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Study the Applications of CO2 Laser in Medicine

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Abstract:

Carbon dioxide (CO2) laser ablative fractional resurfacing produces skin damage, with removal of the epidermis and variable portions of the dermis as well as associated residual heating resulting in new collagen formation and skin tightening. The nonresurfaced epidermis helps tissue to heal rapidly; with short-term postoperative erythemaThe results for 8 patients after a single session of a fractional CO_2 resur- facing mode were studied. The treatments it included traces of burns, traces of surgeries, traces of wounds, open pores, fibrosis and acne scars. The patients had skin prototypes 2 to 4 and wrinkle degrees 1 to 3The histologic effects, efficacy, and treatment safety in various clinical conditions and for dif ferent phototypes are discussed. The CO2 laser for fractional treatment is used in super-pulse mode. The beam is split by a lens into several microbeams, and super-pulse repetition is limited by the pulse width. The laser needs a power adaptation to meet the set fluence per microbeam. Laser pulsing can operate repeatedly on the same spot or be moved randomly over the skin, using several passes to achieve a desired residual thermal effect. Low, medium, and high settings are preprogrammed in the device, and they indicate the strength of resurfacing. A single treatment was given with the patient under topical anesthesia. Howeverthe anesthesia was injected on areas of scar or applied as a cream over the skin.

1-1. Introduction

The word LASER is an acronym for " Light Amplification by Stimulated Emission of Radiation" The laser is an outgrowth of a suggestion made by Albert Einstein in 1916 that under the proper circumstances atoms could release excess energy as light either spontaneously or when stimulated by light. German physicist Rudolf Walther Ladenburg first observed stimulated emission in 1928, although at the time it seemed to have no practical use [1].The Townes-Schawlow proposal led several groups to try building a laser. The Gould proposal became the basis of a classified military contract. Success came first to Theodore H. Maiman, who took a different approach at Hughes Research Laboratories in Malibu, California. He fired bright pulses from a photographer's flash lamp to excite chromium atoms in a crystal of synthetic ruby, a material he chose because he had studied carefully how it absorbed and emitted light and calculated that it should work as a laser. The principle of the laser is the same as that of the MASER "Microwave Amplification by Stimulated Emission of Radiation" which was invented in 1954. Around the time when the laser was invented in 1960, it was called an optical maser or an infrared maser. The word laser has been generally accepted since about 1965. The laser brought about a revolution in optical technology and spectroscopy, and had a far - reaching influence in various fields of science and technology. In the life sciences, medical science, and even in nuclear fusion, many research projects are being carried out using lasers. Furthermore, there are natural phenomena such as self - focusing of light and optical bistability which could only have been discovered through the use of lasers [2]. Tremendous advances have been made in the use of the laser in medicine and surgery since the 1990s, and in the field of dermatology efficacy is now recognized in the treatment of angiomas, nevi of Ota, nevus spilus, telangiectasia, and so on, as well as against superficial pigmented lesions, including chloasma, ephelides, and senile lentigines: in fact, the laser is now the treatment of choice for many of these indications. As a benchmark of the acceptance of laser surgery and medicine, some diseases are now indications for the laser that qualifies for reimbursement by the Japanese National Health Insurance System. The laser has also been recognized as effective in the treatment of common skin diseases, including but not limited to verruca vulgaris, verruca plantaris, verruca senilis, soft fibromas, condylomata acuminata, syringomas, common warts, vitiligo, leukoplakia, skin ulcers, ingrown toenails, and psoriasis vulgaris. Laser treatment is also used in the field of esthetic dermatology to treat alopecia and acne, and many devices designed for facial cosmesis to treat photo- and chronologically-aged skin, including wrinkles and sagging, have become available [3].

2-1. The idea of the laser

The laser idea by expanding the light source and converting it into a single powerful source consisting of a focused beam of light. During its work, the laser needs to be supplied with electricity through the power supply. Which may be batteries, electricity, or even another laser, and the laser must be placed in a circumference that allows the expansion of light, and the laser becomes a focused beam after providing it with energy and providing a passage for it, and the resulting beam can be emitted outward in the form of a single line of bright light. Lasers are formed when electrons from special glass atoms, crystals, and gases absorb energy from an electric current or other laser; Which leads to stimulation; Where stimulated electrons move from low-energy orbits around the nucleus of the atom to higher-energy orbits, then these electrons release photons; That is, particles of light when they return to their normal state[4]. Laser therapy is one of the medical treatments that uses focused light unlike most light sources, and laser light refers to light amplification by emitting activated radiation, and it is tuned to specific positive lengths, allowing it to be concentrated in powerful beams, and laser light is very strong, so It is used in forming diamonds or cutting steel, and laser devices are used in the medical and surgical fields, as they require high levels of accuracy, by focusing on a small area so as not to damage the surrounding tissues, Laser treatment is expensive and requires repeated treatments, but it leaves less pain, swelling and scarring than traditional surgery [5]. One main type of laser consists of a closed tube that contains a pair of mirrors at the end, in the middle of which is a laser that emits different forms of energy to produce visible light, invisible ultraviolet rays, or infrared rays, and the function of the tube is to transmit or reflect light In the form of a focused current called a laser beam, and it should be noted that there are different types of laser beams available, as each type has a different use from the other, and the most common laser contains gases such as: argon, or a mixture of helium and neon, in addition to solid crystals Such as: sapphire, liquid dyes, or chemicals[4].

2-2. Element of Laser

1. An energy source (usually referred to as the pump or pump source).
2. A gain medium or laser medium.
3. Two or more mirrors that form an optical resonator.

As shown in figure (2.1)

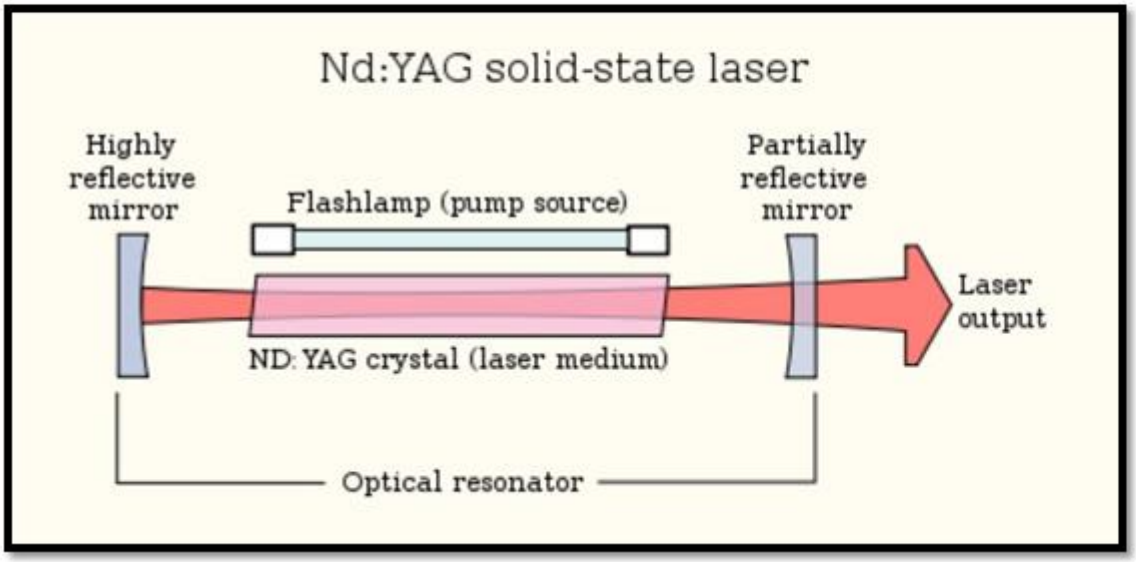

Fig. 2.1 elements of laser

2-3. Pump source

The pump source is the part that provides energy to the laser system. Examples of pump sources include electrical discharges, flashlamps, arc lamps, light from another laser, chemical reactions and even explosive devices. The type of pump source used principally depends on the gain medium, and this also determines how the energy is transmitted to the medium. A helium–neon (HeNe) laser uses an electrical discharge in the helium-neon gas mixture, a Nd:YAG laser uses either light focused from a xenon flash lamp or diode lasers, and excimer lasers use a chemical reaction[6].

2-4. Gain medium / Laser medium

The gain medium is the major determining factor of the wavelength of operation, and other properties, of the laser. Gain media in different materials have linear spectra or wide spectra. Gain media with wide spectra allow tuning of the laser frequency. There are hundreds if not thousands of different gain media in which laser operation has been achieved (see list of laser types for a list of the most important ones). The gain medium is excited by the pump source to produce a population inversion, and it is in the gain medium where spontaneous and stimulated emission of photons takes place, leading to the phenomenon of optical gain, or amplification [6].

2-5. Examples of different gain media include

Liquids, such as dye lasers. These are usually organic chemical solvents, such as methanol, ethanol or ethylene glycol, to which are added chemical dyes such as coumarin, rhodamine, and fluorescein. The exact chemical configuration of the dye .molecules determines the operation wavelength of the dye Laser Gases, such as carbon dioxide, argon, krypton and mixtures such as helium–neon. These lasers are often pumped .by electrical discharge Solids, such as crystals and glasses. The solid host materials are usually doped with an impurity such as chromium, neodymium, erbium or titanium ions. Typical hosts include YAG (yttrium aluminum garnet), YLF (yttrium lithium fluoride), sapphire (aluminum oxide) and various glasses Semiconductors, a type of solid, crystal with uniform dopant distribution or material with differing dopant levels in which the movement of electrons can cause laser action. Semiconductor lasers are typically very small, and can be pumped with a simple electric current, enabling them to be used in consumer devices such as compact disc players [6].

2-6. Optical Resonator

The optical resonator, or optical cavity, in its simplest form is two parallel mirrors placed around the gain medium, which provide feedback of the light. The mirrors are given optical coatings which determine their reflective properties. Typically, one will be a high reflector, and the other will be a partial reflector. The latter is called the output coupler, because it allows some of the light to leave the cavity to produce the laser's output beam [6].

2-7. Laser Types

Although there are several types of lasers, they all share the same characteristics. The laser may be classified into different types depending on the uses, or according to the type of active medium, the pump mechanism or the duration of the laser output. The type of active medium is the most widely used basis for the distinction between the different lasers here. Some types of lasers are characterized by their high power, such as (carbon dioxide laser), which is considered one of the most dangerous Types of lasers, because of its high power of up to tens of kilowatt. Other types of lasers are also very weak, such as those used in daily life in indicators, and these are usually semiconductor laser and Helium Neon laser He-Ne means that the active medium is a mix of helium, neon. Lasers can also be classified according to the duration of the laser output-such as continuous wave laser (CW) or pulsed laser. AQ-Switched laser is a pulse laser that contains a shutter that does not allow the laser light to be emitted until it is opened [7].

Let us consider laser types

1. Solid –State Laser: like ruby laser and neodymium laser.
2. Gas Lasers: like Helium-Neon laser, Argon–Ion and Krypton–Ion Lasers and carbon dioxide gas laser (CO2). Gas lasers are the most common in industry, some of which have low power (0.5-50) mW like Helium-Neon laser. Some of which have high power like carbon dioxide laser.

Wavlength of these lasers ranges between ultraviolet, visible light and infrared ray. External energy is pumped into the active medium is electric pumping, whereby free electrons (between the two electric poles) are accelerated and collide with gases and thus excited into higher energy level. Generally, gas laser systems have three components. Low-power gas lasers are contained in sealed tubes. Gas lasers operating at the milliwatt level do not require active cooling, but as power increases, active cooling becomes important. Moderate-power lasers are cooled with forced air, and higher-power lasers are cooled by flowing water. At very high powers, the laser gas may flow through the tube and be exhausted into the air or pumped into a sealed tank to remove excess heat. Most power used to excite gas lasers is turned into heat, so cooling is very important. Gases have high electrical resistance until electrical breakdown occurs and frees electrons to carry current through the gas. This current is typically used in a gas laser as the pumping source. To create electrical breakdown in a high-resistance gas, a high voltage is needed. However, once electrical breakdown occurs in a gas laser, the voltage can be reduced and stay reduced for normal operation. High voltages in gas lasers represent a safety hazard that must be addressed to prevent injury. Gas lasers operate on various types of transitions. Atomic gases such as neon and argon emit only when electrons drop from a high energy level to a lower energy level. Gas molecules also can emit on electronic transitions in the same bands, or on lower-energy, longer-wavelength transitions between vibrational and rotational states. The physical structure of the molecule provides the mechanism for these transitions, which, like electronic transitions, result from stimulated emission. Vibrational transitions range from the near infrared range out to about 20 µm and often occur simultaneously with a rotational transition, as you will see with the carbon-dioxide laser. Rotational transitions have even lower energy and correspond to wavelengths in the far infrared range, from several tens of micrometers to millimeter waves, in a region also called the terahertz band[8].

3. Excimer laser: Excimer lasers are useful and important type of molecular lasers which utilize transfers between two different electrons. Lasers from noble gases like xenon, Krypton, argon or Flour with Halogen atom to form gas halide like (ArF, KrF, XeCI), these gases produce laser with ultra-violet wavelengths.
4. Dye laser: they are lasers in which the active medium is liquid solution (compounds of organic dye like dissolved Rhodamine 6G in a liquid like methyl alcohol of ethyl alcohol. It produces laser of controllable wavelength.
5. Semiconductor laser: like Gallium Arsenide (GaAs). Semiconductor lasers have become the most important type of laser, with billions sold for use in consumer products, particularly optical disk players for audio and video. The vast majority of semiconductor lasers are diodes, in which electronic current flows between a region where current is carried by free electrons (n-type material) and a second region where the current is carried by “holes” (p-type material) that are vacancies in the electron shells of atoms in the semiconductor, these devices are called diode lasers[9].
6. Chemical Laser: It is the laser, in which population inversion is achieved by the chemical reaction directly like Deuterium Fluoride[7].

2-8. Carbon Dioxide Lasers

Carbon dioxide (CO2) lasers are the best-selling gas lasers in dollar terms. That success comes in large part from their high power and efficiency, which are unmatched by any other commercial gas laser. CO2 lasers also are versatile enough to find many other applications, although materials working (welding, marking, cutting, drilling, etc.) remains by far the largest market. Most generate continuous beams from under a watt to well over 10 kW, but CO2 lasers also can be pulsed. Their output is in a band between 9 and 11 µm. CO2 is a molecular laser. Molecular lasers emit light when the molecule drops from a high-energy vibrational state to a lower-energy state. These transitions are not the typical electronic transitions that most lasers use to produce their output light. This difference occurs because the gas that lasses in these lasers is not composed of a single element, but instead is a molecule with a specific structure.

An electric discharge in the laser excites nitrogen molecules mixed with the CO2, which transfer their energy to CO2 molecules, raising them to the highest-energy state, the asymmetric stretching vibrational mode 3. From there, the atoms can drop to either the bending vibrational mode 2 or the symmetrical stretching vibrational mode 1, with nominal wavelengths of 10.4 or 9.4 µm, respectively. These transitions occur in exactly the same manner as electronic transitions: through stimulated emission caused by the laser light photons in the laser cavity. After the CO2 molecules reach both lower energy levels, they collide with helium, which helps them release energy to depopulate the lower levels and sustain a population inversion [9].

2-9. Applications of CO2 Laser in Medicine

The carbon dioxide (CO2) laser was first introduced in 1964 by Patel and has been extensively used in the next two decades as an incision tool in increasingly wide areas, such as neurosurgery, dermatology and plastic surgery, otorhinolaryngology, ophthalmology, gynecology and general surgery. In 1984, its reliability resulted in its approval by the U.S. Food and Drug Administration, and thus, medical use of lasers became more prevalent. Currently, the CO2 laser is considered an indispensable piece of diagnostic and therapeutic equipment. The CO2 laser produces a beam of infrared light with the principal wavelength bands centering at 10.6µm (the wavelength of light produced by a CO2 laser). Collisional energy transfer between the nitrogen and the carbon dioxide molecule causes vibrational excitation of the carbon dioxide, with sufficient efficiency to lead to the desired population inversion necessary for laser operation. Over the last 40 years, lasers have been used extensively in various fields of medicine. The CO2 laser is a good example, being widely used in ENT (Ear, Nose and Throat) incisions can be achieved by optimizing the oxidation process [10]. Because of the high power levels available, CO2 lasers are frequently used in industrial applications for cutting and welding, while lower power level lasers are used for engraving. They are also very useful in surgical procedures because water absorbs this frequency of light very well. Some examples of medical uses are laser surgery, skin resurfacing and dermabrasion. Researchers are experimenting with using CO2 lasers to weld human tissue, as an alternative to traditional sutures. The common plastic absorbs IR light in (2.8-25 μm) wavelength bands, so CO2 lasers have been used in recent years for fabricating micro fluidic devices from it with channel widths of a few hundred micrometers.The CO2 laser is an integral instrument in all aspects of otolaryngology. The numerous types of uses vary from endoscopic resection of malignant laryngeal tumors to the precision of laser stapedotomy as well as to cosmetic skin treatment, but its most effective use is in laryngology and bronchoesophagology [11]. Sheet-metal cutting is the single largest in terms of sales, global industrial laser application. CO2 lasers dominate this application due to their good-quality beam combined to high output power. It is estimated that more than 40000 cutting machines using CO2 lasers have been installed worldwide [12]. Because of its affinity for water-based tissues, the CO2 laser has become a favorite instrument of oral surgeons for treatment of pathologic conditions of the oral mucosa. The CO2 laser has been recommended to treat benign oral lesions, such as fibromas, papilloma's, hemangiomas, gingival hyperplasia's with different causes, aphthous ulcers, mucosal frenula or tongue ties, as well as premalignant lesions such as oral leukoplakia's. Some reports on the use of the CO2 laser also support the possibility of treating malignant oral diseases in early stages with excisional biopsies. A study demonstrated dissemination of cancer cells into the blood circulation upon incisional biopsies with the scalpel, resulting in an increased risk of metastasis. Here the CO2 laser, with its sealing effect on vessels smaller than 500 μm in diameter, could be an advantage and therefore even prevent occult micro metastasis [13]. More recent reports have also mentioned the diode laser with wavelengths ranging from 810 to 980 nm in a continuous or pulsed mode as a possible instrument for soft tissue surgery in the oral cavity. Based on the photo thermal effect of the CO2 and diode lasers, lesions of the oral mucosa are removed with an excision technique or vaporization procedures [13]. The major advantages mentioned in the literature for the use of CO2 and diode lasers are minimal postoperative swelling and scarring, improved wound healing and decreased postoperative pain. Additionally, both lasers are reported to have some advantages over a scalpel in soft tissue surgery. Unlike the scalpel, the laser instantly disinfects the surgical wound and due to its hemostatic effect affords largely bloodless surgery, allowing a noncontact type of operative procedure and therefore no mechanical trauma to the tissue. The lesser depth of immediate tissue necrosis, in comparison with the mid-infrared wavelengths, together with the possibility of further heat deposition in the dermis, significantly reduces the pain caused by the procedure without decreasing its efficacy. A new CO2 laser with less penetration was shown to be more tolerable, but the 1.3 mm spot still makes some local anesthesia and cooling necessary. The spot distribution is uniform as with the mid-infrared devices. A more recent CO2 laser system with a micro spot system fractional modality has been developed with a new scanning algorithm that keeps the longest possible interval between two adjacent spots, in order to minimize the heat accumulation around the treated areas. This is supposed to significantly reduce the pain during the procedure[14]. Surgical lasers form a mainstay of treatment in many disciplines, including ophthalmology, dermatology, dentistry, plastic surgery, otolaryngology and head and neck surgery. In contrast, lasers tend to be used infrequently in most neurosurgical operating rooms, despite early optimism regarding the application of this technology shortly after its development. Unfortunately, cumbersome ergonomics of the CO2 laser have limited its widespread use. Its long wavelength prevents its transmission using standard fiber optic cables, and bulky articulating arms with mirrors are required to transmit sufficient energy to the surgical site in direct line of sight, restricting freedom of movement. Moreover, resecting a tumor requires constant refocusing of the CO2 beam if it is coupled to a microscope. Without fiber optic delivery, use of a CO2 laser through an endoscope is impossible. These shortcomings have kept most neurosurgeons from adopting the CO2 laser as a regular surgical tool, despite its many potential benefits. Dielectric mirrors are able to efficiently reflect light through a narrow range of incident angles with low absorption losses. The existence of an omnidirectional reflection band allows a dielectric surface to reflect light of any incident angle, known as omnidirectional reflectance. A hollow optical fiber has been created that is lined with an interior omnidirectional dielectric mirror that has a photonic band gap for the transmission of CO2 laser light with low absorptive losses [15].

2-10. Mechanism of Action

The Laser Device:

The laser used was the Pixel CO2 Laser System. This system operates in continuous mode at a power of 1 to 60 W and offers super- pulse mode selection, specifically used for fractional resurfacing. The output power, on-time exposure, off time, and pulse-repetition rate are managed by a microprocessor, which controls the operational treatment method of the laser settings. The handpiece incorporates novel fractional laser beam technology attached to the articulated delivery arm. The handpiece can be fractional, with 7X7 or 9X9 pixels, or surgical, with a 50- and 100-mm focal length. The operator can select power levels (high, medium, or low) and individual beam energy expressed in millijoules of either 9X9(81 pixels) or 7X7 (49 pixels).

Fig (2.2) Laser Device

The energy for the two beams (9X9 or 7X7) range between10and 500 mJ/pixel. Thus, the operator can choose less or more thermal damage by changing the tips (9X9 or 7X7) and by changing the power (high, medium, or low). When the laser is programmed for fractional resurfacing, it can be operated in super-pulse (repeat) mode between 0.5 and 5 Hz. For clinical application, laser settings require a power adaptation to meet a required fluence per microbeam for different tissue responses (less or more thermal damage) within a preset on-time exposure according to three fixed energy super-pulse options offered by the manufacturer: low (20 W), medium (30 W), or high (60 W). Low, medium, and high levels of energy for treatment correspond to a different number of laser on-time exposures or pulses per second (PPS). The number of PPSs is displayed on the device console screen together with the energy in millijoules applied by each beam spot of the grid.

The ‘‘high’’ program selection demands an increase in laser power, which at the tissue level produces rapid vaporization, leaving a deposit of residual heat in the dermis. The ‘‘low’’ program selection, however, produces a greater dermal heat effect and less vaporization.

The preset operating parameters for fractional resurfacing are based on various clinical conditions displayed with their corresponding initials on the LCD touch-control screen. The initials are SR for skin resurfacing, AC for acne, WR for wrinkles, and FL for fine lines. The possibility also exists of selecting the operation mode (OP), which allows the operator to open the control and set the parameters freely for fractional treatment. At the time of ablative fractional resurfacing, the microlesions formed depend, to a large extent, on the spacing of the beams. The density of microholes per area leaves more or less unaffected bridges of skin, which are significant in the speed of tissue reepithelialization and also affect the risk of adverse events. The penetration of the tiny laser beams in the dermis is based on the laser power according to the high, medium, or low energy program. More evident residual thermal damage will be related to the number of super pulses within the on-time exposure that lead to greater tissue inflammation, with a direct implication of collagen formation at the time of tissue repair.

When the settings are programmed for fractional resurfacing, the laser can work by pulsing energy in stacked mode, that is to say, the handpiece is positioned stationary on the same treatment point, and various pulses are delivered. At this moment, tissue removal occurs deeper, and heat buildup is transmitting to neighboring tissue. If the hand- piece is moved randomly over the skin, several laser passes are carried out on the skin surface, which produce a higher density of microholes. When this occurs, the treated area turns a brownish color, with tinier pieces of superficial skin removed, and depending on the number of passes, a residual thermal effect in tissue also is achieved [16].

2-11. Fractional Carbon Dioxide Lasers for Scar Reduction

Although ablative CO2 lasers have been in use for skin resurfacing and scar reduction since 1960s, however, they came heavily upon the downtime and rate of complications. Nonablative lasers which selectively destroyed dermis, give lesser downtime and complications, but inferior results. Fractional lasers bridge the gap between these two modalities. Two main types of fractional CO2 lasers are currently being used by laser surgeons. They are:

1. The scanning CO2 laser
2. The pulsed CO2 laser.

The scanning CO2 lasers use an optomechanical flash scanner connected to a continuous wave CO2 laser, which efficiently distributes laser energy into train of pulses with dwell time shorter than Thermal Relaxation Time (TRT) of the tissue, hence, mimicking a pulsed CO2 laser.

Most conventional continuous wave CO2 lasers can be converted into pulsed lasers by a pulsing technique. These pulsed lasers can produce a train of relatively high power, short duration pulses which work on the principle of selective photothermolysis. Some of these machines have computerized pattern generators which place individual laser beams into a specific pattern [17].

Pulsed Wave Carbon Dioxide Lasers

When the pulse length of the laser beam is shorter than the Thermal Relaxation Time (TRT) of target tissue, it results in quick ablation of tissue with minimal thermal damage:

- ✓ Superpulsed lasers
- ✓ Ultrapulsed lasers.

Superpulsed CO2 lasers were lasers with pulse duration of 10–100 milliseconds which have now been replaced by the ultrapulsed lasers which have pulse durations of submicroseconds. [17]

Scars Amenable to Fractional Carbon Dioxide Lasers

Of the wide variety of clinical scars a dermatosurgeon is confronted with, following types are the ones that show significant improvement with fractional CO2 lasers:

1. Atrophic scars due to acne
2. Atrophic scars due to nonacne etiologies such as trauma, post-varicella infection, or surgical scars
3. Burn scars
4. Striae distensae

Patient Selection

When considering a patient for scar reduction using fractional CO2 lasers, the caveats hold true as for different lasers otherwise and, especially, for ablative ones, the following points can generally be helpful to avoid complications and select patients for the procedure [18].

2-12. Medical laser application

Medical laser application is a broad area armed with advanced technologies to meet challenges in clinical diagnostics and therapy and to address health care issues that impact broad populations. Recent research and emerging developments provide the vision of improving clinical therapeutic procedures or extending the use of lasers to new fields of medicine. Novel biomedical laser applications and new types of lasers widen the possible spectrum of laser-tissue interactions to improve target-oriented, precise application of laser radiation in clinical practice [19].

1. Cancer Therapy Lasers

Combining the nanoparticles, diode lasers have been also used for cancer therapy, bio-sensing, bio-imaging, drug delivery and diagnostics of cancer. Various nanoparticles (gold, polymers, silica etc) have been explored for the use of surface plasmon resonance including shapes in spheres, rods, boxes, cages and shells. For example, by changing the shape of nanogold from sphere to nanorod, the absorption and scattering peaks change from visible (about 530 nm) to the near-infrared (NIR) regime (about 750 to 980 nm) . Comparing to the visible light, light in the NIR regime offers the advantages of larger absorption and scattering cross sections and much deeper penetration depth in tissues [20].

2. Cosmetic and Dermatology Lasers

Figure 2.3 shows various cosmetic lasers and their applications for invasive and non-invasive uses defined by their tissue penetration depth (d). Lasers with small depth ($d<0.1$ mm) suitable for invasive wrinkle or tattoo removal, whereas large depth (with $d> 2$ mm) suitable for non-invasive simulation or hair removal. Figure 2.4 shows the commercial laser for hair removal (using a diode laser at 810 nm with large penetration depth about 4 mm) and hair growth device (using a red, 635 - 690 nm, LED or laser with smaller penetration depth and low power for surface stimulation). Figure 2.5 shows a UV (308 nm) light device for the treatment of psoriasis; and a pen-type blue laser (at 405 nm) combined with a red laser (at 660 nm) for the treatment of acne [21].

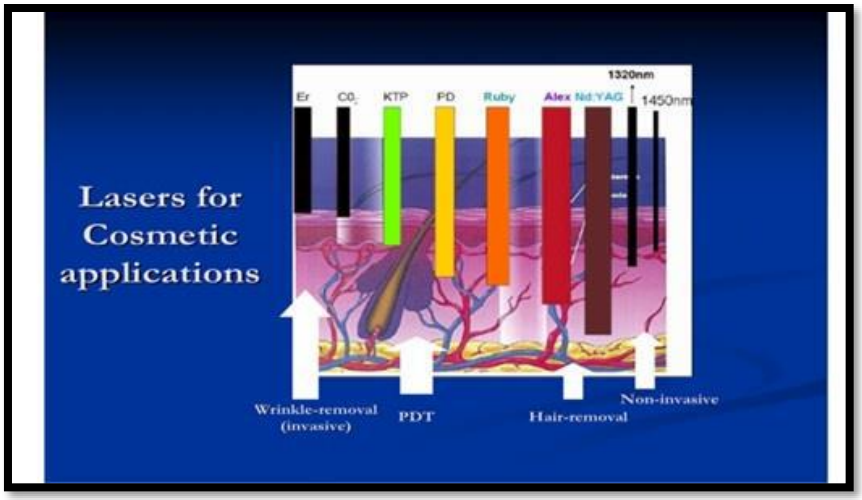

Fig 2.3: Cosmetic lasers and their tissue penetration depth which defined their applications in both invasive and non-invasive uses

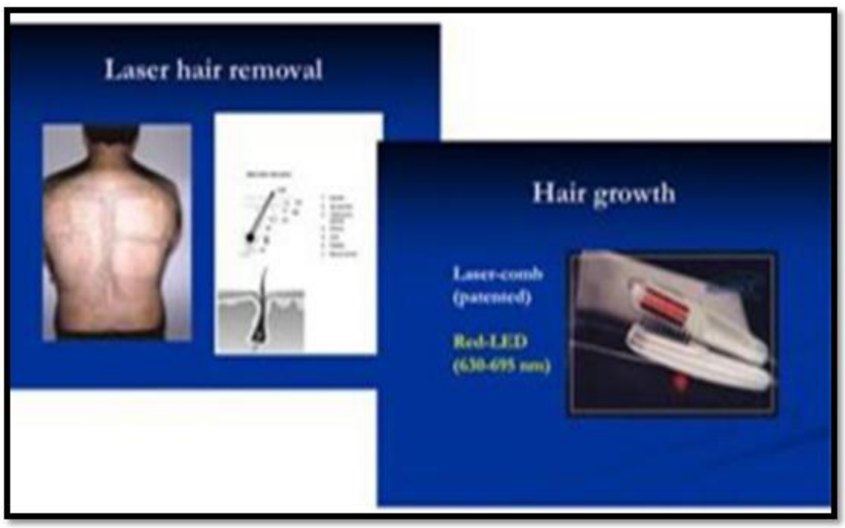

Fig 2.4: The commercial laser for hair removal (using a diode laser at 810 nm) and hair growth device (using a red, 635 - 690 nm LED or laser)

Fig 2.5: Left a UV (308 nm) light for the treatment of psoriasis; (Right) a pen-type blue laser (at 405 nm) for the treatment of acne.

3. Dental Lasers

Lasers (or LEDs) currently commercialized for dental applications include:

1. Low power red laser activating methylene blue for antimicrobial photodynamic therapy (a PDT) to treat periodontal deceases.
2. Diode laser (at 808 or 980 nm) for soft tissue cutting and stimulation.
3. Er: YAG laser, also called as “water-laser” for hard tissue cutting.
4. Low power UV-blue laser (at 405 nm) for caries and cancer detection via light stimulated fluorescence [22]

Fig 2.6: (Right) power red laser (or LED) for antimicrobial photodynamic therapy (aPDT) and (Left) diode laser (at 808 or 980 nm) for soft tissue cutting.

4. Ophthalmology Lasers

Various lasers have been used for various ophthalmic applications including retinal photocoagulation using argon blue-green laser (488/514 nm), double-YAG green laser (at 532 nm), krypton laser (at 647 nm) and diode lasers (at 806-810 nm). Photocoagulation process was also used to seal leak blood vessels for the treatment of age-related macular degeneration. Figure (2.7) shows a surgical procedure called LASIK for vision corrections (myopia, hypeopia and astigmatism) using a UV excimer laser to reshape the corneal surface. Femtosecond lasers combined with excimer laser are alo commercialized for the so-called bladeless LASIK procedure, in addition to the fetomsecond laser cataracts treatment [27].

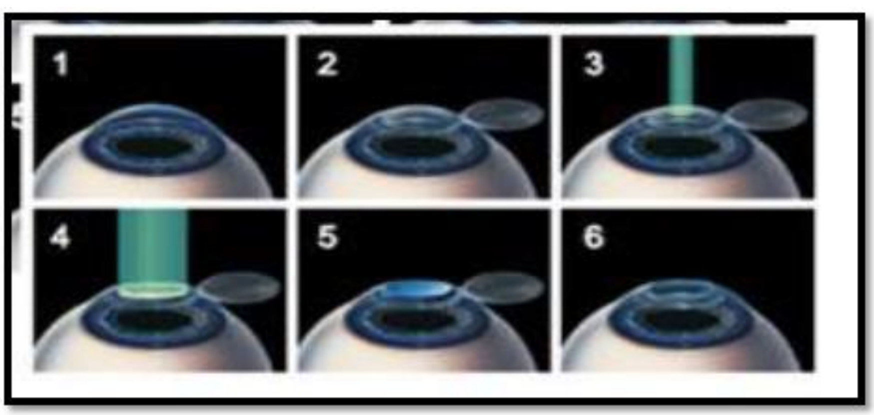

Fig 2.7: Surgical procedure called LASIK for vision corrections, where the corneal flap is prepare (either by microkeratom or a femtosecond laser), then an excimer UV laser (at 193 nm) is applied to cut a thin surface layer of the central part of the stroma tissue to reshape its curvature (for myopic correction); the corneal flat is placed back for healing [27].

2-11. The effect of CO_2 laser radiation on body tissues

Laser radiation is electromagnetic radiation. The spectrum of electromag- netic radiation ranges from radiowave radiation (long wavelength) via micro- wave, infrared, visible, and ultraviolet radiation of short-wavelength X- ray and gamma radiation. Laser radiation used in medicine ranges from the UV to the far IR (193-10 600 nm). Wavelength is usually expressed in nanometers (1 nm =10-9 m). This implies that the visible part of the spectrum of electromag- netic radiation is only a part of the spectrum covered by laser radiation [23]. In an ideal scenario, MTZ are cylindrical microscopic zones in dermis. The reparative capacity and resultant collagen remodeling is dependent upon the surrounding normal tissue. The diameter and depth of these zones is dependent upon a host of factors like fluence, wavelength, machine used, and number of stacking applied. Ablative fractional CO_2 lasers cause disruption of both epidermal and dermal tissue. Studies have shown that by 48 hours, invaginating epidermal keratinocytes replace the MTZ and there is extrusion of necrotic debris by 1 week also known as microscopic epidermal necrotic debris (MEND)[24]. with complete replacement of stratum corneum by 1 month. Remodeling of collagen takes place by 3 months which is indicated by increased expression of heat shock protein 47 (Hsp47)[3]in this tissue, which is a marker of collagen synthesis. The depths of these MTZ vary between 100 and 160 Pm and constitute 15–25% skin surface area under treatment per session. Carbon dioxide lasers vaporizes both epidermis and dermis to a depth of 20–60 μm while the thermal damage zone extends to another 20–50 μm. Approximately, 90% of CO_2 laser energy is absorbed in the initial 20–30 μm of skin. Theory of selective photothermolysis states that selective heating of the target chromophore can be achieved when using laser pulses shorter than the TRT of the chromophore (time required for chromophore to lose 50% of its heat to surrounding tissue). Thermal relaxation time for 20– 30 μm of skin tissue is approximately 1 millisecond. Using the theory of selective photothermolysis, CO_2 lasers with pulse duration of less than 1 millisecond are capable of selectively vaporizing tissue with only very thin zone of residual thermal necrosis measuring approximately 100 μm. To have a clinical effect in the skin, laserenergy must be absorbed by the target chromophore. Energy fluence (density) necessary to vaporize tissue is approximately 5 J/cm2 (ablation threshold). Overall, delivering 1 millisecond CO_2 laser pulse with an energy fluence of approximately 5 J/cm2, leads to tissue vaporization measuring 20–30 μm and residual thermal injury measuring 40–120 μm.5 This zone of thermal necrosis is sufficient to seal small dermal blood vessels and lymphatics, yet narrow enough to reduce incidence of scarring[25]. When the laser light hits the tissue, it can be reflected, dispersed, absorbed or transmitted to the surrounding tissue. Absorption largely controls the extent of reflection, dispersion and transmission, and wave length is the primary determinant of absorption. The CO_2 laser is consistently absorbed by most materials and tissues and the wavelength of the Nd-YAG laser is preferentially absorbed into the pigmented tissue. Factors that determine the initial effect of tissue include laser wavelength, laser strength, laser wave shape, tissue optical properties, and tissue thermal properties[26].

1. Steps and method of fractional laser technique

We took different samples from different people who had injuries in different parts of the body and to varying degrees. This was done in the specialized clinic under the supervision and follow-up by Dr. Ahmed Shami. In the beginning, the doctor treating the case puts a local anaesthetic on the area that the laser beam will be directed at, and it can be a ointment or cream. Then, after this step, the doctor treating the case begins by choosing the appropriate skin temperature which the laser beams will have. Then he focuses the rays on the area to be repaired or tightened in the body. After that, the rays begin to penetrate the outer part of the skin, and then after that it begins to affect the middle class. This previous step stimulates skin cells to produce collagen, which helps restore the skin's natural, attractive appearance. The period in which the operation is performed is not more than 15 minutes, because the skin cells are not affected by the laser rays that are focused on it. After completing the session, we put blood plasma on the place where the operation was performed, in order to increase the speed of recovery. The individual must follow all the instructions which that the doctor sets in order for him to recover completely. It is also possible for the individual to return to practicing his life in a very normal way after the end of the rest period after the operation.

Num.	Before	After
1-		
2-		
3-		
4-		

Table 3.1 samples before and after treatment

1-effect of surgery

- The skin level is approximately back to normal level .
- The affected place has become close to the normal skin color .
- returned to his usual beauty.

2-Fibrosis in the earlobe

- disappearance of swelling in the earlobe.

3-Forehead injury

- The color of the skin returned to its normal color.
- The injury level decreased and returned to normal.
- The face has returned to its natural beauty.

4-Burning in the palm

- reduce deformation.
- Reduce burning area.
- Change in color, but there is a residual effect (due to the patient's failure to comply with post-session instructions).

	Treating open pores
	Scar removal
	Treating the effects of suicide attempts

	Burn treatment

Table 3.2 examples of CO2 laser uses.

Scanning	Overlap (th)	Repeat	Interval (s)	Distance (mm)	Duration (ms)	Power (W)	Functions
1	2-1	8-5	or1-2 0	0.9-0.7	4.0-1.0	%50 start	Scars
3	1	5	or1-6 0	2-0.9	0.8-0.3	%30 start	Acne
3	1	5	4-2	0.8-0.7	1.8-1.2	55-%35 start	Wrinkle
3	1	5	or1-6 0	2-0.8	0.8-0.3	%20 start	Skin Tightening
3/1	1	5	or1-6 0	0.9-0.7	0.8-0.6	%10 start	Pigment removal
3	1	5	or1-6 0	0.8-0.6	0.8-0.3	%30 start	Coarse Pores
3/1	2-1	8-5	or1-6 0	0.9-0.7	3.8-1.2	%80-%65 start	Skin proliferation

Table 3.3 parameters of fractional co_2 laser

Suggestions:

1. The patient's commitment to the sessions prescribed by the doctor.
2. The face should not be exposed to sunlight and use sunscreen continuously.
3. Do not expose the skin immediately after the session to hot water, because it will lead to the appearance of pigmentation in the skin.
4. It should be noted that the person will need not to go out for a period of 7-10 days until he recovers well, and the skin will peel off for 2-7 days after treatment, and it will turn pink for 3-4 weeks.
5. Avoid products, creams, and cosmetics during the recovery period from the Co2 laser as this may cause irritation and may affect the results.
6. It is preferable to avoid certain activities that may increase skin redness for at least two weeks after treatment.

7. Attention of the doctor (operator of the device) not to repeat the blow in a place where the laser was previously shone during one session.

8. It is forbidden to use water immediately after the session.

Conclusion

Fractionated ablative resurfacing seems to hit sweet spot between the minimal benefits of traditional nonablative laser treatment and the considerable downtime and complications of ablative resurfacing. The ablative fractional CO2 laser is now replacing other modalities of acne scar management and dominating them. We used to treat acne scars by surgical deep dermabrasion when the patient must take long recovery time and high complication rates including scarring and hypo or hyperpigmentations. Patients now have a choice, with similar results, when treating acne scars: more treatment sessions, less downtime, and less anesthesia with ablative fractional lasers but with minimal complications. This study reveals improvement in the scar shape and edge and decrease in its size.The surface area and density decreased at the end of last session of treatment. The wavelength of laser light is extremely pure when compared to other sources of light and all of the photons that make up the laser beam have a fixed phase relationship with respect to one another. Because of its affinity for water-based tissues, the CO2 laser has become a favorite instrument of oral surgeons for treatment of pathologic conditions of the oral mucosa. Over the last 40 years, lasers have been used extensively in various fields of medicine. The CO2 laser is a good example, being widely used in ENT and gynecology. It emits infrared radiation, which is readily absorbed by water. During irradiation with CO2 laser, the tissue temperature begins to rise and when it reaches 100°C water begins to evaporate. This increases the pressure within the organic matrix leading to so called micro explosions. Surgical lasers form a mainstay of treatment in many disciplines, including ophthalmology, dermatology, dentistry, plastic surgery, otolaryngology and head and neck surgery. In contrast, lasers tend to be used infrequently in most neurosurgical operating rooms, despite early optimism regarding the application of this technology shortly after its development. Unfortunately, cumbersome ergonomics of the CO2 laser have limited its widespread use.

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