25 Lasers in Aesthetic Surgery

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The term laser originated as an acronym for "light amplification by stimulated emission of radiation". Lasers differ from other sources of light because the lights they emit are coherent, monochromatic, and collimated. Because of these characteristics, lasers can be used for selective photothermolysis. Laser light absorption and heat production in the targeted chromophore ultimately leads to its results. Lasers have been used in aesthetic surgery to improve skin texture, diminish dyspigmentation and rhytides, and tighten skin. More recently, lasers are being used for tattoo removal. In this chapter, we review the physics behind laser technology, the different lasers available, their clinical uses, and how to avoid complications. We will compare lasers to other competing available technologies such as pulse light devices, radiofrequency, and ultrasound therapy.

The primary principle behind laser in aesthetic surgery is selective photothermolysis.

Basic Science

The tissue reaction to lasers is the result of the absorption of light. Light is made of photons. Photons are released from an excited atom. In the case of lasers, photons are organized in a singular color and a non-ionizing radiation (because it is non-ionizing it is not mutagenic). Photons travel in waves.

The electromagnetic spectrum is used to describe the entire range of possible wave frequencies. Waves are typically described based on frequency, wavelength, or photon energy. The ranges include radio wave, microwave, terahertz, infrared, visible spectrum, ultraviolet, X-rays, and gamma rays. The visible spectrum has a wavelength from 390 to 700 nm. ***The fundamental difference between pulse light devices and lasers is in the spectrum of the light source. Lasers have a single wavelength***, ***while pulse light devices include a broader spectrum*** (Table 25.1). Because of the difference in light sources, pulse light devices and lasers have different components and properties.

Laser components include a flashlamp, a pumping source, a medium, and a series of reflective mirrors. A large portion of the photons will scatter (the room gets hot, use fans!). Different available mediums are: alexandrite, Nd:YAG (yttrium aluminum garnet), Ho: YAG, CO_2, Argon. The different wavelengths emitted by the various mediums result in different tissue absorption and relaxation times (Table 25.2). These properties determine a laser's clinical indications.

There are **Three laser modes**: continuous (rarely used), pulsed (most common), and

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Table 25.1 Comparison of laser to intense pulse light (IPL)

Characteristic	Laser	Intense pulse light (IPL) Broad band light (BBL)
Light	Monochromatic Collimated	Polychromatic Non-collimated
Target	Specific chromophores	Various chromophores
Clinical use	Scar revision Skin resurfacing Photorejuvenation Hair removal Tattoo removal	Vascular lesions Hair removal Pigmented lesions Photorejuvenation
Level of discomfort	Low to high	High
Filters	No	Yes
Cooling	No	Yes
Skin types to use it	All	Avoid darker skin types

Table 25.2 Wavelengths emitted by different devices

Device	Wavelength (nm)	Clinical application
CO_2 laser	10,600	Rejuvenation To a lesser extent dyschromia
Er: YAG laser	2,940	Rejuvenation To a lesser extent dyschromia
Vascular pulsed dye laser (PDL)	585 and 595	Vascular lesion
Potassium titanyl phosphate (KTP) laser	532	Vascular lesions
Intense pulse light (IPL)	500–1200	Small vascular lesions Pigmented lesions Hair removal To a lesser degree rejuvenation
Infrared laser Nd:YAG Diode laser Erbium: glass Broad band infrared	1000–1800 1320 1450 1540 1100–1800	Rejuvenation

q-switch or mode locked (extremely short, used for destruction of specific lesions).

The effect of the laser extends beyond the penetration of the light and the **residual thermal damage**. The heat transferred to the underlying collagen is believed to contribute to contraction and remodeling, leading to skin tightening. As an example, CO_2 lasers have a thermal damage zone of 100–150 mcm while Er:YAG lasers have a thermal damage zone of 10–40 mcm.

Fractional lasers treat only a fraction of the skin within a targeted area, leaving intervening areas of skin untouched. To produce this effect, the laser is emitted in numerous narrow, microscopic columns measuring 400 mcm in diameter and up to 1300 mcm deep. Higher energy with smaller spot sizes increases the depth of the laser. Re-epithelialization occurs from the sites of undamaged skin, resulting in shorter recovery. There are fractional varieties of CO_2, Er:YAG, and others.

Variables to Understand When Using the Laser

– Wavelength ≥ determines your targeted tissue.
  Wavelengths will have different chromophores and absorptions. Wavelengths with high absorption target superficial targets while low absorption target deeper targets. Example: At a setting of 5 J/cm^2 and pulse duration of less than 1 ms, CO_2 light penetrates 20–30 mcm (less absorption), while an Er:YAG has more affinity of water and only penetrates 10–15 mcm (higher absorption).
– Power per spot size ≥ density
  By decreasing the spot size you increase the energy.
– Time of pulse or pulse width ≥ thermal relaxation time
  Thermal relaxation time is the time required for the tissues to dissipate more than 67 % of the thermal energy. It tells us the time needed to cool a target before we can safely heat it again to prevent complications. Practical example: Pulse width for hair reduction in lighter skin is usually 15–30 ms, but in darker skin you increase the pulse width to 20–40 ms.

– Cooling ≥ protection for the epidermis and anesthesia

Choice of laser is heavily influenced by patient factors as well as laser availability and clinical expertise. Laser resurfacing first emerged in the 1980s with the use of continuous CO_2 lasers. These lasers were associated with high risks for adverse effects, and were modified, for example, by including rapid scanning to improve safety. In the 1990s, Er:YAG emerged with more precise control of the depth of the ablation and fewer side effects. The depth of penetration for CO_2 is 0.1 mm, while for Er:YAG the depth can range from 4 microns to 200 microns. Multiple passes can be used if necessary. Nanopeels (ranging from 4 to 10 microns) and micropeels (10–50 microns) are now possible with better control of depth. Fractional lasers subsequently emerged in the 2000s with decrease in the recovery time. There are limited studies and a few small, randomized trials. It is difficult to compare results between the different available lasers and settings, given the lack of outcome standardization.

Split-face trails comparing CO_2 and Er:YAG initially showed greater improvement in deep rhytides with CO_2 lasers. When more passes of Er:YAG was compared to CO_2, similar improvements were seen, but with reduced adverse effects. Some authors advocate combining Er:YAG for initial ablation followed by CO_2 for the residual thermal damage-mediated tightening effect. Certainly there is ***less coagulative effect with the Er*:*YAG*** compared to the CO_2 laser, and bleeding can influence the performance of the laser upon multiple passes.

Examples of studies: Khatri et al. (1999); Ross et al. (2001); Adrian (2006).

Pre-operative Evaluation

Selection of therapy depends on the desired goal and expected recovery time. Laser resurfacing can dramatically improve skin wrinkles and texture and moderately improve pigmentation, but the recovery time is more prolonged than non-ablative therapies. Length of time required for healing from full-face ablation with CO_2 laser is 2 weeks and there can be several months of persistent erythema. Shorter recovery times are achieved with Er: YAG and fractional lasers.

Laser resurfacing is particularly good to treat perioral and periocular rhytides; however, nasolabial and pre-jowl areas are best treated with surgery or dermal fillers. Severe skin laxity is best addressed with surgery. Dynamic rhytids usually respond well to neuromodulator injection.

– Skin color influences the decision to proceed with laser.
  Skin phototypes I to II are great candidates, with type III often suitable for skin resurfacing. **Darker skin has a higher risk of dyspigmentation with a laser**. Skin phototypes IV and V have higher risk than lighter skin.
– Non-facial sites (i.e., chest and neck) have a higher risk of scarring
  The re-epithelialization depends on the adnexal structures, which have a lower density in non-facial areas.
– Underlying cutaneous conditions can be considered a relative contraindication. Resurfacing after laser therapy is dependent on intact adnexal structures. Conditions such as scleroderma and prior radiation therapy compromise these structures, and are contraindications. Underlying cutaneous diseases can be exacerbated by cutaneous injury with the laser such as vitiligo, lichen planus, and psoriasis.
– Isotretinoin is a relative contraindication
  Most specialists recommend waiting 1–2 years because of the possibility of atypical scarring.
– Smokers may have delayed healing

Pre-Operative Medications

– Pain management. Local infiltrative anesthesia or nerve blocks are often used in conjunction with systemic anxiolytics and oral

narcotics. Intravenous anesthesia is sometimes utilized.
- Oral antiviral therapy. Usually started the day before the laser session and continues until re-epithelialization. (acyclovir 400 mg tid, valacyclovir 500 mg bid or famciclovir 250 mg bid). Some practitioners treat only patients with history of HSV, while others use routinely in all full face or perioral laser treatments. It is recommended to use it in all patients undergoing a deeper peel (deeper than MLP).
- Antibacterial and antifungal. Opinions vary; most practitioners do not routinely prescribe prophylaxis.
- Pretreatment with topical tretinoin. Pretreatment is often recommended to improve healing time (and assess patient's ability to tolerate post intervention care); however, there is insufficient evidence on the efficacy of this practice. Many practitioners encourage the use for 4 weeks before a treatment.
- Oral glucocorticoids. Some clinicians use oral steroids to decrease edema and swelling post intervention; there is insufficient evidence to substantiate this practice.

Adverse Effects

- Persistent erythema.
  Usually resolved after 2 months of CO_2 laser and 1 month of Er:YAG but may persist for a year. Green-based makeup can help hide erythema. The erythema is predicted to be of shorter duration with fractional lasers (less than a month in most patients).
- Dyspigmentation.
  Transient post-inflammatory hyperpigmentation can occur in 30 % of patients and is more likely to occur in patients with skin photo type III or higher. For these patients, consider to administer laser therapy in the fall and winter (reduced sun exposure). Daily sunscreen and sun protection is recommended. Hyperpigmentation can be treated with topical steroids, hydroquinone, retinoids, and/or peeling agents such as glycolic acid. Unfavorable color contrast between treated and non-treated areas can occur. Full-face treatments or full facial units are advocated and transitioning (feathering) between treatment zones to minimize the color differences.
- Herpes labialis infection may occur after laser.
  Prophylaxis is recommended (as described above).
- Bacterial and candida infections.
- Acneiform eruptions and milia.
  Particularly exacerbated by occlusive ointments often used during healing.
- Scarring.
- Ectropion when the lower lid skin is treated.

Competing Technologies

Ablative Vs. Non-Ablative Skin Rejuvenation

Ablative technologies remove the epidermis and portions of the superficial dermis to stimulate the underlying skin and induce collagen remodeling.

Examples of ablative lasers: CO_2 and Er:YAG.

Non-ablative lasers do not remove the epidermis and instead stimulate skin resurfacing by targeting deeper collagens, pigment, or blood vessels. The advantage is less down time (shorter recovery) and less risks, but might also lead to more modest results in skin tightening.

Example non-ablative technologies: IPL, radiofrequency, infrared, and ultrasound.

Pulse light devices are also called intense pulsed light (IPL) or broad band light (BBL). They are broad spectrum lights that target various chromophores (often pigment, hair, and vascular lesions). Hair reduction will not work in white hair (no chromophore). In this case, electrolysis is recommended. Filters are commonly used to narrow the spectrum (take the forms of the slides). Common filters are 515, 560, 640, and 775 nm and they block shorter wave forms. *Pulse light devices use a crystal and gel* *that is cooled to increase conduction and protect the skin by decreasing the amount of heat that stays in the tissue*. Sapphire is the most common crystal used. IPL was first approved for the treatment of lower extremity telangiectasias by the Food and Drug Administration (FDA). The indications for IPL have expanded to hair removal, treatment of small blood vessels, pigmented lesions, and dyschromias. They can also be used for photoaging, although to a lesser extent than other lasers.

Example of results for intense pulsed light (IPL): Split-face trial of 3 months of once a month IPL, which resulted in improvement in telangiectasias, pigmentation, and skin texture, but there was no difference in rhytides (Hedelund L et al. 2006).

Note: IPL is not recommended for hair reduction for phototype III and higher due to the risk of dyschromia. Near-infrared laser at 1064 nm has a very low absorption in the epidermis and is recommended for hair reduction in darker skin types.

Non-Invasive Skin Tightening

Surgical lifting remains the gold standard for treatment of skin laxity in the face. In this section, we discuss less invasive techniques that are now available. The mechanism of these technologies is heating of the dermis and subdermal region leading to contraction and remodeling while preventing injury to the epidermis. Common adverse effects are pain, swelling, erythema, and epidermal burns.

Radiofrequency devices generate an electrical current and as this current encounters resistance in the dermal tissues, it generates heat leading to collagen remodeling and skin tightening. Wound remodeling takes 3–6 months. Different modalities of radiofrequency are available. The initial studies showed modest and unpredictable results. As a consequence, the protocols were modified so that multiple lower energy passes were used. Results are still considered to be moderate with this technology.

– Monopolar: Thermage is an example of monopolar technology and the first radiofrequency technology to hit the market. Examples of radiofrequency results: The first monopolar study was in the forehead and it showed a 0.5 mm improvement in brow elevation by photoanalysis (Fitzpatrick et al. 2003). Treatment of the jowl leads to a 22 % decrease in 2D surface analysis (Nahm WK et al. 2004). A survey of 5400 patients who had treatment reported 54 % of patients in the original protocol noticed any change while 92 % of the patients on the later protocol noticed tightening (Alam et al. 2003).
– Unipolar*:* A grounding pad is used. Depth of penetration is deeper (20 mm) and, hence, used in body contouring. Similar results as monopolar with concerns for minimal to moderate results in facial skin tightening.
– Bipolar: The current goes between two electrodes and no grounding pad is needed. The depth of penetration is 2–4 mm. Bipolar is frequently used with IPL for synergistic effects. Vacuum technologies to bring the target closer to the machine have also been used.
– Fractional radiofrequency: The tip of the device has an array of needles that are inserted into the skin.

Infrared lasers have wavelengths between 1000 and 1800 nm. They penetrate deeply and exert their effects in the reticular dermis, leading to skin tightening. Technology to cool the skin surface is essential to prevent heat-related damage to the epidermis during treatment. Mild results have been reported, but so have superficial skin burns. Broad band infrared spanning 1100–1800 is also available and is used with minimal discomfort (in contrast to IPL or infrared laser).

Examples of results with infrared technology: wavelengths 1100–1800 nm with 20–40 J/ cm^2 resulted in skin tightening lasting 12 months. Two patients had second-degree burns (Ruiz-Esparza & Gomez 2003). A1450 nm diode laser lead to 15 % of patients having moderate improvement in rhytides, 50 % mild, and 35 % no change. Goldberg DJ, et al. Laser Surg Med 2002.

Intense focused ultrasound tightens the skin by delivering thermal energy to the dermis and subcutaneous tissue. This technology can target deeper tissues including the SMAS, while completely sparing the epidermis. Small areas of coagulative necrosis measuring 1 mm^3 are seen in histological studies. The first technology to be available in the market was Ultherapy.

Example of ultrasound studies: Blinded evaluators reported moderate improvement in the jowl of 50 % of treated patients after two passes (4 MHz 4.5 mm probe and 7 mHz 3.0 mm probe). Lee HS et al. Dermatol Surg 2012.

Laser Tattoo Removal

Tattoos used to be considered permanent but it is now possible to remove tattoos partially or totally. Before laser technology was available, tattoo removal methods were dermabrasion, peels, and surgical excision. Today, **laser tattoo removal usually involves Q-switched lasers**. The laser targets the tattoo pigment particles and fragments it into smaller pieces that can then be removed by the body. The Q-switched laser is ideal because it can heat the ink in a very short pulse that prevents heat dissipation to the surrounding normal skin. Black and darker inks are more completely removed. Multiple passes are required and the number needed is calculated using the Kirby-Desai scale.

Available lasers for tattoo removal:

– Nd:Yag: 532 nm used for red and orange tattoo.
– Ruby: 694 nm green and dark tattoo.
– Alexandrite: 755 nm: green and dark. It is less absorbed by melanin than ruby, resulting in less risk of inflammatory post-hypopigmentation. This also leads to less dramatic results.

Questions:

Alexandrite	2940 nm
CO_2	1000–1800 nm
KTP	532 nm
Er:YAG	10,600 nm
Infrared	755 nm

1. Match the wavelength with the laser:
2. Which is the best technology to treat pigment in the skin?
   (a) CO_2
   (b) Er:YAG
   (c) IPL
   (d) Infrared
3. Which laser has higher absorptions?
   (a) CO_2
   (b) Er:YAG
4. Which laser has higher coagulation?
   (a) CO_2
   (b) Er: YAG
5. IPL is not a laser and eye protection is not needed. True or False
6. Explain what is a fractional laser?
7. Which is considered an absolute contraindication to laser resurfacing?
   (a) Psoriasis
   (b) Smoking
   (c) Isotretinoin therapy
   (d) Neck skin
   (e) Active herpes labialis
8. Radiofrequency, ultrasound, and infrared lasers all have similar skin tightening effects in the jowl as a face lift but with less recovery time. True or False
9. Which is the best mode of laser to use for tattoo removal?
   (a) Continuous
   (b) Pulse
   (c) Q-switch
10. Which is the best technology for hair reduction for darker skin types?
   (a) IPL
   (b) 1064 nm
   (c) CO_2
   (d) Er:YAG

Answers

1. Table 25.2, 2. (c), 3. (b) (12 times higher), 4. (a), 5. not a laser but you do need eye protection False, 6. refer to text, 7. (c), 8. False, 9. (c), and 10. (b)

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