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| RESEARCH ARTICLE

The Use of Lasers (Ablative Laser, Non-ablative Laser, Fractional Laser, Photobiomodulation (PBM)) in Skin Regeneration

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| ABSTRACT
Lasers have been used in a variety of industries, but we will concentrate on their use in medicine, specifically dermatology. I concentrated on three types of lasers in this article (ablation, non-ablative lasers, and fractional lasers). The non-ablative laser causes skin contraction as a result of wound stimulation of collagen during the healing phase in the dermis, upper dermis, and thermal ablation. Laser ablation is more dangerous because it heats up the dermis. A fractional laser affects the inner dermis layer, which contains collagen, rather than the epidermis, which stimulates this vital component. An ablative fractional laser, on the other hand, peels off the skin's outer layer. According to research, these three lasers produce unfavorable outcomes. Therefore, PBM technology was used without thermal interactions and effects on the skin, increasing patient satisfaction with rejuvenation. This is what we concluded through the search engines Scopus, Google Scholar, and the EndNote application.

| KEYWORDS

Laser, photothermal analysis, ablative laser, non-ablative laser, fractional laser, photobiomodulation(PBM)

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1. Introduction

Theodore H. Maiman created the first laser on July 7, 1960, utilizing ruby as the lasing medium and high-energy pulses of light to activate it. More than 10 distinct lasers were created employing solid, gaseous, semi-conductor, and liquid lasing media throughout the 1960s decade(Patil & Dhami, 2008). A laser resurfacing procedure is a skin rejuvenation procedure that uses a laser to improve the appearance of the skin. Ablative treatments include carbon dioxide (CO2) lasers, erbium lasers, and combination systems. The treated area appears smoother and firmer as the outer skin heals and regrows.

A laser is a device that emits an intense beam of light of one specific color (wavelength). Lasers may be used to treat blood vessel tumors, such as hemangiomas. Laser treatment is also used to remove unwanted hair, tattoos, skin discolorations and acne scars (Beigvand et al., 2020).

Non-ablative laser resurfacing is less invasive and requires less recovery time. It stimulates collagen growth, which improves skin tone and texture over time. This method can be used with a variety of lasers as well as intense pulsed light (IPL) devices.

Skin rejuvenation is the process of restoring a youthful appearance to the skin. There are two types of photodermotherapy - the first type focuses on treating uneven pigmentation, skin redness and changes in the sebaceous glands, and the second type improves subcutaneous tissue.

Two types of skin regeneration lasers are being developed by researchers at the University of California, Los Angeles (UCLA) - one is a single laser with water as the active medium and the other pulsed dye lasers (PDL) with hemoglobin oxide as an active medium.

(Alexiades-Armenakas et al., 2008). The development of high-energy lasers and photobiomodulation (PBM) has shown promising results in reducing wrinkles and improving skin elasticity. Treatment and procedures have limitations, and the risks and probable results should be understood before any treatment is carried out.

2. **Laser interaction with biologic tissues**

When the laser is directed at the tissues, it has one of the four states (Mousa, Hoda Khaled, 2016):

1. Reflection: refers to bouncing the laser beam to the desired tissue and returning it. Without any effect on this tissue, it may pose a danger to other tissues due to exposure to the laser, such as the patient's eye, if protective glasses are not worn.
2. Scattering: The spread of the laser beam beyond the boundaries of the target tissue can lead to some damage, and this may sometimes happen through the transfer of heat generated in the area of the target tissue to the neighboring tissues.
3. Penetration (Transmission): It is the penetration of the laser beam directly through the tissue without affecting it.
4. Absorption :It is the desired and most effective goal, where the laser beam can cause the required vital reactions. The degree of absorption depends on how close the wavelengths of the laser beam are to the target tissue or one of its compounds, the intensity of the energy used, the application time, the pulse repetition rate, and the required dose, as shown in figure (1).

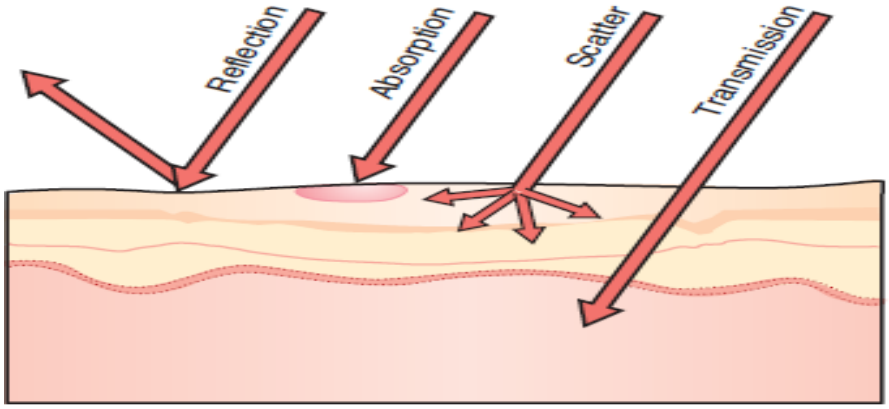

Figure (1) represents the interaction of the laser beam with biological tissues (Mousa, Hoda Khaled, 2016)**.**

Each laser used in medicine has an absorption coefficient specific to each of the different tissues, and accordingly, the laser energy can be either implemented or absorbed depending on the structure of the target tissue. The interaction of the laser with tissues is related to the wavelength of this laser.

Furthermore, this interaction has an impact on • the intensity of the applied laser power, the amount of low-energy energy in the tissues, Mode of release (continuous or pulsed), rate and length of pulses, and touch or remote laser application (Mousa, Hoda Khaled, 2016).

3. Wavelength dependent interaction mechanisms

When laser light interacts with biological tissues, one of three reactions can occur, each of which has an impact on the structure and function of the tissue in question (Bachmann & Zezell, n.d.).

3.1 Photochemistry

Photochemistry is the study of chemical reactions caused by light. Photodynamic therapy (PDT) is a photochemical reaction that requires photosensitizer and oxygen. Photochemical reactions necessitate a low power density ($1W/cm^2$) and a long exposure period (several minutes).

3.2 Photothermal effects

Photothermal interaction is used in a wide range of medical applications, from tumor vaporization to welding gastrointestinal ulcers. Photon energy absorbed by chromophores is converted to heat energy, which can result in a variety of thermal effects ranging from tissue hyperthermia to tissue melting (Sandhya et al., 2020).

4. Ablation, non-ablative and fractional skin laser

4.1 The non-ablative laser

The non-ablative laser works by heating the skin while still allowing the heat to damage proteins such as collagen, stimulating collagen formation and tightening the underlying skin. A non-ablative laser resurfacing procedure is less intrusive and takes less time to recover from than an ablative laser. Microthermal zones can be up to 6.400 treated zones per square centimeter, measuring 1.5 mm deep and 100 to 400 mm wide. (Dolnicar & Chapple, 2015). Non-ablative technologies are becoming more important in photoaging management. Radiofrequency technologies are more effective at targeting pilosebaceous vascular and pigmentary changes. Longer wavelength technologies are most effective at wrinkle reduction mediated by dermal remodeling, say dermatologists.

Heating targeted parts of the skin to boost collagen formation is how this type of laser skin resurfacing works (Ibrahimi et al., 2015).

The new collagen fills in lines and wrinkles, making them disappear while also enhancing skin structure and pigmentation.

4.1.1 Types of non-ablative laser treatments

- **Photo rejuvenation**, also known as Fotofacial, employs intense pulsed light laser treatments to lighten and remove brown age spots or sunspots, as well as improve skin texture and reduce redness caused by skin conditions such as rosacea and broken blood vessels. The majority of people benefit from three to five laser treatments, spaced about a month apart, with improved results appearing after each laser treatment. The effects should last about a year (Tanaka & Matsuo, 2011).

- **Fraxel Restore**: treats fine lines such as crow's feet, brow lines, and minor acne surface scars for the best results. Most patients receive two to three treatments over a six-month period. When compared to other non-ablative laser treatments, this type of laser treatment may have a longer downtime.

- **The Pulsed Dye Laser (PDL)** is a type of vascular laser that uses yellow light to destroy broken blood vessels on the face while leaving the surrounding skin unharmed. PDL is excellent for the repair of broken capillaries, spider veins, and port-wine stains. The cosmetic procedure usually takes only a few minutes, there is no downtime, and the results should be visible right away(Experience, 2015) [2].

4.1.2 Disadvantages of Non-ablative laser

Non-ablative laser resurfacing sometimes causes skin burns, and the chances of skin burns increase with dark skin. Sometimes pigmentation occurs in the skin where some dark spots arise after laser hair removal. Hypopigmentation may occur, and this is caused by cells absorbing the laser. It can cause temporary swelling and redness that usually only last for a few hours or days and can cause an outbreak of the herpes virus(Hassan & El-tabak, 2009)(Prens et al., 2013)(Urdiales-Gálvez et al., 2020).

4.2 Ablation laser:

An ablative laser is a type of invasive laser that eliminates the epidermis (the outer layer of skin) and heats the dermis (the inner layer of skin), encouraging the development of new collagen fibers. The treated region appears smoother and firmer as the surrounding skin recovers and regrows. A powerful beam of light energy is focused toward the skin during ablative laser resurfacing. The laser warms up the underlying layer of skin while destroying the outer layer (epidermis). Over time, this increases collagen formation, resulting in improved skin tone and texture. The use of a continuous wave CO2 laser was the first to be used in the application of laser ablation to facial rejuvenation. This type of laser skin resurfacing removes damaged skin layers. It is most effective for treating scars and advanced signs of aging, such as wrinkles and deep lines (Dolnicar & Chapple, 2015)(Russo et al., 2013).

4.2.1 Ablative laser treatment types

- Fraxel Repair and other CO2 resurfacing lasers tighten skin and remove wrinkles, deep acne scars, and aging, damaged skin. The most common laser is the Erbium-Yak (yttrium aluminum-garnet) (2.940 nm Er: YAG) laser, which has a wavelength of 2.790 nm.

- Erbium lasers, like yttrium aluminum garnet (YAG), are less invasive than CO2 lasers but treat the same skin issues, including visible veins and skin discoloration(Alexiades-Armenakas et al., 2008)(Beigvand et al., 2020).

4.2.2 Disadvantages of Ablation laser

Redness, swelling, and itching are all possible side effects of ablation laser resurfacing. The redness could be caused by a worsening

of a prior skin ailment like rosacea. After treatment, heavy creams and pads might aggravate acne or cause treated skin to produce tiny white pimples (milia). Infections caused by ablation laser resurfacing might be bacterial, viral, or fungal. An outbreak of the herpes virus is the most common infection. (Modena et al., 2020)(Van Den Bos & Proebstle, 2014).

4.3 Fractionated lasers

A fractional laser is used to deliver precise microbeams of laser light into the lower layers of skin. Coagulated tissue in the treatment area promotes natural healing, resulting in the rapid growth of healthy new tissue. The method yields long-term results with little downtime (Graber et al., 2008). A fractional laser is generally used on any area of the body and gives the same effect and result as a regular laser. It is very common to use it on other specific areas such as the hands, neck and face, especially since those places are exposed and used a lot. The fractional laser gives an effective effect when used in different skin conditions, such as removing wrinkles from the hands, face, neck and any other place. It is very effective and widespread in getting rid of the mask of pregnancy, which is a pigmented skin condition that occurs for some women during pregnancy(Metelitsa & Alster, 2010).

Pain, swelling and redness are some of the side effects of using a fractional laser treatment. This type of laser injures the skin's outer layer, causing small wounds that require time to heal. These small wounds may become infected or inflamed in some people, complicating matters(Trelles et al., 2008).

4.3.1 Disadvantages of fractional laser

After fractional laser treatment, you may feel redness and itching in the skin for 24 hours. Immediately after the session, it is important to apply cold water compresses and sunscreen as needed. The skin will be healed after a week following the laser treatment. The skin begins to produce more collagen and elastin to replace the damaged tissue after two or three months following treatment(Hassan & El-tabak, 2009).

4.4 photobiomodulation (PBM)

Red light therapy is also known as photodynamic modulation (PBM), low-level light therapy (LLLT), biostimulation, photostimulation or light box therapy. It involves using specific wavelengths of light to treat different areas of the body, such as the eyes, skin and hair. The most effective wavelengths of red light appear to be in the 630-670 and 810-880. ranges. Laser therapy is a medical treatment that employs concentrated light to promote a process known as photobiomodulation (PBM). Photons enter the tissue and interact with the cytochrome c complex within mitochondria. This interaction sets off a biological cascade of events that results in an increase in cellular metabolism. (Aouizerate, n.d.).

The first PBM procedures were performed using lasers, and it is unclear whether similar therapeutic benefits can be achieved by other light sources(Zhao et al., 2022) (Low-level et al., 2016). Lasers are used to heal, restore, and stimulate physiological cellular processes. They can also repair tissue damage caused by a variety of injuries or diseases. Low-level photomicrography involves modulating biological activity with light in the red and near-infrared range(Del Vecchio et al., 2022)(Del Vecchio et al. 2021)(Ailioaie & Litscher, 2021). Photobiomodulation therapy involves applying a therapeutic dose of light to impaired or dysfunctional tissue. According to research, it can have an effect on pain, inflammation, and tissue repair. Clinical studies have indicated that near-infrared radiation increases the amount of dermal fibroblast collagen and improves skin texture. Fifty Japanese patients have become the first in the world to be given near-infrared radiation therapy with no local anesthetic or pain relievers. Patients were given three cycles of therapy, separated by four weeks, and treated over a period of eight months. PBM's non-thermal approach to skin rejuvenation appears to be safe and effective, with high patient satisfaction and a low price for complete body treatments. Table 1 lists the lasers used for skin rejuvenation.

Table (1) shows the characteristics of three types of lasers used in skin rejuvenation:

laser type	wavelength	laser source	Effective laser on the skin	Ref.
Ablative lasers	10600nm	CO2	It causes epidermal and upper dermis vaporization and thermal ablation.	(Alexiades-Armenakas et al., 2008)(Lin et al., 2014)(Lster & Oshi, 2004)(Lukac et al., 2010)
	Er:YAG	2940nm		(Preissig et al., 2012)(Buzina et al., 2010) (Nisticò et al., 2021)(Lee et al., 2022)

	Er:YAG	2790 nm		
Non-ablative Lasers	500-1299 nm	ILP	The skin tightens as a result of the wound's stimulation of collagen during the healing phase. Laser ablation is more damaging. The dermis warms up.	(Okui et al., 2022)(Kohl et al., 2010) (Alexiades-Armenakas et al., 2008)(Huth et al., 2020)(Review et al., 2022)(Fistoni et al., 2016)
	585-595 nm	High dose PDL		(Russo et al., 2013)(Shanina et al., 2021)(Bjerring et al., 2000)(Badawi et al., 2022)
	589-598 nm	Low dose PDL		
	532nm	PPTP		
	1450 nm	Erbium glass lasers		
	Nd:YAGDiode Lasers	1032 & 1064 nm		
	1540 nm	Alexandrite lasers		
Fractional lasers	2940 nm-10600 nm	Er:YAG	This form of non-ablative fractional laser affects the inner dermis layer, which contains collagen, rather than the epidermis, which stimulates this vital component. Ablative fractional lasers, on the other hand, exfoliate the skin's outer layer.	(Elman et al., 2015)(Albert, 2017)(Mandarim-de-lacerda, 2004)(Hassan & El-tabak, 2009)(Buzina et al., 2010)(Hassan & El-tabak, 2009)
	1540,1550 nm	CO2		(Graber et al., 2008)(Ali et al., 2020)
	1440,1540,1550,1556nm 1556-1550-1540-1440nm	Erbium glass		
PBM	Red & Near infra-red wavelengths	LEDs, lasers, broad lights waves	Treat the lack of thermal responses as a skin symmetry photophysical or photochemical reaction. Patients' satisfaction with skin rejuvenation was considerably increased using PBM technology without thermal responses.	(Aouizerate, n.d.)(Markers et al., 2021)(Agas et al., 2021)(Mosca et al., 2022)

5. Conclusions

Non-ablative laser resurfacing has fewer and milder side effects than ablative laser surgery, such as damage to the skin, which can be caused by exposure to high levels of ultraviolet light

Non-ablative laser therapy is an effective way to rejuvenate skin without damaging the surface of the skin. The heat from the laser stimulates collagen formation, which tightens the skin and makes it appear younger and healthier. It also improves the appearance of wrinkles, dark spots, and minor scars. Nonablative lasers are frequently fractionated, delivering heat to the skin through hundreds of tiny, deep columns known as microthermal treatment zones, with normal untreated skin in between. The skin heals significantly faster with a fractional technique than if the entire area is treated. This method decreases the amount of time it takes

to heal and the number of issues that can emerge. In most cases, multiple sessions are required. PBM is a non-thermal alternative to skin rejuvenation. PBM delivers a safe and long-lasting skin rejuvenation effect; nevertheless, to maintain the results, several treatments are required. The vast array of laser and light technologies available provides numerous alternatives for achieving the desired effects that are most appropriate for the patient. However, depending on the patient's skin type, the laser and treatment parameters should be carefully chosen.

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