Aesthetic Applications of Intense Pulsed Light

Lucian Fodor
Yehuda Ullmann
Editors

Second Edition

Springer

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To my wonderful wife, Adriana, for her unconditional love and her patience with me.
To my children, Clara and Radu, for filling my life with love and happiness.

Lucian Fodor

This book is a small thank to my supportive and loving family: Tami, Liran, Shachaf, and Yotam.

Yehuda Ullmann

Preface to the Second Edition

The field of intense pulsed light therapy (IPL) application has increased in recent years. Nowadays, IPL therapy is widely applied by dermatologists, plastic surgeons, cosmeticians, family practitioners, and others. If, in the beginning of its era, it was applied for skin rejuvenation and pigmented lesions, today, its application is extended to the scars, acne, and other fields. The evolution of aesthetic procedures is toward minimally invasive measures with rapid recovery and a more comfortable procedure with a steady increase in aesthetic procedures. IPL technology has proved to be of real benefit in satisfying patient demands.

At the present time, the medical literature (PubMed) has over 1000 articles on IPL technology. The first edition of this book was published in 2011 and included nine chapters on the basic applications of IPL. The second edition is the most up-to-date text and has 19 chapters with wider applications.

Each chapter is structured with level learning objectives and includes ten multiple-choice questions at the end. The book is written in a format to allow not only physicians dealing with IPL cosmetic procedures but also mid-level providers to understand and perform this treatment.

We are grateful to our contributors to this book for sharing their experience with the readers. We believe that the second edition will provide the practitioners with useful information to optimize the outcome for their patients.

Cluj Napoca, Romania — Lucian Fodor
Haifa, Israel — Yehuda Ullmann

Acknowledgments

I have learned life experience and medicine from many excellent doctors, especially Yehuda Ullmann, who is not only my teacher and a coeditor of this book but also a sincere friend. Because I cannot repay him for all that he has given me, with this book, I share my experience with beginners in this field of medicine.

Lucian Fodor, MD

Special regards to Lucian Fodor, who has been and continue to be the turbo engine behind my academic career.

Yehuda Ullmann

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Lucian Fodor, MD
Yehuda Ullmann, MD

Abbreviations

AFL	Ablative fractional carbon dioxide laser
AK	Actinic keratosis
ALA	5-Aminolevulinic acid
AM	Arterial malformations
ASA	American Society of Anesthesiologists
AVF	Arteriovenous fistula
BD	Bowen's disease
BDD	Body dysmorphic disorder
CEAP	Clinical, Etiological, Anatomical and Pathophysiological classification
CLM	Capillary lymphatic malformation
CM	Capillary malformations
EMR	Electromagnetic radiation
ESA	European Society of Anesthesiology
ETE	Essential telangiectasia
ETR	Erythematotelangiectatic rosacea
FST	Fitzpatrick skin types
HQ	Hydroquinone
IPL	Intense pulsed light
LED	Blue-red light-emitting diode
LPDL	Long-pulse pulsed dye laser
MAL	Methyl aminolevulinate
MASI	Melasma Area and Severity Index
MLH	Melasma-like hyperpigmentation
NMSCs	Non-melanoma skin cancers
OCT	Optical coherence tomography
PDL	Pulsed-dye laser
PDT	Photodynamic therapy
PIH	Post-inflammatory hyperpigmentation
PpIX	Protoporphyrin IX
PPR	Papulopustular rosacea
PWS	Port-wine stains
QSAL	Q-switched alexandrite laser
RCM	Reflectance confocal microscopy
sBCC	Superficial basal cell carcinoma
TEM	Transmission electron microscopy

TNF	Tumor Necrosis Factor
TRT	Thermal relaxation time
VM	Venous malformations
VPL	Variable pulsed light

Contents

Skin Anatomy

1

Lucian Fodor and Dinu Dumitrascu

Level Learning Objectives

- Understand the skin layers
- Understand the collagen types
- Understand the function of the skin
- Understand the histologic aspect of most skin disorders that can be treated by Intense Pulsed Light

The skin is composed of three layers: epidermis, dermis and subcutaneous tissue. The epidermis is the outer layer and is formed mainly by keratinocytes whose main function is to synthesize keratin. The dermis is the middle layer and its main component is collagen. This layer lies on lobules of lipocytes. The thickness of the layers varies with different anatomical regions. The epidermis is thickest on the palm and soles, and very thin on the eyelids, while the dermis is thickest on the back.

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1.1 Epidermis

The epidermis is the outer part of the skin and is composed of three basic cell types: keratinocytes, melanocytes and Langerhans cells. Merkel cells can be found on the palms and soles and are located directly above the basal membrane.

1.1.1 Keratinocytes

Keratinocytes are the main component of the epidermis. Their function is to produce keratin, a complex filamentous protein that forms the stratum corneum of the epidermis.

The epidermis is composed of several layers, beginning with the innermost as follows: basal layer, malpighian layer, granular layer and horny layers (stratum corneum). The palms and soles have also a clear layer called stratum lucidum (above the granular layer). The horny layer and granular layer are the thickest on the palms and soles and are almost absent on the flexor aspect of the forearms. Cycling stem cells, located at the basal layer, provide a pool for epidermal regeneration. As the basal cells divide, they flatten and move upward [1]. The process of desquamation implies degradation of the lamellated lipid from the intercellular space and loss of desmosomal interconnections. The keratinocytes play an important role in the immune function of the skin.

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1.1.2 Melanocytes

Melanocytes are the cells located in the epidermis whose function it is to produce pigment. The ratio is about one in every ten basal keratinocytes. The face and genitalia have a greater amount of these cells. The melanocyte cell is a dendritic type, extending for long distances within the epidermis and in close contact with the keratinocytes. Together they form the "epidermal melanin unit". Melanin is synthetized by melanocytes in the basal layer of the epidermis and transferred to surrounding keratinocytes in melanosomes. Differences in skin color according to race is explained by the number of melanosomes. People with fair skin have fewer melanosomes which are smaller and packaged within membrane complexes. People with darker skin have more melanosomes which are larger and not packed. Sun exposure (Fig. 1.1a, b) stimulates melanocytes to produce larger melanosomes [2]. An increase in the number of melanocytes but with no junctional activity is present in lentigo simplex (Fig. 1.2). In patients with melasma an increased of the melanin content is present, without having an increased in the number of melanocytes (Fig. 1.3).

1.1.3 Langerhans Cells

Langerhans cells represent 3–5% of the cells of the stratum spinosum where they are situated between the keratinocytes. They are responsible for the immunological response of the skin.

1.2 Dermoepidermal Junction

The dermoepidermal junction represents the junction between the epidermis and the dermis. It is located at the basement membrane zone and resembles a semi-permeable filter which allows cells and fluids to travel between epidermis and dermis [3]. It also serves as a structural support for the epidermis.

1.3 Epidermal Appendages

The eccrine and apocrine glands, ducts and pilosebaceous units constitute the skin adnexa. All have a role in epidermis regeneration (reepithelization). When an injury occurs, the keratinocytes from the adnexa migrate to the skin surface [4].

1.3.1 Eccrine Sweat Glands

These glands have three main components:

- The intraepidermal spinal ducts which open directly onto the skin surface
- The straight dermal portion of the duct is composed of cuboidal epithelial cells
- The secretory zone is located in the superficial panniculus. In the back region, this zone is situated in the deep dermis.

The role of these glands is also to produce sweat which is similar in composition to plasma

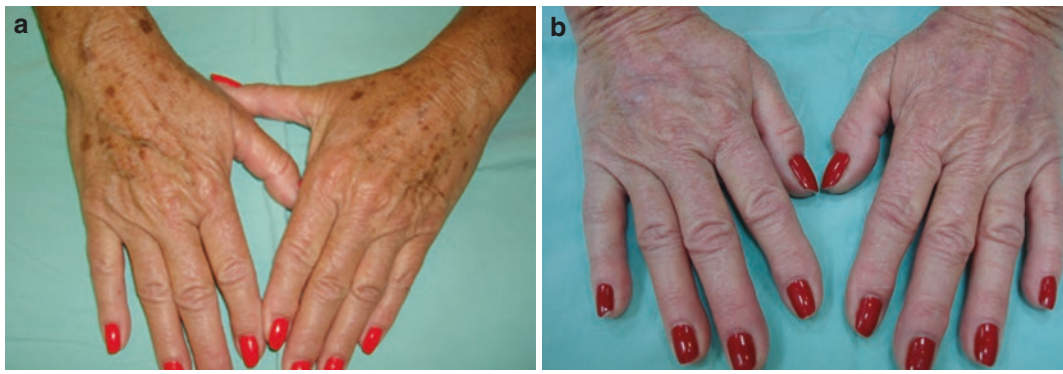

Fig. 1.1 (**a**) Significant photoaging and numerous lentigines prior to treatment (Photos from Fodor and Ullmann first edition). (**b**) Eight weeks after a single IPL treatment (Photos from Fodor and Ullmann first edition)

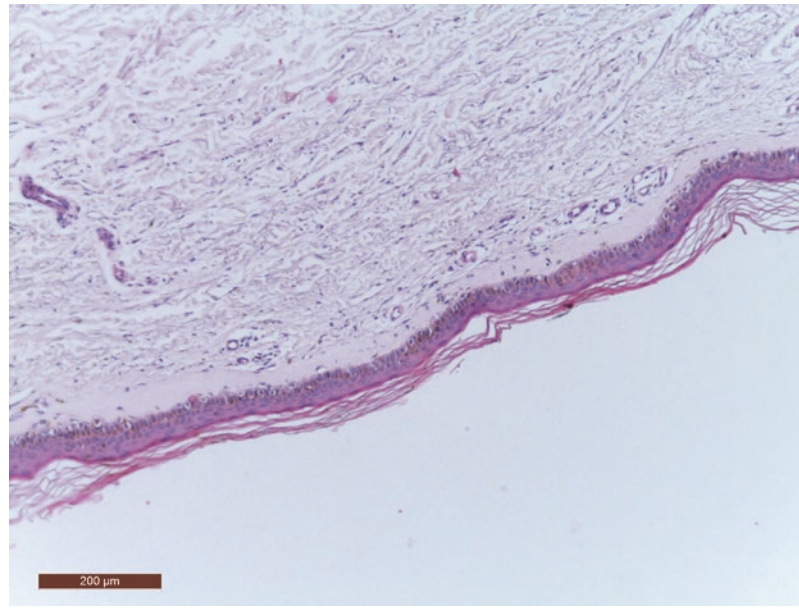

Fig. 1.2 Lentigo simplex with increased and uniformly distributed melanocytes

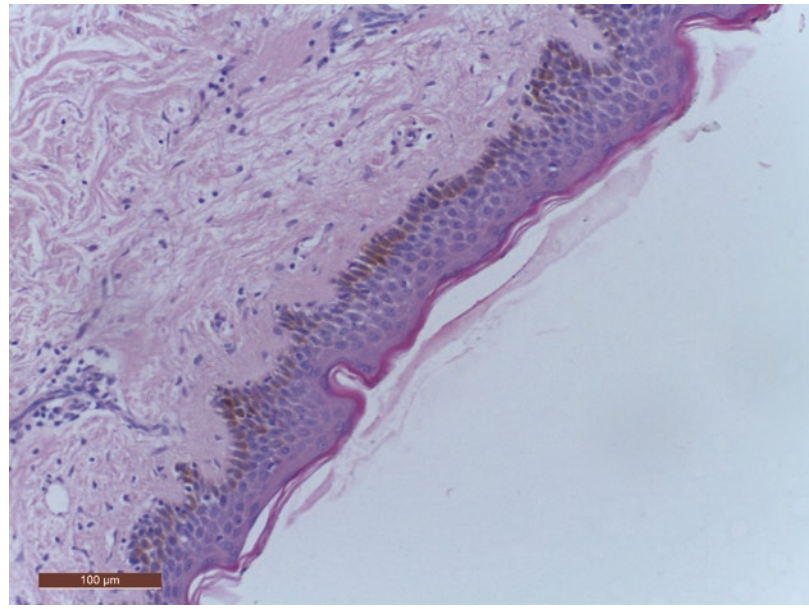

Fig. 1.3 Melasma showing the increase of content of melanin

with regard to the electrolytes. They are important in thermoregulatory function and are present in great amount in the palms, soles and axillae. Some eccrine glands from the axillae have widely dilated secretory coils in patients with hyperhidrosis.

1.3.2 Appocrine Glands

Appocrine glands develop on the infundibular upper portion of the hair follicle. They are intimally related to the pilar units. The coiled secretory gland is present at the junction of the dermis

and subcutaneous fat. Appocrine secretion is odorless and episodic. The appocrine units of the human body are generally confined to the axillae, areolae, genital region, ear canal and eyelids. The glands start to function after puberty.

1.3.3 Hair Follicles

Hair follicles develop in rows of three. Primary follicles are surrounded by the appearance of two secondary follicles. The amount of pilosebaceous units decreases throughout life mainly because of poor formation of secondary follicles. The hair follicle has three main components:

- The lower part beginning at the base of the follicle and extending to the insertion of the arrector pili muscle
- The middle portion, also called the isthmus, from the arrector pili to the entrance of the sebaceous duct
- The upper part, called the infundibulum, extends to the follicular orifice

The lower part of the hair follicle is also subdivided into five components: the dermal hair papilla; the hair matrix; the hair; the inner root sheath and the outer root sheath. The formation of the hair starts at the level of bulb, from the pluripotential cells. The melanin produced by the melanocytes is incorporated into the cells of the future hair through phagocytosis. At the level of the isthmus, the outer root sheath is no longer covered by the inner root. The outer root undergoes keratinization. The bulge cells posses stem cell proprieties, having the proliferative capacity to regenerate not only hair follicles but also sebaceous glands and epidermis [5].

The rate of hair growth depends on the mitotic activity of the cells of the bulb matrix. Hair growth is a cycle having three phases: anagen, catagen and telogen. The histological aspect of the hair follicle is different for each of the phases. The anagen is the growth phase, the catagen represents the regression phase, and the telogen is the rest phase. The hair follicle is the most susceptible to IPL treatment during the anagen phase (Fig. 1.4a, b). During the anagen phase, the stem

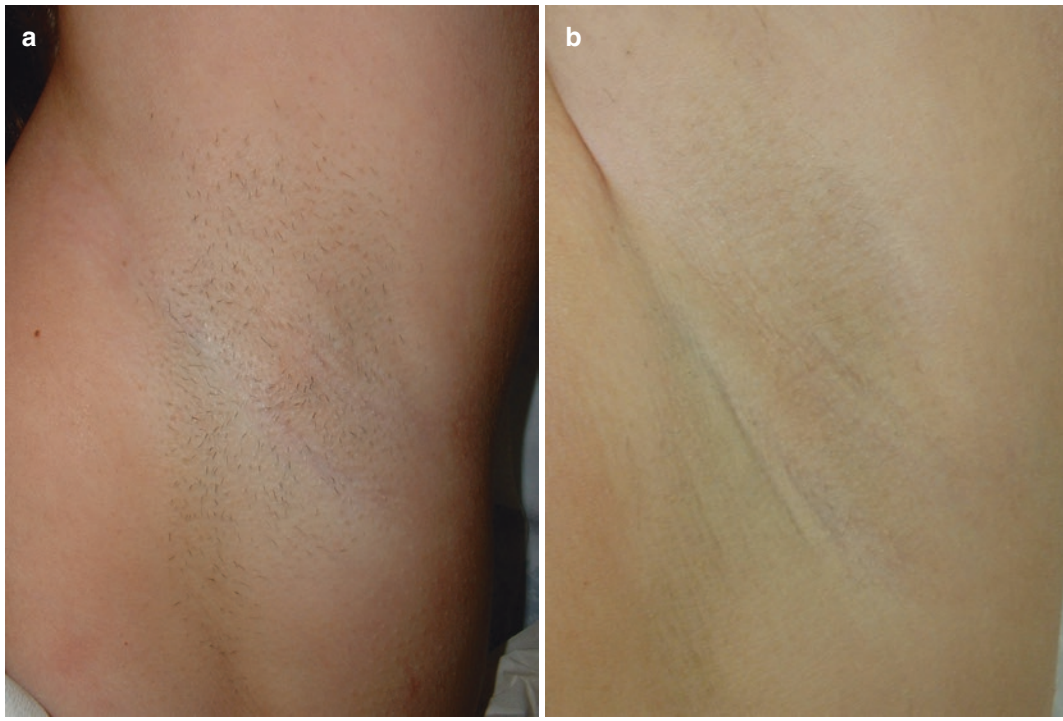

Fig. 1.4 (**a**) Course hair in the axilla prior to IPL treatment (Photos from Fodor and Ullmann first edition). (**b**) One year after six treatments (Photos from Fodor and Ullmann first edition)

cells differentiate into eight different cell types [6]. From the bulge area, the stem cells ascend into the outer root sheath. Those which reach the hair germ transform into matrix keratinocytes to rebuild the hair shaft [7]. The pigmentation and hair shaft synthesis take place in this phase. Three types of melanosomes are present in the hair. The erytomelanin granules are seen in red hair while the pheomelanin granules are found in blond and dark hair. In the dark hair there are more melanosomes than in light hair. In white or grey hair, the melanocytes of the hair matrix are much reduced and show degenerative changes [8]. Melanin synthesis and pigment transfer to bulb keratinocytes depends on the precursors and their regulation is receptor dependent [9].

The transition from the anagen to the catagen phase varies from one skin region to another [10]. There are several molecular regulators of this transition [10, 11]. The catagen phase consists of involution of the hair follicle, apoptosis and terminal differentiation. The first sign of catagen is the cessation of melanin production in the hair bulb. As the lower follicle recedes, a temporary structure, called the "epithelial strand", forms and is considered to be unique to this phase.

After the catagen phase, the hair follicles enter into the telogen phase. In this phase, the follicle has a depigmented proximal hair shaft called "club hair". This club hair most often remains in the hair canal. The transition from telogen to anagen occurs when a few stem cells at the base of the follicle near the dermal papilla are activated [12]. The new follicle takes place adjacent to the old pocket. The hair cycle is a process influenced by many mediators and receptors [13]. The same author [14] suggested an inhibition-desinhibition system that has the epithelial stem cells from the bulge region as the central pacemaker. It seems that the hair cycle clock is located in the dermal papilla [6].

The hair follicle has a strong influence on skin biology and plays an important role in the reparative process, especially in the outer root sheath which provides epithelial cells to cover wounds [15, 16]. The hair follicle has regenerative proprieties also. It has the ability to regenerate itself with the initiation of each cycle. The regenerative potential is demonstrated after massive damage during chemotherapy treatment [17]. It has been shown that the hair follicle influences the angiogenesis process [18]. The dermis in the proximity of anagen follicles is more vascularized than that around telogen follicles. Blood vessel changes in the skin during the hair cycle are also controlled by the follicle.

1.4 Dermis

The dermis consists of a supporting matrix (ground substances) in which polysaccharides and proteins act to produce proteoglycans. The protein fibers inside the dermis are represented by collagen, elastin and other components, such as fibrillin and microfibril proteins.

1.4.1 Collagen Fibers

The collagen fibers within the dermis are 2–15 μm wide [19]. The thin, finely woven meshwork of collagen fibers is found in the papillary dermis. The collagen fibril diameter increases progressively with the depth of the dermis. The rest of the dermis, called the reticular dermis, has collagen fibers united into thick bundles. This part is composed primarily of type I collagen. There are several types of collagen [20]. Type I collagen is predominant in the postfetal skin. Type III is found mainly in reticular fibers and is prevalent in early fetal life. In the postfetal life, it is mainly located in the subepidermal area. Type IV collagen is present in the basement membrane. The fetus has predominantly type III collagen while the skin of the adult contains mainly type I collagen. Collagen is primarily responsible for the skin's tensile strength. In young adults, collagen from the papillary dermis is organized as a meshwork of randomly oriented thin fibers and small bundles [21]. The collagen fibers have a random orientation in normal skin. During scaring formation they develop a direction parallel to the mechanical force in the dermis (Fig. 1.5) [22].

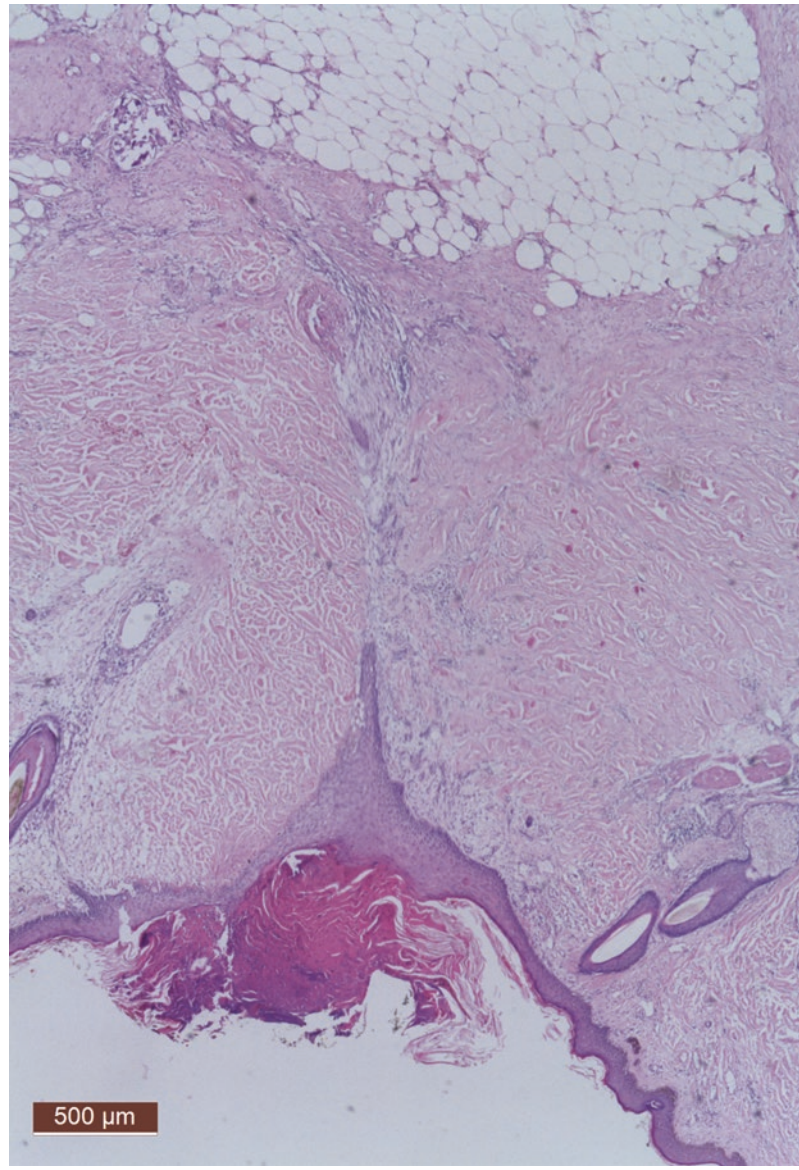

Fig. 1.5 Scar tissue

1.4.2 Elastin Fibers

Elastin fibers are mixed collections of various distinctive glycoproteins which have a microfibril are structure. They are thin in comparison with collagen bundles and measure from 1–3 µm. The fibers are thickest in the lower portion of the dermis. At the level of the papillary dermis, they form an intermediate plexus of thinner elaunin [23].

During life, the elastic fibers undergo significant changes. In young children, the fibers are not fully mature, so the microfibrils predominate. With aging, there is gradual decrease in the number of peripheral microfibrils and the surface of elastic fibers appears irregular and granular.

In very old people, some elastin fibers undergo fragmentation and disintegration.

1.4.3 Ground Substance

The ground substance is an amorphous structure present between the collagen fibers and the collagen bundles. It consists of glycosaminoglycans and mucopolysaccharides [24]. In healing wounds, the ground substance contains sulfated and nonsulfated acid mucopolysaccharides.

1.4.4 Dermal Muscle Cells

Smooth muscles are present as arrectores pilorum in the tunica dartes of the external genitalia and in the areolae of the breast. The muscle fibers of the arrectores pilorum start in the connective tissue and insert in the hair follicle in an obtuse angle bellow the sebaceous glands. By contraction, they pull the hair follicle into a vertical position. Aggregates of smooth muscle cells are present between the arterioles and the venules. They are called "glomus bodies" and serve to shunt blood from the arterioles to the venules. Most are located in the digits.

Striated muscles are present in the skin of the neck as platysma and the skin of the face (superficial face muscles of expression). Their origin is the fascia or periosteum and travel through the subcutaneous tissue into the lower dermis.

1.4.5 Aging and Skin Structure Changes

Skin, like any other organ, undergoes alterations with aging. Several changes have been proved. The collagen matrix starts to defragment although the cross-links prevent complete removal of collagen fragments. The fragments cannot be incorporated into new collagen fibrils and cause defects in the collagen matrix [25]. The fibroblasts cannot attach to the fragmented collagen and the loss of attachments leads to collapse. This will produce less collagen and more collagen-degrading enzymes [26]. In the aged skin, the collagen networks appear to be increased but this is due to adherence to ground substance [21]. Increased age is associated with decreased collagen content and straightening of collagen fibers organized in loose bundles. There is also an increase of type III collagen observed mainly in subjects over the age of 70 [27]. The elastin component starts to show degradation of fibers, resulting in decreased number and diameter (Fig. 1.6a, b). In photoexposed areas, there is an increase in abnormal elastin which is predominantly localized in the upper dermis [28]. Increasing age does not alter the water structure of the skin [29]. However, there is an increase in total water content in photoaged skin. This is paradoxical as aged skin seems dry. The lack of interaction between the water and the surrounding molecules in photoaged skin contributes to its characteristically dry and wrinkled appearance.

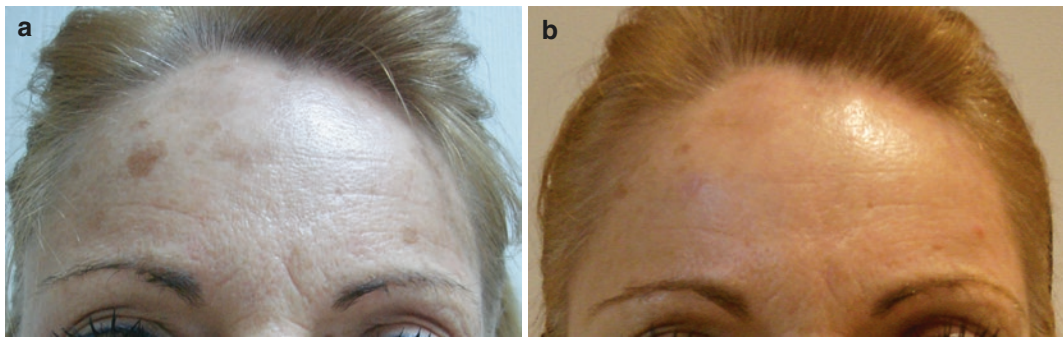

Fig. 1.6 (**a**) Early signs of aging (Photos from Fodor and Ullmann first edition). (**b**) Skin tightening after two IPL treatments (Photos From Fodor and Ullmann first edition)

1.5 Blood Vessels

The blood supply to the skin comes from the deep plexuses located at the fascia and subcutaneous level (Fig. 1.7). Once the vessels enter the space between the subcutaneous tissue and corium they branch out to various cutaneous appendages. The ascending arterioles supply a subpapillary plexus and form capillary loops in the papillary layer between the ridges. From these capillaries, the blood is drained by venules which descend to the plexuses [30]. The blood flow through the superficial layer of the dermis is controlled by arteriovenous anastomoses which can act as shunts to short circuit the flow. These anastomoses are well demonstrated at the level of the fingers.

The peripheral nerves influence the pattern of blood vessel branching and differentiation by secreting the vascular endothelial growth factor [31].

The small arteries of the deep vascular plexus and the arterioles present in the dermis have three layers: (1) intima, composed of endothelial cells and internal elastic lamina; (2) media, with at least two layers of muscle cells in the small arteries and one layer of muscle cells in arterioles; and (3) adventitia of connective tissue. The capillaries located in the dermis have a layer of endothelial cells and a layer of pericytes. The walls of the veins are thinner than those of the arteries and do not have a clear structure of three layers. The postcapillary venule has endothelial cells, pericytes and a basement membrane. A special vascular structure called glomus is present within the reticular dermis of the nail beds, fingers and toes, ears, and face, and is important in thermal regulation. It represents a special arteriovenous shunt that connects the arterioles with the venules.

1.5.1 Aging and Cutaneous Vasculature

With aging, there is a dependent reduction in the total number of papillary loop microvessels, decreased thickness of microvessel basement membrane and decreased number of perivascular cells [32]. These changes lead to decreased perfusion and increased capillary fragility. The clinical manifestation of these changes are purpura [33], telangiectasia (Fig. 1.8a, b), palor [34], angioma and venous lake formation. The function of the

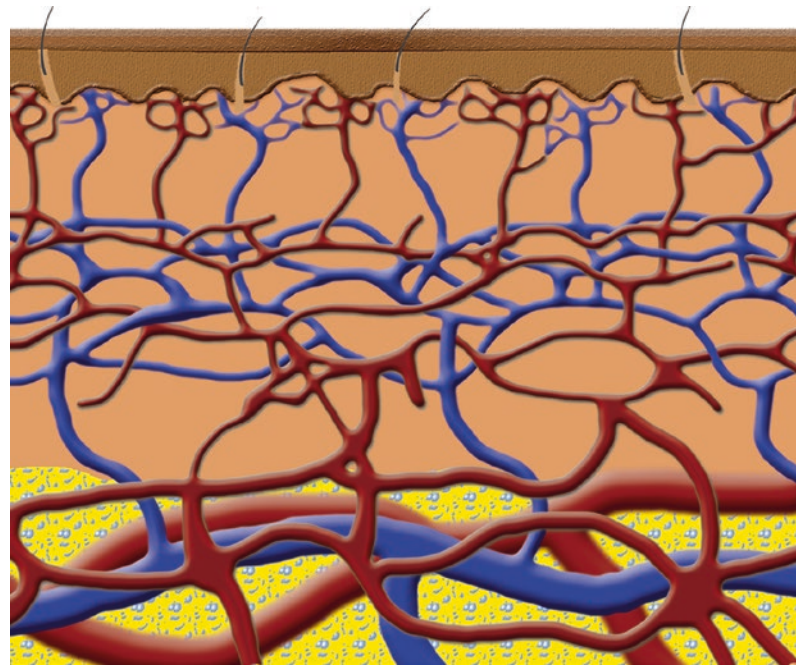

Fig. 1.7 Numerous vascular networks located at different levels between the fascia and the epidermis

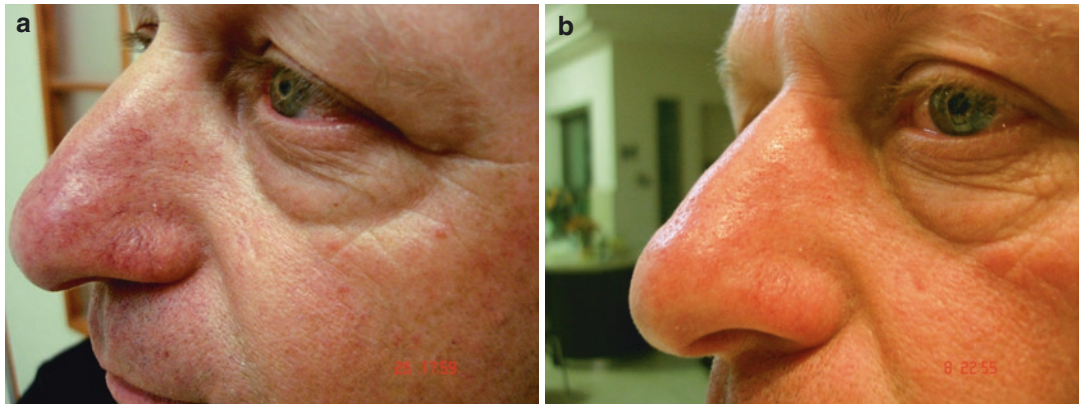

Fig. 1.8 Teleangiectasia of the nostril before (**a**) and 8 weeks after a single IPL treatment (**b**) (Photos from Fodor and Ullmann first edition)

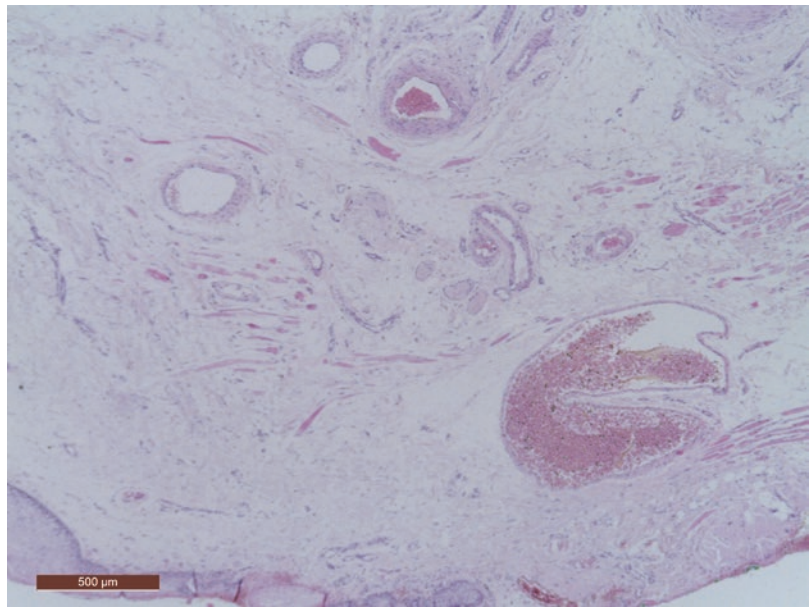

Fig. 1.9 Telangiectasia showing abnormally developed capillaries

skin microvessels is affected by the aging process and leads to decreased vasoreactivity [35] and impaired wound repair [36]. Small dilated blood vessels are called spider veins or telangiectasias (Fig. 1.9). They can be acquired or congenital.

1.6 Dermal Lymphatics

Dermal lymphatics are often hard to see in the normal skin because they do not have the well-developed walls that blood vessels have. They first appear at the subpapillary dermis. When they are seen in the dermal papillae, it is considered abnormal [37]. The initial lymphatic vessels are cylindrical microtubules and are composed of attenuated endothelial cells. They form a mesh-like network of about 200–500 µm in the human scalp [38]. Occasional valves can be seen emerging from the endothelial lining. The dermal lymphatics are easily detected in conditions associated with increased lymphatic drainage, as occurs in urticaria or inflammations.

1.7 Nerves and Sense Organs

The skin is supplied by sensory nerves and autonomic nerves which permeate the entire dermis. The sensory nerves have a myelin sheath. The face and extremities have the highest density of sensory branches. These branches have two main endings: corpuscular, which embrace non-nervous elements, and free, which do not [39]. Examples of corpuscular branches are: Pacinian, Golgi-Mazzoni, Krause or Meissner. In the Ruffini structures, (abundant in human digits) several expanded endings branch from a single myelinated afferent fibre. The "free nerve-endings" are located in the superficial dermis and in the overlying epidermis [40]. In the dermis, they are arranged in a tuft-like manner. Hair follicles also have nerve terminals which run parallel to and encircle the hair follicles.

1.8 Practical Points

- The thickness of the epidermis is variable. It is very thick on the palms, soles and other friction surfaces. These areas are more resistant to treatments using light sources.
- The thickness of the dermis is also variable. In the eyelid, the dermis is thinnest; on the back, it is the thickest. This variable is important when considering IPL treatment in different anatomical regions.
- People with fair skin have fewer melanosomes which are smaller and packed, while people with dark skin have more melanosomes which are larger and not packed. IPL has the best results in fair skinned people.
- The hair follicles and vascular dermal elements are not uniformly distributed at the same level. This is important to take into consideration when choosing IPL parameters.
- In white and grey hair, the melanocytes of the hair matrix are much reduced and show degenerative changes. They are the most resistant to IPL hair removal.
- Hair follicles in the anagen phase are the most susceptible to IPL treatment.
- With aging, there is a decrease in total collagen content in the skin, an increased amount of type III collagen, decreased number and diameter of elastin fibers, and a lack of interaction between water and surrounding molecules which contribute to the dry and wrinkled aspect.
- The face and the hands have the highest density of sensory nerves and are the most painful areas in IPL treatment.

Multiple Choice Questions

Q1: What are the Main Functions of the Skin

(a) Protection of the body.
(b) Physiological regulation for the body.
(c) Fat deposit.
(d) Sensation to central nervous system.

Q2: How Many Layers Has the Skin?

(a) 1.
(b) 2.
(c) 3.
(d) 4.

Q3: Select the Correct Answers Regarding the Epidermis:

(a) The epidermis is the outer part of the skin.
(b) It contains the blood vessels of the skin.
(c) It contains the melanocytes
(d) The Langerhans cells have no immunological activity.

Q4: Which of the Options Is Correct Regarding Skin Vascularization

(a) Aging brings a reduction of papillary microvessels.
(b) The vascularization of the skin comes from the deep plexus situated in the subcutaneous level.

(c) No arteriovenous anastomoses are found in the superficial dermis.
(d) A special vascular structure called the glomus is present in the dermis of the face.

Q5: The Dermal Lymphatics:

(a) Are easily detected in inflammation.
(b) Are easily detected in normal skin.
(c) Are present in the papillary dermis of the normal skin.
(d) Sometimes present in valves.

Q6: Which of the Following About Eccrine Sweat Glands are true?

(a) Patients with hyperhidrosis may have widely dilated secretory coils in the axilla.
(b) They are present in great amounts in the palms and soles.
(c) They are absent in the palms and soles.
(d) Their secretory zone is located in the superficial panniculus.

Q7: Which are True About the Elastin Fibers?

(a) In young children they are no fully matured, so the microfibrils are predominant.
(b) With aging, there is an increase in the number of microfibrils.
(c) With advanced age, some elastin fibers undergo fragmentation.
(d) They are thick in comparison with collagen bundles.

Q8: Select the Correct Answers Regarding Skin Innervation:

(a) The skin has a sensory innervation
(b) The skin has an autonomic innervation.
(c) Face and extremities have the highest density of sensory branches.
(d) The sensory nerves don't have a myelin sheath.

Q9: The Three Main Component of the Hair Follicle Are:

(a) The lower part beginning at the base of the follicle.
(b) The middle portion also called the isthmus.
(c) The upper part called the infundibulum.
(d) The transition part called the glomus.

Q10: Select the Correct Answers Regarding the Hair Growth.

(a) Hair growth is a two cycles.
(b) The hair follicle is the most susceptible to IPL treatment during the anagen phase.
(c) The hair follicle has regenerative proprieties.
(d) The catagen phase consists of involution of the hair follicle.

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Light Tissue Interactions

2

Lucian Fodor and Raluca Sobec

Level Learning Objectives

- Understanding the skin components and properties involved in interaction with the light
- Understanding the heating process and its effects on the skin
- Understanding the light-tissue interaction process and the consequences

The effects of light on skin are due to various degrees of absorption of electromagnetic radiation (EMR). The EMR represents the fundamental form of energy having wave and particle properties. According to Planck's law, long wavelength photons carry less energy than short wavelength photons. The EMR includes radio waves, microwaves, infrared radiation, visible light, ultraviolet radiation and x-rays (Fig. 2.1). EMR is generally classified according to wavelength. The visible light spectrum has a 400–760 nm wavelength. The light-tissue interaction effects are due to absorption and excitation of photons. The effects of photons on tissue depend on optical power density, wavelength, and also the time of exposure [1, 2]. The Intense Pulsed Light is situated in the visible light of the electromagnetic spectrum (Fig. 2.2). To understand the effects of light on tissue, it is necessary to define some terms:

- *Fluence* (F) represents the amount of energy measured in Joules (J) per unit area, measured in cm^2: $F = J/cm^2$
- *Power* measured in watts (W) represents the amount of energy delivered over a certain period of time: W = J/s
- *Thermal relaxation time* (TRT) is the time necessary for an object to cool down to 50% of its original temperature. TRT is further detailed in this chapter.
- *Wavelength* influences selective light absorption by a certain target and also influences the depth of tissue penetration (Fig. 2.3). The majority of light systems have different filters which allow certain wavelengths to enter the tissue, thus producing the selection of the desired light spectrum.
- *Footprint* (device spot) size has an important role in light penetration into the tissue. When a small spot size is used for light emission, only a small part will reach the deep target structures

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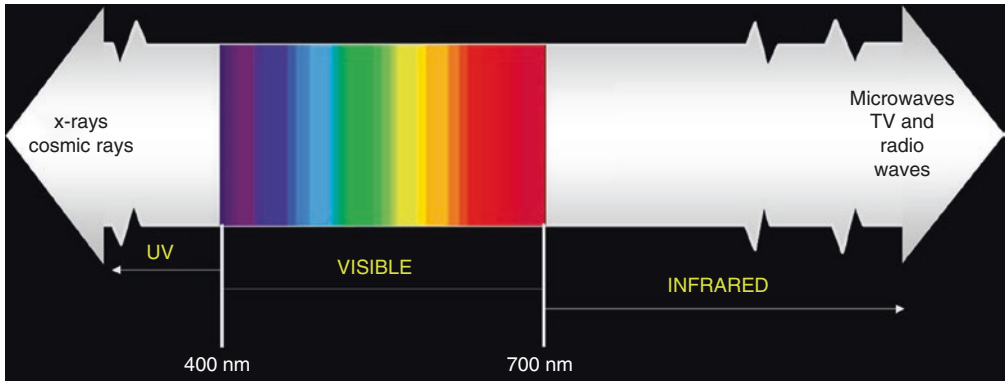

Fig. 2.1 Electromagnetic spectrum (Photos from Fodor and Ullmann first edition)

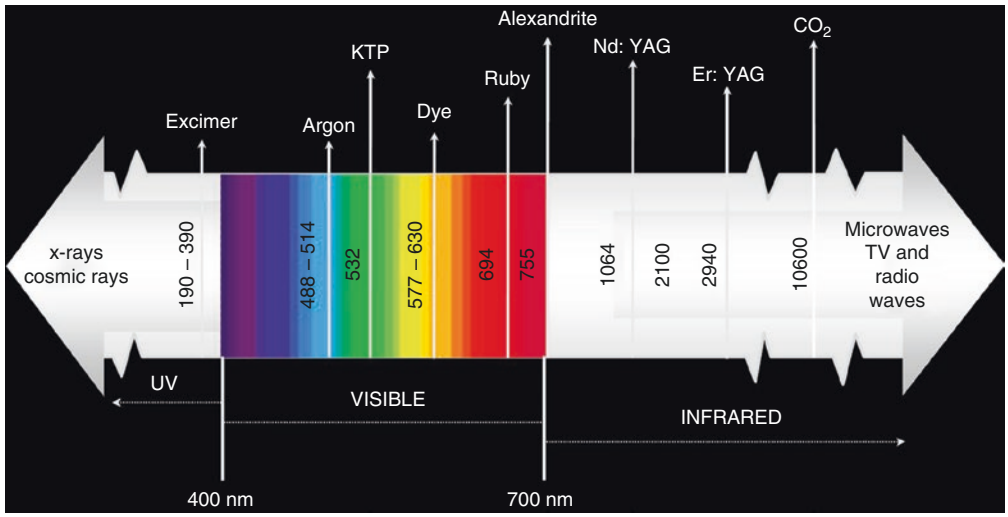

Fig. 2.2 Visible light spectrum (Photos from Fodor and Ullmann first edition)

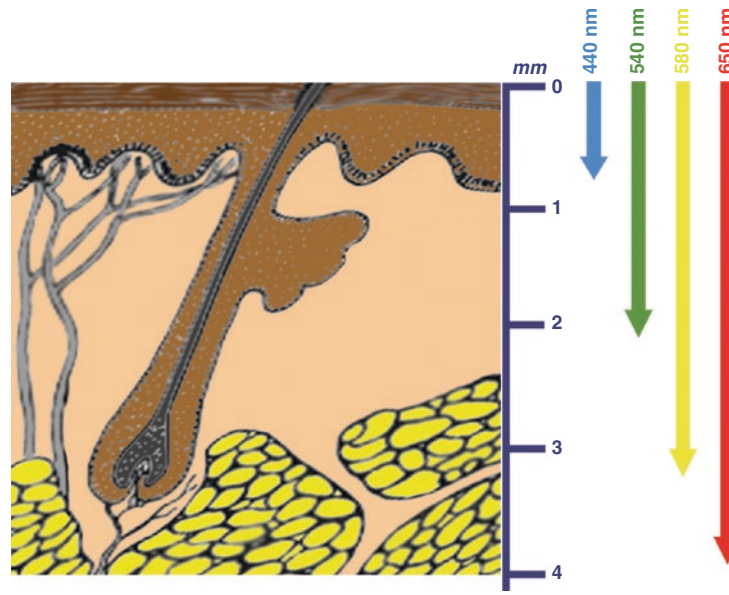

Fig. 2.3 Depth of light penetration into the skin, at various wavelengths (Photos from Fodor and Ullmann first edition)

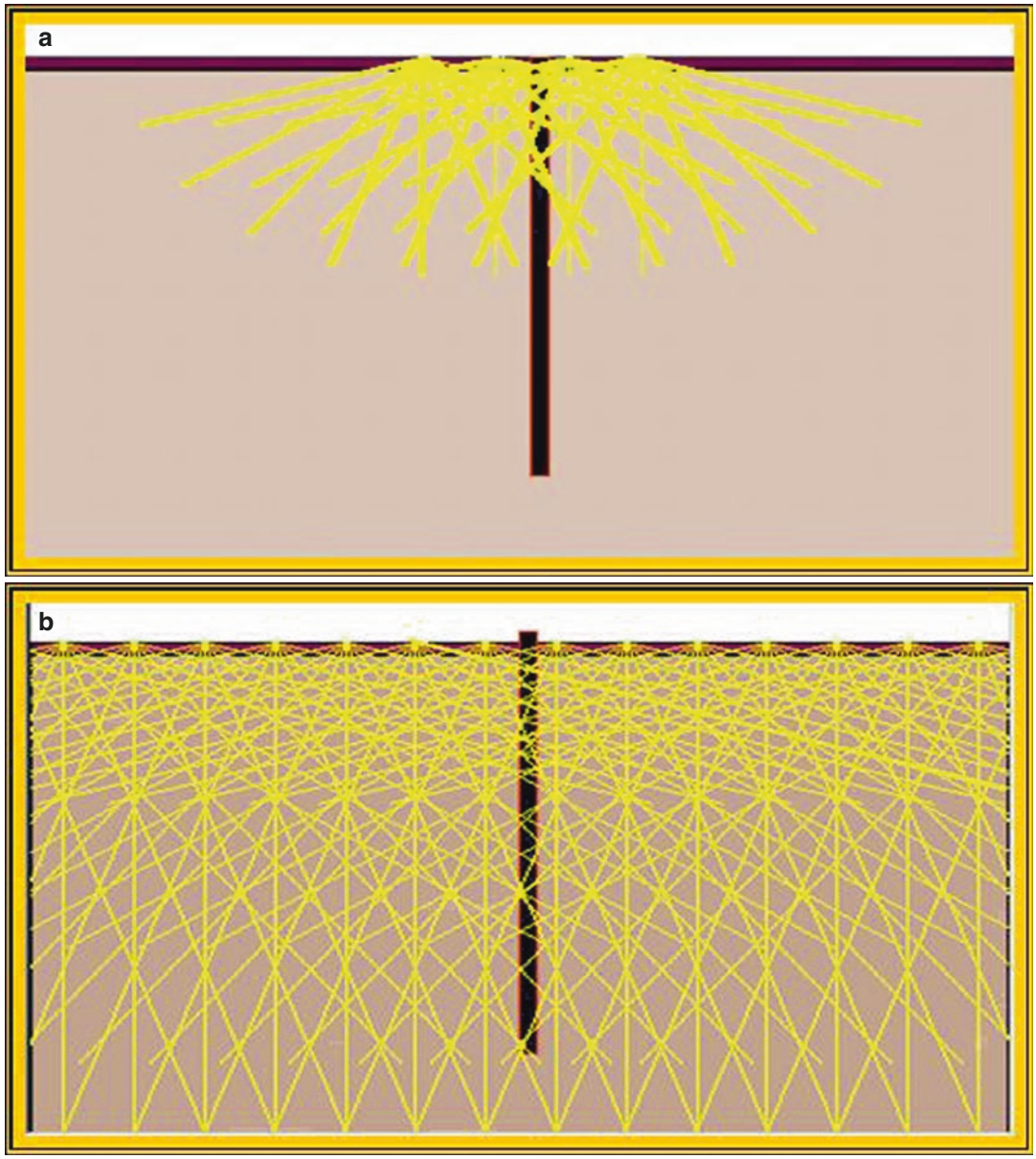

Fig. 2.4 (**a**) Light distribution of a small spot (Photos from Fodor and Ullmann first edition). (**b**) Light distribution of a large spot (Photos from Fodor and Ullmann first edition)

(Fig. 2.4a, b). A larger footprint offers a more planar geometry of light penetration and better efficacy (Fig. 2.5) [3]. A spot size of about 7–10 mm is needed for maximal light penetration to the mid-dermal structures. The bigger the spot, the deeper the level of penetration [4].

- *Pulse duration*. Light can be delivered in a pulsed or continuous wave. The intense pulsed light devices are based on pulsed delivery that allows more selective tissue damage. Pulse duration represents the time of exposure to the light beams. Laser and pulsed light systems enable the selection of pulse duration, which is influenced by the TRT of the target.
- *Pulse delay* represents the tie that allows the skin and blood vessels to cool down between pulses, while the heat is retained inside the targets. When the pulse is shorter than the thermal

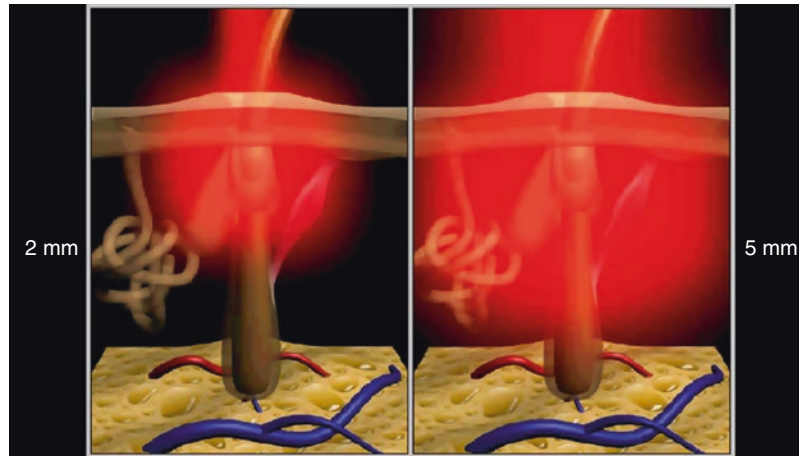

Fig. 2.5 Deeper light penetration using a large footprint (Photos from Fodor and Ullmann first edition)

relaxation time (TRT), the heat will act mainly on the target structures. When the pulse is longer than the TRT, the heat will be conducted to the surrounding structures. It is recommended that the pulse timing be higher than the skin cooling time to avoid damage to the surrounding structures.

2.1 Heating

Heating is one of the effects induced by light absorption. It is not uniformly distributed inside the skin. This process is more representative around the target cells. The temperature is directly related to the excitation of molecules. As the temperature is raised, different changes take place at the molecular level. DNA, RNA and some proteins are affected by the heat which causes them to unwind or even melt at varying temperatures. The final result would be denaturation and coagulation of the above-mentioned structures. These effects are dependent on temperature and length of exposure. Depending on the target tissue, the light-tissue interactions will cause tissue necrosis, blood coagulation and structure alterations. Some of the heating effects are beneficial at the level of the target tissues but are dangerous to the surrounding tissue. This should always be kept in mind when choosing the treatment parameters.

The coagulation damage depends not only on the temperature but also on the exposure time. For instance, a high temperature and a short exposure can be less aggressive than a lower temperature with a longer period of exposure. The dermis, being rich in collagen and elastin, is more thermally stable than the epidermis, mainly due to elastin proprieties.

2.2 Skin Proprieties Regarding Light-Tissue Interaction

Once the light reaches the skin, part of it is absorbed, part is reflected or scattered, and part is further transmitted. The scattering process takes place when the photon particles change the direction of propagation (Fig. 2.6a). This phenomenon takes place inside the skin where different structures have different indices of refraction. The scattering effect makes the light spread out and limits the depth of light penetration. It seems that the dermal collagen is responsible for most of the scattering. The amount of scattering is inversely proportional to the wavelength of the light [5]. Some 4–7% of the light is reflected, this phenomenon being produced by a change in the air and stratum corneum refractive index. The amount of light that is reflected decreases with the decreasing angle of incidence (Fig. 2.6b). The least reflection occurs when the light is perpendicular to the tissue. A very small amount of light is further transmitted (Fig. 2.6c). It has been proved that transmission of the light varies according to the skin type [6]. The white dermis transmits

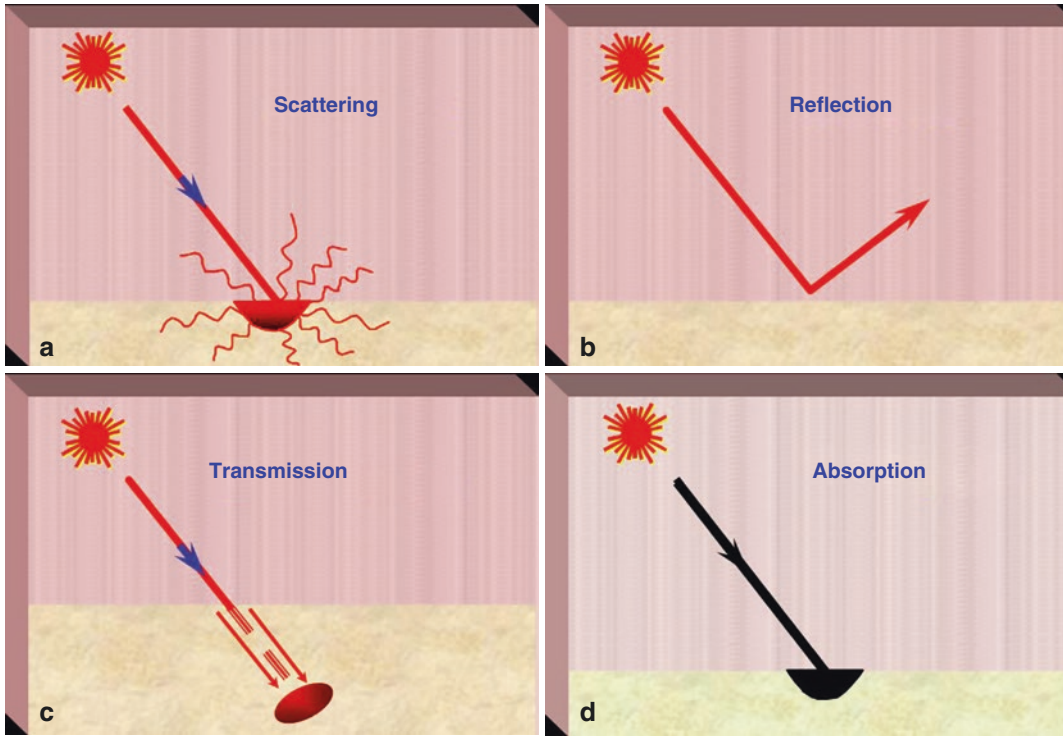

Fig. 2.6 (**a**) Scattering effect (Photos from Fodor and Ullmann first edition). (**b**) Reflection of the light (Photos from Fodor and Ullmann first edition). (**c**) Light transmission (Photos from Fodor and Ullmann first edition). (**d**) Light absorption (Photos from Fodor and Ullmann first edition)

from about 50% at 400 nm to 90% at 1200 nm, while the black epidermis transmits <40% at 400 nm and 90% at 1200 nm. In general, there is a gradual increase in skin penetration at longer wavelengths. Most of the light is absorbed by the skin (Fig. 2.6d). This phenomenon is responsible for the desired effects on the tissue.

The structures of the tissue that absorb the photons are known as chromophores. They have different wavelengths of absorption. The most common chromophores encountered in the skin are hemoglobin and its derivatives, melanin, water and foreign pigmented tattoos (Fig. 2.7). The melanin present in melanosomes of the keratinocytes and basal melanocytes plays an important role in absorption of epidermis. At the dermis level, the blood and water are responsible for absorption [2]. Once absorbed, the chromophores become excited. For wavelengths varying from 300 to 1200 nm, melanin is the dominant absorbent.

Light-tissue effects can be grouped in:

- *Photothermal*—represented mainly by coagulation or vaporization of tissue based on absorption
- *Photomechanical*—tissue disruption often encountered by pulsed laser beams
- *Photochemical*—direct breakage of chemical tissue bonds or chemical interaction with an applied drug
- *Photobiostimulation*—tissue stimulation with very low level laser light
- *Selective photothermolysis*—The concept of photothermolysis was introduced for the first time by Parrish and Anderson in 1983 [7]. According to their description, three effects are necessary to produce selective photothermolysis:
  - Absorption of a specific wavelength by the target structures

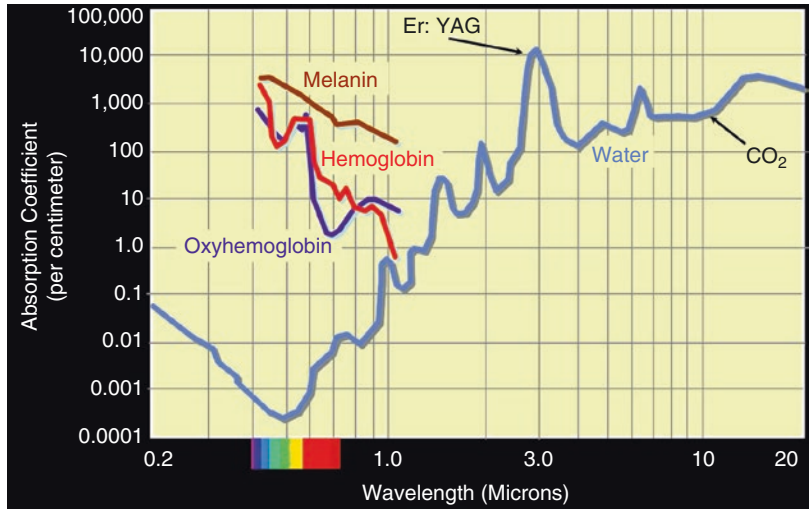

Fig. 2.7 Light absorption for different chromophores (Photos from Fodor and Ullmann first edition)

- The exposure time should be less than or at least equal to the time of cooling of the target structures
- There is a need for enough fluence to produce a damaging temperature within the target structures

The main target structures for Intense Pulsed Light treatment are melanin and blood vessels (Fig. 2.8a–d). To understand the relation between exposure time and extent of thermal damage, it is important to detail the "thermal relaxation time" (TRT). This represents the time required to cool a small target structure. The cooling is achieved by conduction, convection and radiation. Conduction is the main component of cooling.

Smaller objects cool faster than larger objects. The TRT is proportional to the square of the size [8].

$$T = d^2 / k\alpha$$

where: T = relaxation time

D = size of the heated object

A = thermal diffusivity (about 2×10^{-3} cm^2/s for dermis)

K = geometrical factor (for a cylindrical object is 16)

To allow enough time for the epidermis and other skin structures to cool down, the pulse duration should be shorter than the cooling time of the target but longer than the cooling time of the skin. This has clinical implications, especially for hair removal. The hair follicles are grossly grouped into coarse and fine. They have different sizes and, consequently, different TRTs. An epidermal thickness of 0.1 mm has a TRT of about 1 ms, while a vessel of 0.1 mm has a TRT of about 4 ms [9]. A vessel three times bigger (0.3 mm) has a TRT of approximately 10 ms. Larger structure targets cool down slower and need increased delay time and multiple pulsing. Theoretically, most vessels smaller than 0.3 mm require only a single pulse. It is recommended that pulses be spaced at 10 ms or longer to accommodate normal epidermal TRT [9]. Patients more prone to thermal injuries should have at least 20–30 ms of TRT.

When the pulse width is greater than the TRT, non-specific thermal damage occurs because of heat diffusion. The fluence delivered to the chromophores must be high enough to destroy them.

In order to enhance the photodynamic therapy effect which is based on selective photothermolysis, photosensitizers have been introduced as adjuvants. There are topical and systemic photosensitizers. The first generation of photosensitizers was developed about 30 years ago and belongs to the porphyrin family; 5-aminolevulinic acid (ALA) and methyl aminolevulinate (MAL) are the most common sensitizers. Second generation photosensitizers have the advantage of having a limited effective period. ALA is not a photosensitizer

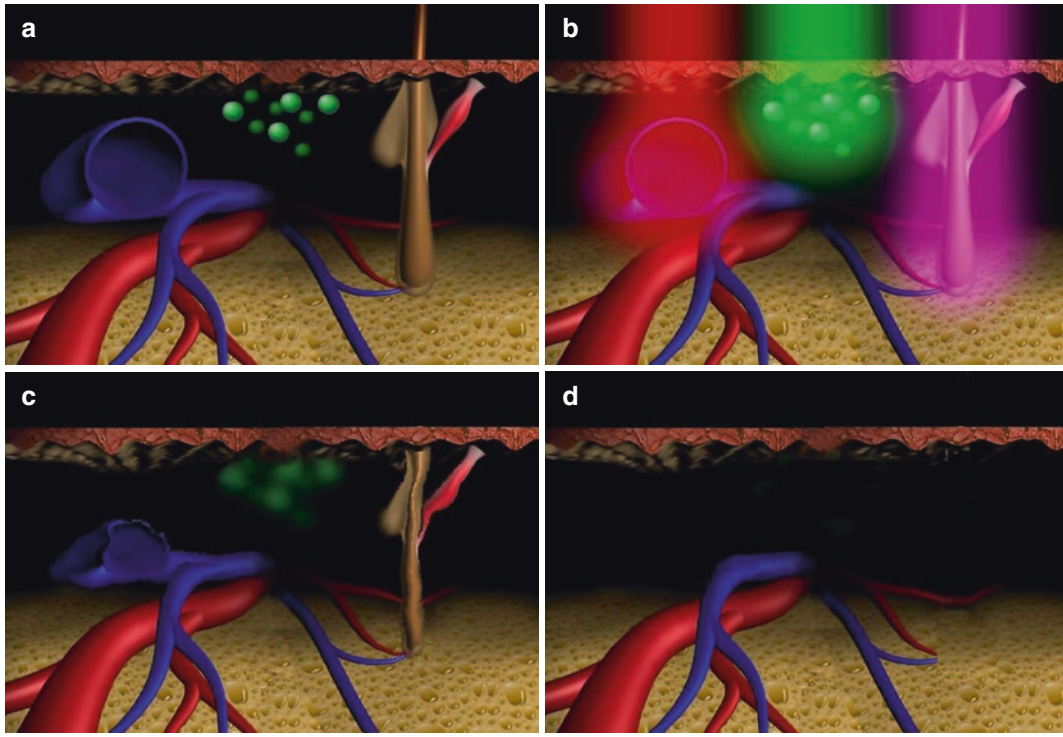

Fig. 2.8 (**a**) Various chromophores in the skin (Photos from Fodor and Ullmann first edition). (**b**) Light interaction with various chromophores (Photos from Fodor and Ullmann first edition). (**c**) Immediate response to light–tissue interaction (Photos from Fodor and Ullmann first edition). (**d**) Late response with destruction of the chromophores (Photos from Fodor and Ullmann first edition)

by itself but it is metabolized to photosensitizing protoporphyrin IX [10]. The spectrum of absorption of protoporphyrin IX is in the visible spectrum. The peak of absorption is 405 nm [11]. Systemic sensitizers are administered intravenously since they do not penetrate the skin. Hematoporphyrin and photofrin have been thoroughly studied [11] with regard to their peak of absorption. Applications of these photosensitizers in association with Intense Pulsed Light may increase the efficacy of the treatment [12]. This concept of combining light with a photosensitizing agent, known as photodynamic therapy, has wider applications, including tumor treatment [13].

2.3 Chromophores of Human Skin

The human skin has several major ultraviolet radiation-absorbing endogenous chromophores. Among them are urocanic acid, amino acids, melanin and its precursors. The chromophore identification can be done by action spectroscopy. Theoretically, an action spectrum for a given photobiological endpoint will be the same as the absorption spectrum of its chromophore. The skin chromophores have an overlying spectra [14]. From all chromophores present in the skin, the melanin and hemoglobin with its derivatives are the most important regarding light pulsed treatment.

The term melanin is widely used to describe the skin's red-brown pigment which resides in the epidermis. The biosynthesis of melanin within melanocytes is a complex process and is incompletely understood. It is believed that they are polymers with multiple-monomer units linked by non-hydrolysable bounds [14]. There are two major classes of natural melanins: the black-brown eumelanin and the yellow-red pheomelanin. They are differentiated by their molecular building blocks [15, 16]. Eumelanin is the dominant pigment, and recent studies showed

that 74% eumelanin and 26% pheomelanin compose the melanin in human epidermis [17, 18]. Eumelanine is photoprotective, while pheomelanin is phototoxic [18].

Human skin coloration is dependent on spatial distribution of the melanin and hemoglobin chromophores [19, 20]. Eumelanin plays a fundamental role in skin appearance and photoprotection. A weak correlation was noticed between the scattering properties of skin and the tissue type with the average scatter size higher in patients with higher melanin content [20]. The skin has a multilayered structure. The two main chromophores in the skin, melanin and hemoglobin, are present in different layers, with the melanin found in the top layer (mainly epidermis) and the hemoglobin found in the bottom layer (vascular network of the dermis) (Figs. 2.9a, b, 2.10a, b, 2.11a, b).

To avoid skin damage, higher cut-off filters, multiple pulses and increased delay time should be chosen for darker skin types. The Fitzpatrick skin typing system (Table 2.1) group from I to IV

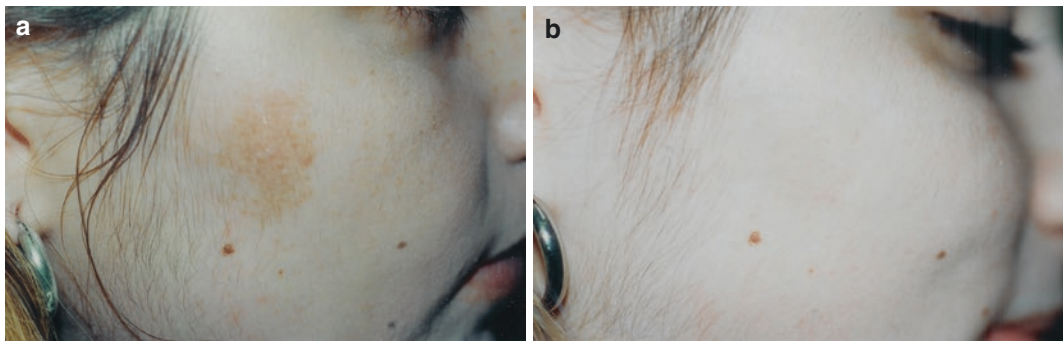

Fig. 2.9 (**a**) Café-au lait in a young person. The melanin is the main chromophore. (**b**) Good result after two IPL treatments. (Photos from Fodor and Ullmann first edition)

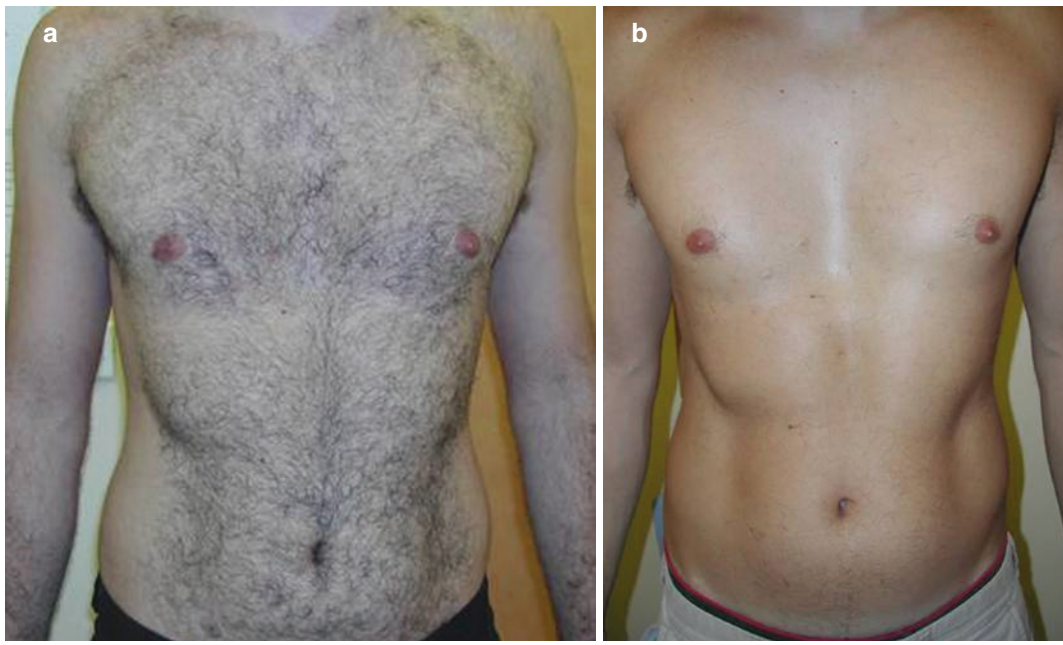

Fig. 2.10 (**a**) Hypertrichosis. The light energy is absorbed by the melanin (endogenous chromophore) present in the hair shaft, outer root sheath of the infundibulum and matrix area pigment from the hair bulb. (**b**) Good result after five IPL treatments. (Photos from Fodor and Ullmann first edition)

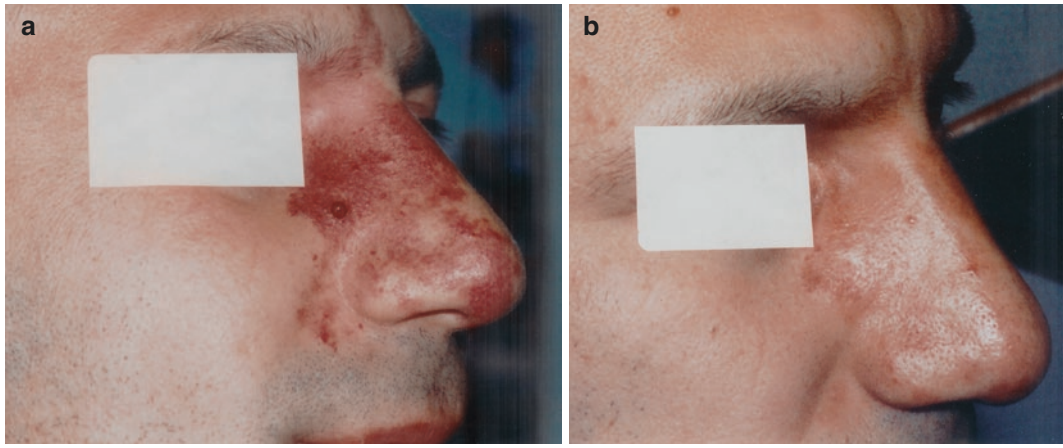

Fig. 2.11 (**a**) PWS—adult type over the nose. The cromophore is the hemoglobin. (**b**) Good result after ten IPL treatments. (Photos from Fodor and Ullmann first edition)

Table 2.1 Data derived from Fitzpatrick-skin color types [21]

Skin type	Skin color	Susceptibility to sun burn	Susceptibility to skin cancer
Type I	Blond or red hair (freckles, fair skin, blue eyes)	Always burns easily; never tans	High
Type II	Blond or red hair (freckles, fair skin, blue eyes)	Usually burns easily; tans with difficulty	High
Type III	Darker Caucasian, light Asian	Burns moderately; tans gradually	Low
Type IV	Mediterranean, Hispanic, Asian	Rarely burns; always tans well	Low
Type V	Latin, light-skinned black, Indian	Very rarely burns; tans very easily; dark skin tone	Very low
Type VI	Dark-skinned black	Never burns; very dark skin tone	Very low

has different skin colors according to pigment intensity [21]. Although it is a widely used scale, it has been criticized that human eye evaluation is subjective and confounded by the presence of hemoglobin [22]. Although the human eye can distinguish adjacent brown and red colors, it is almost impossible to distinguish the relative contribution of melanin and hemoglobin when they overlay one another, as often happens in young and photoprotected skin [23].

There are elaborate methods which try to evaluate skin color objectively. These are based on spectrophotometric or colorimetric techniques. Although these methods are more objective, they still cannot completely separate the individual contributions of the chromophores [23–25].

Exogenous chromophores can be administered to the skin to prevent sunburn (exogenous chromophores from sunscreens) or in combination with ultraviolet radiation for therapeutic benefit [26, 27].

2.4 Practical Points

- The intense pulsed light is situated in the visible light of the electromagnetic spectrum.
- Heating is an important effect induced by light absorption. This often leads to cell necrosis, blood coagulation and structure alterations.
- The light interacts with the skin and part of it is absorbed, part reflected or scattered, and part is future transmitted. The absorption is responsible for the desired effect on the tissue.
- The two main skin chromophores present in the skin and responsible for the light effects are melanin and hemoglobin.
- Selective photothermolysis is the basic principle of Intense Pulsed Light treatment. It consists of matching a specific wavelength and pulse duration to obtain the optimal effect on a target tissue with minimal effect on the surrounding tissues.

- Melanin is located within the top layer of the skin (epidermis) and hemoglobin is found in the bottom layer (vascular network of the dermis).

Multiple Choice Questions

Q1: Choose the Correct Statement:

(a) DNA, RNA are affected by heat
(b) Epidermis is more thermally stable compared to dermis
(c) The main target structures for IPL are melanin and blood vessels
(d) The main component of cooling is convection

Q2: Which are Considered Skin Chromophores:

(a) Melanin
(b) Macrophage
(c) Urocanic acid
(d) Amino acids

Q3: All the Affirmations Are Correct, Except:

(a) IPL is situated in the visible light of the electromagnetic spectrum
(b) Thermal relaxation time represents the time necessary for an object to cool down to 50% of its original temperature
(c) If the pulse is longer than the thermal relaxation time, the heat will act mainly on the target structures
(d) To avoid damage to the surrounding tissues, the pulse timing should be higher than the skin cooling time

Q4: Choose the Correct Answers from Below:

(a) The absorption of the light by the skin is responsible for the desired effects of IPL
(b) The amount of the light reflected increases with the decreasing angle of incidence
(c) The skin type has nothing to do with the transmission of the light
(d) For wavelengths varying from 300 to 1200 nm, melanin is the dominant absorbent.

Q5: All the Answers Are Incorrect, Except:

(a) The structures of the tissue that reflects the light are known as chromophores
(b) The chromophores have different wavelengths of reflection
(c) The photothermal effects is represented by the coagulation or vaporization of tissue based on absorption
(d) To produce selective photothermolysis, only absorption of a specific wavelength by the target structures is necessary, independent of the exposure time.

Q6: After Light-Skin Interaction, Half of The Light Is Absorbed and the Rest Is Transmitted.

(a) True
(b) False

Q7: The Dermal Collagen Is Responsible for the Catering Effect.

(a) True
(b) False

Q8: Thermal Relaxation Time Is the Time Required to for an Object to Cool Down to 50% of Its Original Temperature. The Cooling Can Be Achieved By Conduction, Convection and Radiation, the First One Being the Main Component of Cooling.

(a) True
(b) False

Q9: True or False. Large Structure Targets Cool Down Slower Compared with Smaller Structures and Need a Single Pulse.

(a) True
(b) False

Q10: True or False. Eumelanin, the Yellow Red Pigment, Plays an Important Role in Photoprotection.

(a) True
(b) False

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IPL Safety: Legal Issues

3

Lucian Fodor and Laura Sita-Alb

Level Learning Objectives

- Understand the optical hazard and dangers to the patient and to the staff performing the treatment
- Understand the room and electrical safety.
- Understand other possible hazards during the treatment.
- Understand important legal issues.

3.1 Safety Issues

Even though complications may appear after the medical and cosmetic utilization of the IPL devices, there are no generally applied rules when it comes to the utilization of the IPL, regardless if we speak of the person who is operating the device, the person delegated to use it or the person supervising the procedure.

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Some of the procedures undertaken with the IPL devices are not considered a treatment of a medical disease, but instead they are seen as pure aesthetic procedures. In many countries and also in many states of the US, it is not mandatory that the procedures to be done by a medical doctor and moreover in some countries/states even the medical supervision or delegation are not mandatory.

General guidelines state that only specially trained physicians or supervised specially trained personnel should operate on the IPL devices, the guidelines are not mandatory and it depends of each institution internal standards if this guidelines are applied or not.

Specially trained personnel and continuous improvement and training should be respected.

3.1.1 Optical Hazard

Unwanted exposure to IPL must be avoided, whether it is a direct or an indirect exposure from different reflecting surfaces. Handling the treatment head should be done cautiously to avoid discharges into free space.

The optical hazard it's the main danger. The only safety rule that it's stated by the Occupational Safety and Health Administration of the US is that laser workers require specific goggles [1]. Ocular damage can be done either by direct exposure to the light beam or by indirect exposure; this can be

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found when the laser bean reflects from different surfaces or instruments. The treatment area must be the only one towards which the treatment head should be directed. There are specific eyeglasses for different wavelengths. The optical density of the glasses should at least 4 for each laser wavelength to be considered protective for the physician, patient and all other personnel in the treatment room [2].

Any objects, jewelry, watches or instruments that can reflect the light beam should be kept at distance. Do not look directly at the light emission head. When the treatment is being performed, all personnel in the treatment room along with the patient should wear protective goggles (Fig. 3.1). Usually, the patient wears goggles which allow the doctor to perform treatments in the periorbital area easily (Fig. 3.2).

3.1.2 Treatment Room Safety

Treatments should be carried out in a specially designed room that respects the safety of light and laser radiation. The entrance should be clearly labeled with signs indicating high intensity light. The number of people in the treatment room should be limited and related to the procedure. The system should not be used in the presence of flammable materials. The doors of the treatment room should be closed when the device is in use and a special sign reading "Danger" should be placed outside the treatment room (Fig. 3.3).

3.1.3 Electrical Safety

Electrical precautions should always be applied when working with an IPL system. Some IPL devices might retain high voltages in different components even after the system power is turned off. Any flammable objects or liquids should be kept at distance from the IPL beam [2]. Authorized personnel only should do the entertain and the repairs of the IPL devices. When the system is in use all the device covers should be kept closed. Most devices have an emergency shutdown

Fig. 3.1 Wavelength-specific eye protection should be used by the staff in the treatment room. (Photos from Fodor and Ullmann first edition)

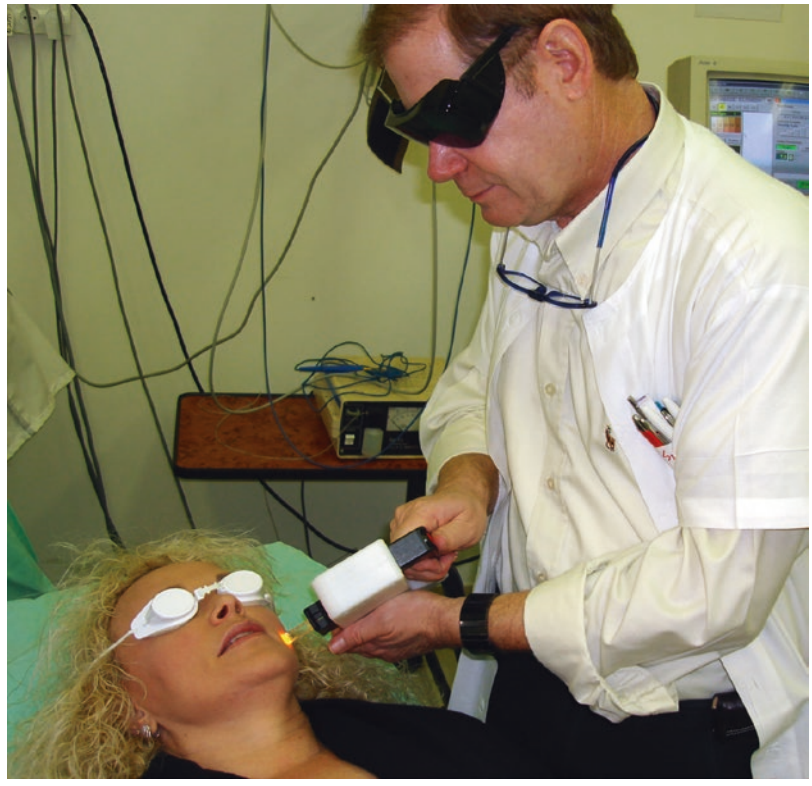

Fig. 3.2 Goggles are worn by patients for eye protection during treatment. (Photos from Fodor and Ullmann first edition)

Fig. 3.3 A warning sign should be displayed on the door. (Photos from Fodor and Ullmann first edition)

button, and it is important to always shutdown the device when it is not being used. Untrained personnel should not operate the IPL devices. Doctors, midlevel providers and technicians should work together to monitor the equipment, the patient and the environment for safety.

3.1.4 Delayed Skin Cancer Diagnosis

IPL utilization on pigmented lesions by an untrained operator can delay the diagnosis serious health problems by masking via depigmentation the skin cancer [3, 4].

Malignant melanoma (MM) is the most dangerous skin cancer; the majority of deaths following a skin cancer are due to MM. Even though studies show that IPL wavelengths do not accelerate tumor cells proliferation, [5] it can be stated that IPL treatment might cause depigmentation to the most superficial layer of the tumor leaving the most deep layers untouched. The deep tumor layers will continue to grow and evolve in their natural way, the same way as if the tumor was not treated with the IPL [5].

Because tumor superficial depigmentation might cause diagnosis delay, it is recommended that all suspicious tumors to be evaluated by a dermatologist prior to IPL treatments. If the IPL treatment is undertaken in a cosmetic facility without medical supervision, a dermatological consultation should be mandatory prior to any treatment.

3.2 Other Possible Hazards

Other complication may arise from the surgical smoke. Small particles with bacteria or viruses even alive particles were found in this smoke [6]. That is why it is important to wear safety measures such as gloves, surgical masks and smoke filter systems to protect the physician and all other personnel from this hazards.

Theoretical potential risk of infection transmission is another hazard [7]. To diminish this risk, in addition to wearing regular gloves, footprints are cleared using chlorhexidine solution between treatments.

While there are no reports on the use of IPL treatment in pregnant women, we do not recommend its use under these circumstances.

3.3 Legal Issues

Even though complications may appear after the medical and cosmetic utilization of the IPL devices, there are no generally accepted laws when it comes to the utilization of the IPL, regardless if we speak of the person who is operating the device, the person delegated to use it or the person supervising the procedure.

In the US the rules change from state to state. There is only one state (New Jersey) that restricts the laser utilization only to physicians. In most of the countries and US states is the responsibility of the physician to delegate the procedure to a second person. It is also important to mention that by physician it is not understood a medical doctor, it could mean also a dentist, a podiatrist, an osteopath, etc. [8]. And still there are studies that investigate the degree of supervision made by the physician responsible, and it was found that many cosmetic facilities only have contracts with a physician and the physician has his own office somewhere else and not working in the same facility. The same ambiguity is found in Australia, and also in most of the European countries [5].

It is important that both patients and medical staff to be conscious that IPL is not a cosmetic risk-free procedure. All the personnel should read the IPL instruction manual.

In the last decade we were able to find more and more home IPL devices. Lasers and IPL devices are classified as hazardous (Class 3B and Class4) [9]. Lasers and IPL devices with a wavelength higher then 180 nm are considered hazardous [10]. Home designed devices have spectral distribution between 475 and 575 nm, and the pulse duration is under 5 ms. All home devices have multiple security features that anoles the retinal risk of the IPL devices. But unfortunately if the safety features fail this may pose a retinal risk [10].

There are many discussions and controversies around these home devices. Even though they have many safety features regarding the ocular hazard, it is difficult to predict whether or not they are being used for the proper indications, for the proper skin type, whether or not the skin has tumors that might suffer depigmentation and their diagnose delayed or missed.

Usually patients perceive the IPL and laser procedures as simple, risk free procedures which give extraordinary results. These unrealistic expectations are mostly due to the intense advertisement that surrounds the beauty industry.

Practitioners need to be extremely careful when explaining to the patient the potential benefits of the IPL treatment, not to give false expectations and also to clearly inform the patients about the possible side effects. Even when IPL is being used for a cosmetic procedure, a written informed consent should be signed, it is important not to rely only on the verbal consent in nowadays litigious society [11]. The goals are to include the patient in the decision-making process, to inform the patient of the various methods and instruments, and to inform the patient about the potential benefits and hazards of the treatment [12]. Most informed consent dealing with aesthetic procedures includes the possibility of patient photography or videotaping. Photo documentation as well as record storage are important for follow-up and possible liability problems.

Working in beauty industry implies also dealing with patients with unrealistic expectations or with different beauty disorders. Body Dysmorphic Disorder (BDD) refers at patients that perceive themselves with an imagined problem but in reality they are normal appearing, or with a minimal defect that is over exaggerated in their mind. The condition where the patient focuses on one part of their body and find this part as being deformed and problematic is called beauty hypochondriasis. These beauty disorders are a major impairment in the patient social and personal life. These patients have also a feeling of inferiority, guilt, or altered body image [12]. The incidence of BDD in the general population was found to be up to 2.4%, with a higher prevalence of 7–15% among patients seeking cosmetic surgery procedures [13–15]. Since these patients have an emotional rather than a physical problem, they are rarely satisfied with cosmetic procedures [16].

Medical practitioners should be very careful and prevent a possible lawsuit, by clearly communicating with the patients and always having informed consents for the proposed procedures. They must be really careful when delegating the procedures, because in these cases the practitioner is held responsible and sued, not the delegated persons.

There is a discrepancy between the percentage Medical practitioners of complications following a non-medical practitioner and the number of law suits that follow. Usually medical practitioners are more frequently suited for complications Medical practitioners than non-medical practitioners. This can be explained by the fact that insurances cover usually de medical practitioners so it's easier and more profitable to sue a doctor Medical practitioners. Also the doctor is behold responsible when delegating the responsibilities [2, 17, 18].

Following is the informed consent that we suggest for IPL treatment.

3.4 Practical Points

1. It is important that both patients and medical staff to be conscious that IPL is not a cosmetic risk-free procedure. The instruction manual should be read by all the personnel working with the IPL device.
2. The optical hazard it's the main danger for both physicians and patients when working with an IPL device. It is important both for the patient and the entire personnel in the treatment room to wear protective eyeglasses during treatment.
3. Because tumor superficial depigmentation might cause diagnosis delay, it is recommended that all suspicious tumors to be evaluated by a dermatologist prior to IPL treatments. If the IPL treatment is undertaken in a cosmetic facility without medical supervision, a dermatological consultation should be mandatory prior to any treatment.

4. There are many discussions and controversies around home devices. Even though if they have many safety features regarding the ocular hazard, it is difficult to predict whether or not they are being used for the proper indications.
5. Some of the procedures undertaken with the IPL devices are not considered a treatment of a medical disease, but instead they are seen as pure aesthetic procedures. In many countries and also in many states of the US, it is not mandatory that the procedures to be done by a medical doctor and moreover in some countries/states even the medical supervision or delegation are not mandatory
6. Practitioners need to be extremely careful when explaining to the patient the potential benefits of the IPL treatment, not to give false expectations and also to clearly inform the patients about the possible side effects.
7. Photo documentation as well as record storage are important for follow-up and possible liability problems

Multiple Choice Questions

Q1: True or False. Is IPL Treatment a Cosmetic Risk-Free Procedure?

(a) True
(b) False

Q2: Which Is the Main Hazard of the IPL?

(a) Optical hazard
(b) Delayed skin cancer diagnosis.
(c) Skin burns
(d) Hypertrophic scars
(e) Infection

Q3: Can IPL Treatment Delay Diagnosis of a Skin Cancer?

(a) No, because IPL treatments remove the skin cancer
(b) Yes, due to stimulation of tumor proliferation
(c) Yes, due to superficial tumor depigmentation
(d) No, because IPL treatment has no effect on superficial tumors
(e) No, because IPL is a hazard free procedure

Q4: Is It Completely Safe to Have an IPL Treatment in a Cosmetic Facility?

(a) Yes, IPL is a cosmetic, risks free procedure
(b) No, specially IPL trained doctors should perform the treatment
(c) No, trained medical staff under specially trained doctor supervision should perform the treatment.
(d) Yes, because I feel safe in my favorite cosmetic facility.
(e) No, because they are never trained

Q5: Is It Mandatory to Have a Physician Perform the IPL Treatment?

(a) Yes, there are standard legal regulations worldwide
(b) No, there are not unanimous rules that oblige the supervision or treatment to be undertaken by a doctor
(c) It depends from country to country, and even from state to state
(d) Yes, because it implies hazards and special medical training
(e) Yes, the cosmetic facilities must have doctors supervising

Q6: Are Home IPL Devices Safe?

(a) Yes, home devices have multiple security features, if used properly, with the safety features working, the optical hazard is anole
(b) If home device safety features fail this may pose a retinal risk
(c) No, they should not be used at home

Q7: Do Many Patients Have Unrealistic Expectations?

(a) True
(b) False

Q8: Why Is the Informed Consent Mandatory?

(a) Informed consent is mandatory to avoid lawsuits
(b) Written informed consent is not mandatory, verbal informed consent is enough.
(c) It is important to inform the patient about the potential benefits and hazards of the proposed treatment
(d) Photo-documentation should be done systematically
(e) No informed consent is needed for the cosmetic industry

Q9: How to Deal Best with a Problematic Patient?

(a) Medical practitioners should clearly communicate with the patients and always having informed consents for the proposed procedures.
(b) Patients with unrealistic expectations and those with Body Dysmorphic Disorder should be identified via a thorough anamnesis
(c) Patients with Body Dysmorphic Disorder have an emotional rather than a physical problem, they are rarely satisfied with cosmetic procedures.
(d) Doctors should not worry about the problematic patients since it is a cosmetic procedure
(e) Doctors must ask a psychiatric evaluation prior to treatment.

Q10: Is It Mandatory to Wear Protective Goggles During the Treatment?

(a) True
(b) False

Intense Pulsed Light Treatment. Informed Consent

The Intense Pulse Light Treatment is based on the light emitted by a flash lamp. Using different wavelengths, the device has proved to be useful in the treatment of vascular lesions, pigmentary lesions and hair removal. Partial skin rejuvenation can be obtained sometimes. More than one treatment may be needed in order to obtain the desired effect.

Patients should not be tanned at the treatment. If they are tanned, delaying the treatment for a few weeks is recommended to diminish the rate of complications. Immediately after the treatment, blue or red discoloration may appear. Usually this disappears within a few days. Most procedures do not necessitate anesthesia. Topical anesthetic creams can be used before the procedure. Eye protection will be used by the patient and the staff for the entire treatment period. Although no reaction on a developing fetus has been reported, the procedure is not recommended for pregnant women.

No guarantees can be made of the exact results from this treatment. Although the treatment is safe, some complications may appear:

- Pigmentary changes can be either of increased pigment (hyperpigmentation) or decreased pigment (hypopigmentation). Most of the time these color changes are temporary and resolve over several weeks to months. Permanent pigmentary changes may also appear.
- Pain. The level of sensation during treatment varies from person to person. A warm or burning sensation can be reduced by using topical anesthetics before the procedure and ice packs after the treatment.
- Excessive redness or swelling. In some instances, excessive redness or swelling can persist for up to a few days after treatment. In certain cases, mild topical steroids can be used to hasten recovery.
- Infection is extremely rare as the technology does not break the skin.
- Blisters can be encountered in certain people, especially in those with higher sensitivity.

- Scarring is possible. Normally, the IPL technology does not produce scarring. However, there are a few reports in the medical literature of scarring.
- Lack of satisfaction. Different patients respond differently to IPL treatment. Most people report significant improvement after a series of treatments. While positive changes can be expected, no changes may occur for reasons beyond the physicians control.

To obtain the best results, the skin should be thoroughly protected from sun exposure after the treatment, using sunscreens with SPF 30 or higher. There is no restriction on washing the treated area right after the procedure.

I declare that the above treatment procedure has been explained to me, along with alternative methods of treatment and the risks of the procedure, and all my questions have been answered. I consent to photographs of the treatment areas before and after in order to document the treatment process.

I consent to the Intense Pulsed Light Treatment and the above listed items.

Signature of patient or legal Guardian	Printed name
Physicians signature	Printed name
Date	Hour

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4 Patient Selection and Treatment Protocol

Dinu Dumitrascu and Lucian Fodor

Learning Objectives

- To choose the wright patient for the treatment
- To identify the patients who are not god candidates for IPL treatment
- How to start the treatment sessions
- Principles of treatment
- Recommendations

Patient selection is one of the most important parts of a successful aesthetic procedure. There are two main categories that make a patient an unlikely candidate for cosmetic procedures [1]. One is anatomical unsuitability and the other is psychological unsuitability. A well-motivated patient seems to have better satisfaction. During consultation, the physician should observe the patient's behavior [2]. The typical complaint that "the doctor didn't spend enough time with me" means that the patient's emotional needs were not satisfied [3]. According to Gorney [1], there are patients with a major deformity and minimal concern. For these patients, any degree of improvement will lead to satisfaction. However, there are also patients with a minor deformity and extreme concern, who are likely to be dissatisfied (Figs. 4.1a, b and 4.2a, b). Potential problematic patients are those with unrealistic expectations, excessive demands, indecisive or immature personalities, secretive or "surgiholic" patients, those with factitious diseases and those with familial disapproval [1, 3].

Patient evaluation regarding health status should be done thoroughly and include a search for conditions that contraindicate IPL treatments. A pregnant woman or a patient with significant venous insufficiency and dilated veins might not be suitable for IPL treatment. The local area examination can also reveal conditions, such as skin malignancy, for which IPL would not be the proper treatment. Particular care should be paid to pigmentary changes. Dermatoscopy or skin biopsy can help in making the correct diagnosis before treatment. Sometimes patient expectations might be higher than the possible IPL results. A woman with severe rhytides is not a suitable candidate for IPL treatment if the expectation is to be rid of the wrinkles.

Conversing with the patient and getting to know his/her expectations might be the key to avoiding liability. All patient data and photodocumentation are kept in a separate record for each

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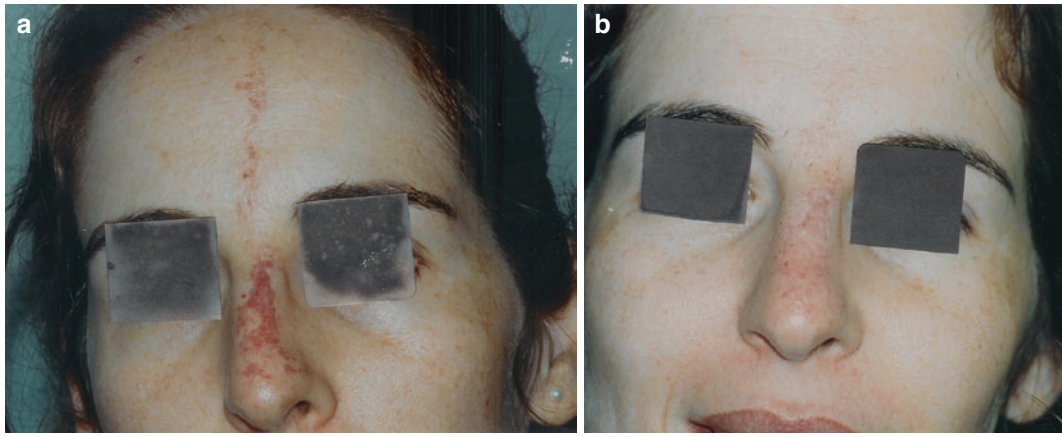

Fig. 4.1 (**a**) Port-wine stain over the nose and forehead (photos from Fodor and Ullmann 1st edition). (**b**) Although partial response was encountered after eight treatments, the patients was very satisfied (photos from Fodor and Ullmann 1st edition)

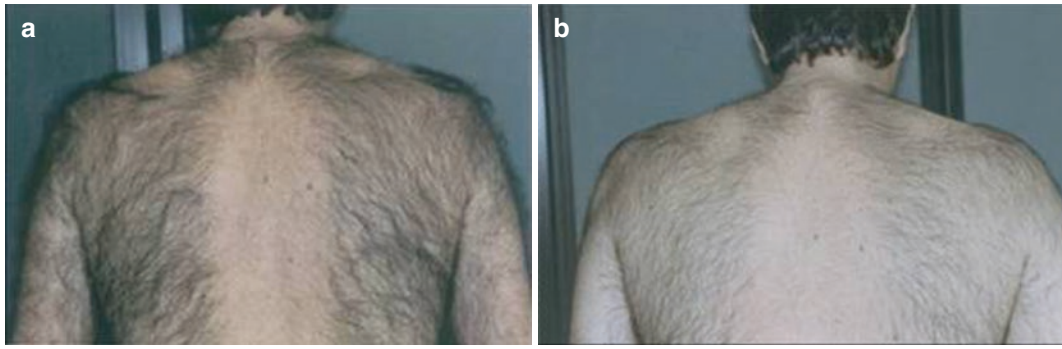

Fig. 4.2 (**a**) Hypertricosis—before IPL treatment (photos from Fodor and Ullmann 1st edition). (**b**) Partial response after five IPL treatments. The patient was unhappy with the result and stopped the treatments (photos from Fodor and Ullmann 1st edition)

patient. The discussion with the patient should include explaining the diagnosis (e.g., why pigmented spots appear), the principle of IPL treatment, treatment alternatives (laser, peelings, surgeries), anesthesia type, length of treatment, recovery period, long-term results, possible side effects and complications, and expected costs. After the first consultation, the patient takes the informed consent home, reads it carefully, and completes it. Very rarely do we perform treatment the same day. We prefer to do a test and invite patient to return in one week for reevaluation. When larger areas (face, hands, legs) are planned for treatment, the test is mandatory. The device is set with the patient parameters and a single light pulse is applied to the area. The reason for doing this test is not to see the possible result but to evaluate the possible side-effects and complications. This test helps in preventing professional errors. In the presence of complications, the treatment parameters are adjusted (e.g., decrease the fluence; increase the pulse delay) and a second test is performed on a different area. Patients should understand that multiple treatments are needed and permanent results should not be expected even after multiple treatments. More precautions should be taken when treating patients with Fitzpatrick skin types IV-VI. The possibility of more complications should also be explained before treatment. Although topical anesthesia will be used before every treatment, patients should be told that some amount of pain

can be expected during treatment. A written informed consent is obtained before any treatment.

It is important to maintain post-treatment communication. A patient who experiences a difficult post-treatment course or complications needs more contact with the physician. These patients are usually more demanding and the temptation to avoid them should be resisted [4].

4.1 Treatment Protocol

The basic treatment protocol is herein described. Specific differences for hair removal, rejuvenation or vascular treatment will be described in the corresponding chapter.

Once the test result shows no sign of complications, the patient is accepted by the assisting nurse. The area that needs to be treated is cleaned with wet gauze. Special attention is paid to removing make-up from the face. Make-up can interfere with light transmission and absorption. Topical anesthetics are widely used for these procedures. Pain perception varies from individual to individual. We have encountered patients who did not need topical anesthetic before IPL treatment as well as patients who complained of pain after topical anesthetics were used. We have found that longer wavelengths and higher fluences are associated with more pain.

Topical anesthetic are typically constructed of three main components: an aromatic ring, an ester or amide linkage, and a tertiary amine. They prevent the initiation and transmission of nerve impulses by targeting free nerve endings in the dermis [5]. Although there are many topical anesthetics, such as Betacaine-LA, Tetracaine, Topicaine, and S-Caine, EMLA (Astra Pharmaceuticals) and ELA-MAX (Ferndale Laboratories) are the most widely used for topical anesthesia [5]. Although many topical anesthetics are effective in reducing pain associated with cutaneous procedures, many necessitate a prolonged application time (more than 1 h) [6, 7]. ELA-MAX and EMLA have superior anesthetic effect 60 min after application when compared to Tetracaine and Betacaine-LA ointment [8]. Invasive anesthesia methods, such as nerve blocks or intravenous sedation, is not needed for IPL treatment.

EMLA cream is a 5% mixture of lidocaine and prilocaine. It consists of 25 mg/ml lidocaine and 25 mg/ml prilocaine in an oil-in-water emulsion cream [8]. Most dermal anesthesia under occlusive dressing is obtained after 60 min. Inadequate analgesia after application for only 30 min has been reported [9, 10]. The analgesic effect of EMLA cream was shown to increase 15–30 min after its removal, probably due to continuous release from a reservoir of anesthetic located in the stratum corneum [9, 11]. ELA-MAX is made up of 4% lidocaine cream in a liposomal vehicle. No occlusion is required and the application time is 15–45 min. ELA-MAX is less expensive than ELA [5].

The use of topical anesthetic is helpful before the procedure and provides effective dermal anesthesia with rapid onset of action and minimal side effects. The most encountered side effects are erythema, edema and skin blanching (Fig. 4.1). Among the patients who used EMLA, Alster [12] found 10% erythema and 90% skin blanching. Among the most serious EMLA complications is the possibility of hemoglobin conversion to methemoglobin and consecutive tissue hypoxia [13]. It seems that this complication is more frequent in infants, patients with glucose-6-phosphate dehydrogenase or methemoglobinemia-inducing drugs [13].

Melanin and hemoglobin are the two dominant chromophores in the skin, both having a significant impact on the reflection spectra. Immediate post-treatment bluish appearance (Fig. 4.2), perilesional erythema, blanching (Fig. 4.3) or "urticariform" reaction (Figs. 4.4, 4.5a, b, and 4.6a, b) are signs of good response for vessels. The different forms of hemoglobin exhibit different characteristic absorption spectra. Any change in hemoglobin concentration will affect the absorption spectra [14]. Arildsson postulated that there is an increase in perfusion in the deep vessels in anesthetized skin, compensating for the decrease in number of physiologically active capillaries [15]. A different study [14] demonstrated that the blood flow in EMLA analgesized skin increased through dilatation of

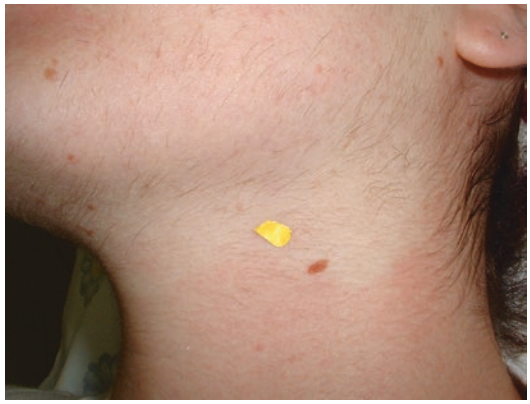

Fig. 4.3 Skin whitening after EMLA application (photos from Fodor and Ullmann 1st edition)

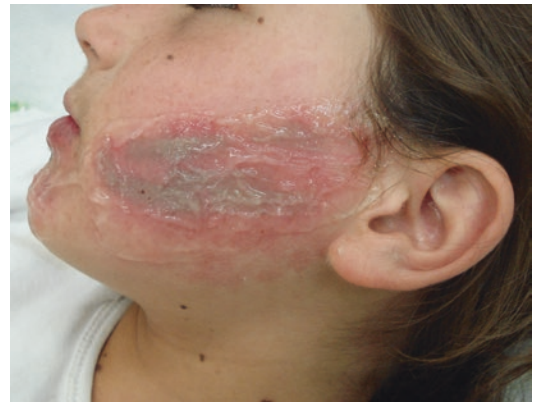

Fig. 4.4 Immediate bluish appearance after port-wine stain treatment (photos from Fodor and Ullmann 1st edition)

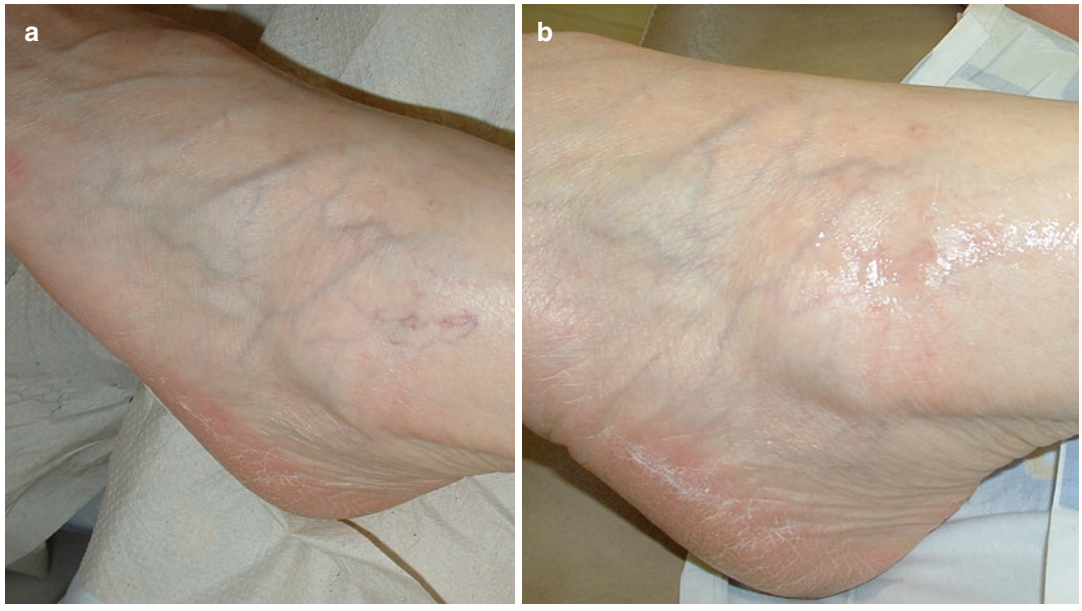

Fig. 4.5 (**a**) Appearance of reticular veins on the leg before treatment (photos from Fodor and Ullmann 1st edition). (**b**) The whitening effect immediately after IPL treatment (Photos from Fodor and Ullmann 1st edition)

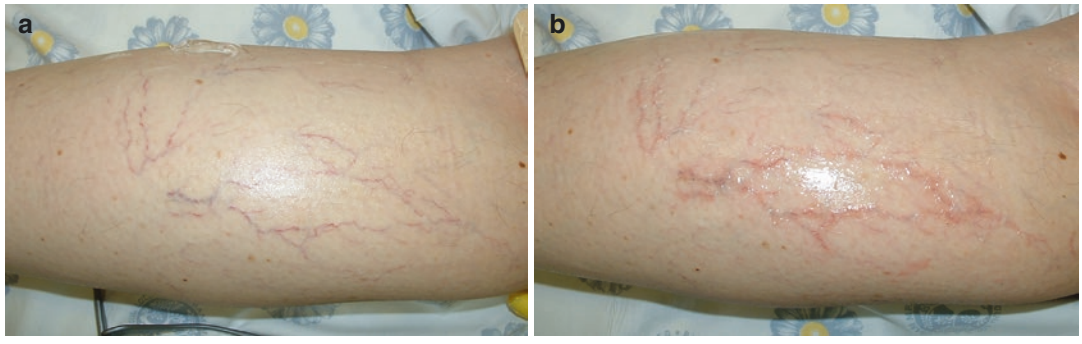

Fig. 4.6 (**a**) Small size leg veins before treatment (photos from Fodor and Ullmann 1st edition). (**b**) "Urticariform" reaction immediately after treatment (photos from Fodor and Ullmann 1st edition)

larger deeper skin vessels. We have observed that EMLA works faster on the face than in other areas, most probably due to higher vascularity and greater absorption in this area.

Once the area is anaesthesized, the patient is brought into the treatment room and laid on a special table to be comfortable during the treatment. The anesthetic cream is removed and the area cleaned with wet gauze. A thin layer (2–3 mm) of cold transparent gel is applied to the skin. Skin cooling during and/or after treatment helps to protect the epidermis from unwanted thermal injury. Contact skin cooling is sometimes used for anesthesia during dermatological procedures. The cooling process is important for most IPL applications. The epidermal temperature is decreased by the cooling method, while the chromophore temperature remains unchanged and effective for the treatment. The cooling method also allows the delivery of higher fluencies with fewer side effects.

There are three main methods of surface cooling during IPL or laser treatment: precooling, parallel cooling and postcooling [16]. Precooling refers to decreasing the temperature of the epidermis immediately before the pulse. Parallel cooling takes place at the same time as the pulse. It is preferable for devices with a longer pulse duration [17]. Postcooling refers to decreasing the temperature immediately after the treatment, usually done with ice packs. Spray and contact cooling are the main methods used for most light pulsed and laser devices [18]. Both methods necessitate control of precooling time to achieve selectivity and to prevent the epidermis from frost injuries. The precooling time of the spray cannot be easily controlled [18, 19]. It seems that an external cooling medium around—50 for 1 s of precooling is ideal to avoid frost injuries. The size, energy and discharge specifications of most IPL devices require a cooling circuit where water is pumped around the flash lamp to cool it [20].

Protective eyeglasses are used by the patient and medical staff for the entire period of the treatment. Particular attention should be paid to selecting proper parameters, taking into consideration the test result. Choosing too short treatment intervals can lead to more complications. At the end of the treatment, area is wiped and cooled with ice packs for about 15 min. When larger areas are treated, the ice packs are placed immediately as each anatomic region is completed. For instance, when IPL is used for leg hair removal, the ice packs are applied as soon as one anatomic area is treated (i.e., anterior or posterior calf, anterior or posterior thigh). Cooling during and after treatment is essential for most procedures. When cooling is not performed, the thermal injury can affect not only the chromophores but also the surrounding tissue. Epidermal damage can be seen easily [21].

The patient is allowed to use make-up immediately. Avoiding sun exposure or photosensiting medication is strongly recommended between treatments. We usually perform treatments one month apart but, in cases of complications, this interval is lengthened. The relatively short time for the procedure and the quick recovery have made IPL treatment to be considered as a "weekend" procedures.

4.2 Practical Points

- A well motivated patient seems to have better satisfaction.
- Identifying the anatomical or psychological unsuitability of the patient is the key to patient selection.
- Problematic patients are usually those with high expectations, excessive demands, indecisive or immature personalities, secretive or "surgiholics", those with factitious disease, and those with familial disapproval.
- Particular attention should be paid to ruling out skin malignancies in the area that needs to be treated.
- Conversation with the patient, getting known his/her expectations, might be the key to avoiding liabilities.
- A short test before starting the treatment provides details about skin reactivity and response. In the presence of side effects, the treatment parameters are adjusted.

- Posttreatment communication with the patient is also important in avoiding liabilities.
- EMLA and ELA-Max are the most used topical anesthetics for IPL procedures.
- Skin cooling during and/or after treatment helps to protect the epidermis from thermal injury.
- Particular attention should be paid to selecting proper parameters, taking into account the test result.
- Avoiding sun exposure or photosensitizing medication is strongly recommended between treatments.

Multiple Choice Questions

Q1: What Are the Side Effects of the Topical Anesthesia?

(a) Nodules formations.
(b) Edema.
(c) Skin blanching.
(d) Hemoglobin conversion to methemoglobin which causes tissue hypoxia.

Q2: What Are the Main Methods of Skin Cooling During IPL Treatment?

(a) Precooling, by decreasing the temperature of the epidermis immediately before the pulse.
(b) The use of cooling circuit with air.
(c) Postcooling, by decreasing the temperature immediately after the treatment.
(d) Parallel cooling is used mainly with devices with short pulse duration.

Q3: Who Are the Potential Problematic Patients?

(a) Patients with major deformities and minimal concerns.
(b) Patients with unrealistic expectations.
(c) Patients with excessive demands.
(d) Patients who are well motivated.

Q4: The Discussion with the Patient Should Include Explaining the Following Topics?

(a) Diagnosis.
(b) Treatment alternatives.
(c) Principles of IPL treatment.
(d) Recovery period.

Q5: Before an IPL Treatment the Following Precautions Should be Taken?

(a) A written informed consent should be signed by the patient.
(b) More precautions should be taken in patients with Fitzpatrick skin types IV to VI.
(c) EMLA topical cream is mandatory.
(d) Patient evaluation regarding health status.

Q6: Who Are the Most Unlikely Candidates for a Cosmetic IPL Procedure?

(a) A well-motivated patient.
(b) A patient with an anatomical unsuitability.
(c) A patient with a major deformity and minimal concern.
(d) A patient with psychological unsuitability.

Q7: Which Are the Signs of Good Vessel Response After IPL Treatment?

(a) Urticariform reaction.
(b) Perilesional erythema.
(c) Blanching.
(d) Bluish appearance.

Q8: What Should the Patient Do After the IPL Procedure?

(a) Use make-up.
(b) Use photosensitizing medication
(c) Avoid sun exposure.
(d) Use anesthetic cream.

Q9: What Is the Main Reason of the Pre-Treatment Test?

(a) To evaluate the post-treatment result.
(b) To evaluate the possible side effects and complications.
(c) To get the patient used with the IPL treatment.
(d) To calibrate the device.

Q10: Which Are the Absolute and Relative Contraindications for an IPL Treatment?

(a) Skin malignancies.
(b) Pregnancies.
(c) Significant venous insufficiency.
(d) Telangiectasia.

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5 Anesthesia for Intense Pulsed Light (IPL) Treatments

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Level Learning Objectives

- To understand the selection of anesthetic methods
- To understand possible complications
- Principles of sedation

5.1 Introduction

Intense Pulsed Light and laser treatments for dermatologic or esthetic reasons rapidly gained acceptance and popularity during recent years. These modern treatment methods need a broad spectrum of expensive and complicated equipment that, in most cases, are not available in clinical settings. Moreover, there are many diseases that can benefit from these treatment methods. Some may be accompanied by discomfort and pain during IPL treatments. To alleviate discomfort and pain, we can do some anesthetic interventions in office-based settings [1–4].

5.2 Office-Based Anesthesia

Office-based anesthesia has gained acceptance for hundreds of surgical or nonsurgical interventions in recent decades. Issues that must be addressed include treatment room concerns, patient selection, qualification of personnel involved, need for monitoring and anesthetic devices and safety care.

Some patients are not suitable for office-based anesthesia: e.g. poorly stabilized cardiac and respiratory patients, age >85 years old and preterm infants, all of whom need a complex medical team that is encountered only in hospital settings [5]. There is much apparatus there, and sometimes there is insufficient room for anesthetic activity. Generally, anesthetic apparatus and monitors outside operating theatres cannot be the same as in operatory theatres, and it is difficult for the personnel and organization to be the same.

Even so, the quality of assistance and the possibility of treating incidents must be the same as in the operating room [6]. Maintaining patient safety is a major concern in cosmetic surgery. Anesthesiologists must exercise their activity with great caution to prevent the appearance of adverse events.

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