acne with the latter causing decreased oiliness.

They can be used in the inflammatory phase of acne by acting on haemoglobin and water as chromophores and for the management

## Laser for treatment of vascular lesions on the face

### Hemangioma

It is the most common type of vascular tumor (**Figure 3**).

Children should be treated when the hemangioma fails to regress. PDL with wavelength ranging from 585–600 nm with pulse width of about 0.45 ms<sup>[21]</sup> can be used to treat these lesions. Residual scarring can be treated by CO<sub>2</sub> or Erbium lasers.

Laser photocoagulation is the method of choice to treat port-wine stain. Argon laser can be used for the treatment of hypertrophied nodule of thickened port-wine stain. However, the disadvantage with Argon, CO<sub>2</sub> and Nd:YAG is scarring<sup>[31]</sup>. Best results are with flashlamp-pulse dye laser<sup>[32]</sup>. Patients are treated at interval of 4–6 weeks or on clinical judgement.

### Venous malformation

Nd:YAG can be used for deeper and superficial lesions with 595–1,064-nm laser (**Figure 4**).

### Lymphatic malformation

Laser is useful in treating superficial lymphatic malformation of the head and neck area. 10,600-nm CO<sub>2</sub> laser is of help for treating mucosal lesions.

### Facial telangiectasia and rosacea

Vascular laser can be used to deal with facial telangiectasia. CO<sub>2</sub> and Erbium:YAG can be used to treat rhinophyma (**Figure 5**). PDL remains the gold standard for the treatment of vascular lesions, though erythema and purpura may persist for a couple of weeks after treatment.



**Figure 3.** Hemangioma of the upper eyelid



**Figure 4.** Venous malformation of the tongue

## Laser for tattoo on the face

Traumatic tattoos can be due to carbon, graphite, *etc.* They can be removed with Q-switch Alexandrite laser<sup>[33]</sup>. Tattoos applied by a professional are deeper and are more difficult to remove. Exogenous ink is the chromophore. Quality switch lasers have been used traditionally to treat these tattoos. Multiple settings are required for complete removal of pigments. The appropriate lasers for different colours of tattoo are as follows:

1. Black and dark blue pigment: QS ruby, QS Nd:YAG (1,064 nm) and QS Alexandrite<sup>[34]</sup>
2. Orange and red brown: 1064-nm QS Nd:YAG doubled in frequency
3. Red: Nd:YAG<sup>[35]</sup>
4. Green pigment: Alexandrite<sup>[35]</sup>
5. Purple and violet: Q-switched ruby laser<sup>[35]</sup>
6. Light coloured/pale: QS Alexandrite and QS Nd:YAG laser<sup>[36]</sup>
7. Newer modalities:
  - a. Multi-pass treatment - multiple passes in one session<sup>[37]</sup>
  - b. Picosecond laser

Black, dark blue and red can all be removed with QS ruby, Nd:YAG and Alexandrite lasers.

## Laser for unwanted hair on the face

Alexandrite (755 nm), diode (800 nm) and ruby (694 nm) lasers can be used to remove unwanted hairs on the face (**Figure 6**). Cutaneous hyper/hypopigmentation is more in these short wavelength lasers as compared to longer wavelength laser such as Nd:YAG (1,064 nm) laser. IPL and Q-switched Nd:YAG are other options for hair removal with good results.

Patients should be educated about the multiple treatment sessions and minor side effects such as itching, edema and redness after the procedure. People with higher Fitzpatrick skin types are more responsive to diode and Nd:YAG.

## Laser for facial scar

Facial scars can be a result of trauma, post-surgery, post-burn or after any inflammatory process (**Figures 7 and 8**). Though many invasive and non-invasive treatment options are available, they are associated with recurrence, side effects, as well as failure rates.

## Specific lasers for different scars

1. Post-burn scars: CO<sub>2</sub> laser
2. Immature post-burn scar: Nd:YAG (1,064 nm)

3. Fibrotic scar: Fractional laser
4. Hyperpigmentation and discolouration in post-burn scars: IPL and Q-switch
5. Hypertrophic scars<sup>[38]</sup>: Nd:YAG (1,064 nm) and CO<sub>2</sub>
6. Post-traumatic scars<sup>[39]</sup>: Erbium glass (1,540 nm)

IPL, PDL and Erbium glass (1,540 nm) have shown decent results.



**Figure 5.** Rhinophyma of the nose



**Figure 6.** Black hairy nevus of the face



**Figure 7.** Post-traumatic facial scar



**Figure 8.** Post-burn hypertrophic scar on the face

### Lasers for cylindroma

The Nd:YAG laser<sup>[40]</sup> and CO<sub>2</sub> laser<sup>[41]</sup> can be used to treat cylindroma (**Figure 9**) in the head and neck region<sup>[40,41]</sup>.



**Figure 9.** Cylindroma of the head and neck region

### Conclusion

Lasers have become a powerful tool for many procedures on the face. Proper training of the care provider along with the staff and maintaining acceptable standards in the clinic makes the process safe. The risk-benefit ratio, the usefulness and the adverse effects of the procedure should not only be kept in mind at the time of procedure but are also explained to the patient and documented in detail prior to the procedure. The safety of medical

personnel and the patient are of paramount importance and laser safety protocols should be followed every time the procedure is performed. Caution should be taken when evaluating the patient with unrealistic expectations.

### Author contributions

Both S Harsh and SB Patil contributed to the drafting of manuscript.

### Conflict of interest

The authors declare no potential conflict of interest with respect to the research, authorship, and/or publication of this article.

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