Chapter 7
Energy-based methods

Most current physical treatments for rosacea focus on destroying growing blood capillaries. Apart from the obvious advantage of this approach in eliminating the key "target" of this pathology, the effects of physical treatment are usually seen within a limited number of sessions, which contrasts with the need for prolonged daily administration of topical or oral products. Once the desired therapeutic effects have been achieved, the results usually persist for several years. Still, given that any damage is associated with regenerative processes, including angiogenesis, the process of new vessel formation continues, and the disease may return.

The primary physiotherapeutic method for treating rosacea is light therapy using lasers and intense pulsed light (IPL) devices as discussed in detail below.

7.1. Light therapy: mechanism of action

The ability of light to affect specific skin targets was noted in the earliest studies of the laser effect on human skin. However, the transformation of these observations into applied technologies became possible with the greater understanding of the scientific principles behind these effects. In this context, the **selective photothermolysis** theory put forward by Richard Rox Anderson and John Parrish of the Wellman Center for Photomedicine at Harvard Medical School (Anderson R.R. et al., 1983) was particularly impactful.

Their idea was to apply a laser beam to a chromophore substance that absorbs certain types of electromagnetic radiation better than others and the concentration of which in the target cell is much higher than in neighboring cells (**Fig. I-7-1**). The light parameters (wavelength, intensity, and duration of exposure) are tailored to the absorption spectrum of the chromophore to transfer as much energy as possible to its molecules. After absorbing light, the chromophore enters an excited state, whereas the reverse transition is

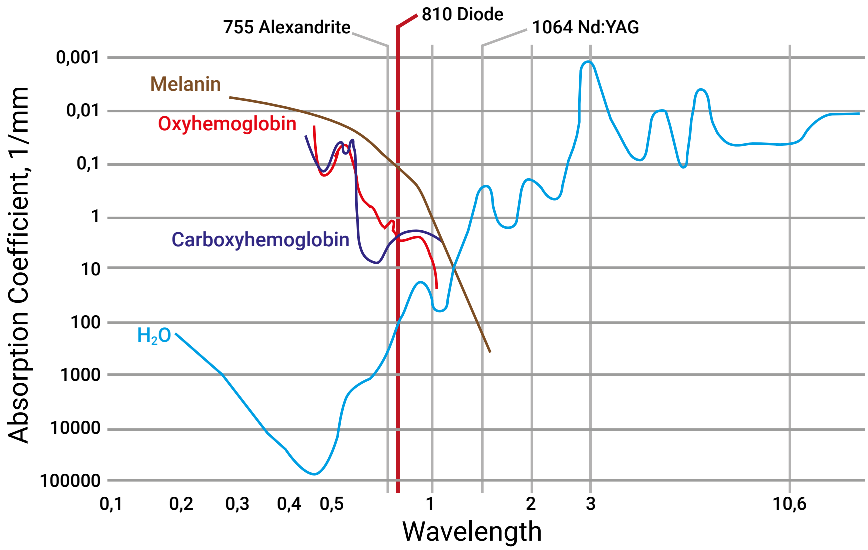

Figure I-7-1. Absorption spectra of skin chromophores

accompanied by the dissipation of excess energy to the surrounding space in the form of heat. Thus, under incident light, heating occurs, causing irreversible destruction of both the target and the cell in which it is located and, if necessary, its immediate neighbors (**enhanced selective photothermolysis**).

In rosacea, the target chromophore is blood erythrocyte hemoglobin (for destruction of vascular structures) or water (for phymatous tissue destruction and remodeling).

In the first case, special selective vascular lasers are used. By absorbing their radiation, hemoglobin is heated, and the vessel walls are also heated, which leads to their coagulation (photothermal effect) or rupture (photomechanical effect).

- **The photomechanical effect** occurs when a large amount of energy is transferred to the chromophore quickly. The resulting so-called photodynamic shock causes the vessel to rupture and release its contents into tissues, leading to the formation of purpura, petechiae, and bruises.
- **The photothermal effect** is induced with slower heating of the target (longer pulse) with gradual adhesion (coagulation) of the vessel. Blood, subjected to photocoagulation, forms a thermal coagulum —

an amorphous accumulation of damaged and agglutinated erythrocytes and plasma components that clog the vascular lumen. Histologically, selective vessel damage with thrombosis, necrosis of the vessel walls, and perivascular collagen damage with relatively minor thermal damage to the epidermis and dermis is noted. The final step will be thrombosis and vessel occlusion (Weinkle A.P. et al., 2015).

Besides vascular lasers targeting hemoglobin, non-selective lasers are used to treat rosacea. In this case, the chromophore will be water, but because water is present in all cells, the effect will not be restricted to some individual targets.

Non-selective photothermolysis is based on **photoablation**, i.e., almost instantaneous tissue evaporation at high temperatures, or **photocoagulation** at less pronounced heating. For ablation to occur, the tissue must be rapidly heated to several hundred degrees Celsius.

Fig. I-7-2 shows a plot of light absorption by tissues and water as a function of radiation wavelength. It is easy to see that the tissues' absorption spectrum correlates with the water's absorption spectrum. Radiation from the far-infrared (IR) and ultraviolet (UV) regions of the spectrum is best absorbed by the body tissues, which means that its penetration beyond the surface layer will be minimal, and all light energy will be released as heat in a minimum volume of tissue. For obvious reasons, UV light cannot be used for heating, because it is harmful in high doses. However, far-IR radiation has no such contraindications, so this part of the spectrum is used in ablative treatment. Such procedures rely on carbon dioxide (CO_2), erbium: yttrium-aluminum-garnet crystal (Er:YAG), and erbium: yttrium-scandium-gallium-garnet crystal (Er:YSGG) lasers, which are appropriately named **ablative** and involve damage to the *stratum corneum*.

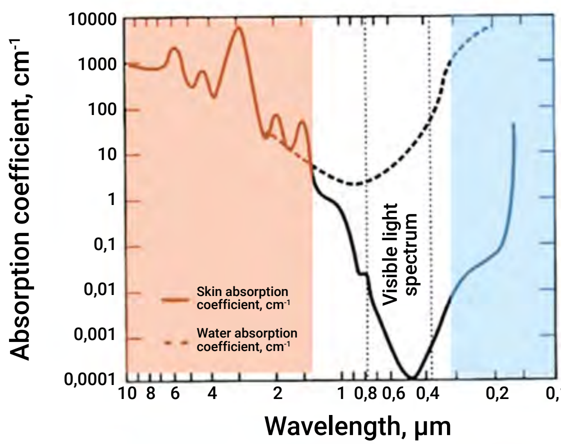

Figure I-7-2. Absorption spectra of skin and water

Water molecules also absorb near-IR radiation, though less actively; this is the radiation of Diode (1440 nm), neodymium: yttrium-aluminum-garnet crystal – Nd:YAG (1320, 1440 nm), fiber Er:glass (1540 and 1550 nm) and Thulium (1927 nm) lasers. As their energy is not high enough for ablation, they work through coagulation without damaging the *stratum corneum* and are classified as **non-ablative**.

In addition to single-wavelength (monochrome) lasers, IPL devices are also used to destroy vascular defects of rosacea. IPL devices emit a wide range of wavelengths that various skin chromophores absorb. Still, surface targets such as melanin spots and dilated vessels absorb most of this energy. IPL therapy can be beneficial in treating rosacea, especially in the initial stage of the disease.

7.2. Laser and IPL devices

Depending on the clinical manifestations of rosacea, two light therapy approaches can be distinguished (**Table I-7-1**):

1) treating vascular and inflammatory skin problems
2) treating tissue dystrophic changes

There are several factors to consider to increase the chances of obtaining the most optimal results:

- **Vessel diameter:** as a rule, vessels 0.1–3 mm in diameter are most effectively treated.
- **Vessel depth:** the superficial vasculature is affected by short-wave radiation (532, 577, and 585 nm), and vessels below the reticular dermis are affected by long-wave radiation (600, 755, 800, and 1064 nm).
- **Skin phototype, pigmentation in the exposed area:** melanin is an oxyhemoglobin-competing chromophore. When treating skin with high melanin levels, it is necessary to use skin cooling during light therapy.
- **Size of the light spot:** the larger the size of the light spot, the deeper the radiation penetration into the tissue. The small-spot-size radiation has less penetrating ability but necessitates the use of more energy for the entire procedure of vascular removal.
- **Energy flux density:** the density of light radiation per unit area needs to be considered. While it is important to use a high-energy flux density,

Table I-7-1. Lasers for rosacea treatment

TARGET PROCESS	DEVICE	EXPECTED RESULT
Vascular changes	• Pulsed dye laser (PDL, 585–595 nm) • Intense pulsed light (IPL, 500–1200 nm) • Potassium-titanium-phosphate laser (KTP, 532, 540 nm) • Neodymium laser (Nd:YAG, 1064 nm)	Reduction in the severity of clinical symptoms, removal of telangiectasias, erythema
Inflammation	• PDL (585–595 nm) • KTP (532, 540 nm)	Reduction in rashes, rapid achievement, and maintenance of remission
Deformational, hypertrophic changes	• Carbon dioxide laser (CO_2, 10600 nm) • Er:YAG laser (2900 nm) • Nd:YAG laser (1064 nm)	Correction of the shape of altered anatomical formations
Dystrophic changes	**Ablative fractional lasers** • CO_2 laser (10600 nm) • Er:YAG laser (2940 nm) **Non-ablative fractional lasers** • Diode and Neodymium lasers (1440 nm) • Thulium laser (1927 nm) • Erbium laser (1550 nm)	Reduction in the severity of clinical symptoms, achievement of long-term remission

the optimal value should be determined by the vessel's color change (as a rule, it darkens).

- **Pulse duration:** for effective and safe impact on the vessel, the pulse should be less than or equal to the duration of the vessel's thermal relaxation time (TRT), as a pulse exceeding the TRT of the vessel causes the spread of heat to the surrounding tissue, which can lead to its coagulation.
- **Limiting insolation before and after the light therapy** is required to avoid the formation of pigment spots.