CHAPTER ONE

Introduction

1.1Back Ground

Laser hair removal is a common light-based aesthetic procedure use for treatment for unwanted body hair.

Some people complain from unwanted excess hair and from hair growth in abnormal sites of the body that cause embarrassment for them (Kamal, 2006).

Many reasons cause unwanted hair growth (Lepselterand Elman, 2004).

I. Polycystic ovary syndrome (PCOS). This condition, which often begins with puberty, causes an imbalance of sex hormones.

II. Cushing syndrome. This occurs when your body is exposed to high levels of the hormone cortisol.

III. Congenital adrenal hyperplasia.

IV. Tumors.

V. Medications.

Excessive hair was categorized as either hirsutism (Oakley, A.M.M. 2005) or hypertrichosis depending on the cause.

Hypertrichosis is excessive hair growth over and above the normal for the age, sex and race of an individual, in contrast to hirsutism, which is excess hair growth in women following a male distribution pattern (Swingler, et al., 2009; Sanchez, et al., 2006).

Many methods were used for unwanted hair epilation. They are mainly divided into two categories, either temporary or permanent. The temporary methods include threading (Kumar, and Narang, 2010), bleaching (Azziz, 2003), shaving, waxing and plucking, while permanent methods include electrolysis (Oner, et al., 2012), laser and IPL (Halachmi, and Lapidoth,2012).

Nowadays, laser and IPL are considered the best and the most effective methods for epilating the unwanted hair with fewer side effects (Cameron, et al 2008). Many laser systems have been devised including the normal mode and long-pulsed such as ruby lasers (694 nm) (Sarkar, and Hirsch, 2010). The long-pulsed alexandrite lasers (755 nm), the diode laser systems (800 - 810 nm) (Lanigan, 2001), the Q-switched Nd: YAG laser system (1064 nm) (Lapidoth, 2010), and non-laser light source the in-tense pulsed light (IPL) which gives a broad range spectrum between (500 - 1200 nm)(Johnson, and Dovale, 1999).

Diode lasers and specifically the long- pulse diode laser 808 nm are the most popular preference for hair removal due to the deep penetration and targeting of the hair follicle. The Diode laser hair removal machine uses the principle of selective photothermolysis technology. The laser target the melanin in the hair follicle. The Diode laser hair removal machine is safe (Anderson, and Parrish, 1983, Cotsarelis G, 1999)

2.1 Research Problem

Human hair plays an important role in the cosmetic appearance of a person. In recent years, females with excess and normal distribution of hair seek long-term hair reduction for social, cultural, cosmetic, or therapeutic reasons.

2.2 Previous Studies

AL-Hamamy, H.R., et al (2015) a more successful treatment with fewer side effects can be achieved if we are able to discriminate between the heat delivery to the epidermis and the hair follicle. The epidermis is protected from the heat produced by laser by cooling the skin surface which is achieved by the sapphire contact surface of the hand piece has cooling effect during laser treatment when laser energy is absorbed in the skin. Selecting a longer wavelength will lead to more penetration of laser energy reaching the deeper (hair follicle).

Y.Bhat et al in 2020 published an article updating the laser treatment in patients with hirsutism. The diode laser system (800-1000 nm) could be used safely in individuals with dark skin owing to its longer wavelength, active cooling and longer pulse widths. It was also being better tolerated by individuals with darker skin types (V-VI) in comparison to ruby laser

Jose A. (2021) Both cooling systems produced a similar and moderate level of pain, with a pricking sensation being the prevailing type of pain due to selective heating of the hair. Regarding the efficacy and safety study, a 43.4% reduction was seen and no side effects were found to last more than 48 hours, with the results being classified as good to excellent for the treated.

2.3 Objectives

2.3.1General Objective

To investigate effectiveness of Diode laser 808 nm with specific laser parameters on hair reduction on some Sudanese women. .

2.3.2Specific Objectives

i. To determine of study group toward effectiveness of 808nm Diode laser with specific laser parameters in the treatment of unwanted hair in individuals with Fitzpatric skin types IV-VI.

ii. To summarize the adverse effect from hair removal of diode laser in different of Fitzpatric skin types IV-VI. On some Sudanese women.

CHAPTER TWO

LITRETURE REVEW

2.1 Introduction of Hair Follicle

The hair follicle is one of the characteristic features of mammals serves as a unique miniorgan (Figure 2.1). In humans, hair has various functions such as protection against external factors, sebum, apocrine sweat and pheromones production and thermoregulation. The hair also plays important roles for the individual's social and sexual interaction (Buffoli,et al., 2014; De Berker, et al., 2012).

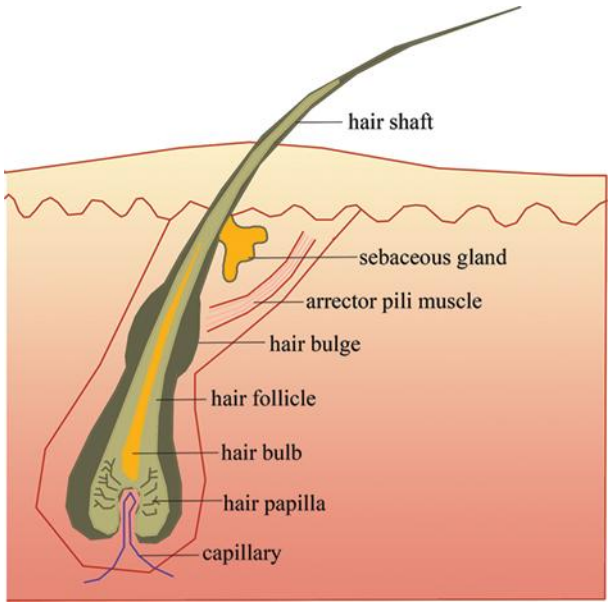

Figure 2.1Diagram of an Anagen Follicle

2.2 Hair Anatomy

2.2.1 Classification of the Hair

Nearly whole body surface is coated with the hairs except a few areas like palms, soles and mucosal regions of lips and external genitalia. Most of these are tiny, colorless vellus

hairs. The ones located in several areas like scalp, eyebrows and eyelashes are thicker, longer and pigmented and are called terminal hairs. Humans have approximately 5 million hair follicles and 100,000 of them are located on the scalp (De Berker, et al., 2012; Krause and Foitzik, 2006).

Basically terminal hairs are found on scalp, eyebrows and eyelashes at birth while the rest of the body is covered with vellus hairs. In puberty, some vellus hairs (i.e. beard, trunk, axilla and genital area) by the influence of androgens differentiate to terminal hairs, which are long (>2 cm), thick (>60 μm), pigmented and medullated. The bulb of the terminal hairs is located in the subcutaneous fat; however, the bulb of vellus hairs is in the reticular dermis. Vellus hairs are thin (<30 μm), short (<2 mm) and mostly nonmedullated.

The hair is classified into three main ethnic subgroups (Asian, African and European). However in a recent study, this classification is expanded to eight main subgroups by considering three parameters: curve diameter, curl index and number of waves (De La Mettrie and Saint-Leger, 2007).

Structural features of the hair follicle have to be considered during the classification process. Hair shaft diameters, hair follicle density and follicular infundibulum volume are some of them. Hair shaft diameters represent little variations and hairs are found to be thicker in androgen dependent areas. Hair follicle density is much more condense in the forehead and follicular infundibular volume is also bigger. It is important just because of the large follicular infundibular volume that is associated with more follicular reservoir ability (Buffoli,et al., 2014;Otberg and Richter, 2004).

2.2.2 Structure of the Hair

Hair is consisted of two distinct structures: follicle the living part located under the skin and hair shaft fully keratinized nonliving part above the skin surface. The arrector pili muscle, takes place between the hair bulge area and dermoepidermal junction. Above the insertion of the arrector pili muscle, sebaceous glands and, in some certain regions, apocrine glands are opened into the follicle.

Hair shaft consisted of three layers: cuticle, cortex and in certain cases medulla. Flat and square-shaped cuticle cells are adhered tightly to the cortex cells proximally. Peripheric movements of cuticle cells make the direction of the distal free edge upward and cause extensive overlapping. These imbrications are crucial. By interlocking with the cuticle cells of inner root sheath, they contribute to the follicular anchorage of the growing hair. These imbricated surfaces also facilitate removal of dirt and desquamated cells from the scalp. Cuticle has also important protective properties and barrier functions against physical and chemical insults (Sperling, 1991), Messenger AG, De Berker DAR, et al., 2010).

During the migration of the cells from the hair bulb to compose the cortex, the shapes of them become more fusiform. These cells coalesce tightly and are placed parallel to the axis of the shaft. Axial keratin filaments (microfibrils) that are formed from multiple hard α-keratin intermediate filaments (α-KIF) molecules, packs each cortex cells. Several microfibrils come together to form larger units called macrofibril which represents almost 50% of the cortex material. The cortex comprises the bulk of the shaft and also contains melanin (De Berker, et al., 2012), Messenger AG, De Berker DAR, et al., 2010; De Berker,et al., 2012).

Medulla is located in the center of the hair shaft preferably presented in coarser fibers. The hair medulla contains structural proteins that are markedly different from other hair keratins and eosinophilic granules that are filled by an amino acid, citrulline and eventually form internal coatings within the membranes of mature cells (Sperling, 1991; Messenger and De Berker, 2010;Jones, 2001).

The follicle is the essential growth structure of the hair and basically has two distinct parts: upper part consisting of infundibulum and isthmus whereas the lower part comprising of hair bulb and suprabulbar region. The upper follicle remains constant, while the lower part has continuous cycles of regeneration (Buffoli B, et al2014, De Berker D,et al2012, Messenger AG, De Berker DAR, Sinclair RD. 2010,Randal VA, Botchkareva NV.2009).

The infundibulum, the uppermost portion of the hair follicle extending from the opening of the sebaceous gland to the surface of the skin, is a funnel-shaped structure filled with sebum, the product of the sebaceous glands. The upper part named acroinfundibulum, the keratinization of epithelium turns into the "epidermal mode", with formation of stratum granulosum and stratum corneum like a similar manner to epidermis (Buffoli B, et al2014, Sperling LC 1991, Messenger AG, De Berker DAR, et al 2010).

The isthmus is the lower portion of the upper part of hair follicle between the opening of the sebaceous gland and the insertion of arrector pili muscle. At the isthmus level, epithelium keratinization begins with the lack of granular layer named "trichilemmal keratinization" (Sperling LC: 1991, Messenger AG, De Berker DAR, et al 2010). Only few differentiated corneocytes remain and the invagination of the epidermis in this area

must be considered as highly permeable for topically applied compounds (Blume-Peytavi and Vogt 2011). Hair follicle stem cells are thought to reside in the bulge area on the isthmus close to the insertion of the arrector muscle (Oshima et al., (2001). Lineage studies have proven that bulge cells are multipotent and that their progeny generate the new lower anagen hair follicle (Ito M, Kizawa K, et al.2004). One of the most distinguishing features of stem cells is their slow-cycling nature, presumably to conserve their proliferative potential and to minimize DNA errors that could occur during replication. They migrate in a downward direction. On entering the hair bulb matrix, they proliferate and undergo terminal differentiation to form the hair shaft and inner root sheath. They also migrate distally to form sebaceous glands and to proliferate in response to wounding (Messenger AG, De Berker DAR, Sinclair RD. 2010, Oshima H, Rochat A, et al. 2001Cotseralis G, Sun TT, et al. 1990)

The suprabulbar region of the follicle, below the isthmus and above the hair bulb, is comprised of three layers from outermost to innermost: outer root sheath, inner root sheath and hair shaft (Figure 2.2).

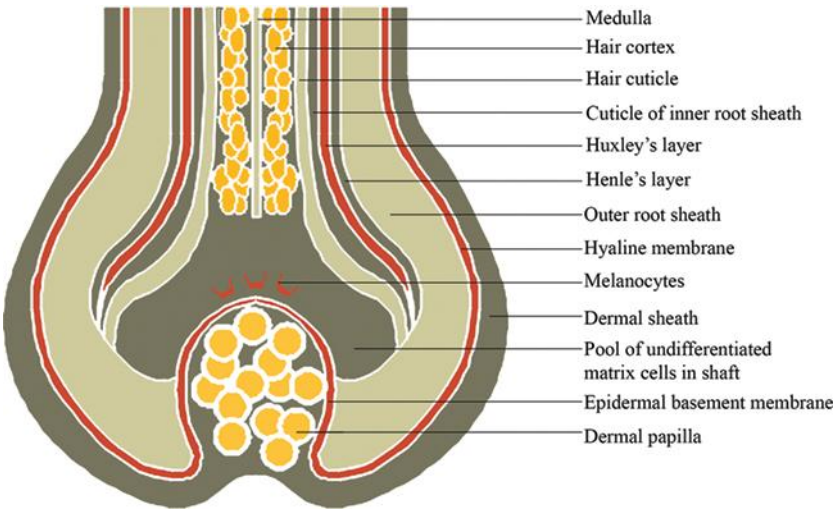

Figure 2.2 Diagram of Proximal Hair Follicle.

Outer root sheath (ORS) extends from the epidermis at the infundibulum and continues to the hair throughout the follicle. In the infundibulum, it resembles epidermis, whereas in the isthmus level, ORS cells begin to keratinize in a trichilemmal mode. Keratinocytes in the ORS form the bulge area at the base of the isthmus. At the lower tip of the hair bulb it consists of a single layer of cuboidal cells, becoming multilayered in the region of the upper hair bulb. In some follicles, there is a distinct single cell layer interposed between the outer and inner root sheaths, known as the companion layer (Rothnagel JA, Roop DR. 1995). Companion layer cells show numerous intercellular connections to the inner root sheath and are thought to migrated distally along with the inner root sheath to the isthmus region and to form the plane of slippage between the inner and outer root sheaths (Buffoli B, etal 2014, De Berker D, etal 2012, Sperling LC: 1991, Messenger AG, De Berker DAR, Sinclair RD. 2010). The ORS of the hair follicle also contains melanocytes, Langerhans cells and Merkel cells. These cells take place in certain functions of the

follicle such as acting as a sensory organ and serving as an immunologic sentinel for the skin (De Berker D, etal 2012).

Inner root sheath (IRS) contains three layers: Henle's layer, Huxley layer and cuticle layer. The innermost layer is the cuticle of IRS whose cells interlock with those of the hair cuticle. This connection, anchoring the hair shaft to the hair follicle, is so tight. The inner root sheath hardens before the presumptive hair within it, and so it is thought to control the definitive shape of the hair shaft. Each of the three layers of IRS undergoes abrupt keratinization. This occurs at different levels in each layer; however, the patterns of change are similar. Keratinization first appears in Henle's layer, the outermost. Huxley layer is keratinized above the Henle's layer at the region known as Adamson's fringe. The IRS coats and supports the hair shaft up to the isthmus level where the IRS disintegrates (De Berker D, Higgins CA, et al 2012, Sperling LC: 1991, Messenger AG, De Berker DAR, et al. 2010).

The expanded onion-shaped portion of the lower hair follicle, including the hair matrix and the follicular papilla is known as the hair bulb which is the active reproductive portion of the hair follicle. The hair bulb encloses follicular dermal papilla, mucopolysaccharide-rich strome, nerve fiber and capillary loop. The matrix cells are localized to the lowermost portion of the follicle and surround all sides of the follicular papilla. The hair shaft and IRS are derived from the matrix cells. The IRS is derived from the lower and laterally located matrix cells, whereas the hair shaft is originated from upper and centrally located cells. In addition to producing the main structural components of hair, they also produce the hair keratins, and their associated proteins (KAPs) (Rogers MA, Langbein L, Praetzer-Wundel S et al. 2006). Melanocytes reside among matrix stem

cells to produce the pigment of the hair. During their differentiation phase, matrix cells phagocytes melanin or pheomelanin from the dendritic elongations of melanocytes. The hair assumes its color via the amount and the type of the phagocytized major pigment (Buffoli B, etal 2014, De Berker D, etal 2012, Sperling LC: 1991,Jankovic SM, Jankovic SV. 1998).

Follicular papilla, which is derived from a condensation of mesenchymal cells at the early stages of follicular embryogenesis, is one of the most important players during the induction and maintenance of the follicular epithelial differentiation. It is responsible for determining the follicle type. The volume and secretory activity of follicular papilla and also the number of matrix stem cells determine the size of the anagen hair bulb, the duration of anagen phase and the diameter of the hair shaft (Krause K, Foitzik K. 2006,Jahoda CA, Reynolds AJ.1996,Paus R, Müller-Röver S,et al.1999). Moreover the follicular papilla is an essential source of growth factors (Buffoli B, et al2014, De Berker D,et al2012, Sperling LC: 1991, Jankovic SM,Peus D,et al 1996).

2.2.3 Molecular Structure

Keratin proteins can be divided into two major families: the type I (acidic) keratins and the type II (basic-neutral) keratins. About 54 functional keratin genes (28 type I and 26 type II keratins) have been identified to date. There are 11 type I hair keratins, designated K31–K40, and 6 type II hair keratins, designated K81–K86, and the remainder are epithelial keratins (Rogers MA, Langbein L, et al (2006)) [32].

The keratin-associated proteins (KAP), is a large group of proteins which constitutes the matrix of the keratin. The matrix proteins are separated to three major subgroups

according to their amino acid compositions (Roger GE. (2004)). Different hair and epithelial keratins are expressed in the various concentric layers of the hair follicle, with hair keratins found primarily in the cortex and hair cuticle(Buffoli B,et al(2014), De Berker D,et al(2012)).

2.2.4 Hair Follicle Innervation and Vascularization

Nerves related to the hair follicle are identical to the dermal nerve network including sensory afferents and autonomic sympathetic nerves. Smaller nerve fibers form a circular layer around the bulge area of terminal follicles and the bulb area of vellus follicles. There are several types of nerve endings associated with the hair follicle: free nerve endings, lanceolate nerve endings, Merkel cells and pilo-Ruffini corpuscles. Each nerve ending responds to distinct stimulus. Free nerve endings transmit pain, lanceolate nerve endings detect acceleration, Merkel cells responsible of pressure sensation and pilo-Ruffini corpuscles detect tension. Perifollicular nerves related neuromediator and neuropeptides, that is, substance P, calcitonin gene-related peptide influence follicular keratinocytes and hair follicle cycling (Buffoli B, etal 2014, De Berker D, etal 2012, Sperling LC: 1991, Jankovic SM, Peus D.).

Cutaneous vascularization is provided by arterioles, which are concentrated at the lower portion of the hair follicle and compose vascular network. During the hair cycle phases, there are some alterations in the density of perifollicular vascularization due to the upregulation of vascular endothelial growth factor expression(Buffoli B, Rinaldi F, et al.2014).

2.2.5 Immunology of Hair Follicle

The immunology of hair is very amazing and complicated. The hair follicle represents an immune privileged (IP) site, which is defined basically as a location in the body where foreign tissue grafts can survive for longer periods of time without immune rejection.

Until recently, the IP of the hair follicle is considered to be restricted to the matrix region during the anagen phase. However, evidence has accumulated that the IP of the hair follicle extends to the bulge region and is present at this site during the entire hair cycle. Since the bulge represents the hair follicle stem cell niche, sustained IP in this region may be essential for the survival of the follicle.

Hair follicle IP occurs during anagen (Christoph T, Müller-Röver S, et al. 2000). Thus hair follicle IP is limited to the proximal epithelium of anagen hair follicles. During anagen, melanogenesis is activated in the hair bulb and suggests that hair follicle melanocyte autoantigens play a key role as potential immune targets (Peus D, Pittelkow MR. 1996, Ito T. 2010).

The hair follicle IP is maintained by several factors (Paus R, Ito N, Takigawa M et al. 2003).

I. Downregulation of MHC class I expression in the proximal ORS and matrix cells.

II. Local production of potent immunosuppressants like TGF-β1, IL-10 and α-MSH.

III. Functional deterioration of antigen presenting cells.

IV. Absence of lymphatics.

V. Establishment of extracellular matrix barriers to hinder immune cell trafficking.

VI. Expression of non-classical MHC class 1.

2.2.6 Pigmentation of Hair Follicle

Hair shaft pigmentation ensures multiple benefits including UV protection, thermoregulation and sexual perceptions. Furthermore, the hair pigment, melanin, is a potent free-radical scavenger. Melanin production inside the active anagen hair bulb may, therefore, help to buffer cell stress induced by reactive oxygen species.

In contrast to the continuous melanogenesis observed in epidermal melanocytes, follicular melanogenesis is a cyclic phenomenon. It is ceased in early the anagen-catagen transition, restarted with the down-regulation of key enzymes of melanogenesis, followed by hair follicle melanocyte apoptosis.

Hair follicle melanocytes and their precursors reside in the hair matrix and along the outer root sheath of anagen hair follicles. However, production of hair pigment (black eumelanin and/or the reddish pheomelanin) only occurs in the specialized hair follicle pigmentary unit, located above and around the dermal papilla during anagen III–VI. Melanin synthesis is established in lysosome-related organelles named melanosomes. In the precortical matrix, these melanosomes are transferred to the hair shaft keratinocytes and formed a pigmented hair shaft. The hair follicle also contains melanocyte stem cells, which are located in the bulge and in the secondary hair (Stenn KS, Paus R. 2001, Thibaut S, Gaillard O, et al. 2005).

2.3 Physiology of the Hair

2.3.1 Hair Growth Cycle

Hair development is a continuous cyclic process and all mature follicles go through a growth cycle consisting of growth (anagen), regression (catagen), rest (telogen) and shedding (exogen) phases (Figure2.3). The duration of the phases changes based on the location of the hair and also personal nutritional and hormonal status and age (De Berker D, etal 2012, Stenn KS, Paus R. 2001).

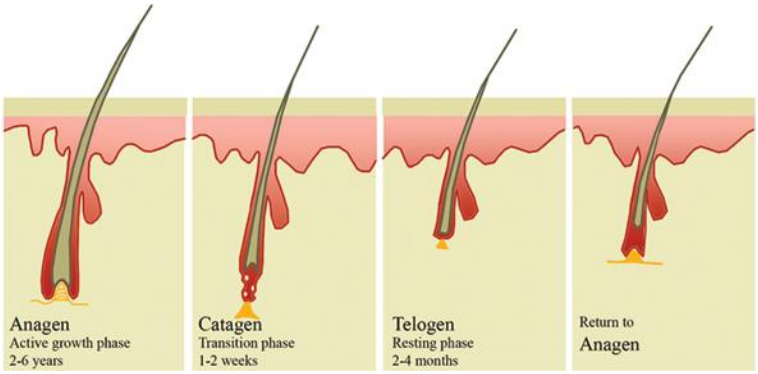

Figure 2.3 The Hair Cycle.

I. Anagen

The inception of anagen phase is presented by the onset of the mitotic activity in the secondary epithelial germ located between the club hair and dermal papilla in telogen hair follicle (Messenger AG, De Berker DAR, et al. 2010, Paus R, Cotsarelis G. 1999). The anagen is the active growth phase in which the follicle enlarges and takes the original shape and the hair fiber is produced. Almost 85–90% of all scalp hairs are in anagen.

Six portion of the anagen stage is demonstrated. Through the anagen I–V, hair stem cells proliferate, encloses the dermal papilla, grow downwards to the skin and begin to proliferate hair shaft and IRS, respectively. Subsequently, hair matrix melanocytes begin to develop pigment and the form of the hair shaft begins to arise; in anagen VI, hair bulb and adjacent the dermal papilla formation is realized and the new hair shaft appears from the skin. This phase can last up to 6–8 years in hair follicles(Buffoli B, Rinaldi F, Labanca M et al. 2014,Krause K, Foitzik K.2006,Randal VA, Botchkareva NV(2009) .

Hair shaft synthesis and pigmentation only take place in anagen (Krause K, Foitzik K. (2006)) . The degree of axial symmetry within the hair bulb determines the curvature of the final hair structure (Thibaut S, Gaillard O, et al. 2005). Fiber length is often dependent on the duration of the anagen or actively growing phase of the follicle. The featured regulatory proteins in anagen phase are BMPs, sonic hedgehog, several WNT proteins and receptors. Insulin like growth factor-1 (IGF-1), fibroblast growth factor-7 hepatic growth factor (HGF), and vascular endothelial growth factor (VEGF) are thought to be important for anagen maintenance (Schneider MR, Schmidt-Ulrich R, et al. 2009).

II. Catagen

At the end of anagen, mitotic activity of the matrix cells is diminished and the follicle enters a highly controlled involutionary phase known as catagen. Catagen lasts approximately 2 weeks in humans, regardless of the site and follicle type (Kligman, 1959). During catagen the proximal of the hair shaft is keratinized and forms the club hair, whereas the distal part of the follicle is involute by apoptosis(Messenger AG, De Berker DAR,et al 2010),Paus R, Foitzik K.2004).

Catagen phase is consisted of eight different stages. The first sign of catagen is the termination of melanogenesis in the hair bulb. Follicular epithelium, mesenchyme, neuroectodermal cell populations and also perifollicular vascular and neural systems demonstrates cyclic changes in differentiation and apoptosis. However, any apoptosis is occurred in dermal papilla due to the expression of suppressor bcl-2(Krause K, Foitzik K. 2006).

Catagen is a process of bulbar involution. The perifollicular sheath collapses and vitreous membrane thickens. Eventually, the lower hair follicle becomes reduced to an epithelial strand, bringing the dermal papilla into close proximity of the bulge (Schneider MR, Schmidt-Ulrich R, et al. 2009). The epithelial strand begins to elongate and finally reaches to just below the insertion of pilar muscle. After the keratinization of the presumptive club hair, the epithelial strands begin to involute and shorten progressively followed by the papilla which condenses, moves upward and locates to rest below the bulge. The column eventually reduces to a nipple and forms secondary hair germ below the club. The club hair itself is formed from cortical and cuticle cells only, and it is characterized by a lack of pigmentation (De Berker D, Higgins CA, Jahoda C et al. 2012, Kligman AM. 1959).

III. Telogen

The telogen stage is defined as the duration between the completion of follicular regression and the onset of the next anagen phase. Telogen stage lasts for 2–3 months. Approximately 10–15% of all hair is in telogen stage. During the telogen stage, the hair shaft is transformed to club hair and finally shed. The follicle remains in this stage until

the hair germ which is responsive to anagen initiating signals from the dermal papilla, starts to show enhanced proliferative and transcriptional activity in late telogen, leading to the initiation of anagen(De Berker D, Higgins CA, Jahoda C et al. 2012,Greco V, Chen T, Rendl M et al.2009).

Telogen is one of the main targets of hair cycle which is influenced by several modulatory agents like androgens, prolactin, ACTH, retinoid and thyroid hormones (Paus, 1998). No unique molecular markers associated with the telogen follicle are determined yet; however, estrogen receptor expression is reported to be limited to the telogen papilla fibroblasts. Germ cells of telogen follicles also express basonuclin and FGF-5 (Stenn KS, Paus R. 2001). The bone morphogenic protein-4 (BMP-4) as a growth factor plays an essential role in suppressing follicular growth and differentiation at telogen stage (Messenger AG, De Berker DAR, et al. 2010).

The macro-environment surrounding the hair follicle also takes part in regulating cycle transitions. BMPs in the subcutaneous fat are capable of maintaining follicles in a "refractory" telogen, and cessation of this inhibitory activity by BMPs enables the follicle to progress to a "competent" telogen with a hair germ that is responsive to anagen-initiation signals and capable of entering a new anagen phase (De Berker D, Higgins CA, et al. (2012, Plikus MV, Mayer JA, et al. 2008).

IV. Exogen

There is less interest for the mechanism of the hair shedding but from the patient's perspective it is probably the most important part of the hair growth. It is not unusual for human telogen hairs to be retained from more than one follicular cycle and this suggests

that anagen and exogen phases are independent. The shedding period is believed to be an active process and independent of telogen and anagen thus this distinct shedding phase is named exogen (Messenger AG, De Berker DAR, et al.2010, Stenn KS, Paus R.2001).

2.3.2 Hair Cycle lock

Based on the observations: the hair follicle has no need for intact innervation, vascularization or other extra follicular components to maintain cycling, and the basic oscillator system which controls hair cycling is located presumably in the follicle (Sten KS, Nixon J, et al. 1999). The principal challenge is to define the underlying "oscillator" system. Probably, the hair cycle clock is controlled by regulating the balance of the interactions between the follicle epithelium and the surrounding mesenchyme. This might be provided by the rhythmic secretions of growth/modulatory signals from follicle epithelium or mesenchyme as well as the rhythmic alterations in the expressions of corresponding receptors (Paus R. 1998).

2.4 Excessive Growth of Hair

Growth of hair that at any given site is coarser, longer or more profuse than is normal for the age, sex and race of the individual is regarded as excessive. The term hirsutism will be restricted to androgen-dependent hair patterns of, typically, terminal hair, and the term hypertrichosis will be applied to other patterns of excessive hair growth. Hypertrichosis can be classified as either localized or generalized, of congenital or acquired pattern where congenital is loosely interpreted as that seen in infancy.

2.4.1 Hypertrichosis

2.4.1.1 Classification

2.4.1.1.1Congenital Generalized Hypertrichosis

2.4.1.1.1.1 Definition and Nomenclature

In congenital generalized hypertrichosis, the fetal pelage is not replaced by vellus and terminal hair but persists, grows excessively and is constantly renewed throughout life.

It is associated with a number of different genetic mutations and chromosomal aberrations. Some types are associated with gingival hyperplasia and other malformations.

2.4.1.1.1.2 Associated Syndromes

Congenital hypertrichosis can be associated with other syndromes, which include the following.

I. **Hurler syndrome and other mucopolysaccharidoses**
II. **Cornelia de Lange syndrome**.
III. **Winchester syndrome.**
IV. **Berardinelli syndrome**
V. **Fetal alcohol syndrome.**

2.4.1.1.2 Congenital Localized Hypertrichosis

2.4.1.1.2.1 Definition and Nomenclature

Congenital localized hypertrichosis refers to both areas of excess hair present at birth and

hamartomas that may have a delayed clinical presentation. They may occur in isolation as an area of increased hair density or in association with congenital melanocytic naevi, Becker naevi, spinal dysraphism or neurofibromas.

2.4.1.1.2.2 Congenital Localized Hypertrichosis of Specific Anatomical Sites

There are a number of congenital conditions associated with increased hair growth in a specific anatomical site such as hypertrichosis cubiti or hairy elbow syndrome. In a number of these conditions there is a clear pattern of inheritance. Whilst hypertrichosis may be evident at birth, it may not become apparent until later in childhood or adolescence.

I. Naevoid hypertrichosis. Naevoid hypertrichosis refers to a localized area of hypertrichosis. (Gupta L, Gautam RK, et al. 2011).

II.Congenital melanocytic naevi and neurofibromas. Congenital melanocytic naevi are often associated with prominent terminal hairs. The hair may be present from infancy or may develop after puberty. Plexiform neurofibromas are also associated with hypertrichosis.

III.Lumbosacral hypertrichosis. Lumbosacral hypertrichosis or the faun tail sign is a tuft of hair in the lumbo-sacral region that is often associated with spina bifida or diastematomyelia.

IV.Becker naevus. Becker naevus or pigmented hairy epidermal naevus is a hamartoma that usually presents with hyperpigmentation affecting the upper back, flanks or upper

chest. It is frequently associated with the development of terminal hair from puberty.

2.4.1.1.3 Malignant Acquired Generalized Hypertrichosis

2.4.1.1.3.1 Definition and Nomenclature

This is the sudden and generalized development of lanugo or nonandrogen-dependent hair in adult life. This presentation is often a sign of underlying malignancy but can also be due to other factors including drugs. It is a rare sign most commonly associated with carcinomas of the gastrointestinal tract, lung or breast (Hegedus SI, Schorr WF. 1972, Hensley GT, Glynn KP. 1969, Hensley GT, Glynn KP. 1982). The hypertrichosis may precede the diagnosis of the neoplasm by several years.

2.4.1.1.3.2Clinical Features

In the milder forms (‘malignant down’), hair is confined to the face, where it attracts attention by its appearance on the nose and eyelids, and other sites that normally are clinically hairless (Davies RA, Newman DM, etal 1978). As the growth of hair continues, it may ultimately involve the entire body, apart from the palms and soles. Existing terminal hair of the scalp, beard and pubes may not be replaced, and may contrast in color and texture with the very fine, white or blonde lanugo. Such hair may grow abundantly, even on a previously bald scalp. The hair may grow exceedingly rapidly, up to 2.5 cm/week, and may be more than 10 cm long.

2.4.1.1.3.3 Investigations

If the development of generalized lanugo hair precedes a known diagnosis of a neoplasm,

then patients should be radiologically screened for cancer, concentrating on the lung and gastrointestinal tract.

2.4.1.1.4Non-Malignant Acquired Generalized Hypertrichosis

2.4. 1.1.4 .1 Definition

Generalized hypertrichosis can occur as the consequence of systemic disease and medications. Generally, the hair is coarser and less profuse than the lanugo hair associated with malignancy.

2.4.1.1.4 .2 Associated Disorders

I. **Drug-induced hypertrichosis.** The most common cause of acquired hypertrichosis is systemic medications. Drug-induced hypertrichosis is a well-known side effect of ciclosorin (Tsuji Y, Iwabuchi T, Hamada C, et al. 1999), phenytoin (Parker LN, Lifrak ET, Odell WD.1982) and minoxidil(Parker LN, Lifrak ET, Odell WD.(1982),Burton JL, Marshall A.1979), which has been turned to commercial benefit in the case of the latter. It has also been described with diazoxide (Parker LN, Lifrak ET, Odell WD. 1982) and psoralens (Singh G, Lal S. 1967).

II. **Hypothyroidism**. A profuse growth of hair on the back and the extensor aspects of the limbs develops in some children with hypothyroidism (Perloff WH. 1955).

III. **Eating disorders.** An increased growth of fine downy hair on the face, trunk and arms, sometimes of severe degree

IV. **Dermatomyositis.** Excessive hair growth has been noted mainly in children and principally on the forearms, legs and temples, but it may be more extensive (Reich MG,

Reinhart JB.1948).

V. **Epidermolysis bullosa.** Gross hypertrichosis of the face and limbs has occurred in association with epidermolysis bullosa of the dystrophic type, although this is rare.

2.4.1.1.5Acquired Localized Hypertrichosis

2.4.1.1.5.1Associated Disorders

I. Porphyria. Hypertrichosis of exposed skin is a common feature of the very rare congenital erythropoietic porphyria. Appearing first on the forehead, it later extends to the cheeks and chin and, to a lesser degree, to other exposed areas. It is also present in some cases of the much more common erythropoietic protoporphyria (Dean G, ed. 1963).

II.Topical medications. Localized hypertrichosis can be seen at sites of topical corticosteroid application. It has also been seen after sclerotherapy (Oh TS, Kim Y,et al 2010) and topical tacrolimus (Prats Caelles I, Herranz Pinto P, et al 2005). The prostaglandin analogues lanatoprost (Demitsu T, Manabe M, et al 2001) and bimatoprost (Tosti A, Pazzaglia M, etal 2004) cause increased growth of eyelashes when used in the treatment of glaucoma.

III.Graves disease. The growth of coarse terminal hairs is a common feature in plaques of pretibial myxoedema associated with Graves disease.

IV.Miscellaneous. Localized hypertrichosis may occur at sites of chronic skin trauma, rubbing and around skin cancers.

2.4.1.2Treatment of Hypertrichosis

Treatment of hypertrichosis is basically hair removal. Several methods are available but need to be repeated regularly as hair continues to grow back. They may also cause scarring, dermatitis or hypersensitivity reactions.

I. Repeated shaving

II. Chemical epilation

III. Electrolysis and thermolysis

IV. Waxing

More recently, laser hair removal has been proposed as a treatment option. It appears to have fewer side effects and produces a longer lasting result.

2.4.2Hirsutism

2.4.2.1 Definition

Hirsutism refers to excess terminal hair in a woman that occurs in a male pattern involving areas such as the beard, moustache and chest. Hair at these sites in men is often under the influence of androgens and occurs after puberty. In women, hirsutism may occur with or without a detectable increase in androgens.

2.4.2.2 Introduction and General Description

The presence of terminal hair in a male pattern in women is referred to as hirsutism. Both the severity of the hirsutism and the degree of its acceptance depend on racial, cultural

and social factors. The scheme employed in the study by Ferriman and Gallwey has become the standard grading system and defines hirsutism on quantitative grounds (Ferriman D, Gallwey JD. (1961).

2.4.2.3 Epidemiology

2.4.2.3.1Incidence and Prevalence

Because of different scales used to determine hirsutism and varying perception by patients based on race and social factors, it is difficult to state incidence accurately but it is estimated that it affects5–10% of women.

I. Age. Hirsutism usually becomes apparent after the onset of puberty. In the presence of ectopic androgens it can occur at any age.

II. Sex. By definition, hirsutism is a condition that affects women.

III. Ethnicity. Facial and body hair is less commonly seen in Asian peoples, African peoples and indigenous Americans than in white people. Even among white people there are differences; hair growth is heavier in those of Mediterranean than those of Nordic ancestry. The pattern of hair growth in hirsutism within different racial groups is identical.

2.4.2.4Associated Diseases

Hirsutism is a feature of polycystic ovary syndrome (PCOS). It is also a feature of endocrine disturbance leading to androgen excess.

2.4.2.5 Pathophysiology

Terminal hair in a male pattern is governed by circulating androgens. In women, androgens originate from the ovaries and the adrenal glands. The first sign of androgen production in women occurs 2–3 years before the menarche and is caused by adrenal secretion. The major androgens secreted by the adrenals are androstenedione, dehydroepiandrosterone (DHEA) and DHEA sulphate (DHEAS). Ovarian androgen production begins under the influence of the pubertal secretion of luteinizing hormone (LH) and takes place in the theca cells. The predominant androgen secreted by the ovaries is androstenedione during the reproductive years, and testosterone after the menopause.

In normal women, the majority of testosterone production (50–70%) is derived from the peripheral conversion of androstenedione in the skin and other extrasplanchnic sites. The remaining proportion is secreted directly by the adrenals and ovaries.

In non-pregnant women, the majority of circulating androgens are bound to a high-affinity β-globulin, sex hormone-binding globulin (SHBG). A further 20–25% is transported loosely bound to albumin, and approximately 1% circulates freely. The free steroid is believed to be active, and the binding protein is therefore of paramount importance.

Whilst abnormal degrees of hair growth are often seen in endocrine disorders characterized by hyperandrogenism, many women with hirsutism will lie within the range of normal for their age and ethnic origin. For those objectively classified as hirsute, many will have underlying PCOS. Most of the others will have no detectable hormonal

abnormality and are usually classified as having‘idiopathic’ hirsutism. In addition to an increase in circulating androgens, an increased sensitivity to normal levels of androgens or metabolism of the end organ, the dermal papilla of the hair follicle, may well be relevant.

2.4.2.6 Clinical Features

2.4.2.6.1 Presentation

Women present with terminal hair that is frequently coarse and pigmented in areas that are usually typical for men only. Seborrhoea, acne and female pattern hair loss may also be evident. Frequently, measures will be taken to deal with the hair, such as shaving, and therefore only stubble may be visible.

2.4.2.6.2 Clinical Variants

I. SAHA syndrome. The term SAHA syndrome is used by some to describe the constellation of features that arise with cutaneous virilization. The acronym stands for Seborrhoea, Acne, Hirsutism and Androgenetic alopecia.

II. Polycystic ovary syndrome. The 2003 Rotterdam consensus defined PCOS as having two out of the following criteria:

a. Clinical (acne or hirsutism) and/or biochemical hyperandrogenaemia (measured elevated androgen levels).
b. Menstrual irregularity.
c. Polycystic ovarian morphology on ultrasonography.

It is necessary to exclude other specific disorders, such as non-classic adrenal 21-hydroxylase deficiency, Cushing syndrome, hyperprolactinaemia and androgen-producing tumors.

Polycystic ovaries can occur in normal women or mildly polycystic ovaries in hirsute women with normal menses; women can have the metabolic syndrome of PCOS with normal ovaries on ultrasound. An estimated one-third of women in the UK have polycystic ovaries – defined as 10 or more follicles per ovary detected on ultrasound. One-third of these women will suffer from PCOS. The pattern of these features will depend upon the presenting complaint, be it dermatological, endocrinological or gynaecological.

III. Ovarian tumours. Hirsutism is an almost universal feature in virilizing ovarian tumours; however, functioning tumours that cause virilization represent only about 1% of ovarian tumours.

IV. Congenital adrenal hyperplasia. Cholesterol is metabolized in the adrenal cortex, via a complex pathway, into aldosterone, cortisol, androgens and oestrogens. A defect in cortisol synthesis results in redistribution of the precursors to other pathways, which results in overproduction of the other hormones. In approximately 95% of cases, 21-hydroxylation is impaired so that 17-hydroxyprogesterone (17-OHP) is not converted to 11-deoxycortisol. Because of defective cortisol synthesis, adrenocorticotrophic hormone levels increase, resulting in overproduction and accumulation of cortisol precursors, particularly 17-OHP. This causes excessive production of androgens, resulting in virilization.

V. Acquired adrenocortical disease. Adrenal carcinomas usually present with abdominal swelling or pain; however, 10% of both adenomas and carcinomas may present with isolated virilization. The combination of virilization and Cushing syndrome strongly suggests the presence of a carcinoma. The testosterone level is usually markedly raised in the latter.

Patients with Cushing syndrome are said to have both hypertrichosis, a generalized diffuse growth of fine hair resulting from hypercortisolaemia, and androgen-induced coarse hair in the usual male pattern.

VI. Idiopathic hirsutism. Idiopathic hirsutism is the diagnostic label given to those hirsute women in whom no overt underlying endocrine disorder can be detected.

2.4.2.7 Classification of Severity

Clinical severity can be assessed by examining the extent and distribution of hair, associated features (acne, seborrhoea, pattern hair loss), signs of virilization (clitoromegaly, deepening of voice) and assessing the impact on quality of life. The Ferriman–Gallwey system is the current standard for evaluating hirsutism, which records the presence and degree of hair at different body sites to produce a cumulative score. A score greater than 8 is regarded as diagnostic of hirsutism.

2.4.2.8 Investigations

A short history with dramatic change should prompt investigation for an underlying androgen-secreting tumour. Whilst a sudden change from regular to irregular menses is concerning, normal menses is typical of hirsutism without any endocrine disturbance.

Lifelong irregular menses would be in keeping with PCOS.

The extent to which it is necessary for hirsute women without suspicious signs or history to be investigated is debatable. If the primary concern is to exclude an androgen-secreting tumour, a measure of serum testosterone is a good screening tool. It can be supplemented by measurement of DHEAS. Clarifying the diagnosis of PCOS may be appropriate or further investigation arranged in collaboration with a primary care physician, endocrinologist or gynaecologist.

2.4.2.9Management

The treatment of hirsutism can be broadly divided into measures aimed at removing unwanted terminal hair and those that reduce the androgen drive to vellus–terminal conversion.

2.4.2.9.1 Physical Methods of Hair Removal

There are a number of approaches to hair removal in hirsutism:

I. The most widely used methods are shaving and plucking. Shaving the face is unpopular as it seen as a male activity. Various means of plucking hairs include the use of tweezers, waxing, sugaring and threading.

II. Depilatory creams contain thioglycolates that dissolve sulphur bonds within the keratin molecules, making the hair gelatinous. They are irritant and require care in terms of strength of preparation and duration of exposure.

III. Electroepilation (‘electrolysis’) is a more permanent method of hair removal. A fine

wire is slid into the hair follicle, which is ablated by an electric current using galvanic electrolysis, thermolysis or a combination of the two ('blend'). Electroepilation is a slow method most suited to relatively small areas of hirsutism but good results can be obtained by skilled therapists.

IV. Laser thermolytic hair removal is now widely used. Although its long-term efficacy is not yet known, laser-assisted hair removal has been in use for sufficient time to allow a reasonable estimate of its efficacy and safety. A Cochrane review observed that the data to support laser and intense pulsed light (IPL) treatment were poor, but favoured alexandrite and diode lasers over others. Lack of follow-up data was a particular shortcoming (Haedersdal M, Wulf HC. 2006). Most practitioners will select patients with dark hair and light skin. This maximizes the absorption of laser energy by the hair and minimizes absorption by the skin. Nevertheless, it is still possible for soreness and crusting to occur following treatment. In darker skin this can be associated with post-inflammatory pigmentary changes. Treatments are usually administered as part of a course of at least three visits separated by intervals of several weeks. This reflects the biology of the follicle, which is most responsive to abalation when in anagen. The gap between treatments allows those hairs initially in telogen to move into anagen. Broad-band IPL represents a cheaper technology with less restriction on the licensing of those who use it. It is likely to achieve some of the benefits of laser therapy (Sadick NS, Weiss RA, et al 2000).

2.4.2.9.2 Topical Medication

Topical eflornithine cream reduces the rate of hair growth by inhibiting the enzyme

ornithine decarboxylase. Limited clinical trial evidence suggests around one-third of women are helped by using topical eflornithine and it achieves an average reduction in hair growth of about 20%. Treatment has to be continued to maintain the response (Wolf JE, Jr, Shander D, etal 2007). There is some evidence that supplementing laser therapy with eflornithine cream results in a greater benefit sooner than with either treatment alone (Hamzavi I, Tan E, et al2007).

2.3.2.6.8.3 Oral Drug Therapy

The main systemic therapies for hirsutism are antiandrogens (Rittmaster RS. (1999))[86]. The benefits in terms of reversing existing terminal hair growth are relatively modest but it is logical to assume antiandrogens will help to prevent further conversion of vellus follicles to terminal ones. Any benefits are lost within months of stopping treatment (Yucelten D, Erenus M, et al 1999).

I. Cyproterone acetate. Cyproterone acetate (CPA) is a synthetic progestogen that acts as both an antiandrogen and an inhibitor of gonadotrophin secretion (Van der Spuy ZM, le Roux PA. 2003).

II. Spironolactone. Spironolactone is a popular and relatively safe treatment for hirsutism.

III. 5α-reductase inhibitors. Finasteride inhibits the type 2 isoenzyme of 5α-reductase and has been assessed in small placebo-controlled trials, with some benefit after 6 months' therapy.

IV. Metformin. Metformin is a biguanide originally used in the treatment of type 2 diabetes. It has found a place in the treatment of hirsutism associated with hyperinsulinaemia and insulin resistance

V. Flutamide. This acts as a pure antiandrogen and works by binding to androgen receptors.

2.3.2.6.8.4 Weight Loss

Polycystic ovary syndrome is often associated with obesity. Weight loss will help to reduce insulin resistance and circulating testosterone, and excessive hair growth.

2.5 The Laser

2.5.1 Laser Definition

The word **LASER** stands for **L**ight **A**mplification by the **S**timulated **E**mission of **R**adiation.

2.5.2Historic Review

Since the first report on laser radiation by Maiman (1960), many potential fields for its application have been investigated. Among these, medical laser surgery certainly belongs to the most significant advances of our present century. Actually, various kinds of lasers have already become irreplaceable tools of modern medicine. Although clinical applications were first limited to ophthalmology– the most spectacular and today well-established laser surgery being argon ion laser coagulations in the case of retinal

detachment – the fields of medical laser treatment have meanwhile considerably widened. Due to the variety of existing laser systems, the diversity of their physical parameters, and last but not least the enthusiasm of several research groups almost every branch of surgical medicine has been involved. This should not be interpreted as criticism, although much damage has been done in some cases – especially in the field of biostimulation when researchers have lost orientation due to striving for new publications and success, and industries have praised laser systems that later turned out to be completely useless. In general, though, many really useful laser techniques have been developed and clinically established with the help of all kinds of scientists. These methods of treatment have been reconfirmed by other researchers and properly documented in a variety of well-accepted scientific journals. And, even with early laser applications primarily aimed at therapeutic results, several interesting diagnostic techniques have recently been added from the historic point of view, lasers were first applied in ophthalmology. This was obvious, since the eye and its interior belong to the easiest accessible organs because of their high transparency. And it was only a few years earlier that Meyer-Schwickerath (1956) had successfully investigated the coagulative effects of xenon flash lamps on retinal tissue. In 1961, just one year after the invention of the laser, first experimental studies were published by Zaret et al. (1961).

2.5.3Basics of A Complete Laser System

I. Light Sources (pumping sources)

II. Gain medium

III. Mirrors

- The gain medium is pumped by some method.
- Some of the atoms/molecules are excited.
- Spontaneous emission occurs, in all directions.
- Emission along long axis of cavity is reflected back through the gain medium.
- The spontaneously emitted photons stimulate further emission from the medium.
- A large radiationdensity quickly builds up.
- One of the mirrors is usually partially transmitting to allow some of the laser radiation to escape.(William T. Silfvast(2004)

2.5.4 Laser Light Properties

Laser light has the following properties:

I. Monochromaticity (monochromatic light)

The color of the light is determined by the length of its waves (λ). Laser light is single colored light (has one λ, or monochromatic). Each type of lasers has single wavelength.

II. Directionality (directional light)

The characteristic of laser light that causes it to travel in a single direction within a narrow cone of divergence.

III. Coherence (coherent/collimated light)

Coherence is the term used to describe the in-phase property of laser beam.

V. High intensity

Laser light is the intense light ever be known. Each laser type has its own intensity which can be defined as the number of photons emitted per unit surface area per unit solid angle.

Even lasers with low intensity, compared with other lasers, are intense more than the sun light. This property is due to huge number of coherent photons emitted with very small angle (little divergence) (OrazioSvelto 2004).

2.5.5 Laser Types

Lasers are divided according to the state of matterof the active medium to:

I. Solid lasers

II. Liquid lasers

III. Gas lasers

IV. Plasma lasers

V. Junction between two slabs of semiconductor Materials

2.5.6 Laser Parameters

I. Spot size

11. Pulse width

III. Fluence

IV. Repetition Rate

2.5.7Interaction Mechanisms

The variety of interaction mechanisms that may occur when applying laser light to biological tissue is manifold. Specific tissue characteristics as well as laser parameters contribute to this diversity. Most important among optical tissue properties are the coefficients of reflection, absorption, and scattering, (Roggan, A., Albrecht, et al 1995b).

During the first decades after the invention of the laser by Maiman, 1960, many studies were conducted investigating potential interaction effects by using all types of laser systems and tissue targets. Although the number of possible combinations for the experimental parameters is unlimited, mainly five categories of interaction types are classified today. These are photochemical interactions, thermal interactions, photoablation, plasma-induced ablation, and photodisruption.

2.5.7.1Thermal Interactions

Assuming a body temperature of 37◦C, no measurable effects are observed for the next 5◦C above this. The first mechanism by which tissue is thermally affected can be attributed to conformational changes of molecules. These effects, accompanied by bond destruction and membrane alterations, are summarized in the single term hyperthermia ranging from approximately42–50◦C. If such a hyperthermia lasts for several minutes, a significant percentage of the tissue will already undergo necrosis as described below by Arrhenius' equation. Beyond 50◦C, a measurable reduction in enzyme activity is observed, resulting in reduced energy transfer within the cell and immobility of the cell.

Furthermore, certain repair mechanisms of the cell are disabled. Thereby, the fraction of surviving cells is further reduced. At 60◦C, denaturation of proteins and collagen occurs which leads to coagulation of tissue and necrosis of cells (Weinberg, W.S.et al (1984)) [98]. The corresponding macroscopic response is visible paling of the tissue. Several treatment techniques such as laser-induced interstitial thermotherapy (LITT) aim at temperatures just above 60◦C. (Roggan, A., M¨uller, G. (1993)) [99]. At even higher temperatures (> 80◦C), the membrane permeability is drastically increased, thereby destroying the otherwise maintained equilibrium of chemical concentrations. At 100◦C, water molecules contained in most tissues start to vaporize. The large vaporization heat of water (2253 kJ/kg) is advantageous, since the vapor generated carries away excess heat and helps to prevent any further increase in the temperature of adjacent tissue. Due to the large increase in volume during this phase transition, gas bubbles are formed inducing mechanical ruptures and thermal decomposition of tissue fragments. Only if all water molecules have been vaporized, and laser exposure is still continuing, does the increase in temperature proceed. At temperatures exceeding 100◦C, carbonization takes place which is observable by the blackening of adjacent tissue and the escape of smoke. To avoid carbonization, the tissue is usually cooled with either water or gas. Finally, beyond 300◦C, melting can occur, depending on the target material.

2.5.8Medical Applications of Lasers

Laser applications in ophthalmology. Even today, the majority of medical lasers sold is applied in this field. Dentistry was the second clinical discipline to which lasers were introduced. However, although considerable research has been done, the results were not quite as promising in most cases, and the discussion on the usefulness of dental lasers still

proceeds. Today, the major effort of clinical laser research is focusing on various kinds of tumor treatments such as photodynamic therapy (PDT) and laser-induced interstitial thermotherapy (LITT). These play a significant role in many other medical disciplines like gynecology, urology, and neurosurgery. Due to recent advancements in instrumentation for minimally invasive surgery (MIS), e.g. the development of miniature catheters and endoscopes, novel techniques are under present investigation in angioplasty and cardiology. Very interesting laser applications were found in dermatology and orthopedics. And, recently, successful laser treatments have been reported in gastroenterology, otorhinolaryngology, and pulmology. (Markolf H. Niem. (2007)

2.5.9Laser Hair Removal

Unwanted hair is a common aesthetic problem. Excessive hair can be a marker for an underlying endocrine disorder or a side effect of medication. Patients should be assessed for potential aetiologies prior to photoepilation. Hair removal by shaving, waxing, plucking, chemical depilatories and electrolysis can improve one's quality of life, but many of these techniques provide only temporary solutions to unwanted hair. Although electrolysis has the potential to permanently remove hair, it is a tedious procedure with variable efficacy, which is highly operator dependent.

Laser treatment has emerged as a reliable and effective method of hair removal and is an extremely popular aesthetic request as it provides a longer lasting hair-free period than other methods. In 1996, the 694 nm ruby laser was the first laser device formally studied for hair removal (Grossman MC, Dierickx C, et al 1996).

Photoepilation is based on the selective delivery of energy to the hair follicle, specifi

cally to the bulge region, causing destruction to the follicle stem cells, while minimizing non-selective injury to the surrounding tissues. Additional melanin targets are located in the follicular hair shaft, the outer root sheath of the infundibulum and the hair bulb matrix. Melanin in the hair matrix absorbs wavelengths between 600 to 1100 nm. Thus, the long-pulse ruby (694 nm), long-pulse alexandrite (755 nm), long-pulse diode (810 nm), long-pulse Nd: YAG (1064 nm) and intense pulsed light (IPL, 590–1200 nm) can all destroy hair using selective photothermolysis. Energy is converted into heat, which diffuses laterally beyond the actual follicle to the biological 'target', namely the stem cells in the bulge region.

The safety and efficacy of laser hair removal is dependent on the operator's knowledge of the practical application of laser–tissue interactions. Selection of the appropriate pulse duration is critical for effective photoepilation. Since the thermal relaxation time of a hair follicle is 10–50 ms, the pulse duration should be adjusted to match these parameters (Van Gemert MJ, Welch AJ. 1989). Extension of the pulse duration beyond the thermal relaxation time of the follicular unit could promote delivery of thermal damage to the surrounding non-pigmented stem cells and is likely to induce more consistent follicular destruction (Dierickx CC. 2002).

Different devices should be utilized for varying skin types. Lighter skin phototypes (I–III) show improved response to treatment with the 755 nm alexandrite or the 800 nm diode laser, while darker skin phototypes (IV–VI) have a better outcome with the1064 nm Nd: YAG laser. The ideal patient for hair removal is someone with lighter skin (phototypes I–III) and dark brown to black hair. Most studies have shown comparable efficacy rates when sufficient fluence is used and multiple treatments are performed.

Fluence should be titrated up, if necessary, with each treatment. Typically, three to eight treatments spaced at 6–10-week intervals are recommended. Response rates of 70–90% hair reduction at a6-month follow-up have been reported (Lepselter J, Elman M. 2004).

Cooling of the epidermis is essential with hair removal devices, and this can be applied immediately prior to (pre-cooling), during (parallel cooling) or after (post-cooling) laser pulsing. Application of the cooling device not only protects the epidermis from excessive heat, but direct contact with the cooling handpiece allows for compression of the skin and facilitates deeper delivery of laser energy to the targeted hair follicles.

Paradoxical hypertrichosis is a fairly common side effect, seen in0.6–10% of patients treated with diode and alexandrite lasers and IPL devices (Alajlan A, Shapiro J, Rivers JK, et al. 2005, Willey A, Torrontegui J, 2007, Desai S, Mahmoud BH, 2010). Although the exact mechanism is unknown, it is proposed that the laser or light source stimulates new hair growth through the synchronization of dormant hair follicles into terminal anagen hair growth. Overall, hair density appears to be greater than the previously asynchronous hair growth. Another hypothesis is that suboptimal fluences may induce terminal hairs from vellus hairs. Risk factors for this complication include: darker skin types (III–VI), for example patients of Mediterranean, Middle Eastern, Asian and South Asian descent; dark, thick hair; and underlying hormonal conditions. Despite initial hypertrichosis, continued treatment with laser therapy to the affected area will eventually reduce the hair growth, and appropriate reassurance should be given to the patient.

Laser hair removal in patients with darker skin can be more difficult as the epidermal melanin competes with the follicular target. The 1064 nm Nd:YAG laser is considered

the optimal laser for hair removal in such patients because of the dramatically reduced epidermal melanin absorption with this wavelength(Alster TS, Bryan H,et al. 2001). Conversely, the poor melanin uptake requires the use of high energies, resulting in increased pain and reduced efficacy Pre-treatment consultation and preparation of the skin is required in laser epilation in order to maximize results and avoid complications. Patients with tanned skin should not be treated in order to reduce the risk for burns, scarring and permanent pigmentary changes. Patients should avoid hair plucking, waxing, threading and electrolysis prior to laser treatment as these will remove the follicles and the target chromophore, but shaving and the use of depilatory creams is permitted as these do not affect the follicle and target chromophore. Laser treatment can be uncomfortable, therefore the use of topical anesthetic creams applied prior to treatment may be of benefit, although it should be performed in a controlled environment to avoid anaesthetic toxicity.

The expected acute phase response to treatment is a perifollicular reaction, namely erythema and focal oedema surrounding the follicle, indicating a good uptake of laser/light energy. The laser surgeon should remain vigilant in inspecting the skin for evidence of blanching, blistering or crusting. Grey or white epidermal discoloration is an ominous sign as this indicates nonspecific dermal heat injury and is a marker of an inappropriately high fluence. Blister formation and epidermal necrosis may ensue, and in severe cases may result in dermal necrosis and marked scarring.

2.5.10 Laser Hazards and Safety. By (Markolf H. Niemz. 2007)

2.5.10.1 Introduction

The increasingly widespread use of lasers requires more people to become familiar with the potential hazards associated with the misuse of this valuable new product of modern science. Applications exist in many technologies, including material processing, construction, medicine, communications, energy production, and national defense. Of recent importance from a safety consideration, however, is the introduction of laser devices into more consumer oriented retail products, such as the laser scanning devices, office copy and printing machines, and audio/visual recording devices. Most devices in these markets emit relatively low energy levels and, consequently, are easily engineered for safe use.

2.5.10.2 Laser Hazards

The basic hazards from laser equipment can be categorized as follows:

2.5.10.2.1 Laser Radiation Hazards

Lasers emit beams of optical radiation. Optical radiation (ultraviolet, visible, and infrared) is termed nonionizing radiation to distinguish it from ionizing radiation such as X-rays and gamma rays which are known to cause different biological effects.

I. Eye hazards: Corneal and retinal burns (or both), depending upon laser wavelength, are possible from acute exposure; and corneal or lenticular opacities (cataracts), or retinal injury may be possible from chronic exposure to excessive levels.

II. Skin hazards: Skin burns are possible from acute exposure to high levels of optical radiation. At some specific ultraviolet wavelengths, skin carcinogenesis may occur.

2.5.10.2.2 Chemical Hazards

Some materials used in lasers (i.e. excimer, dye, and chemical lasers) may be hazardous and/or contain toxic substances. In addition, laser-induced reactions can release hazardous particulate and gaseous products

2.5.10.2.3 Electrical Hazards

Lethal electrical hazards may be present in all lasers, particularly in high power laser systems.

2.5.10.2.4 Other Secondary Hazards

These include:

I. Cryogenic coolant hazards,

11. Excessive noise from very high energy lasers,

III. X radiation from faulty high-voltage (> 15 kV) power supplies,

IV.Explosions from faulty optical pumps and lamps,

V. Fire hazards

2.5.10.2.5 Associated Hazards from High Power Lasers

Can give rise to respiratory hazards. Laser welding, cutting, and drilling procedures can

create potentially hazardous fumes and vapors. Fortunately, the same localized and general ventilation procedures developed for similar conventional operations apply to this type of laser application.

Some applications of high-power lasers, especially in materials processing, the most lethal hazards associated with the laser involves electricity. There have been several fatal accidents associated with lasers due to electrocution these occurred when commonly accepted safety procedures were not. Followed when individuals were working with dangerous, high-voltage components of a laser system. Proper electrical hazards controls should be used at all times when working with laser systems.

Fire hazards may exist with some high-power laser devices, normally those with continuous wave (CW) lasers having an output power above 0.5W. Another hazard sometimes associated with high-power laser systems involves the use of cryogenic coolants used in the laser system. Skin contact can cause burns, improper plumbing can cause explosions, and insufficient ventilation can result in the displacement of oxygen in the air by liquefied gas vaporizing (most commonly nitrogen). Cryogenic hazards are normally, but not exclusively, limited to research laboratories. Noise hazards are rarely present in laser operations.

2.5.10.3 Laser Safety Standards and Hazard Classification

The basic approach of virtually all laser safety standards has been to classify lasers by their hazard potential which is based upon their optical emission. The next step is to specify control measures which are commensurate with the relative hazard classification. In other words, the laser is classified based upon the hazard it presents, and for each

classification a standard set of control measures applies. In this manner, unnecessary restrictions are not placed on the use of many lasers which are engineered to assure safety.

2.5.10.3.1 Laser Safety

The (American National Standards Institute's) ANSI scheme has four hazard classifications. The classification is based upon the beam output power or energy from the laser (emission) if it is used by itself. If the laser is a component within a laser system where the raw beam does not leave the enclosure, but instead a modified beam is emitted, the modified beam is normally used for classification. Basically, the classification scheme is used to describe the capability of the laser or lasersystem to produce injury to personnel. The higher the classification number, the greater is the potential hazard. Brief descriptions of each laser class are given as follows:

I. Class 1 denotes lasers or laser systems that do not, under normal operating conditions, pose a hazard.

II. Class 2 denotes low-power visible lasers or visible laser systems which, because of the normal human aversion response (i.e. blinking, eye movement, etc.), do not normally present a hazard, but may present some potential for hazard if viewed directly for extended periods of time (like many conventional light sources). Safety glasses are required for prolonged viewing only.

III. Class 3a denotes the lowest class of lasers or laser systems that always require protective eyewear. These lasers would not injure the eye if viewed for only momentary periods (e.g. within the aversion response period of approximately 0.25 s) with the

unaided eye, but may present a greater hazard if viewed using collecting optics or if viewed without the possibility of an aversion response (as for UV or IR radiation).

IV. Class 3b denotes lasers or laser systems that can produce a hazard if viewed directly. This includes intrabeam viewing of specular reflections. Normally, Class 3b lasers will not produce a hazardous diffuse reflection. Protective eyewear is always required.

V. Class 4 denotes lasers and laser systems that produce a hazard not only from direct or specular reflections, but may also produce hazardous diffuse reflections. Such lasers may produce significant skin hazards as well as fire hazards. Protective eyewear is always required.

CHAPTER THREE

Material and Method

3.1 Introduction

This chapter will deal with different objects used, as well as the procedures followed in this study.

3.2 The materials

3.2.1 Study Area

The study was held in the Laser Clinic, Institute of Laser-Sudan University of science and technology, Khartoum-Sudan.

3.2.2 Study design and study population

This is a prospective, clinical descriptive, intervention was performed between September 2021 to February 2022.

Ten patients, whose ages are more than or equal to 18 years, were selected for this study from different dermatology clinics in Khartoum state and were considered as the study population.

3.2.3 Inclusion criteria

Selected patients were:

- Over 18 years of age.
- Able to give informed consent.
- Willing to come back for one week and three weeks follow-up.

3.2.4 Exclusion criteria

Those excluded were:

- Less than 18 years of age.
- History of photosensitive disease or drugs.
- Patients who received systemic retinoid within six months
- Patients on systemic Anticoagulants treatment
- Patients with history of keloids.
- Patients with history of vetiligo.
- Patients with history of psoriasis.
- Pregnant woman.
- Unable to give informed consent.
- Unable to follow up for post-operative evaluation.
- Unable to understand consent process or risks.

3.2.5 Data collection, Tool and Techniques

3.2.5.1 The Laser Medical System

Diode laser, Terminator T808 system, with 808 nm wavelength, manufactured by Company omega xp in China was used in this study. Diode laser parameters used were the standard mode, two mode hair removal(HR), fast hair removal(FHR), non-contact applications of handpeice prop ,Sapphire handpeice cooling system, a power of 20 watt , and spot size 12mm, fluence 8-9J/cm^2, repetition frequency1HZ,pulse wide 36 ms . The diode laser system is composed of one unit containing the different touch switches, cables screen of control panel …etc. The opening of laser outcome was manifested spontaneously when laser was activated. The display screen allowed the options of the different laser parameters.

The aim of the diode laser in this study was to coagulate the melanin and concerned blood vessels in the hair follicle. The absorbed laser power is converted into heat, causing coagulation of the targeted vessels.

3.2.5.2 The Patients Record

A data collection form was designed to record patients information (age, skin type, hair color, area of body treated, laser parameter, hair density, side effect, and patient's satisfaction.).

3.2.5.3 Some Drugs Were Used to Help in the Procedure

Magic cream was used post-operatively at site of treatment. Sun block: Photo block sun block gel SPF 50 was used on face post-operatively as topical sun screen.

3.2.5.4 Photographs of patients

Depicted actual patients included in the study before the treatment and at interval of one week and three weeks after the last session.

3.2.5.5 Ethical and legal considerations

All patients were requested to participate voluntarily, and written informed consent was done with ethical clearance from participates themselves before being enrolled in the study. They were informed about the possible side effect and hazards of laser therapy. Confidentiality of the patients was maintained.

3.2.5.6 Time Schedule

Table 3.1 Time Schedule

Activity	**Time**
Proposal writing	September-021 to October-021
Clearance and approval	October-021 to November-021
Data collection	November-021 to December-021
Data entry, clearance and thesis report writing	December-021 to January-022
Data analysis	January-022 to February

3.2.5.7 Financing of the Research Project

All the treatment procedure required for the research purpose was done freely in Sudan University of Science and Technology, Institute of Laser other expenses of the research project were covered by researcher.

3.2.5.8 Patients Grouping

Patients were classified into two groups according to area treated, underarm and chin.

3.3 Checking the Safety Measures

The diode laser system emits 808nm wavelength is classified as class IV laser that may cause both optical and cutaneous damage through direct laser beam and by reflected laser beam (specular or diffuse reflection). Other hazards electrical hazards may be encountered .The laser safety precautions followed in this study were including.

3.3.1 Safety Features of the diode laser system

They contain electrical lock switch which connect the electrical power supply from the wall to the cable, then the key lock switch which is considered the second safety switch in the path of electrical current, laser emergency stop switch, a red button, which when pressed the power stops immediately and when the switch is put on an audible beep is heard, hand piece prop switch which is controlled by operator and finally the lasing button which when pressed the process of lasing starts.

3.3.2 Laser Room Precautions

All warning signs were made clear and put in the appropriate location. Reflective objects like mirror and shiny instruments were strictly prohibited in the operation room. The walls were made rough, the windows were closed and covered with opaque material to prevent unintended viewing or escaped laser from room.

3.3.3 Optical Hazards Precautions

Doctors, patients and any other personnel attending the operating room should never look directly to the laser beam and should wear the appropriate goggles that coincide to wavelength. The laser beam should never be directed to any site except the intended site of treatment.

3.3.4 Electrical and Mechanical Hazards

Precautions were precisely followed and unconcerned related materials were not allowed.

3.4 The Methods

These procedures start after the arrival of patient. After a proper history and consent was taken from patient, pre-operative photo was depicted from the site of treatment. The patients advised to shave the preference hair area 48 hours before every session. Patient was undressed and a gown was put on (under arm site treatment), before laying on the operating table.

3.4.1 Checking the Safety Measures

Safety precautions were rechecked by turning on the warning sign, getting rid of any available shiny materials in the operating room, putting on the sucker machine and wearing appropriate goggles, masks, by all attending personnel.

3.4.2 Preparing the diode laser system

The circuit breaker in the wall was put on, the key-lock switch was put on and the emergency red switch was pulled up. The operating standard mode was displayed on the screen and the exact parameters were chosen. The terminal device of the hand piece prop delivering, the guiding light was turned away from the patient and attending personnel.

3.4.3 The laser Surgery

The patients were put on the operating table, exposing only the wanted area and patient's eyes were shielding properly. The hand piece prop was held close to the treated area in non-contact mode.

The lasing switch was turn on. The hand piece prop button was pressed repeatedly and different numbers of exposure intervals were applied. Point by point on the area treated and then opening of hair follicle and tip of hair was shrinking. Before the treatment the area was cooled by placing the end of the prop in contact mode, after that lift the prop from the area about 1cm, was emitting the laser light in the area in sequence respectively covering the area needed .and then re-cool the area in between using the laser light then after finishing re-cool the whole area. Sessions were done on three weeks intervals. The lasing switch was turn off first followed by the key switch ending with the circuit breaker in the wall.

3.4.4 Post-operative Care

Sun block cream was prescribed for daily used when exposed to sun light (at chin treatment), also avoid scrubbing the area and use abrasive skin cleansers. After the last

session, one week and three weeks follow up appointments were given to the patient to evaluate the results. A post-operative photo was taken from site of treatment at one week and three weeks after the last session.

3.4.5 Evaluation of the Result

For evaluation of the treatment response, ten elements of evaluation were considered according to hair, skin and patient's satisfaction for every element of evaluation developed, 10% was given for the response of treatment.

Evaluation of response was conducted using both observation and clinical examination. For the evaluation of the treatment response, it was considered that, for every element of evaluation developed, has percent was given for the response of treatment. Ten elements of evaluation are considered below. The patients were evaluated by a preformed clearance sheet at the end of the follow up period, they were asked to rate of hair reduction on a 10-point likert scale. Rating above 6 was graded as (excellent response), rating between 4 and 6 served as (good response) and rating below 4 labeled as (poor response).

3.4.5.1 Elements for Evaluation of the Treatment Response were:

1. Reduction in number of hair three weeks after the third session.
2. Hair texture observe by doctor(coarse, fine)
3. Hair color.(black, brown, grey and white)
4. Skin texture.
5. Prolong erythema lasting more than 24 hours, purpura last >14 days.
6. Hypo-pigmentation and hyper-pigmentation >3 weeks)
7. Keloid formation.

8. Post-operative blister.
9. Wound infection**.**
10. Patient satisfaction.

Data analysis

Data was analyzed manually and was usedexcel program to made result tablesand chart graph.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1. RESULTS

4.1.1. Study Sample

The study involved treating and assessing the hair reduction in 10 female patients, with Diode (808nm) laser.

4.1.2. Age Distribution

Figure 4.1 below shows the age distribution of the treated patients, namely 4 patients between the ages of 18-32 years, and 6 patients between the ages of 33-47 years.

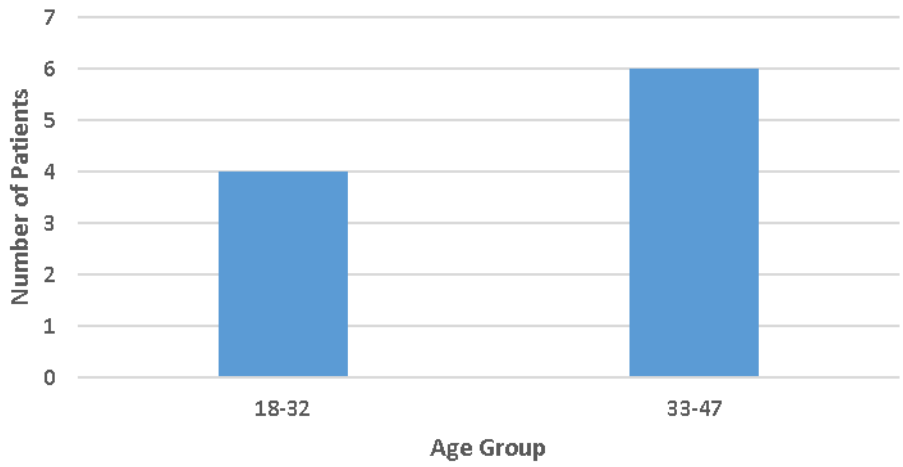

Figure 4.1 Age group of study sample

4.1.3. Skin Type

Table (4.1) below shows the skin type according Fitzpatrics classification, where within the study sample the most common group skin type was type V found in 4 patients (40%), whereas skin type IV and VI was found in 3 patients (30%) for each.

Table 4.1 Skin Type According Fitzpatrics Classification

Skin type	N	%
I	0	0
II	0	0
III	0	0
IV	3	30
V	4	40
VI	3	30
Total	10	100

4.1.4. Hair Color

All patients had black hair as can be seen in Table 4.2 below.

Table 4.2 Hair Color

Hair color	N	%
Black	10	100
Brown	0	0
Grey	0	0
White	0	0
Total	10	100

Treated Body Part

Figure (4.2) below shows the part of body that was treated; 6 patients (60%) were treated in the under-arm area and 4 patients (40%) were treated in the chin area.

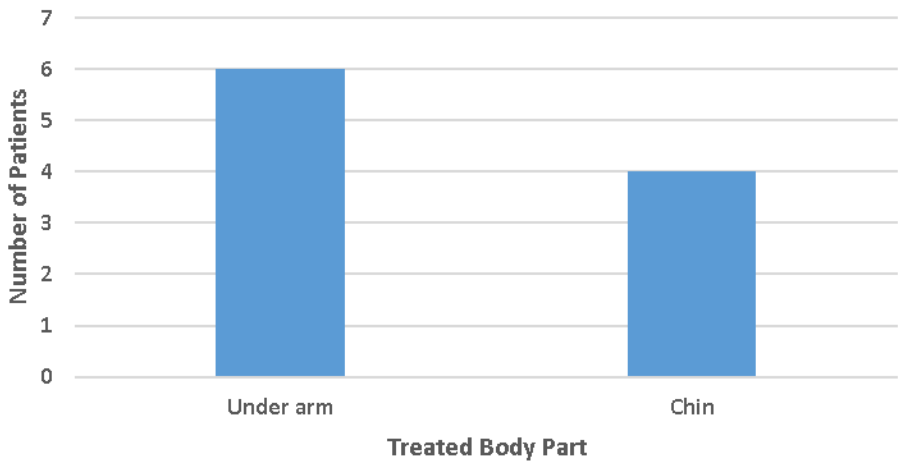

Figure 4.2 Body Part Treated

4.1.5. Hair Reduction in Under-Arm Treatment

Table 4.3 below shows the effectiveness of diode (808nm) laser on hair reduction in the under-arm area. The average reduction after the 1st session, as a percentage of the initial hair count, was 23.2% with a range 14.3% - 33.3%. The average reduction after the 2nd session, as a percentage of the initial hair count, was 34.6% with a range 23.8% - 42.4%. The average reduction after the 3rd session, as a percentage of the initial hair count, was 57.9% with a range 45.7% - 66.7%.

Table 4.3 Hair Density (hair no. /cm^2) in the Under-Arm Area

Patient number	Hair count before treatment	Hair count 3 weeks after 1st session	Hair reduction** after 1st session (%)	Hair count 3 weeks after 2nd session	Hair reduction** after 2nd session (%)	Hair count 3 weeks after3rd session	Hair reduction** after 3rd session (%)
1	35	25	**28.6**	22	**37.1**	19	**45.7**
2	33	22	**33.3**	19	**42.4**	11	**66.7**
3	30	24	**20**	19	**36.7**	12	**60**
4	25	20	**20**	18	**28**	10	**60**
5	24	20	**16.7**	16	**33.3**	9	**62.5**
6	21	18	**14.3**	16	**23.8**	10	**52.4**
Average	28	21.5	**23.2**	18.3	**34.6**	11.8	**57.9**

*****Interval between each session= three weeks, were taken before each session.

**Hair reduction %= Difference between before treatment average (laser treatment) and the session/before treatment average *100

4.1.6. Relation Between Percentages of Hair Reduction and Sessions Number In Patients Treated in the Under-Arm Area

Figure 4.3 below shows the relation between percentages of hair reduction and sessions in the patients treated in the under-arm area. The graph show an increase in the percentage of hair reduction in comparison with the initial hair count after each session.

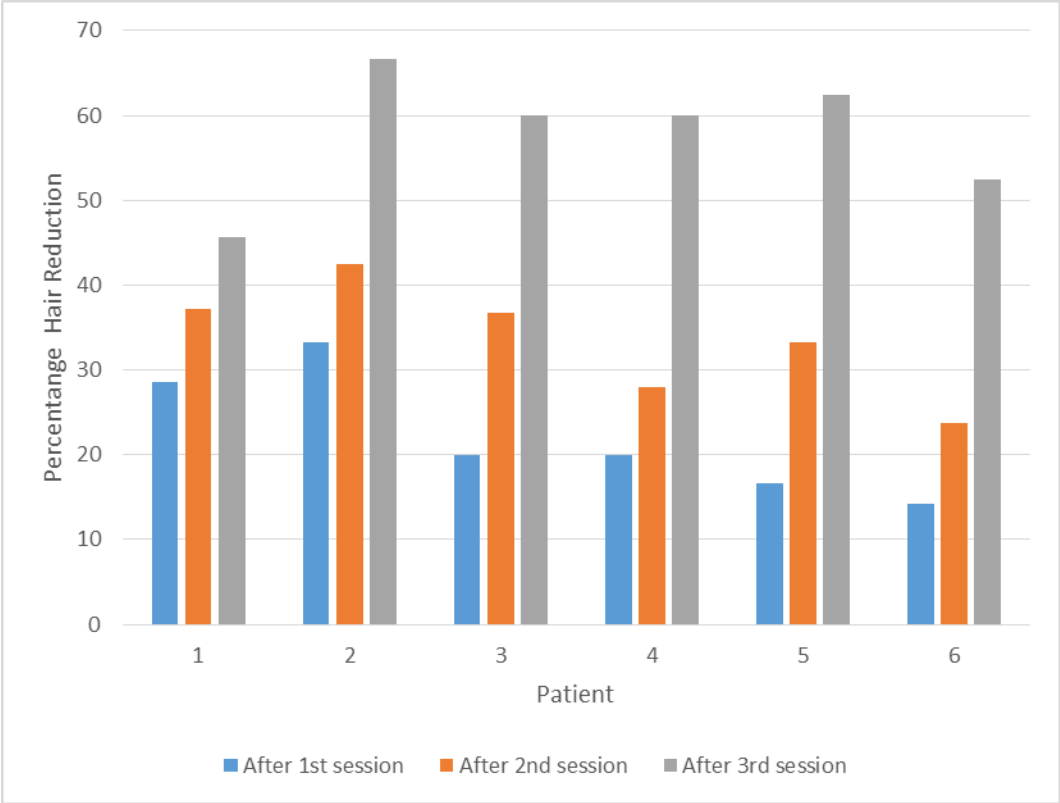

Figure 4.3 Relation Between Percentages of Hair Reduction and Sessions Number in Patients Treated in the Under-Arm Area

4.1.7. Hair Reduction in Chin Treatment

Table 4.4 below shows the effectiveness of diode (808nm) laser on hair reduction in the chin area. The average reduction after the 1st session, as a percentage of the initial hair count, was 20.9% with a range 13.6% - 37.5%. The average reduction after the 2nd session, as a percentage of the initial hair count, was 31.2% with a range 22.7% - 50%. The average reduction after the 3rd session, as a percentage of the initial hair count, was 56.7% with a range 45.5% - 70.8%.

Table 4.4 Hair Density (hair no. /cm^2) in the Chin Area

Patient number	Hair count before treatment	Hair count 3 weeks after 1st session	Hair reduction** after 1st session (%)	Hair count 3 weeks after 2nd session	Hair reduction** after 2nd session (%)	Hair count 3 weeks after 3rd session	Hair reduction** after 3rd session (%)
1	24	15	**37.5**	12	**50**	7	**70.8**
2	22	19	**13.6**	17	**22.7**	12	**45.5**
3	22	19	**13.6**	17	**22.7**	12	**45.5**
4	18	15	**16.7**	13	**27.7**	6	**66.7**
Average	21.5	17	**20.9**	14.8	**31.2**	9.3	**56.7**

*****Interval between each session= three weeks, were taken before each session.

**Hair reduction %= Difference between before treatment average (laser treatment) and the session/before treatment average *100

4.1.8. Relation Between Percentages of Hair Reduction and Sessions Number in Patients Treated in the Chin

Figure 4.4 below shows the relation between percentage of hair reduction and sessions number in the patients treated in the chin area. The graph show an increase in the percentage of hair reduction in comparison with the initial hair count after each session.

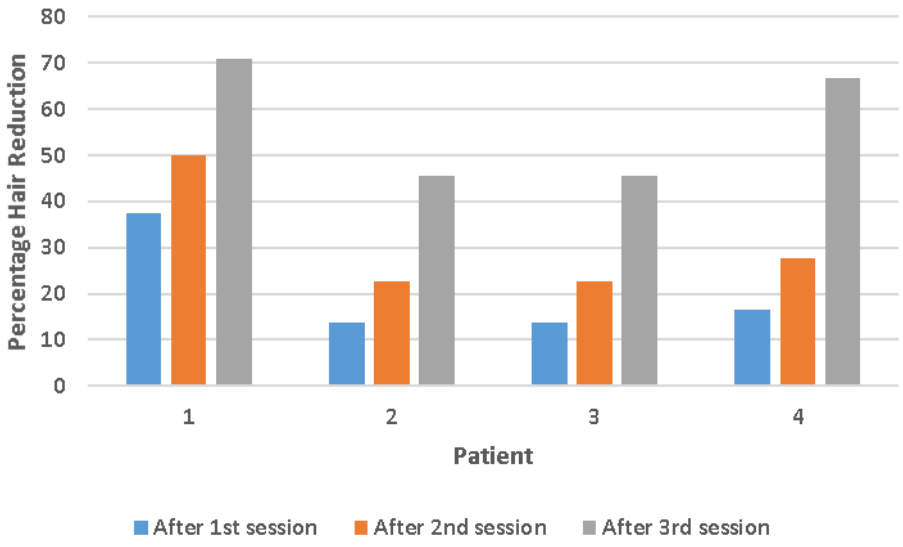

Figure 4.4 Relation between Percentages of hair reduction and session's number in patients treated in the chin area

4.1.9. Side Effect on Laser Hair Reduction

Side effect observed for three sessions collectively and for each side effect. There no keloid formation, post treatment scar, Wound infection, Prolong erythema, purpura, and Hypo-pigmentation or hyper-pigmentation one patient (10%) (Skin type VI) an under arm site feel pain during session. One patient (10%) (Skin type VI) experienced an under arm superficial post treatment blister after the first session using fluence 9J/cm^2 as per the laser manual guide according to her skin type. On second session the patient was treated using 8-9J/cm^2 fluence with no complication or side effects, table 4.5.

Table 4.5 Side effect

Side effects	1st session	2nd session	3rd session
Pain	1	0	0
post-operative blister	1	0	0
Keloid formation	0	0	0
Post treatment scar	0	0	0
Wound infection	0	0	0
Prolong erythema	0	0	0
Purpura	0	0	0
Hypo-pigmentation or hyper-pigmentation	0	0	0
Side effect %*	20	0	0

* Side effect % = Side effect/total number of patient*100

4.1.10. Patient's satisfaction

All patients were satisfied (100%).Table 4.6

Table 4.6 Patient's satisfaction

Patient's satisfaction	Yes	No
Self-Satisfaction	10	0
Back for follow up sessions	10	0
Recommended treatment	10	0
%	100	0

4.1.11. Satisfaction Rate

According likert classification (10 point scale) above 6 was graded (excellent response) was 8(80%), rating between 4-6 served as (good response) was 2(20%), There was no poor response. Table 4.7

Table 4.7 Satisfaction Rate by 10 point scale

Satisfaction Rate	Number of patient	%
>6 (excellent)	8	80
6-4 (good)	2	20
<4 (poor)	0	0

4.1.12. Qualitative result

It was observed that the hair texture changed from course to fine after the first treatment on wards, with some hair falling after the second and the 3rd session. When number of fine hair is more than coarse hair; hair color was observed change during the course of treatment along with change in hair texture.

In all patients three weeks after the first session evaluation smooth texture and lightning of skin was observed.

4.2. Discussion

Diode laser hair reduction procedures depend on the principle of selective photothermolysis (Anderson, R.R. and Parrish, J.A.1983). This involves using a wavelength that is specifically absorbed by the chromophore (melanin in hair follicle) (Lin, T.Y., Dierickx,et al 2000). In our work we have used diode laser wavelength (808 nm) is absorbed by melanin.

In our treatment we are targeting the melanin *i.e.* we are aiming to deliver the maximum amount of heat to melanin to be transferred to the hair bulb and a consequent hair removal. To perform this task we have to be careful to deliver maximum heat to the hair follicle melanin. Melanin is composed of eumelanin and pheomelanin, different proportion can give different colors (Altshuler, and Yaroslavsky, 2004).

The wide range of melanin absorption with a little absorption in the other chromophores has enabled us to use different types of lasers with different wavelengths such as ruby 694 nm, alexandrite 755 nm, diode laser 810 nm, and Nd:YAG 1064 nm also the broad

band IPL (500 - 1200) nm. Again, if the treatment is out of this range (700 - 1000) we may get unnecessary skin heating with less benefit in hair removal. Obviously the increase in the concentration of melanin leads to an increase in the laser or IPL absorption (. Patil, et al., 2008).

AL-Hamamy, H.R., et al (2015) a more successful treatment with fewer side effects can be achieved if we are able to discriminate between the heat delivery to the epidermis and the hair follicle. The epidermis is protected from the heat produced by laser by cooling the skin surface which is achieved by the sapphire contact surface of the hand piece has cooling effect during laser treatment when laser energy is absorbed in the skin. Selecting a longer wavelength will lead to more penetration of laser energy reaching the deeper (hair follicle), this can enable us to accomplish our treatment with the least of side effects.

Y.Bhat et al in 2020 published an article updating the laser treatment in patients with hirsutism. The diode laser system (800-1000 nm) could be used safely in individuals with dark skin owing to its longer wavelength, active cooling and longer pulse widths. It was also being better tolerated by individuals with darker skin types (V-VI) in comparison to ruby laser. This result same from that of our study, diode laser effective on dark skin type IV-VI by fluence less than 9J/cm^2.

Jose A. (2021) Both cooling systems produced a similar and moderate level of pain, with a pricking sensation being the prevailing type of pain due to selective heating of the hair. Regarding the efficacy and safety study, a 43.4% reduction was seen and no side effects were found to last more than 48 hours, with the results being classified as good to excellent for the treated. This result same from that of our study. Regarding the efficacy

and safety study, a 57.9% reduction (under arm) 56.6% reduction (chin) was seen and no side effects were found.

4.2.1. Limitation of Study

I. Do just chin and under arm areas, because limited was set by patients.

II. Our social limit some areas in the body like bikini area are viewed as taboo.

4.2.2. CONCLUSION

The 810 nm diode laser is one of the safe and effective laser device systems available for hair reduction in individuals with darker skin types (Fitzpatrick IV–VI) with thick, coarse hair. It offers a good cosmetic result with minimal side effects and is easily tolerated by most of the patients. Moreover, the present study could provide a simple yet resourceful objective method of assessing the efficacy of diode laser in hair reduction, thus overcoming the biases associated with observation and clinical examination.

4.2.3. RECOMMENDATIONS

In the future studies in this topic the following is recommended:

I. Need more studies in Sudan.

II. Recommended to increase number of session.

III. Follow up of our patients is recommended after 6 months and best to do once session every one year to maintain reduction of hair.

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Appendix A: Evaluation sheet

Sudan University of science and Technology Institute of Laser

Laser Application in Medicine (Dermatology)

Evaluation Sheet

Personal Data:

Name:……..

Telephone Number:……..

Address……

Age:

18-32( ) 33-47( ) 48-52( ) 53-66( )

Skin type according Fitzpatrics classification:

IV ( ) V ( ) VI ( )

Hair color:

Black ( ) brown ( )

White ( ) grey ( )

Area of body treated:

……

Device type:……..

Laser Parameter:

Wave length used:…….

Fluence:……

Spot size:……..

Pulse width:…….

Hair density in 1*1cm^2 was calculated:

Before session ( ) 1st session ( )

2nd session ( ) 3rd session ( )

4th session ( ) 5th session ( )

6th session ( )

Side effects were recorded after treatment such as:

Pain ( )

Post-operative blister ( )

Prolong erythema erythema lasting more than 24 hours ( )

purpura last >14 days. ( )

Keloid formation ( ) post treatment scar ( )

Hyperpigmentation ( ) hypopigmentation ( )

Patient's Satisfaction:

- Are you satisfied by treatment?

  Yes ( ) No ( )

- Will you recommended this treatment to others?

  Yes ( ) No ( )

- Back for follow up

  Yes ( ) No ( )

- On scale of 10, what is your evaluation of treatment?

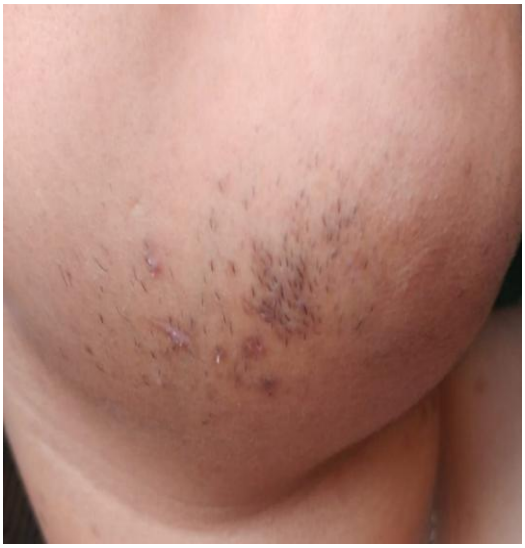
>6( ) 4-6( ) <4( )

Appendix B: Diode Laser Device

Diode Laser Device

Appendix C: Figures

Before treatment



After treatment