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Study the Mechanism of Color Depigmentation by Q-Switched Nd-Yag Laser Photoacoustic Shouckwave

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Annotation: his project aims to investigate the efficacy and safety of utilizing Q- switched Nd: YAG laser technology generating photoacoustic shockwave for color depigmentation in dermatological applications. The proposed research seeks to address the increasing demand for advanced treatments for various pigmentation disorders, including hyperpigmentation, melasma, post-inflammatory hyperpigmentation and hair bleaching. The project will involve an exploration of the photoacoustic effect induced by Qswitched Nd: YAG laser pulses on pigmented skin lesions. By leveraging the ability of laser-induced shockwaves to disrupt melanin pigment within the skin and hair, the study aims to achieve selective depigmentation while minimizing damage to surrounding tissues.

General Introduction

1. Laser Technology

A LASER is a technology that emits radiation of coherent light through an optical amplification process. A laser contains four main components: gain medium, high reflector, pumping source, and the output coupler. A laser is formed when the electrons in the active medium atoms absorb energy from the pumping source to become excited. The excited electrons transfer from a lower energy level to a higher energy level around the nucleus of the atom. The moment they return to their normal state the electrons release photons in a stimulated emission process with energy equal to:

$E=hv$ (1.1)

The laser beam forms focused photons of light on a small area, having higher intensity than a beam of normal light. Laser technology has many applications, including astronomy, communication, computer devices, cutting equipment, robotics, surgery, health, barcode readers, fiber optics, and 3D scanners [1]

1.2. Human Skin

Human skin is the organ that covers the body's surface that both provides protection and receives sensory stimuli from the external environment.

The skin consists of three layers of tissue: the epidermis, an outermost layer that contains the primary protective structure, the stratum corneum. the dermis is a fibrous layer that supports and strengthens the epidermis; and the subcutis, a subcutaneous layer of fat beneath the dermis that supplies nutrients to the other two layers and that cushion and insulates the body as shown in figure (1.1).

Human skin is enormously well supplied with blood vessels; it is pervaded with a mass of arteries, veins, and capillaries. Such a supply of blood is evidence that the skin is at the service of the blood vascular system, functioning as a cooling device.

To aid in this function, sweat glands pour water upon its surface, the evaporation of which absorbs heat from the skin. If the environment is cold and body heat must be conserved, cutaneous blood vessels contract in quick, successive rhythms, allowing only a small amount of blood to flow through them. When the environment is warm, they contract at long intervals, providing a free flow of blood. During muscular exertion, when great quantities of generated heat must be dissipated, blood flow through the skin is maximal [2].

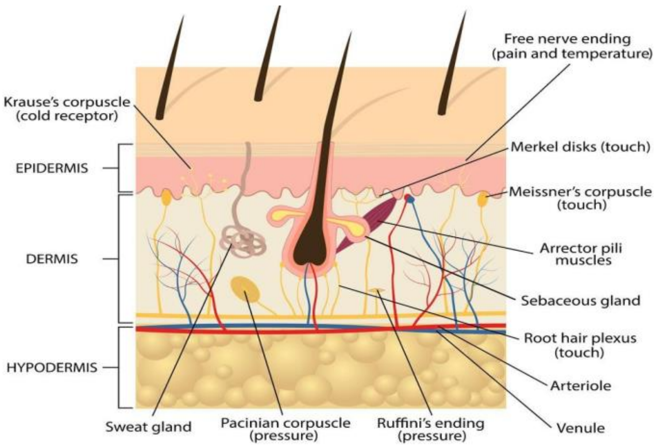

Figure (1.1): *Human skin Anatomy.*

1.3. Laser Technology in Dermatology

Laser Technology is considered one of the best technologies when treating different indications in Dermatology because it can selective. Being selective means that with a laser; we can damage the target within the skin without affecting the surrounding tissues. Four main parameters are used to select the proper laser for a specific treatment, these four parameters are [3]:

1.3.1. Wavelength

must be chosen depending on the absorption coefficient of the target. Whatever the target was it's necessary to know its absorption coefficient which will determine the wavelength of the laser used. To
reduce undesired side-effects, it's preferred that this wavelength is not highly absorbed by the surrounding tissue.

1.3.2. Fluence

is the energy of the laser divided by unit area. Laser fluence provides the necessary heat required for a specific application [3].

$$Fluence = \frac{Energy}{Area} \quad (1.2)$$

1.3.3. Pulse Duration

It's the time that a specific target is exposed to laser radiation. Pulse duration selection depends on the thermal relaxation time TRT of the specified target. TRT is the time required for the cells to lose 63% of the acquired heat after the laser pulse through heat transfer to the surrounding tissue or by thermal diffusion and it depends on the target area [4].

1.3.4. Spot size

This parameter varies from fractions of millimeters to a few centimeters, depending on the size of the target it's necessary to adjust the laser spot size to obtain the best results without damaging the surrounding tissue or having loss in laser power. On the other hand, in some applications like hair removal, large spot sizes are required to cover a large skin area in a single pulse.

These four parameters are essential in every laser-based treatment. To obtain the best results, one must be familiar with the targeted area as well as the laser device [4].

1.4. Skin Chromophores and Laser Depth of Penetration

The skin chromophores that deal with laser radiation can be divided into three sections illustrated in the table below: Table (1-1): Skin chromophores.

Melanin	Hair, pigments	Ruby 694nm, Alex 755nm, Diode 808nm, Nd: YAG 1064nm
Water	Skin problems	Er: YAG 2940 nm, CO_2 10600 nm, Er: Glass 1540 nm, Nd: YAG 1064 nm
Hemoglobin	Vascular lesions	PDL 585nm, PDL 595nm, Nd: YAG 1064 nm

Figure (1.2) below shows the absorption spectrum of the three basic skin chromophores versus wavelength, firstly, it's seen that the black line that represents the Melanin absorption ranges from 300 to 1500 nm roughly, with maximum absorption lies in the UV region. Secondly, we have the Oxyhemoglobin absorption represented by the red line. Finally, the blue line stands for the water absorption spectrum. Noticing that the absorption spectrum at 1064 nm Nd: YAG laser, it roughly has a close absorption coefficient of the three chromophores making it optimum to operate in various medical applications, with setting the right laser parameters i.e. pulse duration, flounce, and laser spot size [5].

Depending on the wavelength, the depth of penetration of laser radiation inside the skin tissue can be shown in figure (1.3). Penetration depth is mainly determined by wavelength. As a rule, longer wavelengths have less scattering and a larger penetration depth. Theoretically, longer wavelengths may therefore be preferred for deeper and larger vascular lesions treatments such as reticular veins, whereas shorter wavelengths may be suited for superficial vascular lesions such as telangiectasias [6].

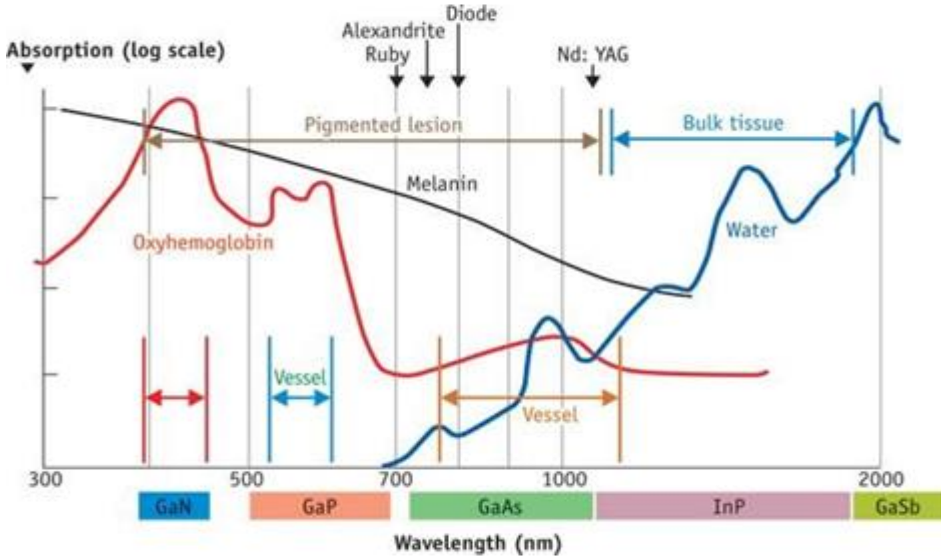

Figure (1.2): *Skin chromophores absorption spectrum Vs. wavelength*

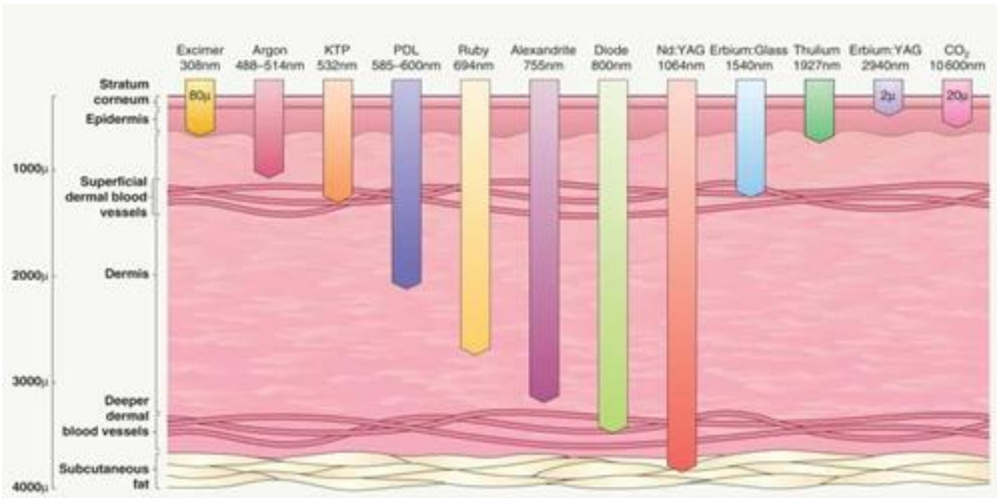

Figure (1.3): *Laser types and depth of penetration.*

1.5. Nd: YAG Laser

Nd: YAG (neodymium-doped yttrium aluminum garnet; Nd: Y3Al5O12) is a crystal that is used as a lasing medium for solid-state lasers. The dopant, triply ionized neodymium, Nd (III), typically replaces a small fraction (1%) of the yttrium ions in the host crystal structure of the yttrium aluminum garnet (YAG), since the two ions are of similar size. It is the neodymium ion that provides the lasing activity in the crystal. Nd: YAG laser system configuration is shown in figure (1.4) below.

Nd: YAG lasers are optically pumped using a flashlamp or laser diodes. These are one of the most common types of lasers and are used for many different applications. It typically emits light with a wavelength of 1064 nm, in the infrared region of the spectrum. Nd: YAG lasers operate in both pulsed and continuous modes. Pulsed Nd: YAG lasers are typically operated in the so-called Q-switching mode.

Nd: YAG absorbs mostly in the bands between 730–760 nm and 790–820 nm. At low current densities, krypton flashlamps have higher output in those bands than do the more common xenon lamps, which produce more light at around 900 nm. The former is therefore more efficient for pumping Nd: YAG lasers [1].

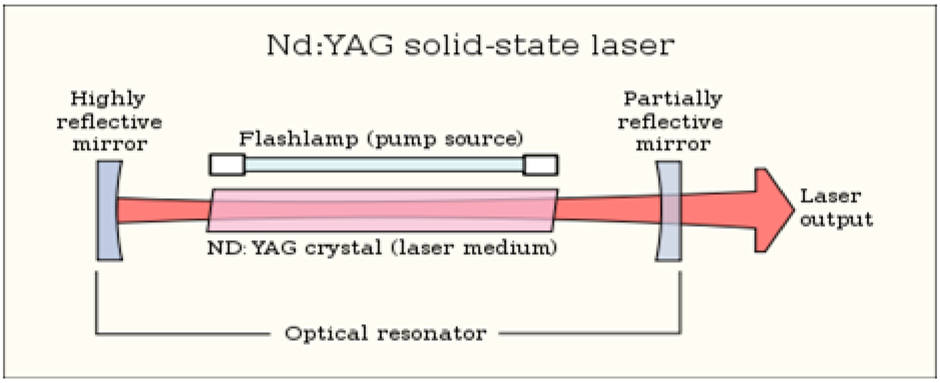

Figure (1.4): *schematic diagram of Nd: YAG Laser.*

Q-switching is a technique by which a laser can be made to produce a pulsed output beam. The technique allows the production of light pulses with extremely high (gigawatt) peak power, much higher than would be produced by the same laser if it were operating in a continuous wave (constant output) mode. Q-switching leads to much lower pulse repetition rates, much higher pulse energies, and much longer pulse durations.

Q-switching is achieved by putting some type of variable attenuator inside the laser's optical resonator. When the attenuator is functioning, the light which leaves the gain medium does not return, and lasing cannot begin. This attenuation inside the cavity corresponds to a decrease in the Q factor or quality factor of the optical resonator. A high Q factor corresponds to low resonator losses per roundtrip and vice versa. The variable attenuator is commonly called a "Q-switch" when used for this purpose. Normally, Q-Switches are classified into two types: Active switches like shutters and motors, or Passive Q-switches like saturable absorbers.

By Q-Switching technology, it's possible to control the laser pulse duration. The length of the pulse duration is an important characteristic of any pulsed laser/light device. Pulses lasting a few milliseconds (10 -3) are generally characterized as long pulses. Nanosecond (10-9) pulses are considered short. It is due to this technique the principle of selective photothermolysis can be applied to the pigmented lesions to achieve the desired clinical results without much damage to the surrounding area [7].

1.6. Q-Switch Nd: YAG Laser in Dermatology

Nd: YAG laser has become the most talked-about technology in dermatology mainly because, in cosmetic practice, there is a demand for treatments with no or minimal downtime. Q-Switch Nd: YAG laser (Q-SNDYL) is ideal for multiple uses in cosmetic practice. In this chapter, we will demonstrate the established uses of this laser technology. The most famous conditions that are treated with Q-SNDYL in dermatology up to this day are:

1. Vascular lesions.
2. Hair reduction.
3. Pigmented lesions and tattoo removal
4. Skin Rejuvenation.

In this research we focus on pigmented lesions and tattoo removal as a major contributor to skin staining and coloring.

1.6.1. Hyperpigmentation

Hyperpigmentation is caused by an increase in melanin. Melanin is the natural pigment that gives our skin, hair, and eyes their color. Several factors can trigger an increase in melanin production, but the main ones are sun exposure, hormonal influences, age, and skin injuries or inflammation. Mainly, there are three types of pigmented lesions [8]:

1. Epidermal pigments, see images below:

Café au lait macules *Post-inflammatory pigment alteration* *Lentigines*

Figure (1.5): Epidermal pigments

2. Epidermal- Dermal Pigments, like:

Figure (1.6): Epidermal-dermal pigments, Melasma

3. Dermal Pigments, like:

Figure (1.7): Dermal pigments, Nevus of Ota

In general, the principal work of removing skin pigmented lesions is destroying the colored cells causing the abnormality, laser produces a wavelength of high energy light, which is then converted into heat energy. This can target the specific area of pigmentation because the laser is absorbed only by cells containing an excessive concentration of pigmentation. This causes efficient destruction while leaving the surrounding tissue undamaged. The short pulse laser systems can effectively treat the lesions by confining their energy to the melanosomes, which are the tiny granules containing melanin inside the pigment cells. The results of laser treatment depend on the depth of the melanin and the color of the lesion and are to some degree unpredictable. Superficially located pigment is best treated with shorter wavelength lasers like KTP 532nm while removal of deeper pigment requires longer wavelength lasers like Q-Switched Nd: YAG 1064 nm that penetrate to greater tissue depths. Caution is needed with laser therapy in the skin of color, as permanent hypopigmentation and depigmentation may occur. Successfully treated lesions may recur [8].

1.6.2. Tattoo Removal

Due to its longer wavelength, higher fluence, and shorter pulse, Q- SNDYL 1064 nm has emerged as a better laser for the black and dark blue/ black tattoo pigment. The textural changes, scarring, and hypopigmentation of earlier lasers are remarkably low, figure (2.2). 1064 nm is a longer wavelength, minimally absorbed by the epidermis, hence is the safest choice with minimal adverse effects on the skin. the treatment is based on selective photo-thermolysis. This principle focuses on the lasers' specificity to a wavelength that targets a dedicated chromophore, in this case, ink particles. Additionally, melanin absorption decreases as the wavelength increases, which allows safe laser use even in darker skin types [9].

Figure (1.8): *Tattoo removal; after 3 sessions of Q-SNDYL*

1.6.3. Skin Rejuvenation

Skin rejuvenation and whitening are huge cosmetic demands for most practitioners. A laser facial with low fluence, and a large spot size of 1064 nm, is ideal for immediate skin lighting as well as hair reduction with minimum or no downtime. Immediate skin cooling and application of a facial peel-off mask gives an immediate skin brightening and even skin tone. This procedure can be repeated once in 4-6 weeks for maintained results.

No-ablative resurfacing is a technique in which lasers are used to resurface the skin to improve pigment and texture without physical injury to the skin surface. Non-ablative non-fractionated lasers create uniform thermal damage to the dermis while sparing the epidermis. They are best for the treatment of mild-to-moderate photodamage and early signs of skin aging.

The laser delivers energy through a process called fractional photo- thermolysis, in which an array of small laser beams creates many microscopic areas of thermal injury within the range of 100 - 400 um in width and 300-700 um in depth. These areas, referred to as microscopic treatment zones, are columns of thermal damage surrounded by areas of normal skin that serve as a source of healthy tissue and stem cells for remodeling and effective rejuvenation and allow for safe and rapid healing. Non-ablative fractionated lasers combine the best of the gentle and safe aspects of both fractionated and non-ablative technologies and are ideal for patients seeking moderate improvement with minimal post-recovery time.

The most common uses of non-ablative resurfacing lasers include the treatment of photoaging, rhytids, scars, skin pigmentation, and overall skin rejuvenation. [9].

1.7. Complications of Q-SNDYL

Like any laser, the use of Q-SNDYL too is haunted by a few complications. However, most are transient reactions and do not require termination of treatment. These include erythema, physical urticaria, acneiform eruption, petechiae, whitening of fine hair, and rebound hyperpigmentation. On the other hand, the occurrence of mottled hypo/ hyperpigmentation, leukoderma, severe urticaria or acneiform eruption, and activation of herpes simplex warrants modification of laser parameters and if required, even termination of therapy. Ghost shadows and scarring are adverse effects associated with tattoo removal at higher fluencies. Low fluence, large spot size, and frequent treatments i.e. weekly or fortnightly, done for longer periods of 1-2 years were deemed to be responsible for reducing the undesired side effects. Hence, caution is advised. Indication, skin type, parameters, and duration of therapy should be well considered before undertaking laser treatment [9].

2.1. Laser-Tissue interaction

The interaction between laser light and biological tissues involves several complex processes that depend on various factors such as the wavelength of the laser, the duration of exposure, the optical properties of the tissue, and the specific target within the tissue. Here's a detailed explanation of the laser-tissue interaction [10]:

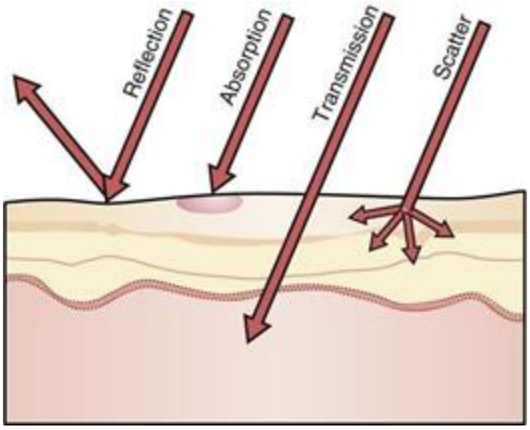

Figure (2.1): Laser Surface interaction.

2.1.1. Absorption of Laser Energy

The first step in laser-tissue interaction is the absorption of laser energy by the tissue. Different wavelengths of light are absorbed to varying degrees by different components of the tissue. For example, hemoglobin and melanin absorb light in the visible spectrum, while water and certain chromophores absorb light in the infrared spectrum [10].

2.1.2. Photothermal Effects

When laser energy is absorbed by tissue, it can induce photothermal effects. This means that the energy is converted into heat, leading to temperature increases in the tissue. Depending on the laser parameters and the tissue properties, this heat can cause coagulation, vaporization, or thermal damage to the tissue [11].

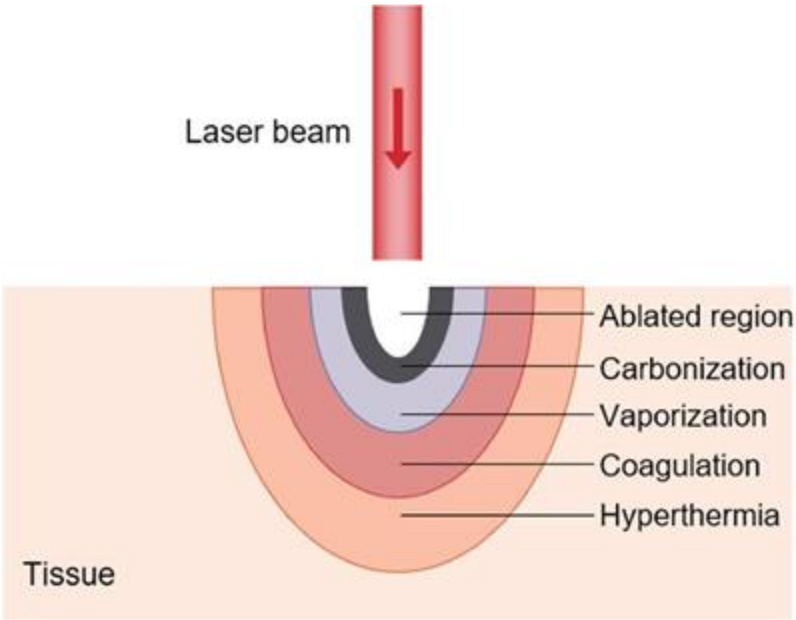

Figure (2.2): Photothermal effect.

2.1.3. Photochemical Effects

In addition to photothermal effects, laser energy can also induce photochemical effects in tissue. Certain molecules within the tissue may undergo photochemical reactions when exposed to specific wavelengths of light. For example, photodynamic therapy involves the use of photosensitizing agents that are activated by light to produce cytotoxic reactive oxygen species, leading to cell death [11].

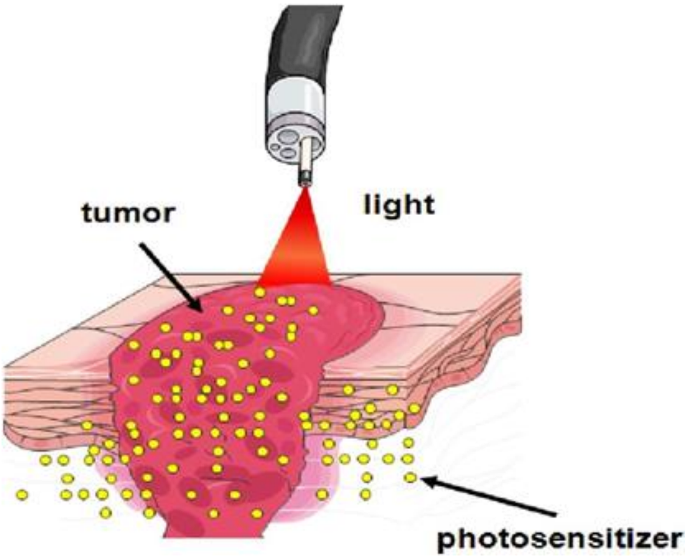

Figure (2.3): Photodynamic therapy.

2.1.4. Photoacoustic Effects

Laser energy can also produce photoacoustic effects in tissue. This occurs when rapid absorption of laser energy leads to a sudden expansion of the tissue, generating acoustic waves. Photoacoustic effects can be harnessed for various applications such as imaging, drug delivery, and tissue ablation [11].

2.1.5. Selective Photothermolysis

The concept of selective photothermolysis is central to many laser-based medical treatments. It involves selectively targeting specific chromophores within the tissue while minimizing damage to surrounding structures. This is achieved by choosing a laser wavelength that is preferentially absorbed by the target chromophore and adjusting the laser parameters to deliver energy in short pulses, thus limiting heat diffusion [10].

2.1.6. Tissue Response and Healing

Following laser treatment, the tissue undergoes a series of responses and healing processes. This may include inflammation, cell proliferation, collagen remodeling, and tissue regeneration. The extent of tissue response depends on factors such as the depth of tissue penetration, the degree of thermal damage, and the individual's healing capacity.

Understanding the complex interplay between laser light and biological tissues is crucial for the development of safe and effective laser- based medical treatments across various specialties, including dermatology, ophthalmology, surgery, and oncology [11].

2.2. Applications of laser photoacoustic shockwave

Laser-induced photoacoustic shockwaves have several applications across various fields. Here are some of the key applications.

2.2.1. Biomedical Imaging

Photoacoustic imaging combines the high contrast of optical imaging with the high resolution of ultrasound imaging. By using laser-induced shockwaves to generate acoustic signals from tissue, photoacoustic imaging can provide detailed images of tissue morphology, vasculature, and functional parameters such as oxygen saturation. This technique is particularly useful for non-invasive imaging of deep tissues with high spatial resolution [12].

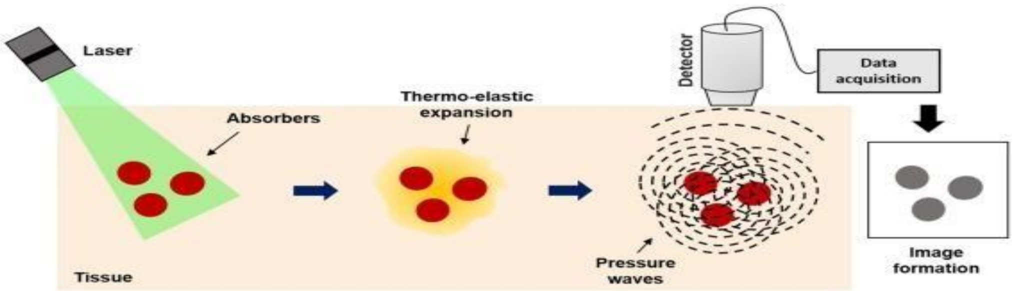

Figure (2.4): Photoacoustic imaging.

2.2.2. Therapeutic Applications

Laser-induced shockwaves can be used for therapeutic purposes in a technique known as laser-induced shockwave therapy (LISWT) or laser- induced shockwave angiogenesis (LISA). This approach has been investigated for various medical conditions, including promoting tissue regeneration, enhancing wound healing, and treating musculoskeletal disorders such as tendonitis and osteoarthritis [13].

Figure (2.5): Laser-induced shockwave therapy.

2.2.3. Drug Delivery

Laser-induced shockwaves can enhance drug delivery by promoting the penetration of therapeutic agents into target tissues. This technique, known as laser-induced forward transfer (LIFT), involves depositing drug- containing materials onto a target surface and using laser-induced shockwaves to propel the materials into the tissue. LIFT has applications in delivering drugs to specific sites within the body, such as the skin, eyes, and mucosal surfaces [14].

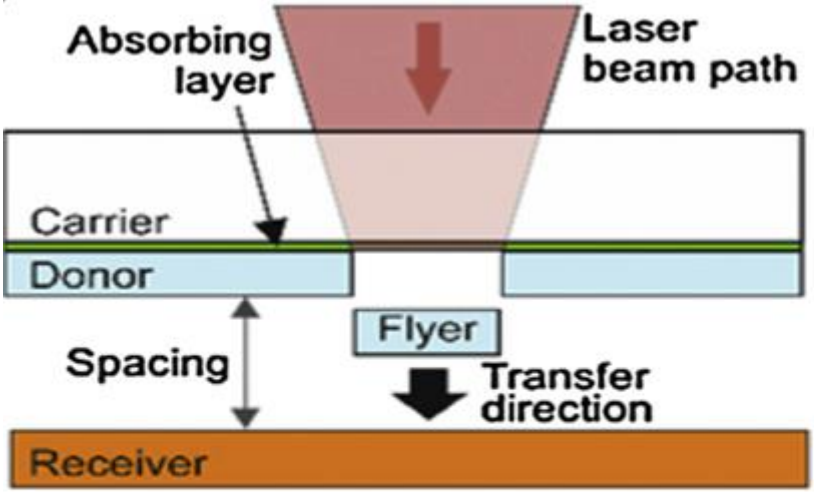

Figure (2.6): Drug delivery by laser radiation.

2.2.4. Biomedical Sensing

Laser-induced shockwaves can be used for biomedical sensing applications, such as detecting biomolecules or monitoring physiological parameters. For example, photoacoustic sensing techniques can be used to detect specific molecules based on their absorption spectra, enabling sensitive and selective detection of analytes in biological samples [15].

2.2.5. Materials Processing

Laser-induced shockwaves can be utilized for materials processing applications, such as surface cleaning, ablation, and micro structuring. By focusing laser energy onto a target material, shockwaves can be generated to remove surface contaminants, modify surface properties, or create precise microfeatures. This technique has applications in various industries, including electronics, aerospace, and manufacturing [12].

Laser-induced photoacoustic shockwaves offer versatile capabilities with diverse applications in biomedical imaging, therapy, drug delivery, sensing, and materials processing. Ongoing research and technological advancements continue to expand the potential uses of this powerful technique across different fields [14].

2.3. laser-induced shockwave therapy (LISWT)

Laser-induced shockwave therapy (LISWT) procedures using laser radiation are primarily used to remove excess or abnormal pigmentation in the skin. This can include:

2.3.1. Hyperpigmentation

Laser treatments can effectively target and reduce the appearance of hyperpigmentation, which refers to areas of the skin that are darker than the surrounding areas. Common types of hyperpigmentation include age spots, sunspots, freckles, and melasma [16].

2.3.4. Birthmarks

Certain types of birthmarks, such as café-au-lait spots and pigmented nevi (moles), can be treated with laser depigmentation procedures to lighten or remove the pigmentation [17].

2.3.3. Tattoos

Laser tattoo removal involves using laser radiation to break down the ink particles within the skin, leading to gradual fading and removal of the tattoo. This process effectively targets the pigment in the tattoo without causing significant damage to surrounding tissues [14].

2.3.4. Post-inflammatory Hyperpigmentation

Laser treatments can also be used to address post-inflammatory hyperpigmentation, which occurs because of inflammation or injury to the skin, such as acne scars or trauma.

Hyperpigmentation

Birthmarks

Tattoos

Post-inflammator Hyperpigmentation

Figure (2.7): Indications of laser-induced shockwave therapy (LISWT) on human skin.

Laser depigmentation procedures are used to target and remove excess or abnormal pigmentation in the skin, resulting in a more even complexion and improved skin appearance [18].

2.4. The Mechanism of Color Depigmentation by Nd:YAG Laser laser-induced shockwave therapy (LISWT)

Color depigmentation by Q-switched ND: YAG laser involves a sophisticated mechanism that targets and disrupts pigmented cells within the skin. Here's a detailed breakdown of the process:

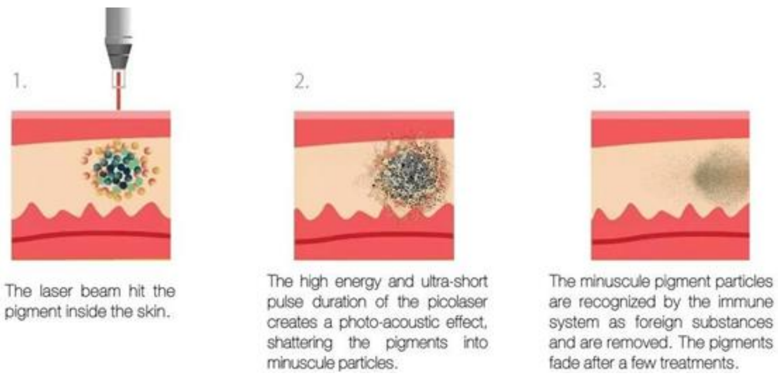

Figure (2.8): The mechanism of laser induced photoacoustic shockwave.

2.4.1. Absorption of Laser Energy

The Q-switched ND: YAG laser emits short pulses of high-energy light in the near-infrared spectrum. This wavelength is selectively absorbed by melanin, the pigment responsible for skin coloration. Melanin absorbs laser energy more efficiently than surrounding tissues due to its higher concentration in pigmented cells [19].

2.4.2. Thermal Disruption

When laser energy is absorbed by melanin, it generates heat within the pigmented cells. This localized heating causes thermal disruption, leading to the fragmentation of melanin particles [19].

2.4.3. Photoacoustic Effect

In addition to heat generation, the laser pulses create a photoacoustic effect within the targeted pigmented cells. This effect occurs when the rapid absorption of laser energy results in a sudden expansion of the cell, leading to mechanical disruption and fragmentation of melanin particles [19].

2.4.4. Selective Targeting

The Q-switched technology allows for precise targeting of pigmented cells while minimizing damage to surrounding tissues. This is achieved by delivering extremely short pulses of laser energy (nanoseconds) with high peak power. The short duration of the pulses ensures that the energy is deposited quickly, limiting heat diffusion to adjacent tissues [18].

2.4.5. Immune Response and Clearance

Following fragmentation of melanin particles, the body's immune system recognizes them as foreign substances and initiates a process of clearance. Macrophages, specialized immune cells, engulf the fragmented melanin particles and transport them away from the treatment area for elimination through the lymphatic system [20].

2.4.6. Skin Regeneration

After the pigment particles are cleared, the treated skin undergoes a process of regeneration and remodeling. This may involve the production of new collagen and elastin fibers, leading to improvements in skin texture and tone over time [19].

2.4.7. Multiple Treatment Sessions

Achieving optimal results typically requires multiple treatment sessions spaced several weeks apart. This allows for gradual fading of pigmentation and minimizes the risk of adverse effects [19].

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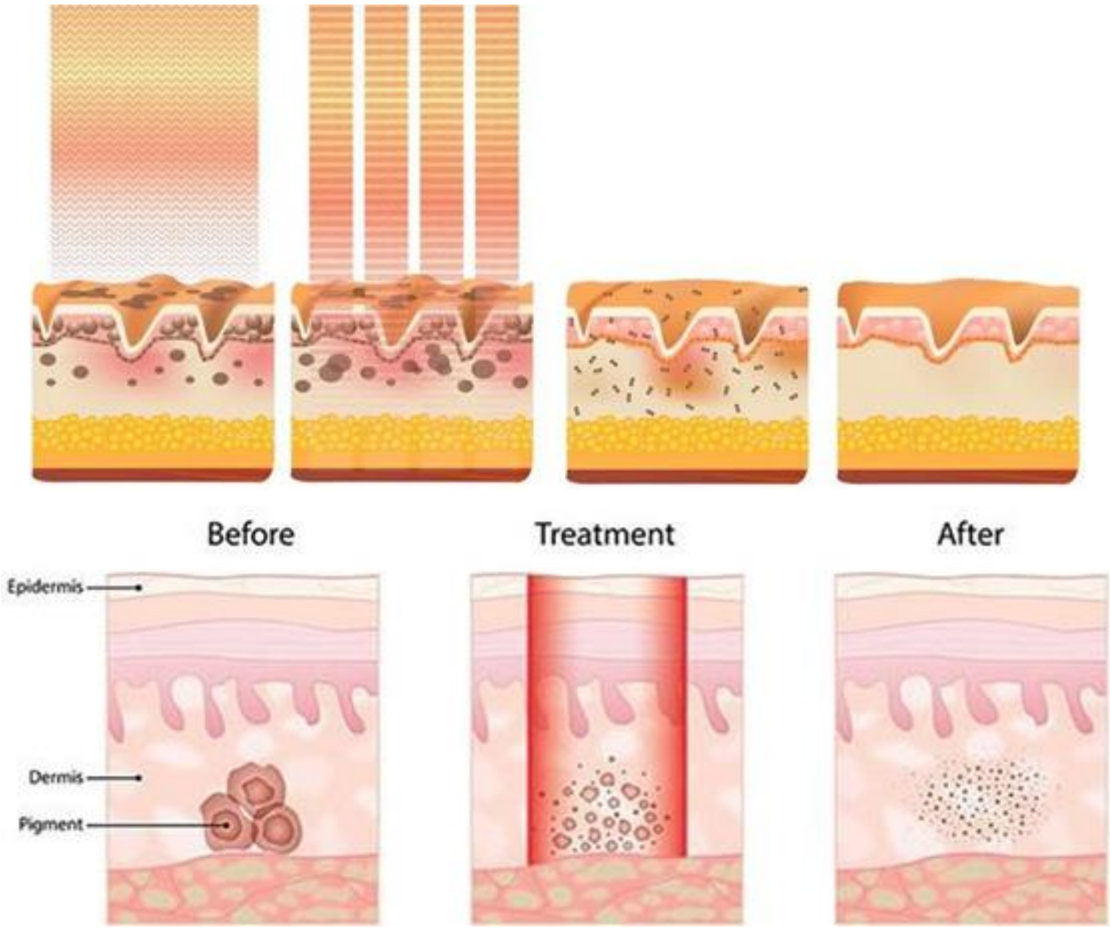


Figure (2.9): Color depigmentation by QSNDL.

Overall, the mechanism of color depigmentation by Q-switched ND:YAG laser involves selective targeting and disruption of melanin pigment within the skin, leading to gradual fading of pigmented lesions and improvement in skin appearance [19].

2.5. Treatment time and post-operative care

The treatment time for photoacoustic shockwave therapy (LISWT) by laser can vary depending on factors such as the specific condition being treated, the size of the treatment area, the laser parameters, and the individual's response to treatment. Typically, a single session of LISWT may last anywhere from a few minutes to around 30 minutes. However, multiple treatment sessions are often required to achieve optimal results, with sessions spaced out over several weeks [16].

As for post-operative care following LISWT treatment, it's essential to follow any specific instructions provided by your healthcare provider. However, here are some general guidelines:

2.5.1. Protect the Treatment Area

Avoid exposing the treated area to direct sunlight or harsh environments immediately following treatment. Use sun protection measures such as wearing protective clothing and applying sunscreen to minimize the risk of sunburn or hyperpigmentation [16].

2.5.2. Manage Discomfort

Some mild discomfort or tenderness may be experienced in the treated area following LISWT. Over-the-counter pain relievers or anti- inflammatory medications may be recommended to manage any discomfort. Your healthcare provider may also suggest using ice packs or topical treatments to alleviate discomfort [17].

2.5.3. Stay Hydrated

Drink plenty of water to stay hydrated, as adequate hydration is important for the body's healing process [17].

2.5.4. Follow-Up Appointments

Attend any scheduled follow-up appointments with your healthcare provider to monitor your progress and determine if additional treatments are needed [14].

2.5.5. Avoid Strenuous Activities

Avoid strenuous activities or heavy lifting for a certain period following LISWT treatment to allow the body to heal properly. Your healthcare provider will provide guidance on when it's safe to resume normal activities [17].

2.5.6. Adhere to Skincare Recommendations

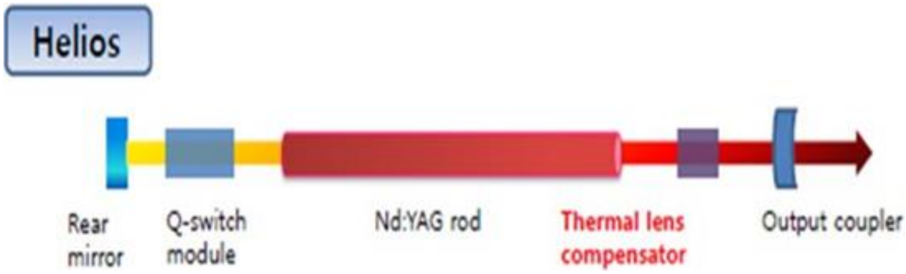
Follow any skincare recommendations provided by your healthcare provider, such as avoiding harsh skincare products or exfoliants in the treated area [17].

It's important to communicate with your healthcare provider if you experience any unusual or concerning symptoms following LISWT treatment. They can provide guidance and address any questions or concerns you may have during the recovery process[19].

3.1. Q-Switched Nd: YAG Laser

The Q-Switched Nd: YAG laser (Helios III, Laseroptek, Hyundai, Republic of Korea) operating with the wavelength of 1064 nm has a deep penetration property that is less absorbed by the epidermis and well penetrated the dermis, hence effective for the treatment of dermal melanocytosis. The laser system is shown in figure (3.1).

Laser Hand-piece



Laser System confegration

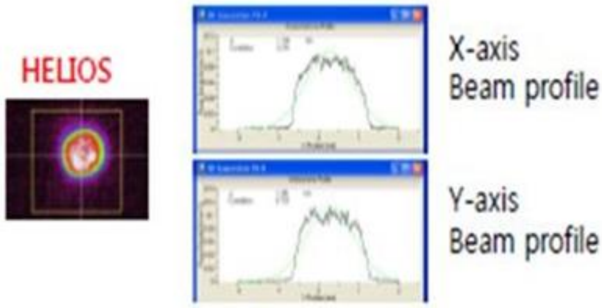


Figure (3.1): *Helios III Nd: YAG laser.*

3.2. Experimental Work

Part A: Treating Skin Pigmentations by photoacoustic shockwave.

Firstly, the skin is cleaned with soap and warm water, then cleansed with an alcohol rub to ensure that the skin is perfectly clean of facial oils, makeup leftovers, and sunblock. A special sunglass was given to the patients to protect their eyes from any reflected laser radiation. For the skin rejuvenation of the face and carbon peel, a special carbon mask is placed over the surface of the face, this helps enhance the absorption of 1064nm radiation and restricts it to the surface of the skin to remove the dead skin as seen in figure (3.2).

Figure (3.2): *Carbon Power Reacted by Laser, Removal of Dead Skin cell.*

The process of carbon peel is illustrated in figure (3.3) below:

Figure (3.3): preparation of the face and laser treatment technique

All the areas to be treated were covered in 3 passes (horizontal, vertical, and diagonal) with 25 to 30% overlapping until the popping sound was no longer heard. The process parameters were chosen by a dermatologist and listed in the table (3-1).

Table (3-1): Carbon peel parameters.

Step	Mode	HP Type	Energy (mJ)	Fluence (J/cm^2)	Number of passes	Endpoint/ interval
1	1064	collimator	500-600	1	1-2	Removed carbon
2	FR	Collimator	1500-2500	3	1-2	Erythema/ Patient starts to feel hot

Part B: Laser Hair Bleaching by Photoacoustic Shockwave

The Helios III Q-switched Nd:YAG laser is a device used for various dermatological treatments, including hair bleaching. This laser system emits high-energy pulses of light at specific wavelengths that can target the melanin pigment in the hair shaft. Here's how the procedure typically works:

The treatment area is cleaned and prepared. Protective eyewear is worn by both the patient and the practitioner to shield the eyes from the laser light. The Helios III laser emits short pulses of high-energy light of 532 nm that are selectively absorbed by the melanin pigment in the hair shaft. This energy heats up the hair, causing the melanin to break down and lighten in color. Unlike traditional hair bleaching methods that may involve multiple steps and chemical agents, the Helios III laser offers a single-step solution for hair bleaching. The laser treatment effectively lightens the color of the hair in a single session. During the procedure, cooling measures such as chilled air or cooling gels may be applied to the skin to minimize discomfort and protect the surrounding tissue.

3.3. Results and Discussion

We present herein the case of two women who complained of oily skin, dilated pores, solar lentigines, and post- inflammatory skin pigmentations.

The patients were treated with the carbon peel laser technique after acquiring informed consent. Before treatment, the patient’s face were washed, and the carbon lotion (carbon pigments; Relive Cosmeceuticals, Dueville, VI, Italy) were applied evenly over the face, except for the upper eyelids, eyebrows, and lips, and allowed to penetrate the skin and hair follicles for 10 minutes. The excess carbon was removed and then the Q- switched to 1064-nm Nd: YAG laser was employed to vaporize the skin surface.

Two sessions of treatments were performed. Clinical pictures were taken before the laser sessions and 42 days after the last laser session with 2 days apart between sessions.

Figure (3.4) shows clinical pictures before and after treatment, showing the improvement in the skin, mainly with a reduction of solar lentigines and skin pore size. No severe adverse events were reported. Only mild erythema after treatment was observed.

Patent A. before **Patient A: After**

Patent B: Before **Patient B: After**

Figure (3.4): *Results after carbon peel process.*

Interestingly, the carbon peel laser technique has been proven to provide a peeling effect, cleaning off the skin surface and the plugged pores, thereby correcting the hyper cornification of follicular epithelium that might block the physiologic outflow of sebum to the skin surface and reducing skin inflammation.

As for the other three patients for hair bleaching. the results were shown in figure (3.5) below. After the procedure, patients experienced some mild redness or irritation in the treated area, which typically resolved within a few hours after the session. The results lasted for mostly two weeks then the old, bleached hair fell off and new dark hair is grown back.

This procedure is considered temporary, but in case of facial hair, it's considered best to bleach the unwanted hair than removing it because using Alexandrite hair removal laser may stimulate fine hair to grow thicker than before. Laser hair bleaching by photoacoustic shockwave is considered very much less aggressive than the chemical bleaching process with little down-time and immediate results.

Patent A: Before **Patient A: After**

Patent B: Before **Patient B: After**

Figure (3.5): *Results after hair bleaching process.*

4.1. Conclusion

The QSNDYL is one of the most resourceful and versatile lasers in dermatology. No other laser provides such a wide spectrum of applications, that too without much downtime. However, complications like recurrence, post-inflammatory hyperpigmentation, mottled hypopigmentation, and ghost shadows still limit its use in various conditions. It is a therapeutic gold standard for tattoo removal, pigmented lesions, hair bleaching and many more of its utilities are either being studied or yet to be discovered. Furthermore, in today's day and age, the proactivity about delaying the natural aging process as well as reversing, what can be reversed, the existent damage has made Q-SNDYL a cosmetologist's ace tool for the treatment of skin pigmentation, photoaging, rhytids, and dullness. Nonetheless, with so many effective anti-aging modalities already present, it also finds its place as a maintenance system. It is a must for cosmetic practice considering its multiple applications.

References

1. W. Koechner and M. Bass, *Solid-state lasers: a graduate text*, 2nd ed. Verlag, New York: Springer, 2003.

2. T. Ruzicka and J. Ocampo-Candiani, *Textbook of Lasers in Dermatology*, First eddi. india: The Health Sciences Publisher, 2016.

3. M. Adamic, A. Troilius, M. Adatto, M. Drosner, and R. Dahmane, "Vascular lasers and IPLS: guidelines for care from the European Society for Laser Dermatology (ESLD).," *J. Cosmet. laser Ther. Off. Publ. Eur. Soc. Laser Dermatology*, vol. 9, no. 2, pp. 113–124, Jun. 2007, doi: 10.1080/14764170701280693.

4. S. Thornton, T. Galloway, and P. Bailin, *Laser treatment of vascular lesions*. 2016.

5. M. Wassef *et al.*, "Vascular Anomalies Classification: Recommendations From the International Society for the Study of Vascular Anomalies.," *Pediatrics*, vol. 136, no. 1, pp. e203-14, Jul. 2015, doi: 10.1542/peds.2014-3673.

6. P. Nymann, L. Hedelund, and M. Haedersdal, "Long-pulsed dye laser vs. intense pulsed light for the treatment of facial telangiectasias: a randomized controlled trial.," *J. Eur. Acad. Dermatol. Venereol.*, vol. 24, no. 2, pp. 143–146, Feb. 2010, doi: 10.1111/j.1468-3083.2009.03357.x.

7. R. Trebino *et al.*, "Highly reliable measurement of ultrashort laser pulses," *J. Appl. Phys.*, vol. 128, no. 17, pp. 0–43, 2020, doi: 10.1063/5.0022552.

8. S. H. Kong, H. S. Suh, and Y. S. Choi, "Treatment of Melasma with pulsed-dye laser and 1,064-nm Q-switched Nd:YAG laser: A split-face study," *Ann. Dermatol.*, vol. 30, no. 1, pp. 1–7, 2018, doi: 10.5021/ad.2018.30.1.1.

9. A. Goel, V. Gatne, and M. Molvi, "QS Nd YAG Laser: Single Technology with Multiple Cosmetic Applications," *Gavin Publ.*, vol. 2016, no. 1, pp. 4–7, 2016.

10. J. Tong, L. Liu, J. Du, Y. Gao, D. Song, and D. Huang, "Effect of photon -induced photoacoustic streaming and shock-wave enhanced emission photoacoustic streaming technique on the removal of the smear layer after root canal preparation in curved root canals," *J. Dent. Sci.*, vol. 18, no. 1, pp. 157–164, 2023, doi: 10.1016/j.jds.2022.06.019.

11. L. A. Trídico and C. R. Antonio, "Quality-switched laser (Q-switched): Review of their variations and main clinical applicabilities," *Surg. Cosmet. Dermatology*, vol. 11, no. 4, pp. 274–279, 2019, doi: 10.5935/scd1984-8773.20191141419.

12. S. C. Jantzi, V. Motto-Ros, F. Trichard, Y. Markushin, N. Melikechi, and A. De Giacomo, "Sample treatment and preparation for laser-induced breakdown spectroscopy," *Spectrochim. Acta - Part B At. Spectrosc.*, vol. 115, pp. 52–63, 2016, doi: 10.1016/j.sab.2015.11.002.

13. S. Parker, "Verifiable CPD paper: Laser-tissue interaction," in *British Dental Journal*, 2007, pp. 73–81. doi: 10.1038/bdj.2007.24.

14. I. Majid and S. Imran, "Depigmentation therapy with Q-switched Nd: YAG laser in universal vitiligo," *J. Cutan. Aesthet. Surg.*, vol. 6, no. 2, p. 93, 2013, doi: 10.4103/0974-2077.112670.

15. G. Olivi *et al.*, "Disinfection efficacy of photon-induced photoacoustic streaming on root canals infected with Enterococcus faecalis: An ex vivo study," *J. Am. Dent. Assoc.*, vol. 145, no. 8, pp. 843–848, 2014, doi: 10.14219/jada.2014.46.

16. R. O. Esenaliev, A. A. Oraevsky, V. S. Letokhov, A. A. Karabutov, and T. V. Malinsky, "Studies of acoustical and shock waves in the pulsed laser ablation of biotissue," *Lasers Surg. Med.*, vol. 13, no. 4, pp. 470–484, 1993, doi: 10.1002/lsm.1900130412.

17. A. Salem, M. El Harras, A. Ramadan, H. Gamil, A. Abdul Rahman, and K. El-Said, "Use of the Q-switched Nd:YAG laser for the treatment of pigmentary disorders in Egyptians," *J. Cosmet. Laser Ther.*, vol. 12, no. 2, pp. 92–100, 2010, doi: 10.3109/14764171003706109.

18. J. A. Shaik and R. K. Reddy, "Review Article Prevention and Treatment of White Spot Lesions in Orthodontic Patients," *Contemp. Clin. Dent.*, vol. 8, no. September, pp. 11–9, 2017, doi: 10.4103/ccd.ccd.

19. G. Cannarozzo *et al.*, "Q-Switched Nd:YAG Laser to Manage Hyperpigmentation in Asians: A Multicenter Study," *Cosmetics*, vol. 10, no. 2, 2023, doi: 10.3390/cosmetics10020044.

20. X. Chen, R. Q. Xu, J. P. Chen, Z. H. Shen, L. Jian, and X. W. Ni, "Shock-wave propagation and cavitation bubble oscillation by Nd:YAG laser ablation of a metal in water," *Appl. Opt.*, vol. 43, no. 16, pp. 3251–3257, 2004, doi: 10.1364/AO.43.003251.