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Efficacy of Laser Hair Removal According to Skin color

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DEDICATION

This effort i dedicate to allah almighty , my lord , my powerful foundation , my source of inspiration wisdom, knowledge , and understanding . Throughout this project, he was the source of my energy.

ACKNOWLEDGMENTS

I begin with , thanks (allah) for his blessing and for his health that give it to me , which made me able to complete and perform this study with success .the lord of universe , blessing and peace be on **muhammad** (allah's peace and prayers be upon him) I also thank myself to complete this research in time under a high pressure that we have in our life's with this bad period . Finally , i want to say thank to my supervisor , **Dr.Dilshad Salih Ismael** for his help in this research . And all those i forget them here to mention his/her name , who assisted me even by our useful scientific word directly or indirectly .

Abstract

This review article deals with hair removal by laser, for long-term results and has become the leading therapy choice. With the increase in demand, the regulation of these treatments has increased. for them, in the present study, the relation between skin color and the type of lasers are used when treating it. The wavelength of the lasers used to destroy the hair follicles it's in the range of 600 to 1100 nm, and the possibility of complications harmful to the skin decreases by increasing the accuracy of the laser energy delivery to the hair follicles. therefore, the lasers technology used for this purpose are specierfic and the most appropriate types of lasers to be used is the Pulsed Diode for skin phototypes light brown, brown, and black, Nd:Yag for brown and black skin, Alexandrite for plane white, white, cream white, and light brown skin and Ruby for plane white, white and cream white skins, which are a little more particular when it comes to heating the melanin that helps to eliminate the hair follicles. There is no harmful technology, but it is more important to understand the skin and also understand the technology behind a laser, so it is known how this skin can respond and what to do with the laser. If it is financially feasible, it will be easy to deal with all types of skins in terms of color by using different types of lasers according to the type of cases.

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Chapter one

1-1- Introduction

The word Laser is an acronym standing for “Light amplification by stimulated emission of radiation”. Over last few decades also presently it is being used in different directions such as medicalsciences[1],Lasers are within the range of (10-5 to 10-8) meters under the electromagnetic spectrum, including infrared, visible light, and ultraviolet (UV) radiation. There are many applications of laser in different fields, including medicine, especially in photodynamic therapy [2, 3].For several years, temporary hair removal treatment solutions have been used and are still being used, such as waxing, threading, tweezing,and depilatory creams.While these strategies are relatively cheap,simple,and readily available,the effects are short-lived and require frequent repetitivetherapy[4].The first laser was developed by Theodore H. Maiman, a physicist, in Malibu in 1960, using a synthetic ruby cylinder. Then In 1963, Leon Goldman was the first to use the laser in dermatology, also known as the "father of lasers in medicine. After that Mester discovered the beneficial effects of low-energy red lasers on hair growth in rats in 1966 [5] The first laser-assisted hair removal device was cleared in 1995, more than 15 laser systems have been approved by the Food and Drug Administration (FDA) to specifically target hair follicles [6] Currently, permanent hair removal can be done by electrolysis and light-based procedures, for this reason, lasers have been used by dermatologists as a good tool for hair removal based on light treatment. Laser hair removal (LHR) techniques are currently the most frequently requested cosmetic procedure in the world, particularly for female customers [4, 7]. Several types of lasers, which are based on the light treatment, are available for hair removal and they are effective for different types of skins, such as, ruby lasers (694 nm) for fair skin types, alexandrite lasers (755 nm) for lighter skin types, Nd:YAG (1064 nm) for darker skin types and diode lasers (800-810 nm) for all skin types I-VI. Since all these lasers operate by using selective photothermolysis [4,6,7,8,9], the Fitzpatrick scale is known as the human skin color classification (I to VI) and is used to estimate the response of different skin types to light exposure. However, it is a challenging job to customize these devices according to the patient's skin and hair condition, to improve outcomes and minimize adverse effects. Laser hair removal is also a slow process that requires at least six to eight months to remove the hair [8, 9].Pulse width, spot size, and fluence are the important parameters that should be taken into account during laser hair removal treatments. Inside the hair shaft, the pulse width is a particular amount of energy required to heat the tissue and heat the melanin in such a way that the hair is destroyed. A larger spot size creates more

energy dispersion or distribution. Fluence is the amount of energy that we are delivering per treated area, in joules per square cm. So fluence is the same as Energy Density[10]. On the other hand, the color of the skin and hair color affect the effectiveness of laser hair removal. Laser beam penetration into 1 human skin for hair removal is highly dependent on the skin's optical properties.The absorption coefficient of the epidermis varies according to the amount of the melanosome fraction and the concentration of melanin in the epidermis.The light absorption and dispersion in the skin layers decide the rate of fluency of the light reaching the intended treatment site to successfully destroy the target [7].

Chapter Tow

2-1-Structure and morphology of human hair

Human hair is mainly composed of fibrous a-keratin proteins. Hair fibres are not continuous in their full length, but rather result from compact groups of cells within the fibre follicle, from which three further basic morphological components of hair structure originate: the multicellular cuticle sheath, the fibrous cortex and the medulla .At the follicular level, a single layer of cells gives rise to the cuticle, a pro- tective layer covering the core of the fibres. It is mainly composed of b-keratins and displays a scaled structure, possessing between seven and ten superimposed layers with the cuticle edges pointing toward the tip of the fibre.The outer surface of the culticle's scale cells is coated by a thin membrane called the epi- cuticle, which covers the cysteine-rich exocuticle, a constituent that contains most of the cysteine residues present in the scales . Finally, there is the endocuticle, which is located at the interface of the cortex and is mainly composed of the remaining cell organelles. Endocuticle consists of proteins that, unlike those found in other parts of the hair fibre, have very low sulphur content; thus, it is poor in cysteine, which causes the endocuticle of the scales to swell considerably more in water than the cysteine-rich exocuticle. This might explain the pronounced pro- jection of the scales and the tendency for wool felting in the presence of water The matrix proteins that surround the Ifs through intermolecular disulfide bonds act as a disulfide crosslinker holding the cortical superstructure together and conferring high mechanical strength, inertness and rigidity to keratin fibres. High sulphur proteins, ultra-high sulphur proteins and high glycine-tyrosine proteins are present in matrix proteins (c-keratins), depending on their cysteine, tyrosine and glycine content Apart from albinos, all normal humans have melanin hair pigmentation, whatever the colour. Dispersed throughout the structure of the cortex in granular form are the melanin pigment particles. The number, chemical characteristics and distribution pattern of these cells determine the colour of the hair . Hair is an important feature of mammalians, where hair shafts fulfill a number of different functions such as thermoregulation, collection of sensory information, protection against environmental trauma, social communication and camouflage. Each of us displays an estimated total number of 5 million hair follicles (HF), of which 80,000–150,000 are located on the scalp The hair growth cycle describes the changing histological morphology of the shaft and of the follicle over time. Starting with anagen (rapid growth and hair shaft elongation), the follicle and its shaft progress through catagen (involution and apoptosis-driven regression), telogen (resting) and finally exogen (shedding) Human hair is usually

categorised ethnically into three major distinct groups: Asian, Caucasian and African. Looking from the perspective of biological vari- ability, environmental effects and diversity of fibre texture, it is remarkable how uniformly the amino acid makeup of protein components is across ethnic groups. The amino acid makeup of the protein components was reviewed by Wolfram and is depicted in Fig. 2.1 .[11]

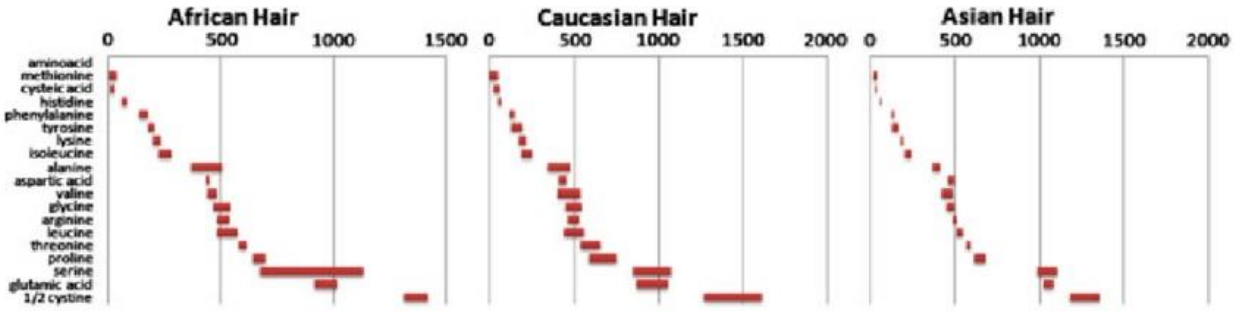


Fig2.1: amino acid content of human hair of diverse ethnic origins (µM/g) (adapted from [11])

Human hair grows in a cyclic pattern. The cycle consists of a growth or anagen phase followed by intermediate degradation of a portion of the follicle, known as the catagen phase and then by a resting period when no growth occurs – the telogen phase.7 Figure 2.2 describes the three phases of the hair growth cycle. It appears that different areas of the body, in addition to having shorter anage cycles, have varying percentages of hairs actually in the anagen phase.[12]

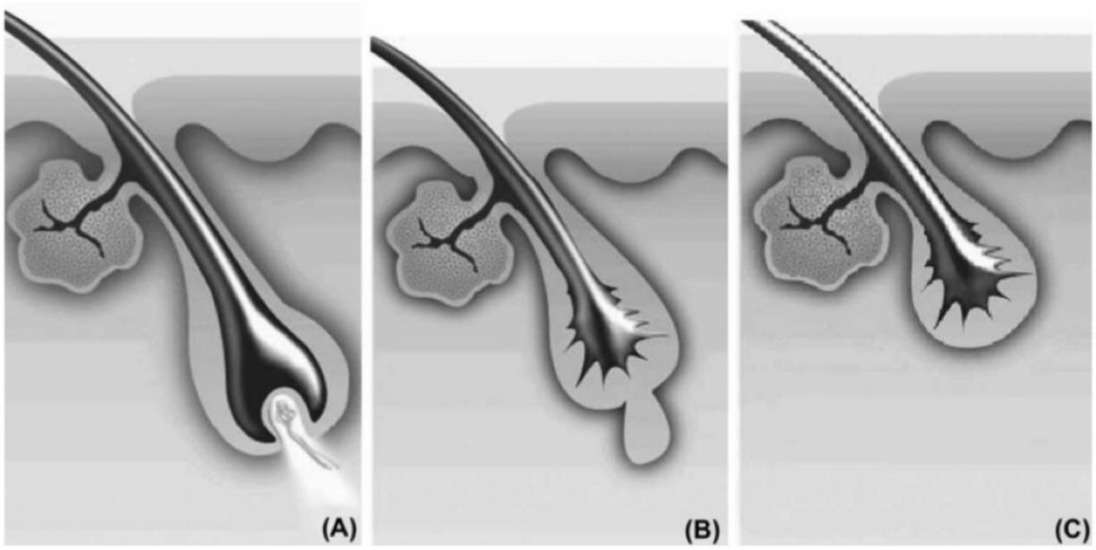


Figure 2.2
Hair follicle cycle. (A) ***Anagen phase****: hair matrix cells migrate outward from the shaft and the melanin load is at its highest. (B)* ***Catagen phase****: the follicle detaches from the papillae and contracts – eventually falling out. (C)* ***Telogen phase****: mitosis ceases, the hair matrix regresses and the papilla retracts to a place near the bulge (apoptosis).*

The methods of treatment of unwanted body hair fall into three broad categories: control of unwanted hair growth (hor-monal treatment); temporary alleviation of hair (physical meth-ods of hair removal); and permanent/curative hair removal (elec-trosurgical and laser-assisted hair removal). Hormonal treatment has many physiologic adverse effects, it can feminise male fetuses and its long-term tolerability is unknown. Although electrosurgi-cal epilation has, until the introduction of laser hair removal, been the only available method of reputed long-term hair removal, the efficacy of this method is absolutely dependent on correct tech- nique.[13] Nevertheless, even after correct application of this tech-nique, re-growth of the hair has been reported to be as high as 50%.[14] In addition, electrosurgical epilation is an extremely la-bor-intensive technique, with each hair follicle requiring separate and often repeated treatment. The adverse effects of this tech-nique include significant discomfort and a small but definite risk of punctate scarring, inflammation and post-inflammatory changes in skin color. Direct comparisons between electrolysis and alexandrite lasers have shown that laser-assisted hair removal is superior to electrolysis, achieving 74% hair clearance com-pared with 35%, achieved by electrolysis at 4 months after last treatment.[15]

2-2 Structure and function of the skin

Located on the outermost layer covering a living body, skin is an organ which protects the underling body from external environment such as shocks, temperature, ultraviolet radiation, chemicals and other threats. The skin is composed of three layers, listing from the outside, which are the epidermis, the dermis, and the subcutaneous fat tissues 1). The epidermis is the outermost layer of the skin with a thickness of 0.2 mm on average. The epidermis can be further subdivided into four layers, beginning with the outermost layer; stratum corneum, granular cell layer, prickle cell layer and basal cell layer (Fig. 2.3). The stratum corneum, which is the outermost layer of the epidermis, has multifarious functions to repel water, acts as a barrier against bacterial and viral intrusion, and protects internal organs such as muscles, nerves, blood vessels and others from external injuries. Therefore, the stratum corneum plays the most important role to sustain the organism**.** Keratinocyte accounts for 95% of the cells that constitute the epidermis. Epidermal turnover time is the time taken for the epidermis to replace itself. Keratinocytes are divided and proliferated in the undermost layer, matured, and then migrate to the surface. Through the cell division in the basal cell layer, to the division of daughter cells and shedding from the surface of the epidermis, the turnover time is

approximately 40to56days The stratum corneum, losing their nucleus, constitutes approximately ten layers of a network and exfoliates sequentially as scurf. The stratum corneum is composed of keratin and lipids produced by keratinocytes.The keratinocytes are proliferated in the basal cell layer, produce keratin, differentiate, mature, and migrate to the upper layer. Keratin 5 and keratin 14 are formed in the basal cell layer and keratin 1 and keratin 10 are formed in the prickle cell layer and the granular cell layer. Inside the epidermis,the following exists: melanocytes,

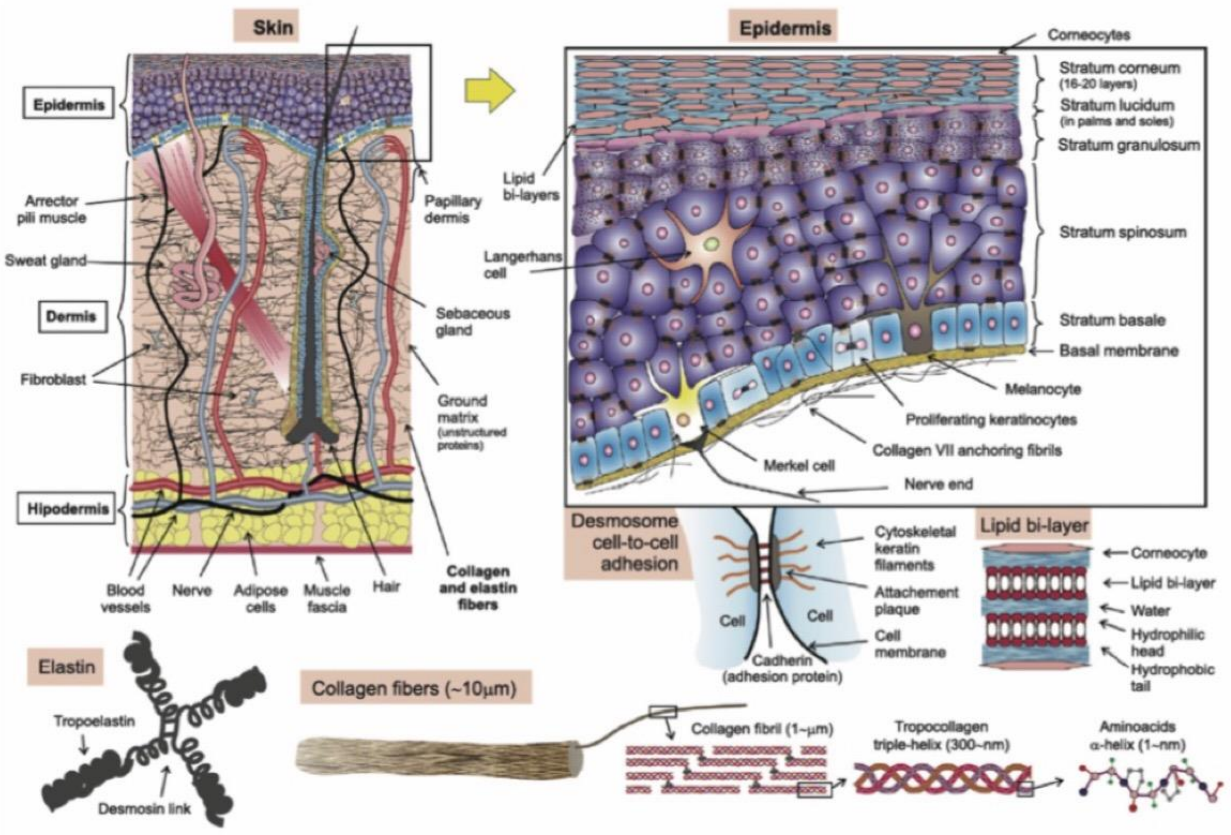


Fig 2.3 **Structures of the skin.**
The figure is adapted from adapted from Reference [1].

which are responsible for dark skin color, Langerhans cells, which are related to the immune function of the skin, and Merkel cells, which are sensory recipient cells.The dermis tissues with a thickness of 2.0-3.0 mm, are located under the epidermis and separated by the epidermis and the basement membrane. Anatomically the dermis has a three-layer structure consisting of the papillary layer, subpapillary layer and the reticular layer. The dermis provides elasticity and strength to the skin. Substances that composes the dermis are interstitial components (extracellular matrix), which compose fibrous tissues, and its productive cells. The main component of extracellular matrix is collagen fiber (mainly type I collagen and type III collagen). Other components are elastic fiber

(elastin fiber), proteoglycan (hyaluronic acid, chondroitin sulfate and others) and others. Collagen accounts for 70% of the dry weight of the dermis and provides firmness to the skin. Elastin fiber with a crosslinked structure accounts for 1-2% and provides elasticity to the skin. Proteoglycan forms colloidal gel holding abundant water and provides moisture to the skin. Inside the dermis, sensory nerve endings sense feelings, comfortability and temperature. Further, the dermis has hair follicles (folliculus pili), blood vessels and secretory glands (sweat glands and sebaceous glands), controlling body temperature, providing moisture to the skin and maintaining a resilient condition. Subcutaneous tissues are a fatty layer with a thickness of several mm located under the dermis. The thickness of the layer is different, depending on which part of the body it is located. The functions of the subcutaneous fat tissue are to protect the body from the heat or the cold of outside air and to absorb a shock as cushioning. Furthermore, it plays the role of energy storage, where fat is stored in adipose cells of the subcutaneous tissues.[16]

2-3 Important parameters in laser treating

2-3-1 Power

The more power laser can generate the more flexi-bility the designer has . these arw pulsed laser.the power is measured in joules. The maximum power of the laser is the maximum amount of energy(measure in joules) it can deliver in one pulse.[17,18,19] the total energy (in joules) the laser can deliver in one pulse divided by the surface area it is delivered upon (spot size) determines the fluence that is measured (in J/cm2). The same laser can diliver very high fluences with a small spot size or lower fluences with a larger spot size.[20]

2-3-2-Spot size

The spot size is important for two reasonse.First ease and speed of use. Whith larger spot size it is ease to avoid overlapping, and at equal repetitive ratese (Hz=pulses/sec),larger surface areas will be covered faster. Second, due to beam is scatter properties, a larger spot size can deliver much higher(effective fluences) at the depth of the target tissue. Working with a larger spot size, we can deliver a mucn greater percentage of the laser is skin of surface measured fluence to the depth of the target than using a smoller spot size.[21,22] for the 775nm alexandrite laser a spot size of the at least 12mm (>110mm2) appears to be needed and at least 10mm (>80mm2) for the 800-810nm diode laser.[21]

2-3-3 Pulse width

The pulse width is the amount of time(in milliseconds) over wich the total energy (is joules) contained in one pulse is delivered to the surface of the skin. In other words, the energy in one pulse can be dumped on the spot size very fast or it can be poured slowly. Pulse width takes advantage of the principle of thermal relaxation time(TRT)[19,23] very small structures, such as melanosomes present in the epidermis, can dissipate heat very quickly, and if heated slowly enough, they can dissipate the heat fast enough to avoid thermal damage. larger hair structures, such as hair follicles(especially the coarser/thicker hair follicles), dissipate heat slower. Thus if a pulse width longer than the TRT of ather skin structure, but shorter than the TRT of hair follicles is selected, hair follicles will be heated beyond the thermall damage threshold, while the surrounding tissues, especially the epidermis, wont.[19] But if the pulse width is too iong, thinner and ligher hairs may not be affected.[20]

2-3-4 -fluence

Fluence is the amount of energy, in joules per square cm, that we deliver per treated area. Fluence is also the same as energy density [24].For hair follicle coagulation, the required energy density (i.e. fluence) is proportional to the diameter of the hair shaft, as long as the bulb and follicle thickness is proportionate to the diameter of the hair shaft; the thinner the hair, the lower the amount of energy density. In general, for tissue destruction, the laser fluence should be greater than or equal to the threshold fluence [6]. When the dermal-epidermal junction is broken, a burn occurs, so epidermal cooling is important. When the dermal-epidermal junction remains intact, a burn will never occur. Cooling devices exist, but most lasers have a cooling system built into the handpiece itself [10].

2-4 Common types of lasers for hair removal

2-4-1-Ruby laser

Ruby ,694 nm,was the first such laser for hair reduction. It was quite effective, but had many complications such as burns and pigmentary changes, hence its not favoured in treating ethnic skin[25] Pain, blistering, crusting, erosions, purpura, thrombophlebitis, hyperpigmentation, hypopig- mentation, scarring (higher incidence of pig- mentary alterations and scarring with darker skin types)[26]

2-4-2-Nd:YAG laser

The Nd:YAG The Nd:YAG has got the longest wavelength, but the melanin absorption is less, making it very safe on darker skin types. Low melanin absorption means it can be used safely with high energy and the penetration is comparatively less, but more energy can be used.It is safer, but we require more number of sittings and still Diode is preffered as Gold standard for Laser hair removal and also for ethnic skin[25] Purpura, folliculitis, pain, rarely hyperpigmenta- tion and hypopigmentation (safer for darker skin types.[26]

2-4-3-Intence pulse light (IPL)

In contrast to laser light, which is monochromatic (produces a single wavelength or narrow band of wavelengths) and has high power density and minimal coherence (divergence), the IPL device uses a xenon polychromatic broadband flashlamp with optical filters to generate noncoherent light beams in the visible to infrared spectrum (500–1,200 nm). Based on the type of cut-off filters used, an IPL device emits a defined range of wavelengths to reach the desired depth of the target structures. Similar to lasers, IPL technology is based on the principle of selective photothermolysis. Because of its ability to emit a spectrum of wavelengths, a single light exposure can excite multiple chromophores in the skin (hemoglobin, water, and melanin) at one time.Thus, in the hands of an inexperienced physician or nonmedical personnel, complications from nonspe-cific thermal damage could easily ensue.Advantages and disadvantages arise from the dis-tinct differences in technical qualities and operation between an IPL device and a laser. An advantage of IPL is its lower cost. In addition, the large spot size of an IPL device makes it easy to treat large surface areas such as the back, chest, and legs. Treatment duration for a given area is shorter than for a smaller spot size. A disadvantage is the heavy weight of the IPL handpiece, which houses the lamp and lamp-cooling device. This can be bulky and somewhat difficult to maneuver. When using the device, an optical coupling gel application and direct skin contact with the handpiece is required, hindering visualization of the immediate local reaction. Fur-thermore, the immediate inducible perifollicular edema and erythema seen with lasers is infrequentlyencountered with the IPL, which makes it difficult to accurately place the next pulse immediately adjacent to the previous pulse and may inadvertently cause patches of skin to be left untreated. Finally, IPLdevices have been shown to emit inconsistent fluence and wavelengths from pulse to pulse, making clinical results unpredictable.46 The

mechanism of generat-ing light and the range of wavelengths emitted from the IPL is inherently different from that of lasers, conferring a distinct set of advantages and disad-vantages. The low wavelengths emitted in the spectrum of light from an IPL device can disadvan- tageously target epidermal melanin, so IPL devices with a light range that starts in the lower wavelength range are not recommended for darker skin.[27]

2-4-4 alexandrite laser

In 1997, Finkel and colleagues first reported effective hair removal on the face, arms, legs, and bikini lin with the long-pulse 755-nm alexandrite laser.16 Long-term efficacy for the long-pulsed alexandrite laser ranges from 65% to 80.6%.17,18 Equivalent hair removal for up to 6 months can be achieved using the alexandrite laser with pulse durations of 5, 10, and 20 ms.19 Noninferiority studies demonstrate equiv- alent efficacy of the alexandrite laser and other similar laser devices. Bouzari and colleagues did not find any significant difference in efficacy between the alexandrite and diode lasers when treating patients with skin types I to V.20 Similarly, Handrick and Alster found equivalent clinical and histologic responses using a long-pulse alexandrite and long-pulse diode laser in treating skin types I to IV, although the diode had more side effects than the alexandrite laser.21 Treating patients with skin types I to IV sequentially with the diode followed by alexandrite laser did not produce greater mean hair reduction than an equivalent number of treatments with the alexandrite laser alone, although the former was associated with more side effects of folliculitis, erythema, and blistering.22 The long-pulse alexan-drite laser and long-pulse diode laser have been shown to have similar efficacy whether used indi-vidually or sequentially when treating skin types I to IV. Because the alexandrite laser is capable of shorter pulse durations than the diode laser, the alexandrite laser may be better suited for treating fine vellus hairs. The long- and short-pulse alexandrite lasers show no statistically significant difference from IPL in efficacy in skin types II to IV. Transient side effects including erythema, edema, and paradoxical hair growth were greatest with the long-pulse alexandrite and least with the IPL system.23 In summary, the alexandrite laser effectively removes hair with results compara-ble with those of the diode laser and IPL devices. We suggest using the alexandrite laser on skin types I to III because of the paucity of competing epidermal melanin and low risk of laser induced dyspigmentation or burns.[27]

2-4-5-diode laser

The hair count reduction reported with the long-pulse 810-nm diode laser ranges from 22% to59%.15,24–28 In skin treated with the diode laser,histologic analysis showed a statistically significant reduction in hair density and thickness.29 Lasers with longer wavelengths such as the diode and the 1,064-nm Nd:YAG lasers are preferred when treating darker skin types because they result in fewer side effects such as pain and postinflam-matory hyperpigmentation than lasers with shorter wavelengths. Longer wavelengths induce less epidermal melanin absorption. Efficacy of hair removal between the diode and the Nd:YAG lasers is inconsistent among studies. Li and colleagues showed greater hair removal efficacy using the diode laser (78.6%) than with the long-pulse Nd:YAG laser (64.5%),31 whereas Chan and colleagues did not find a difference.30 The diode laser was less painful than the Nd:YAG when treating Asian skin.30–32 Most studies have found few and transient side effects using the diode laser to treat patients with skin types III to V. Studies using the diode laser have recently suggeste a shift away from the criterion standard high-fluence devices in favor of a low-fluence (5–15 J/cm2)approach. The latter provides comparable hair reduction, less discomfort, and fewer adverse effects even when treating phototype V skin and tanned individuals.33–39 The most common side effects were slight and transient erythema and pigmentary changes. No long-term adverse effects were noted. The mechanism of hair removal using low-fluence devices may be through an induction of hair mini-aturization of coarse terminal hairs. In contrast to photodestruction of stem cells using the conven-tional technique, low-fluence lasers may also trigger photomodulation of germinative cells, leading to altered hair growth.13 Individuals with skin photo-types III to V can be effectively and safely treated at low fluence (5-15 J/cm2) using the diode laser.[27]

2-5-Electromagnetic waves

Electromagnetic waves are non- mechanical waves which move with speed equals to the speed of light (in vacuum). It is a transverse wave. In the following subsections, we discuss the production of electromagnetic waves and its properties, sources of electromagnetic waves and also classification of electromagnetic spectrum.[28]

2-5-1 Properties of electromagnetic waves

1. Electromagnetic waves are produced by any accelerated charge.

2. Electromagnetic waves do not require any medium for propagation. So electromagnetic wave is a non- mechanical wave.

3-Electromagnetic waves are transverse in nature. This means that the oscillating electric field vector, oscillating magnetic field vector and propagation vector (gives direction of propagation) are mutually perpendicular to each other. The electric and magnetic fields are in the y and z directions respectively and the direction of propagation is along x direction. This is shown in Figure 2.4

4-Electromagnetic waves travel with speed which is equal to the speed of light in vacuum or free space, c=$\frac{1}{\sqrt{\varepsilon^\circ \mu^\circ}} = 3 * 10^8 ms^{-1}$,

Where ε° is the permittivity of free space or vacuum and μo is the permeability of free space or vacuum (refer Unit 1 for permittivity and Unit 3 for permeability).

5-In a medium with permittivity ε and permeability μ, the speed of electromagnetic wave is less than speed in free space or vacuum, that is, v < c. In a medium of refractive index,

$\mu = \frac{c}{v} = \frac{\frac{1}{\sqrt{\varepsilon^\circ \mu^\circ}}}{\frac{1}{\sqrt{\varepsilon \mu}}} \rightarrow \mu = \sqrt{\varepsilon r \, \mu r}$, wher εr is the relative permittivity of the medium (also known as dielectric constant) and μr is the relative permeability of the medium.

6- Electromagnetic waves are not deflected by electric field or magnetic field.

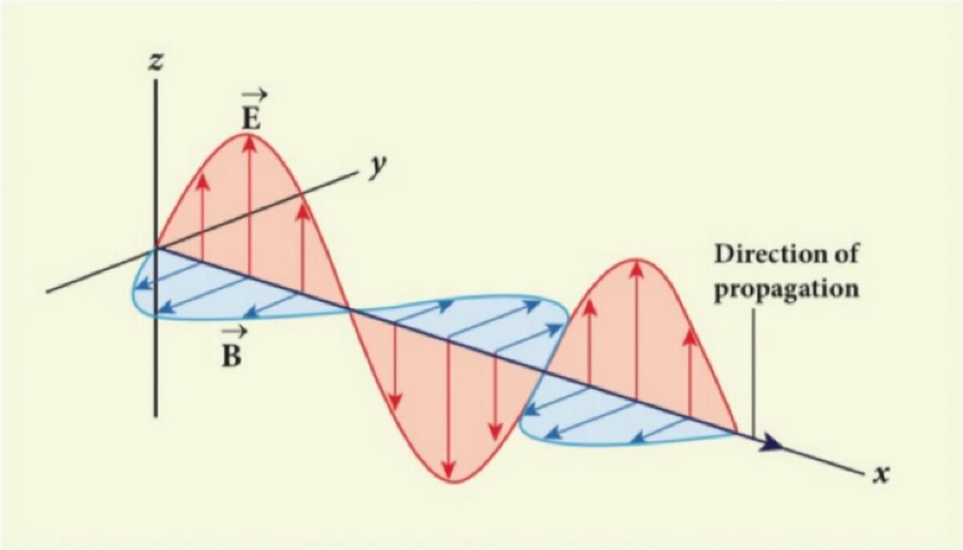


Figure 2.4 Electromagnetic waves – transverse wave

7-Electromagnetic waves can show interference, diffraction and can also be polarized.

8-If the electromagnetic wave incident on a material surface is completely absorbed, then the energy delivered is U and momentum imparted on the

surface is p=$\frac{U}{c}$.

9-Electromagnetic waves carries not only energy and momentum but also angular momentum.

10-If the incident electromagnetic wave of energy U is totally reflected from the surface, then the momentum delivered to the surface is $\Delta p = \frac{U}{c} - \left(-\frac{U}{c}\right) = 2\frac{U}{c}$.[28]

Chapter three

3-1-Mechanism of laser hair removal (LHR)

The theory of selective photothermolysis enables one to selectively target pigmented hair follicles by using the melanin of the hair shaft as a chro- mophore However, to achieve permanent hair removal, the biological “target” is likely the follicular stem cells located in the bulge region and/or dermal papilla. Based on the slight spatial separation of the chromophore and desired target, an extended theory of selective photothermolysis was proposed which requires diffusion of heat from the chro- mophore to the desired target for destruction This requires a laser pulse duration that is longer in duration than if the actual chromophore and desired target were identical. Temporary LHR can result when the follicular stem cells are not com- pletely destroyed, primarily through induction of a catagen-like state in pigmented hair follicles. Tem- porary LHR is much easier to achieve than perma- nent removal, using lower fluences. Long-term hair removal depends on hair color, skin color, and tol- erated fluence. Roughly 15–30% long-term hair loss may be observed with each treatment when optimal treatment parameters are used A list of laser and light devices that are commercially available at the time of this publication for hair removal[29] For hair removal, the lasers work on three layers of skin, including the stratum corneum, epidermis, and dermis [2], see Figure (5). The stratum corneum, a 0.01 mm-thick top layer containing primarily keratin and dead cells, is the first layer. The epidermis, a 0.0875 mm- thick layer that mainly contains living cells, is the second layer. This layer includes a portion of chromophore and melanin on the side of predominantly living cells. The third layer is the dermis, a 1.8 mm thick layer that primarily includes oxyhemoglobin and deoxyhemoglobin [7,30]. In general, the hair follicle, which locates between the epidermis and dermis, consists of three regions: the infundibulum, isthmus, and hair bulb, hair follicle. Laser hair removal is a multifactorial process that involves complex photothermal reaction via the epidermis– dermis. The chromophore is located inside the hair bulb and the hair shaft is melanin, see Figure (3.1). In the case of removing hair by laser, a high-intensity pulsed laser beam is guided at the target during laser hair removal. The emitted light is mainly absorbed in the hair by melanin which turns the light energy into intense energy of heat that diffuses into the hair follicle and kills it. Although stem cells located in the hair bulge do not contain melanin, the diffusion of heat energy from the hair follicle also targets and removes thermal damage. This harm to the stem cells prevents potential regrowth of hair [18]

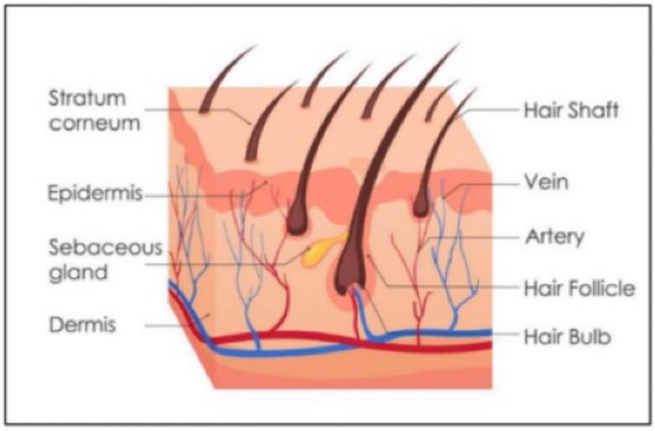


Figure 3.1 Model specifying skin layers, parameters of the hair when using lasers.

Laser hair removal depends on three main parameters. Right wavelength selection up to approximately 1100-1200 nm in the recommended visible to near-infrared (NIR) region; pulse duration (in milliseconds, ms); and which is related to the total exposure time [18]. Energy is calculated in joules and refers to the number of photons delivered (J). Power is expressed in watts (W) and corresponds to the energy rate of delivery (1W=1 J/s). Fluence is the total energy density delivered per unit area and is measured in (joules per square centimeter J/cm2). Pulse duration is the amount of time laser energy is applied (nanosecond ns, millisecond ms). The pulse frequency is measured in hertz (1 Hz=1 pulse/s). Wavelength is measured in nanometers (nm) and refers to the distance between the peaks of the light waves and is used to characterize the type of light [6].

3-2-Appropriate laser systems to treat darker skin types safely

Laser light must pass through the pigmented epidermis to treat the dermal hair target. The main challenge in treating pigmented skin is that the melanin in the epidermis competes as a chro- mophore for the laser light The light is absorbed within the pigmented epidermis and is converted to heat, which can lead to epidermal blistering, dyspigmentation, and scarring. Epidermal melanin absorption of laser light causes less light to reach its intended chromophore. However, utilizing longer wavelengths, longer pulse durations and more efficient cooling devices, the laser surgeon can safely and effectively treat darker skin types. By manipulating laser parameters, new genera- tion laser hair removal devices can provide the safety necessary to effectively treat darker ethnic skin. The absorption spectrum of melanin is in the range of 250–1200 nm. The absorption of melanin decreases as wavelength increases. Also with longer wavelengths, there is a greater depth of penetra- tion and less superficial chromophore absorption. Thereby, longer wavelengths make i Longer pulse durations allow for more efficient cooling of the epidermis. The more slowly the light energy is deposited into the skin, the slower the epidermis heats, making cooling of the skin more efficient. The main cause for laser-induced side-effects is epidermal thermal damaget possible to treat patients with darker skin. If heat can be effectively removed from the epidermis, the risk for thermal-damage-induced epidermal side-effects is minimal. Longer pulse durations are also safer for darker skin types based on the theory of thermokinetic selectivity. The theory states that smaller structures (e.g., epidermal mela- nin) will lose heat quicker than larger structures (dermal hair follicles). The quicker dissipation of heat of the epidermal melanocytes in comparison to the larger hair follicle serves as a protective mechanism for the epidermis In addition to longer pulse durations which help to protect pigmented skin, inherent laser cooling devices are imperative to minimize thermal damage in the pigmented epidermis. Cooling devices cool the skin either by direct contact of a cooling plate or by noncontact cooling by emitting cooled spray, air or gas. Caution must be employed with overzealous cooling devices on pigmented skin. Excessive cooling can produce unwanted side- effects including blistering and dyspigmentation. In terms of safety, the lasers of choice for hair removal on darker ethnic skin are systems which combine longer wavelengths, longer pulse dura- tions and efficient cooling devices. The two wave- lengths which can safely be used for laser hair removal on darker skin types are the diode (810 nm) or Nd:YAG (1064 nm). Of these options, the longer- wavelength laser (Nd:YAG) is the safest type to treat darker

ethnic skin (6), but in terms of efficacy, the shorter-wavelength lasers (diode) are probably more effective, because of their higher melanin absorp- tion value. The FDA (Food and Drug Administra- tion) has approved both the long pulsed diode and Nd:YAG laser systems for laser-assisted hair removal in darker phototypes.[31]

3-3-Benefit of laser hair removal

There are many benefits of laser hair removal, and this method is superior to other traditional methods despite its high cost. Among these benefits are [21] [22] 1.Efficiency: as the laser is considered one of the most efficient hair removal methods, and its effect lasts in the long term.

2.Speed: The laser permanently removes hair in a relatively short time, according to the area undergoing treatment.

3.Simple pain: removing hair with a laser is less painful than removing it with wax or thread, and the skin is treated with an anesthetic cream before treatment because it may lead to feeling By simple stinging with each pulse of the laser.

3.Skin smoothing: Removing unwanted hair with a laser softens the skin and increases its beauty, and the laser is safe for sensitive areas such as around the mouth and eyes.

4.Rarity of side effects: Side effects of removing unwanted hair Laser is rare and not permanent.

3-4-Damages of laser hair removal

The laser hair removal is a safe option, but it can cause some damages, including.[22]Burns in the skin due to exposure to the heat released by the laser, especially on brown skin because it absorbs heat more Damage to eyes, so protect eyes during treatment. Skin redness and swelling around hair follicles after treatment for a few days. Feeling of pain, tingling and numbness in the areas treated with the laser. Peeling skin, bruising, especially on sensitive skin, usually fades soon after treatment. A change in the color of the skin to a purple color in the areas that were exposed to the laser, which is very rare.

Chapter four

Discussion

Lasers are now used in various fields in our lives, especially in cosmic clinics in medicine, so many articles were focused on lasers and their application in this area, particularly in hair removal [34]In a research performed by Atta-Mobtte and Załęska (2016-2019) from Poland and the United Kingdom on citizens of different racial backgrounds (Asian 29, black 25, mixed 34 and white 127) using diode lasers of 805 nm wavelength, 2100 W minimum peak power and 15 to 400 ms pulse duration and 10 to 100 J/cm2 pulse energy density for all treatments. The outcome revealed that the incidence of sensitivity depended statistically significantlyon ethnicity. The incidence of hyperpigmentation is statistically significantly dependent on race,as well as the rate of burns was statistically strongly dependent on ethnicity, while race did not have a major effect on the prevalence of erythema, as shown in Table (4.1).

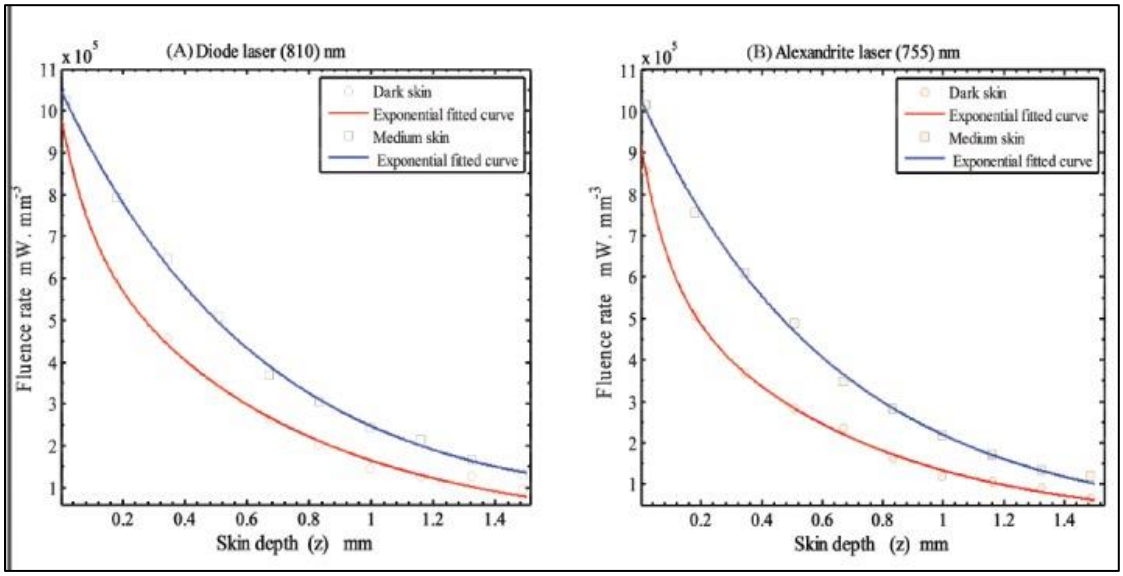
Table (4.1): The occurrence of side effects and ethnicity.

Ethnicity	Types of Side Effects			
	Sensitivity	Erythema	Hyperpigmentation	Burns
Asian (n=29)	5 17.24%	2 6.90%	3 10.34%	3 10.34%
Black (n=25)	12 48.00%	0 0.00%	7 28.00%	9 36.00%
Mixed (n=34)	17 50.00%	4 11.76%	11 32.35%	10 29.41%
White (n=127)	30 23.62%	15 11.81%	0 0.00%	13 10.24%
Significance of differences	$P=0.002$	NS	$P<0.001$	$P=0.001$

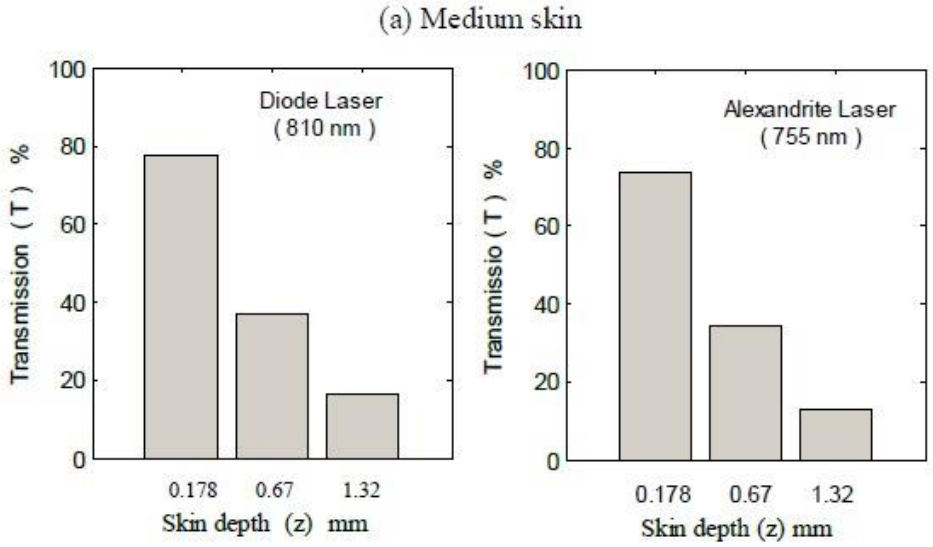
The study also showed that following the diode laser hair removal treatment, the side effects occurred in the pubic region. The groups of Black and Mixed-race respondents had several side effects much more often compared to the White and Asian survey groups, Sensitivity,erythema, and burns were observed as side effects. Erythema alone

did not 8have a statistical correlation with ethnicity among all the side effects observed, however, it was not observed in the black participant population, and hyperpigmentation was not found among white participants [33]. This phenomenon maybe refers to the long wavelength of diode laser that decreases the melanin absorption in the dermis of the skin by that the diode needs more flounce to heat the tissue and destroy of the hair follicle well. while this high energy is not affected the black citizens with skin type IV to VI as it observed in the Atta-Mobtte and Załęska study, tabulated in the Table (1), the diode lasers are considered as a more suitable and safer type of lasers for hair removing in darker skin persons, as well as, this type of lasers have a temporary effect on the other types of skin such sensitivity, erythema, hyperpigmentation, and burning [35]

Mustafa et al. (2014) they used Alexandrite laser (755nm) and Diode laser (810nm) with irradiation power (1000mW) and a beam diameter of (5mm) was used in the model for hair removal in medium and dark skin. The result was that, in both samples, the ratio of photons transmitted through the laser diode was not equal to the ratio of photons transmitted through the alexandrite laser skin layers. This finding shows that the number of photons transmitted from both laser sources through dark and medium skin varied. With depth, the rate of fluency declined quickly within the skin as shown in Figure(4-1). Although the decrease in the rate of fluency was more significant after a depth of 0.2 mm, a rapid decrease in the rate of fluency in the epidermis and dermis layer was observed for both laser sources, the amount of radiation transmission was measured for both laser sources in dark and medium skin with differing skin layer depths as shown in Figure(4-2). The transmission ratio of the diode laser to the dark skin dermis was approximately 4% more than that of the alexandrite laser for the same skin type. The results of Mustafa et al. (2014) showed that the diode laser was better than the alexandrite laser because the short-wavelength alexandrite laser would require a higher fluence rate to achieve the same dose-effect due to the high risk of thermal damage to the surrounding tissue, especially the epidermis, while the diode may penetrate deeper into the dermis layer [32].



Figure(4-1): Fluence of two types of laser; (A) Diode laser (810 nm) and (B) Alexandrite laser (755 nm) as a function of skin depth for both dark skin and medium skin.



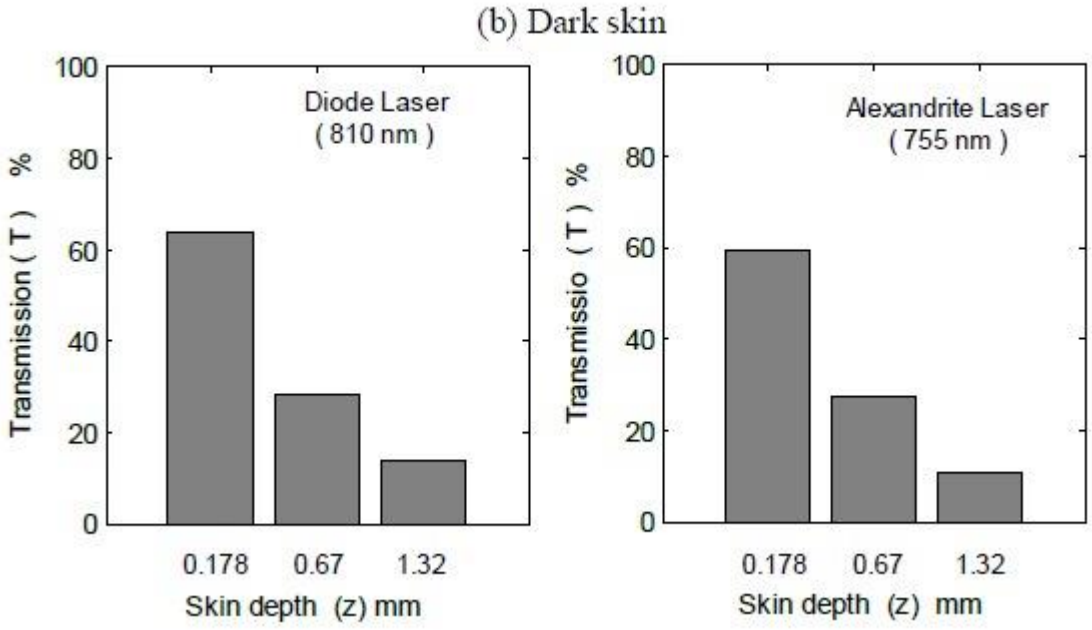


Figure (4-2): Variation of laser transmission ratio as a function of laser source and skin depth for two types of skin: (A) Dark skin and (B) Medium skin.

Jansy et al. (2018) used Nd:YAG laser (1064nm, fluence 40-50J/cm2, 5mm spot size) for darker-skinned Indian patients, including 40 women in the 18-35 age group, and 32 patients completed all treatment sessions. for 28 patients after the first treatment session, a strong hair reduction (50-75 %) was seen. Excellent hair reduction (>75%) was observed after 3 sessions for 10 patients and strong hair reduction for 18 patients. In 12 patients at month 6, excellent hair reduction was observed, and a good response was observed in 16 patients. The side effects were noted in the post-procedure erythema and perifollicular edema analysis (50 %). The study findings support the safe and successfui use of four consecutive 1064 nm Nd:YAG long-pulse laser sessions for facial hirsutism in Indian patients with darker IV and V skin imaging with limited side effects. In terms of effectiveness, the shorter laser wavelength is usually considered more efficient because of the higher absorption value of melanin, which decreases with increases of wavelength. However, because of decreased dispersion and deeper penetration of laser light, the longer wavelength Nd:YAG laser is considered suitable for the treatment of patients with darker skin[15].

Table 4.2: Percentage of hair reduction in the study population.

	At 4 weeks	At 8 weeks	At 12 weeks	At 6th month
Excellent (>75% reduction)	-	2	10	12
Good (50-75% reduction)	28	26	18	16
Fair (25-50% reduction)	12	9	4	4
Poor (< 25% reduction)	-	-	-	-
Lost to follow up	-	3	3+4	Total-8

Chapter five

Conclusion

For hair removal or to reduce hair growth in unwanted places of the human body, laser have been used., there are different kinds of lasers available, but the selection of an ideal laser for ethnic skin has its limitations. It is very important to pick the right laser for the right type of skin. It is necessary to determine the skin type of the flounce, the pulse length and the laser type to be used before beginning the laser therapy.[26]

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