Introduction

Perhaps you have been considering cosmetic laser surgery. A cosmetic surgical treatment is voluntary and not medically necessary. You must decide if such a treatment is right for you, and you will have to pay for the procedure with your own money. Health insurance does not cover cosmetic procedures. How do you know if a cosmetic laser procedure is worth it? How much improvement can you expect in your appearance? What are the advantages of a laser procedure compared to more traditional surgery? What is the down side of a given procedure? What are the risks, and how do these risks compare to those of alternative treatments? How do you know if a surgeon is qualified and can give you the best possible results?

The purpose of this book is to answer these and other questions about cosmetic laser surgery. Lasers have unique properties unlike any other surgical instruments. In fact, some cosmetic procedures would simply not be possible without a specialized laser. For decades many surgical procedures have been done using traditional instruments but can now be performed with lasers that offer significant advantages to the patient: advantages such as less bleeding or no bleeding at all (“bloodless surgery”), no scarring, much greater speed of treatment, much less pain of treatment so that little if any anesthesia is required, less postoperative swelling, and faster healing and recovery.

How can lasers offer so many advantages? One reason is that there are now many different lasers used for cosmetic purposes. Engineers and scientists have been hard at work developing new, specialized lasers for specific cosmetic applications. To understand why these machines work so well, one must have some understanding of human skin. Many lasers affect a precise component of the skin (usually the structure one hopes to eliminate) and that component only. The laser is designed for the express purpose of eliminating the unwanted skin component—for example, excessive facial blood vessels, pigmented birthmarks or age spots, aged or wrinkled skin, or sagging eyelid skin. However, lasers are not magical, and much
Low energy photons have low frequencies and long wavelengths. The entire spectrum of electromagnetic energy ranges from very short ultraviolet (above the color violet) wavelengths to very long infrared (below the color red) wavelengths (fig. 1.3). Visible light is produced by photons with wavelengths lying between 400 nanometers (nm) and 700 nm. (A nanometer is one billionth of a meter; a meter is 39.4 inches.)

The visible part of the electromagnetic spectrum includes light of all colors that together appear white. A glass prism or raindrops
deep into the dermis; thus, they are literally epidermal appendages. The specialized keratinocytes that compose hair follicles differentiate into a hair shaft rather than into the stratum corneum that lies atop the epidermis. Many hair follicles, especially on the face, are associated with sebaceous (oil) glands, which are themselves composed of another type of modified keratinocyte (fig. 2.2). The lowermost extent of larger hair follicles may lie near the bottom of the dermis, and sometimes deeper still in the subcutaneous fat. Just as in the basal layer of the epidermis, there are melanocytes in the deeper part of the hair follicle. These melanocytes produce melanin, which is transferred to the keratinocytes within the developing hair shaft. The amount of melanin and even the type of melanin will determine the color and darkness of the hair. Some areas of skin contain great numbers of sweat glands (the underarm area, for example) or sebaceous glands (the oily areas of the face).

One common type of skin wound is an abrasive injury in which the epidermis has been completely removed and must then grow back. Hair follicles and glands within the dermis provide myriad sources from which epidermal cells may grow out to cover the wounded area. The modified epidermal cells from these glands and follicles are capable of reverting to typical epidermal keratinocytes as they proliferate and repopulate the resurfaced area. In this way, a new epidermis is regenerated and takes the place of the old epidermis. In facial laser resurfacing, the epidermis (and some of the superficial dermis) is purposely removed. Epidermal cells rapidly proliferate and migrate, covering an area as large as the entire face in about a week and a half.

The predominant cell type in the dermis is the fibroblast. Fibroblasts, which produce the dermal proteins, lie embedded in a protein-rich fluid and are separated from each other by at least several cell diameters. The major protein within the dermis is collagen, the most prevalent protein in the body. Collagen molecules are arranged into large, linear fibers (fig. 2.3). Water accounts for 70% of the mass of the dermis, whereas collagen constitutes 75% of the dry weight. After an injury, the fibroblasts sometimes produce excessive amounts of collagen during healing, resulting in a thick hypertrophic scar. The second most abundant dermal protein is
these lesions can give rise to malignant melanoma, one of the dead-
liest forms of cancer. The key to combating melanoma is prevention,
including behavior modification (avoiding excessive sun exposure,
especially sunburn) and clinical surveillance. Dermatologists are
highly trained in the recognition of abnormal nevi and subsequent
biopsy (sampling) or surgical removal of these lesions. A computer-
ized skin surface imaging system presently under development
holds great promise to increase the efficiency and “throughput”
of screening the entire skin surface for abnormal pigmented
lesions.

Because of their increased size, congenital nevi pose a signifi-
cantly greater risk of melanoma than do acquired nevi, and surgical
removal of congenital nevi, if feasible, is frequently recommended.
Very large lesions may be impossible to remove by conventional sur-
gery; laser surgery may be the only option.

The Nevus of Ota (first described by M. Ota, a dermatologist in
Japan) is a variant of congenital nevus that occurs (usually) on one
side of the face. This lesion is relatively common in Asians and is a
major cosmetic concern. The cells that make up the Nevus of Ota
are located deep in the dermis. The lesion is generally flat and is
usually dark blue due to the optical properties of light reflected
from the skin.

Cafe-au-lait spots are common birthmarks composed of epider-
mal melanocytes that are increased in density as well as in activity
(melanin production). These spots are a light brown or tan color and
are usually one to two inches in diameter. They occur in up to 10%
of the population. Cafe-au-lait spots are totally flat and smooth.

**Scars**

A scar is a permanent alteration in the skin’s texture. Hypertrophic
scars are thicker than the surrounding skin; atrophic scars are thinner (depressed). A scar is usually the result of an injury. Scars are an
alteration of the connective tissue of the dermis. An injury that
heals with the production of too much dermal collagen may result
deep level atrophy is unknown; it is probably determined by genetic tendencies. Certain disease states (e.g., AIDS) can greatly accelerate facial atrophy. The solution to atrophy is volume augmentation with natural materials (most useful is a patient’s own fat tissue) or with synthetic implants (usually made of a plastic or silicon material). Fat augmentation has the advantage of being totally natural and works best when the fat cells are placed within the facial muscles. Fat augmentation is permanent and can restore volume deficits that result from atrophy of both muscle and bone. Alternatively, anatomical implants made of artificial materials can be placed in the chin or cheek areas. Implants are usually placed immediately above bone.

To restore youthfulness, all three levels (skin, fascia, and muscle) at which aging occurs must be addressed. Because aging occurs independently at each level and for different reasons, in certain individuals there may be a greater need to rejuvenate one level over the others. For example, in a patient who has suffered a great deal of sun damage, laser resurfacing, which rejuvenates the skin, would be the top priority. Those with less sun damage may benefit more from fascia tightening (e.g., facelift) or volume restoration (e.g., fat augmentation). In practice, most patients benefit from rejuvenation procedures at all three levels but can expect the greatest overall improvement from the procedure that they need the most.

In the next chapter we will learn about some of the actual cosmetic lasers that are commonly used to improve the skin’s appearance, including why and how these machines work.
Q-switch is a device in the laser cavity that includes a polarizing filter to block the passage of photons. The material in the laser cavity is kept in a highly excited state and then an electrical signal changes the polarity for an extremely short time, allowing the passage of light through the filter. The Q-switch is many thousands of times faster than any mechanical switch and produces a very high energy laser pulse of extremely short duration.) These researchers observed an immediate whitening of the treated tattoo and correctly surmised that this effect was something other than simple heating of the skin. There was only mild pain and no adverse effect on the skin. Although they did not know it at the time, their treatment of this tattoo was the first ever example of selective photothermolysis.

**Surgical Lasers for Treating Skin**

After Dr. Goldman’s early efforts, the first truly useful lasers to treat skin disease were used to aid in surgery.

In the 1970s carbon dioxide (CO\textsubscript{2}) lasers were developed for surgical use. (Most lasers are named after the chemical substance within the laser cavity responsible for producing the laser energy. In the case of the CO\textsubscript{2} laser, this substance is carbon dioxide, a gas. The specific wavelength of a given laser is determined by the energy levels of the electrons within the molecules of the chemical substance [see chapter 1].) The CO\textsubscript{2} laser has a wavelength of 10,600 nm, which is quite far into the infrared region of the electromagnetic spectrum, much longer than the wavelengths of visible light (400–700 nm, fig. 4.2). This wavelength is well absorbed by water molecules; thus, water acts as a chromophore for the CO\textsubscript{2} laser. Water is ubiquitous in human skin except for in the topmost cornified layer of the epidermis (stratum corneum). The viable layers of the epidermis, like nearly all living tissue, have a high water content and the dermis is composed primarily of water. Because there is so much water in skin, the effect of the CO\textsubscript{2} laser is not specific and treatment with this laser results in vaporization of all skin components;
applied, sometimes causing unforeseen damage. CO₂ laser energy, in contrast, is immediately absorbed and thus does not penetrate significantly beyond the surface on which it is used. This confined tissue effect is another advantage of the CO₂ laser over scalpel/electrosurgery techniques.

By the late 1980s, early attempts at resurfacing facial skin for the purpose of removing wrinkles were made using the CO₂ laser. Resurfacing facial skin with a continuous-wave CO₂ laser was a challenging proposition because the only way to achieve selective photothermolysis was to move the laser beam rapidly over the skin, avoiding a prolonged dwell time (remember the hot stove analogy discussed earlier in this chapter). Because of the risk of scarring, few surgeons were eager to attempt facial resurfacing with the continuous-wave CO₂ laser.

In the early 1990s, the UltraPulse CO₂ laser was introduced. The UltraPulse technology enabled very high-energy laser output delivered during a very brief (one millisecond: one thousandth of a second) pulse. For the first time, selective photothermolysis was possible with a CO₂ laser. I first heard of this new technology in June 1992 at the inaugural meeting of the International Society of Cosmetic Laser Surgeons (ISCLS). Dr. Richard Fitzpatrick, a dermatologist from San Diego, CA, reported using the UltraPulse laser to remove pre-cancerous skin lesions (solar keratoses). To his surprise, after healing, these patients also demonstrated significant improvement in facial wrinkles. Dr. Fitzpatrick coined the term “laser resurfacing” to describe this new technique. Laser resurfacing was the procedure most responsible for the rapid growth of cosmetic laser surgery during the 1990s.

In the mid-1990s a new, even more precise laser was introduced for skin resurfacing: the erbium:YAG laser. This laser is similar to the CO₂ laser in that its chromophore in the skin is water, and its wavelength is in the infrared region of the electromagnetic spectrum. The special properties of the erbium:YAG laser are due to its wavelength, 2940 nm, which almost exactly matches the highest peak of the absorption spectrum for the water molecule (fig. 4.1). At 2940 nm water absorbs over ten times as much energy as it does
vessel dies and will disappear as macrophages remove the resultant debris.

Treatment of small (one-eighth inch or less) hemangiomas with krypton or argon lasers is relatively painless and requires no anesthesia. Very small lesions will shrink and disappear immediately, healing with no visible scar. Larger lesions may turn gray and heal by forming a scab. A scab forms because the epidermis overlying the hemangioma is destroyed and the blood within the hemangioma, now coagulated, is on the surface. (A scab is dried, coagulated blood on the surface of the skin.)

Larger hemangiomas are more difficult and painful to treat. These lesions may require an injected anesthetic before treatment. The laser energy may need to be administered through repeated pulses or even continuous, non-pulsed treatment. Large lesions, because of their size, absorb a large amount of laser energy and are heated to a relatively high temperature. If enough heat is conducted to adjacent skin, there will be a localized burn, possibly resulting in a wound that heals with a visible scar. Because continuous-wave lasers such as krypton and argon produce coagulation within targeted blood vessels, there is no purpura. In the days following treatment, there may be superficial crusting or scabbing to which a topical antibiotic such as bacitracin or Polysporin should be applied once or twice a day.

A telangiectasia is a visibly dilated, linear blood vessel. Telangiectases, which may be associated with a diffuse redness or blush due to accompanying microscopic capillaries, occur primarily on the face and may be associated with a skin disease such as rosacea. Rosacea is an acne-like condition that occurs in adults. People with rosacea experience frequent flushing (blushing) of facial skin. During flushing, facial blood vessels dilate, producing visible redness. Many vessels eventually become permanently dilated (telangiectases). Telangiectases also frequently occur as a consequence of excessive sun exposure.

Because they are small, facial telangiectases may respond to treatment with the pulsed dye laser. This laser is more likely to work on small-diameter vessels and capillaries and usually produces purpura,
which may persist as long as two weeks after treatment. Krypton, argon, and 532 nm diode lasers are useful for treating telangiectases and have the advantage of not producing purpura. For this reason, most patients prefer these over the pulsed dye laser. None of these lasers require anesthesia in the great majority of patients. The final result of a treatment may not be apparent for several weeks.

After treatment with the krypton or argon laser the blood within many of the telangiectases will undergo coagulation, so blood flow within the vessels stops. Once the blood within a vessel coagulates, the body disposes of the vessel’s remains and the vessel is obliterated.

Removing Brown Pigmented Lesions

Several types of lasers are effective for treating lentigenes because melanin absorbs light of many wavelengths. Anesthesia is generally not required. The lesions may turn a gray or whitish color immediately upon treatment. There may be an additional purple discoloration (purpura) upon treatment with the Q-switched Nd:YAG laser. This purpura is caused by a shock wave effect on nearby blood vessels similar to that produced by the pulsed dye laser. Other lasers used for treating lentigenes are Q-switched ruby and alexandrite lasers, and continuous-wave krypton and diode lasers.

Other flat pigmented lesions, including freckles and cafe-au-lait spots, are treated the same way as lentigenes. All are likely to fade completely with one or two treatments. Darker lesions tend to respond better than lighter ones because they absorb more laser energy. Very light pigmented lesions absorb less laser energy, possibly not enough to cause significant damage to the pigment cells. For unknown reasons, cafe-au-lait spots are quite likely to recur within a few months and may require repeated treatments.

Melanocytic nevi (moles) are commonly considered for cosmetic removal. Because melanocytic nevus cells have the potential to become malignant, they must be dealt with cautiously. For many
Anatomical studies have demonstrated that tightening of the cheek skin diminishes the depth of this fold more than does tightening of the deeper fascia layer. With expert surgical technique, full-face laser resurfacing can erase twenty or more years from the perceived age of a patient. The patients shown in figs. 6.3 and 6.4 were both treated only with laser resurfacing.

Because the CO₂ laser produces greater heating of the skin than does the erbium:YAG laser, resurfacing with the CO₂ laser is inherently more painful. In almost all cases, injected anesthetics are required. It is not unusual to use even general anesthesia for CO₂ laser resurfacing. For several reasons, my preference is to use local anesthesia. General anesthesia carries certain systemic risks; there's even a small but finite risk of death. Upon reversal of general anesthesia (waking up), there is no continued anesthetic effect in the

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**Fig. 6.3** This 87-year-old patient with severe photo-aging is shown before and two months after full face laser resurfacing with the CO₂ and erbium lasers. Notice the tightening of the skin resulting in elevation of the eyebrow and improvement in the deep folds around the mouth. Only local anesthesia was used.
Local anesthesia is extremely safe. Properly administered local anesthetics are 100% effective. The treated area is completely numb and the laser treatment is thus painless. Another great advantage of local anesthetics is that their effect lasts for several hours. There is generally a stinging sensation felt as the local anesthetics wear off; this pain is significantly lessened by the use of occlusive (covering) dressings over the treated skin.

I routinely perform full-face CO₂ laser resurfacing using only local anesthesia. Before anesthetics are given, pretreatment photographs are taken and major wrinkles marked with a pen. Larger areas of the face, including the forehead and the central face below the outer corners of the eyes, are efficiently numbed with nerve
Fig. 6.5 This patient underwent CO₂ laser blepharoplasty to remove redundant skin and excessive fat in the upper eyelids. She is shown a) before surgery, b) with marking for planned removal of skin, and c) six days after blepharoplasty, with stitches removed and SteriStrips placed over the incision line. Notice that the skin removal extends slightly onto the temple and that there is minimal swelling or bruising six days later.
extends laterally to the outer corner of the eye and the skin excision must include this lateral skin. The size and shape of this skin excision is the most important factor that determines the aesthetic quality of the surgical result. After the skin surface is marked, the eyelids are numbed with a local anesthetic injection. Special eye shields, much like contact lenses, are placed directly on the eye surface after it has been numbed with anesthetic eye drops. Next, the focused CO₂ laser is used to slice through the eyelid skin. Some of the superficial herniated orbital fat is removed by slicing off fragments using the laser. The opening in the skin is stitched together to re-approximate the skin edges. Ice packs are applied for several hours after the surgery to chill the skin, constricting blood vessels and reducing swelling.

Stitches are removed by the seventh postoperative day (fig. 6.5). With proper technique, there is minimal scarring along the suture line. Because upper eyelid skin heals extremely well, this scar should be virtually undetectable to the casual observer (fig. 6.6).

In the lower eyelids, the primary problem that occurs with aging is bulging of the orbital fat pads as opposed to the presence of excessive skin. In lower lid blepharoplasty, the herniated, superficial portions of the fat pads are removed. Excessive skin, if present, is best removed by laser resurfacing, which results in contraction of this skin. Using a focused CO₂ laser instead of a scalpel for blepharoplasty offers the significant advantage of bloodless surgery, affording the surgeon better visualization of important anatomic structures.

The safest approach to lower lid blepharoplasty is to access the fat pads through an incision of the conjunctiva (inner lining) of the lower lid, rather than through the skin. This transconjunctival approach has two major advantages over the skin approach. Because the fat pads lie behind the orbital septum (connective tissue layer), this septum must be traversed if the skin approach is used. Unfortunately, the orbital septum frequently heals by contracting excessively, possibly resulting in a permanent pulling down of the lower eyelid. Such pulling down can cause an unnatural shape to the eye or may reveal the white of the eye below the iris, also an unnatural appearance. With the transconjunctival technique, the fat
Coblation is that the treatment head is a fixed size and thus requires that a swath of skin of this width be treated. In contrast, the erbium:YAG laser employs various spot sizes, some less than 2 mm wide, enabling greater precision of skin removal. Skin surface features such as wrinkle shoulders and acne scars can be selectively ablated with the erbium:YAG laser.
High-quality results are attributable much more to the surgeon than to the laser. Although any physician who follows a rote “cookbook” approach to laser surgery can achieve results, outstanding results require significant skill on the part of the surgeon. Top-quality laser surgeons usually develop their own techniques. Surgeons who perform many laser procedures constantly refine their technique and are able to achieve substantial improvement for the patient while avoiding the risks associated with over-treatment.

One of the strongest indicators of the commitment and skills of laser surgeons is whether they possess their own laser equipment. Lasers are very expensive machines and for economic reasons will not be acquired by a physician who has only a casual interest in using them. Many laser rental companies will bring a laser into a physician’s office on a per case or per diem basis. A physician who rents a laser once a month is clearly not dealing with many laser surgery cases and in all probability lacks sufficient experience to achieve optimal results. Surgeons who use a laser only in a hospital or outpatient surgery center are also less likely to have a great deal of experience. It is a very good sign that you are dealing with an experienced laser surgeon if the surgeon owns the equipment and uses it in his or her office.

How do you find the best surgeon? By far the best way is through word of mouth. The recommendation of a trusted friend or family member is an excellent indicator of the surgeon’s quality. An impartial physician such as your primary care provider may also be able to recommend a laser cosmetic surgeon in whom they have confidence. Any surgeon can pay to advertise or gain recognition in the media through a public relations agent. The surgeon you have heard a lot about in the media may not be the best one in your area.

What about the medical specialty of the laser surgeon? Dermatologists are the ultimate skin care experts and dominate the field
Coherence A property of laser energy that describes the fact that light waves of laser energy are in synchrony with each other. The peaks and troughs of the light waves are perfectly in line.

Collagen The major component of the dermis. Collagen fibers are inelastic and provide the skin's strength.

Collimation A property of laser energy that describes the fact that light waves of laser energy are parallel to each other.

CoolTouch (trademark) An infrared laser used for non-ablative facial rejuvenation.

Dermis Layer of the skin beneath the epidermis. The dermis varies widely in thickness in different parts of the body and is composed mostly of extracellular material including proteins and water. The major proteins of the dermis include collagen and elastin (elastic fibers). The predominant cells in the dermis are fibroblasts (the cells that produce collagen and elastic fibers). The dermis also includes blood and lymph vessels, glands, hair follicles, and nerves.

Differentiation A complex maturation process in which newly produced cells undergo transformation into a more specialized cell type. Best illustrated in the epidermis, in which keratinocytes multiply in the innermost basal layer (where they are small and round) and progressively differentiate into the large flat (dead) cells that compose the outermost stratum corneum. The cells demonstrate obvious changes in appearance as they progress through the intervening prickle cell layer and granular cell layer.

Electromagnetic spectrum The full range of electromagnetic energy from very high energy (short wavelength) gamma rays to very low energy (long wavelength) radio waves. Visible light ranges from 400 nm (violet) to 700 nm (red) wavelength. Shorter wavelengths are referred to as ultraviolet, longer wavelengths are called infrared.

Electron Subatomic particle that orbits the nucleus of an atom. The electron carries a negative charge and will occupy specific orbits determined by its energy level.

Epidermis Outer layers of the skin comprising a dead portion and an inner living portion. Contains several layers of keratinocytes in
Infrared  Electromagnetic energy with wavelengths longer than 700 nanometers. Beyond the visible light spectrum, with energy levels lower than those of red light (infra = below).

Keratinocyte  The predominant cell type of the epidermis. These cells produce a protein called keratin.

Laser  An acronym for Light Amplification by the Stimulated Emission of Radiation. This term is used to describe the physical process by which laser energy is produced as well as the machine (a laser) that produces laser energy.

Laser resurfacing  A surgical procedure in which an ablative (see ablation) laser is used to remove superficial layers of skin.

Lentigo  See solar lentigo.

Liposuction  Surgical procedure in which subcutaneous fat is removed via suction. Usually done with tumescent anesthesia (tumescent liposuction).

Macrophage  A relatively large white blood cell that migrates from capillaries to other tissues, including the dermis. These cells ingest debris (including tattoo ink particles) and remove it from the skin by migrating into lymphatic vessels and transporting the debris to nearby lymph nodes or to the liver.

Melanin  Proteinaceous pigment in skin that screens out ultraviolet light.

Melanocyte  Melanin-producing cell in the epidermis.

Melanosome  The organelle (membrane-bound structure) within the melanocyte that synthesizes melanin. Melanin gets into keratinocytes by the transfer of melanosomes.

Microdermabrasion  A mild facial treatment in which tiny particles (usually aluminum oxide) are blown against the skin at high velocity, gently “sandblasting” superficial epidermal layers.

Monochromicity  The property of being composed of a single wavelength of electromagnetic radiation (for example, a single color of light in the visible spectrum) (mono = one, chroma = color). A feature of laser energy.

Nanometer  One billionth of a meter. Abbreviated as nm.

Nanosecond  One billionth of a second. Abbreviated as nsec.

Nevus  (pl. nevi)  A skin lesion composed of cells that are normally