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Evaluation of 1470nm Laser in management of Pilonidal Sinus Disease

A Dissertation Submitted to the Institute of Laser for Postgraduate Studies, University of Baghdad in Partial Fulfillment of the Requirements for the Degree of Higher Diploma in Laser in Medicine / Surgery.

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بِسْمِ اللَّهِ الرَّحْمَنِ الرَّحِيمِ

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DEDICATED TO

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Abstract

Background: Pilonidal sinus is a common problem in young people, affecting most commonly men between the 2nd and 4th decade of life. Patients may present with symptoms of acute disease or may suffer from the chronic form of the disease with purulent discharge from one or multiple sinus tracts. There are different pilonidal sinus disease treatment modalities including surgery and laser. Diode laser (1470 nm) is one of the recent method for treatment of pilonidal sinus disease.

The Objectives: To evaluate the treatment of pilonidal sinus disease using Diode laser (1470 nm).

Materials & Methods: Prospective study was conducted over 6 months from Augustus 2021 to January 2022 in specialized surgical clinic in Baghdad city, Iraq.

Results: post-operative pain was presented in 9 cases. wound infection happened in one case only (in stage 3), no case detected regarding post-operative hemorrhage, 2 cases were delayed healing more than 60 days. The most common finding in the current study is the immediate return to work; 4 cases in stage 2, 5 cases in stage 3, and 3 cases in stage of recurrent. The mean time needed for the complete healing in all patients was (53.3±10.4) days with range between (40-70) days

Conclusion: The benefits of Pilonidal sinus disease treatment by laser diode 1470 nm for patients are Immediate return to usual physical activity, no recurrence of the disease during the period of the study and mild post-operative pain.

Keyword: Pilonidal sinus, Diode laser 1470 nm, stage of recurrent.

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List of abbreviations:

Abbreviation	Text
CBC	Complete Blood Count
CO_2	Carbon Dioxide
CW	Continuous Wave
DH	Double heterostructure
GaAs	Gallium-Arsenide
GaAIAs	Gallium-Aluminum-Arsenide
GE	General Electric
Hz	Hertz
IBM	International Business Machines
Kg	Kilogram
LED	Light-emitting diode
LPE	Liquid phase epitaxy
μm	Micrometer
MMS	Multimodal spectroscopy
MRI	Magnetic Resonant Imaging
m W	Milli watt
Nd: Yag	Neodymium: Yttrium Aluminum Garnet
nm	Nanometer
PIN	Positive-intrinsic Negative diode

PDT	Photodynamic therapy
PNS	Pilonidal sinus disease
RAC	Radio Corporation of America
sec	Second
Sig	Significant (Statistic)
SPSS	Statistical Package for Social Sciences
us	Ultra second
UV	Ultra-violate
VCSEL	Vertical Cavity Surface Emitting Laser
W	Watt

CHAPTER ONE

INTRODUCTION

AND

BASIC CONCEPTS

Pilonidal sinus disease

1.1 Background

Pilonidal sinus is a common problem in young people, affecting most commonly men between the 2nd and 4th decade of life. [1] Patients may present with symptoms of acute disease (pain in the sacrococcygeal region due to abscess formation) or may suffer from the chronic form of the disease with purulent discharge from one or multiple sinus tracts. [2]However, there is still no consensus as for the ideal treatment of this disease. [3] Often, the method applied relies solely on the preference of the surgeon and his familiarity with each technique. [4] During the recent decades, in the context of less invasive surgical procedures being more broadly used in everyday clinical practice, several non-surgical or less aggressive surgical techniques have also been tested in the treatment of pilonidal cyst. The present study aims at presenting our initial experience in the outpatient treatment of pilonidal disease using a 1470 nm diode laser. [5]

1.2 Pathophysiology of Pilonidal sinus

Pilonidal disease was thought to be of congenital origin, but increasing evidence indicates an acquired etiology. Firstly, occupation plays a major role with reports of occurrences between the fingers of sheep shearers, dog groomers, and barbers. Further risk factors include, a sedentary lifestyle, positive family history, obesity, hirsute body habitus, local irritation or trauma. Secondly, blocked hair follicles can lead to enlargement and rupture of the pilosebaceous glands with either abscess formation or a chronically discharging sinus. In addition, Bascom postulated pilonidal disease as originating from a

stretched midline hair follicle of the epidermal skin layer, analogous to an epidermal inclusion microcyst, thereby advising against resecting deep tissue during surgery. However, Karydakis reported loose hairs, burrowing into otherwise normal tissue, inducing a foreign body reaction leading to secondary pits and cyst formation. The source of the hair can either be the natal cleft itself in hirsute individuals, or hair from the head or back that falls into the natal cleft. The hair follicle becomes distended and obstructed leading to oedema and inflammation. Subsequently, a chronic abscess may develop, with a track draining it known as a sinus. [5]

Furthermore, epidermal and deep tissue disruption are amplified by changes in the cleft microenvironment including increased moisture, anaerobic environment and bacteria in the natal cleft. Anaerobic bacteria (Bacteroides and Enterococci) predominate in the development of follicular infection and abscess formation and subsequent wound breakdown following surgery. However, in postoperative wound complications, aerobic bacteria were isolated in 43% of cases vs 40% anaerobic isolates. [6]

Moreover, preoperative antibiotic usage did not shown reduction in the wound complication or recurrence rate after 30–42 months follow-up. Therefore, the role of bacteria in initiating, persisting and recurrent pilonidal sinus disease evolves with disease progression and host response. These factors have implications for both the extent of disease expression and progression. This was incorporated in a mathematic model following review of over 6000 patients. The three primary variables were: loose hair or ‘‘invader’’ (H) applies some force (F), which is influenced by secondary factors such as the depth, narrowness, and friction of the natal cleft to create an insertion process. The third factor of vulnerability, (V), refers to the local tissue susceptibility. In this

model, the primary sinuses represent the hair entry sites and secondary sinuses represent the exit points: [7]

Pilonidal Disease = Hair (H) × Force (F) × Vulnerability $(V)^2$

The nature and variability of these causative elements have implications for persistent or recurrent disease. For example, the type and number of bacterial colonies present may be related to delayed wound healing following treatment. Furthermore, deep tissue hypoxia is implicated in persistent pilonidal disease, with healing of complex wounds demonstrated by moving the suture lines to the open air. These in turn have influenced various surgical treatment strategies. [7]

1.3 Classification according to area concept

Using this anatomical definition of the natal cleft, we have found it useful in decision taking according to the anatomical pathology of PND in relation to the navicular area. A classification of the disease into five types is proposed:

Type I: Asymptomatic pit(s) without a history of abscess and/or drainage. The pits are almost always within the navicular area and require no surgical therapy. We recommend local hair removal and good personal hygiene.

Type II: Acute pilonidal abscess. The treatment is always drainage using with a lateral incision. Type II PND usually requires further surgical treatment after acute symptoms resolve.

Type III: Pit(s) within the navicular area with a history of abscess and/or previous drainage. We prefer the Bascom procedure for patients with type III PND.

Type IV: Extensive disease where one or more sinus opening lies outside the navicular area. Such patients usually have a history of multiple abscess formation and drainages without definitive pilonidal surgery. The surgical treatment of choice in these patients is the Bascom procedure combined with separate excision of pits outside the navicular area.

Type V: Recurrent pilonidal sinus following any surgical treatment. We recommend again the Bascom procedure in such patients. [8]

1.4 Evaluation

Diagnosing pilonidal disease is clinical, and no further labs, tests, or imaging is required. However, imaging may be helpful in cases where the diagnosis is less clear. Imaging modalities have been used to differentiate and/or rule out more significant disease processes and can aid in determining the extent of disease and required excision when combined with surgical treatment.

Methylene blue has been used to evaluate the extent of pilonidal sinuses and can be used in conjunction with surgery. One study found that the use of methylene blue may reduce the long-term recurrence rate of pilonidal disease by showing the extent of necessary resection of soft tissue at the time of surgery. Doll et al. studied 247 patients with a mean follow up of about 15 years and found that intraoperative methylene blue had a decreased recurrence rate of 16% vs. 30%. [9] Another study evaluated 33 patients in a prospective randomized trial where methylene blue was injected into each sinus, with subsequent resection of stained areas; microscopic parameters were assessed, but the authors warn that the use of methylene blue to direct surgical excision may cause inadequate excision. [10] This differs from a more recent study assessing the volumes of specimens surgically removed with methylene blue. In a

retrospective study looking at 135 specimens, Ardelt et al. found that samples excised using methylene blue had significantly higher volumes facilitating complete resection; interestingly, volumes were also larger in recurrent disease. [11]. Modifications to methylene blue have been used to make it more manageable by turning it into a gel with the addition of chloramphenicol ointment. [12]

Ultrasound can be used to evaluate pilonidal disease. Mentes et al. evaluated 73 patients with preoperative ultrasound and found that determining pilonidal disease borders with ultrasonography was consistent with palpation 76.7% of the time, but in the remaining patients, ultrasound detected sinus tracts that exceeded the planned margins of excision with palpation alone. They concluded that ultrasound provides more information in regards to the borders of pilonidal disease when compared to palpation and methylene blue. [13] Both external ultrasound and endoanal ultrasound were found to be useful in evaluating the extent of pilonidal disease and excluding perianal sepsis in a more recent study. [14] This was corroborated with another study using transperineal ultrasound to evaluate for low perianal fistula. [15] When comparing ultrasound findings of pilonidal disease with hidradenitis suppurativa, there were no statistically significant differences in morphological characteristics, but the density of hair tracts was higher in pilonidal disease. [16]

MRI is more expensive and time-consuming than ultrasound but may aid in diagnosis when there is a concern for inflammatory bowel disease, fistula in ano, pelvic sepsis, or neoplastic processes. Recent studies have also suggested a role for a photodynamic with indocyanine green for the elucidation of disease extent to aid in resection. [17-19]

1.5 Treatment of pilonidal sinus:

To date, there is no treatment that can be considered a gold standard for this condition. Although acute abscesses are generally treated with incision and drainage, the chronic manifestation of the disease can be treated with wide excision. In these cases, gradual deroofing of the cavity is performed with diathermy and laser ablation and the resulting large wound is left open (or sutured, according to the personal preference of the physician), with complete healing in 2 months. Various techniques for plastic reconstruction of larger wounds have also been used, such as the application of skin flaps, Z-plasty, Karydakis plasty, Bascom flap and Rhomboid flap. These complex techniques are often associated with increased morbidity. Abramson described for the first time the simple incision and ablation of the cyst walls in patients with simple or complicated disease (abscess, chronic and relapsing conditions) with a healing rate of 93%. Surgical management can be divided into two categories: excision of the diseased tissue with primary closure, using various techniques, or excision and healing with secondary intention. Both techniques have a healing rate of over 80%, but a higher complication rate has been reported with the first technique and a longer healing time with the second one. In the past years, simple techniques, such as laying the sinus open, simple cavity ablation, the use of fibrin glue and chemical phenol injection, have been more widely used in the management of pilonidal sinus, with moderate results and healing rates of 60–80% in small series of patients. The ideal procedure should be simple, with minimal tissue loss and a low recurrence rate. Furthermore, it should require a short hospital stay and a quick return to daily activities. In this regard, there is growing evidence in small series of patients that the use of a diode laser in the treatment of pilonidal sinus

may represent a good solution, being a minimally invasive procedure with minimal damage to proximal tissues and with reported success rates of 80–90%. Failed cases usually require more aggressive surgical treatment. [20]

1.6 Light :

is electromagnetic energy, comprising of an electric and magnetic field. An electric field is undulating in the **vertical** direction, while a magnetic field is undulating in the **horizontal** direction, and both of them fluctuate perpendicularly to the direction of propagation. Each wave is characterized by temporal frequency, spatial period (wavelength). As higher frequencies are synonyms with shorter wavelengths & vice versa. [21]

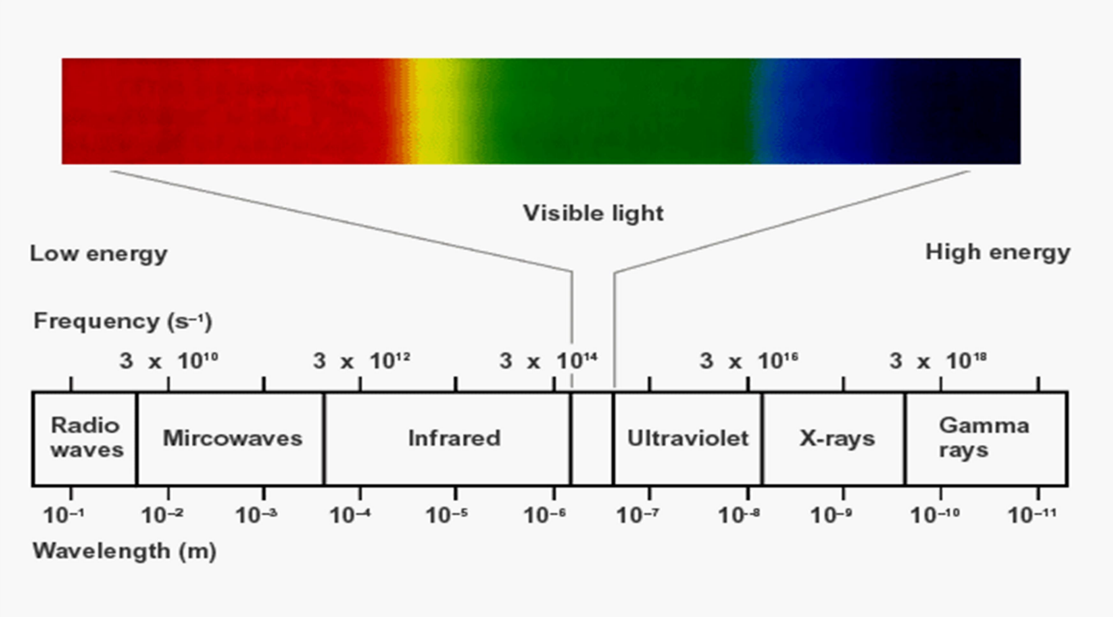


Figure (1.1) Electromagnetic Spectrum. [21]

The precise relationship between frequency, wavelength and energy is:

λ=c/v , E=h(v)

Where **λ**= spatial period (wavelength) of the light in meter.

C= speed of light in meter/second. **v**= temporal frequency in hertz.

h= Planck's constant, **E**= energy in joule.

Visible light is the most form of electromagnetic radiation. As EM spectrum starts with along wavelength (spatial period) and a short temporal frequency, including long radio waves, microwaves, and so on to infrared region, where CO2 & Nd: YAG lasers.

Then visible light region includes Helium-Neon and Argon lasers. Ultraviolet region is the shorter wavelength with higher frequency including nitrogen and Excimer lasers. The region is followed by X-Rays and Gamma rays. [21]

1.6.1 Light Basics:

Light is a form of energy that can be released by an atom.. Atoms release light photons when their electrons become excited. Once an electron moves to a higher-energy orbit, it eventually wants to return to the ground state releasing its energy as a **photon** -- a particle of light. [21]

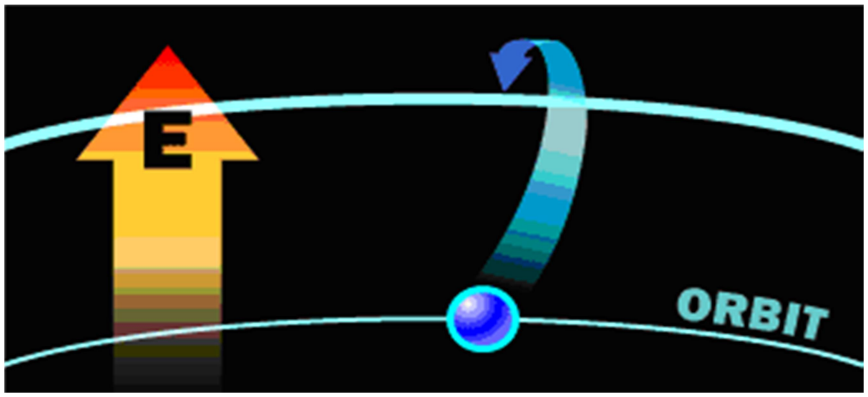


Figure (1-2) Absorption of energy. [21]
An atom absorbs energy in the form of heat, light, or electricity. Electrons may move from a lower-energy orbit to a higher-energy orbit.

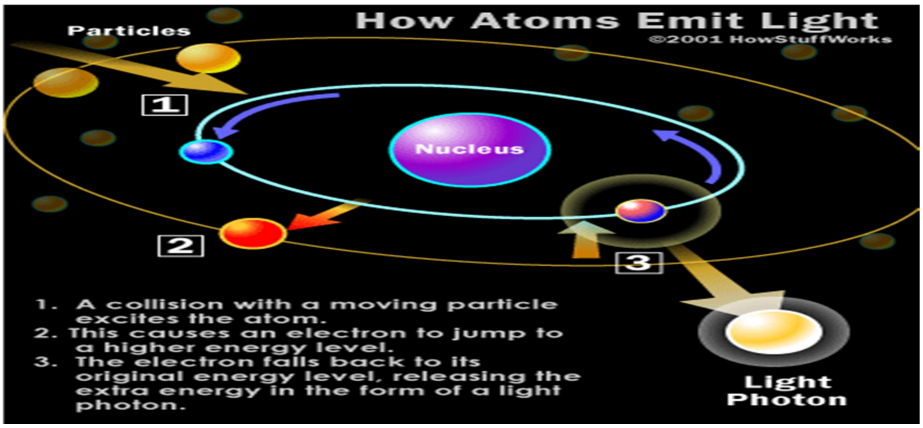


Figure (1.3) Emission of light. [21]

The **wavelength** of the emitted light (which determines its color) depends on how much energy is released, which depends on the Particular position of the electron. The color of light is determined by its frequency or wavelength. The shorter wavelengths are the ultraviolet and the longer wavelengths are the infrared. The energy of photon must correspond exactly to the energy difference between two levels of the atom (E2 –E1= hμ). If a photon with an amount of energy hits an excited atom, it is absorbed and re-emitted; together with a second photon exactly has the same wavelength & phase as the first.

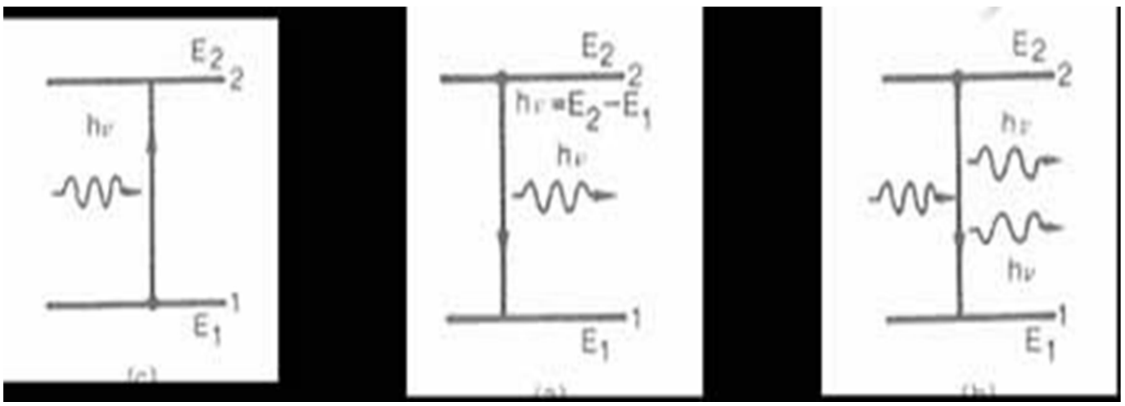
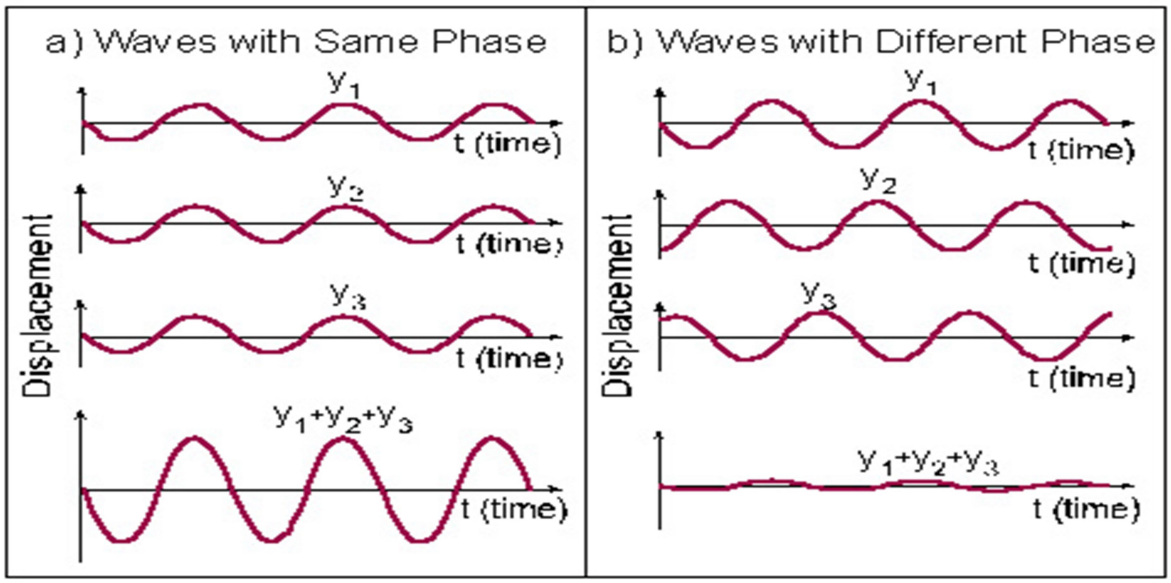


Figure (1.4): stimulated emission Laser –tissue interaction:[21]

1.7 LASER-BASIC:

The word “LASER” is an acronym for “Light Amplification by Stimulated Emission of Radiation”.

A laser device produces *coherent* light through a process termed (stimulated emission). It can produce light in ultraviolet, visible, infrared region of electromagnetic spectrum. [22]



(A)Coherent Light. (B)Incoherent Light.

Figure (1.5) Coherent light.[22]

Characteristics of Laser :

The laser diode is characterized as follows:

- **Monochromatic:** An insubstantial width of radiated narrow light containing only a single color.
- **Well-directed:** In this type, the light is will be directed in a narrow beam. It is easy to launch through an optical fiber.

- **Coherent:** A light with a single wavelength emitted by LED with a wide wavelength.

Lasers are widely used now for medical, scientific, commercial, and industrial applications. They can be extremely hazardous if not understood & properly controlled. Albert Einstein in 1917, postulated the process of "stimulated emission" of radiation. But it was decades later before a practical device was demonstrated.

In 1954 the first "stimulated emissions" of microwave radiation (MASER) were generated by Charles Townes at Bell Laboratories, and independently, Basov & Prokhorov in Russia, by using Ammonia gas. For this they shared the 1964 Nobel Prize in physics. The first laser was built in 1960 by Dr. T.H. Maiman at Hughes Aircraft Company, using synthetic Ruby rod stimulated by high intensity flash lamps which generated millisecond pulses of coherent 694 nm Ruby laser (red) light.

In 1964, the Nd: Yag (Neodymium: Yattrium Aluminum Garnet) 1060 nm laser and CO2 (carbon dioxide) laser 10600nm were developed at Bell Laboratories.CO2 laser is a continuous wave gas laser, emitting infrared light & well absorbed by water. Researchers found that a CO2 laser beam could cut tissues like a scalpel, but with minimal blood loss. So it is used in ENT & Gynecological surgery. In 1964, Argon ion laser was developed. This continuous wave 488/514 nm(blue/green) gas laser was easy to control, and its high absorption by hemoglobin made it well suited retinal surgery.

In 1969, Dye lasers became available, and noble gas –halide, or Excimer lasers in 1975.Since then, many other different

laser systems have become available for industrial, scientific, tele communication, as well as medical uses. [23]

1.8 Laser tissue interaction:

The interaction of laser light with a biological tissue depends mainly on:

1. Properties of laser light.
2. Optical properties of tissue.
3. Thermal properties of tissue.

There are several processes by which laser energy can interact with biological systems: [23]

1. **Ionization by** high energy photons or by multiphoton processes, and its effects are chemical reaction, lumen sense, heat, photoablation, photo disruption.
2. **Electron excitation** by UV and Visible radiation, and its effects are photochemical reaction, lumen sense, heat.
3. **Oscillation and rotational** induction modes by IR radiation, and its effects is heat due to photothermal. When IR radiation is applied to tissue, all the energy is transformed into heat.

With electron excitation only a portion of the energy is converted to heat. When the laser beam delivered to the target tissue site, it can have four different interactions and effects. Generally, all of these interactions occur each time with each **wavelength** and each **tissue type.**

1. **Reflection:** is the first interaction; laser energy may reflect off of a surface in a direct or diffuse fashion. This presents a safety concern when laser energy is directed toward unintended targets; appropriate wavelength-specific eye protection is mandatory for patients and all operating personnel.

2. **Absorption:** is the second and the most beneficial tissue interaction. The treatment objective is accomplished with its effect.

3. **Transmission:** of the laser beam is the third interaction; the energy travels directly through tissue, causing no effect.

4. **Scattering:** is the fourth interaction; the tissue can cause the laser beam to spread out into a larger area. But as the beam scatters, its power density eventually decreases to the point where it has no significant biologic effect. [24]

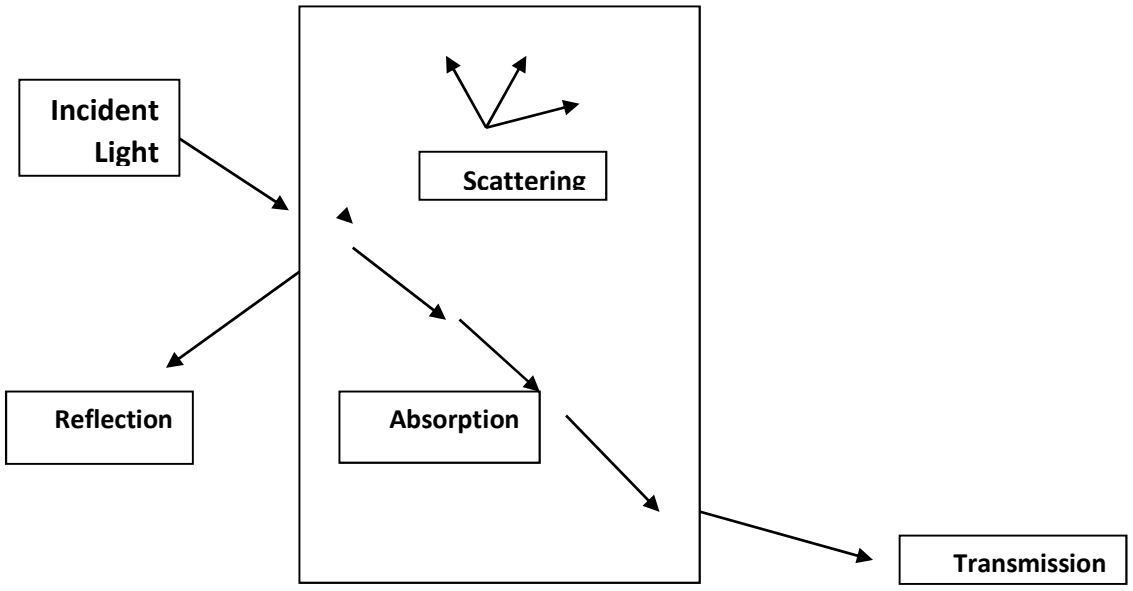


Figure (1.6) Reflection, Absorption, Scattering and Transmission of laser light when it strikes a tissue. [24]

Scattering & reflection of laser can be used for diagnosis depending on spectroscopic characters of tissue as for sperms velocity by laser doppler velocimetric. (24)

1.9 Diode laser:

A laser diode is a semiconductor device similar to a light-emitting diode in which a diode pumped directly with electrical current can create lasing conditions at the diode's junction. Stimulated emission can be produced when the process is continued and further generates light with the same phase, coherence and wavelength. [24]

The choice of the semiconductor material determines the wavelength of the emitted beam, which in today's laser diodes range from infra-red to the UV spectrum. Laser diodes are the most common type of lasers produced, with a wide range of uses that include fiber optic communications, barcode readers, laser pointers, CD/DVD/Blu-ray disc reading/recording, laser printing, laser scanning and light beam illumination. With the use of a phosphor like that found on white LEDs, Laser diodes can be used for general illumination. [25]

1.9.1 History:

As early as 1953 John von Neumann described the concept of semiconductor laser in an unpublished manuscript. In 1957, Japanese engineer Jun-ichi Nishizawa filed a patent for the first semiconductor laser. It was an advancement of his earlier inventions, the PIN diode in 1950 and the solid-state maser in 1955. [26]

Following theoretical treatments of M.G. Bernard, G. Duraffourg and William P. Dumke in the early 1960s coherent light emission from a gallium arsenide (GaAs) semiconductor diode (a laser diode) was demonstrated in 1962 by two US groups led by Robert N. Hall at the General Electric research center and by Marshall Nathan at the IBM T.J. Watson Research Center. [27]

There has been ongoing debate as to whether IBM or GE invented the first laser diode which was largely based on theoretical work by William P. Dumke at IBM's Kitchawan Lab (currently known as the Thomas J. Watson Research Center) in Yorktown Heights, NY. The priority is given to General Electric group who have obtained and submitted their results earlier; they also went further and made a resonant cavity for their diode. It was initially speculated, by MIT's Ben Lax among other leading physicists, that silicon or germanium could be used to create a lasting effect, but theoretical analyses convinced William P. Dumke that these materials would not work. Instead, he suggested Gallium Arsenide as a good candidate. The first visible wavelength GaAs laser diode was demonstrated by Nick Holonyak, Jr. later in 1962. [28]

Other teams at MIT Lincoln Laboratory, Texas Instruments, and RCA Laboratories were also involved in and received credit for their historic initial demonstrations of efficient light emission and lasing in semiconductor diodes in 1962 and thereafter. GaAs lasers were also produced in early 1963 in the Soviet Union by the team led by Nikolay Basov.

In the early 1960s liquid phase epitaxy (LPE) was invented by Herbert Nelson of RCA Laboratories. By layering the highest quality crystals of varying compositions, it enabled the demonstration of the highest quality heterojunction semiconductor laser materials for many years. LPE was adopted by all the leading laboratories, worldwide and used for many years.

Diode lasers of that era operated with threshold current densities of 1000 A/cm2 at 77 K temperatures. Such performance enabled continuous-lasing to be demonstrated in the earliest days. However, when operated at room temperature, about 300 K, threshold current densities were two orders of magnitude greater,

or 100,000 A/cm2 in the best devices. The dominant challenge for the remainder of the 1960s was to obtain low threshold current density at 300 K and thereby to demonstrate continuous-wave lasing at room temperature from a diode laser.

The first diode lasers were homojunction diodes. That is, the material (and thus the bandgap) of the waveguide core layer and that of the surrounding clad layers, were identical. It was recognized that there was an opportunity, particularly afforded by the use of liquid phase epitaxy using aluminum gallium arsenide, to introduce heterojunctions. Heterostructures consist of layers of semiconductor crystal having varying bandgap and refractive index. Heterojunctions (formed from heterostructures) had been recognized by Herbert Kroemer, while working at RCA Laboratories in the mid-1950s, as having unique advantages for several types of electronic and optoelectronic devices including diode lasers. LPE afforded the technology of making heterojunction diode lasers. In 1963 he proposed the double heterostructure laser. [29]

The first heterojunction diode lasers were single-heterojunction lasers. These lasers utilized aluminum gallium arsenide p-type injectors situated over n-type gallium arsenide layers grown on the substrate by LPE. An admixture of aluminum replaced gallium in the semiconductor crystal and raised the bandgap of the p-type injector over that of the n-type layers beneath. It worked; the 300 K threshold currents went down by 10× to 10,000 amperes per square centimeter. Unfortunately, this was still not in the needed range and these single-heterostructure diode lasers did not function in continuous wave operation at room temperature.

The innovation that met the room temperature challenge was the double heterostructure laser. The trick was to quickly move the wafer in the LPE

apparatus between different "melts" of aluminum gallium arsenide (p- and n-type) and a third melt of gallium arsenide. It had to be done rapidly since the gallium arsenide core region needed to be significantly under 1 μm in thickness. The first laser diode to achieve continuous wave operation was a double heterostructure demonstrated in 1970 essentially simultaneously by Zhores Alferov and collaborators (including Dmitri Z. Garbuzov) of the Soviet Union, and Morton Panish and Izuo Hayashi working in the United States. However, it is widely accepted that Zhores I. Alferov and team reached the milestone first. [29]

1.9.2 Types of Laser Diodes

The following are the types of laser diodes:

- Double heterostructure laser diode: Heterostructure is a material that is sandwiched between two n-type and p-type materials. Because of the presence of heterostructure material, this type of laser diode is called a double heterostructure (DH) laser diode. The main advantage of this diode is that the active region is used for better optical amplification.
- Quantum well laser diode: The quantum well is a very thin middle layer in the diode. The quantum energy is used for converting the electrons from higher energy to lower energy and is responsible for better efficiency.
- Separate confinement heterostructure laser diode: There are two additional layers along with three layers. These layers have a lower refractive index and the emission of light is also improved. [30]
- Vertical cavity surface-emitting laser diode: In this type of laser diode, the optical cavity is along the axis of current flow.

1.9.3 Applications of Laser Diode

The following are the applications of laser diode:

- **Consumer electronics:** This includes laser printers, CDs and DVD players, and fiber optic communication.
- **Industrial applications:** When it comes to industrial applications, laser diodes are preferred as it is a source of a high-intensity laser beam and used for cutting, drilling, welding, etc.
- **Medical applications:** Laser diode is used for the elimination of unwanted tissues and tumors and also in dental medication.
- **Scientific instrumentation:** Instruments like spectrometer, range finders, contact-less measurements can be done with the help of laser diodes.
- **The laser diode in telecom:** Laser diodes with 1.3 μm and 1.55 μm bands are used as the main source of light in telecom and as the band changes laser diodes find application in optical amplification. [31]

1.9.4 Advantages of Laser Diode

The following are the advantages of laser diode:

- When laser diode is compared with other light-emitting devices, the operational power is less in the laser diode.
- The handling of these diodes is easy as they are small.
- The light generated by these diodes is of high efficiency.

1.9.5 Disadvantages of Laser Diode

The following are the disadvantages of laser diode:

- These diodes are expensive when compared to other light-emitting devices.
- The light generated by these diodes adversely affect the eyes. [31]

1.9.6 Medical applications of diode laser

One of the most useful applications of diode laser technology is in medicine for diagnosis and treatment of diseases. The range of available wavelengths that make high power diode lasers perfect tools for a variety of medical applications especially surgery, are overviewed in Table 1. Some proofs of diode laser spectroscopy as promising means to extract biochemical and morphological information concerning tissue in relevance to the diseases progression and diagnosis are also accounted here. Diode lasers working in the wavelength range of 630 to 740 nm are considered ideal for photodynamic therapy (PDT) and dermatological applications. [32] To meet the needs of high power for interstitial photodynamic therapy (IPDT) which is a promising treatment method for curing deep-lying tumors; Fraunhofer Institute for Laser Technology, Germany developed a system comprising of a demonstrator module with individually addressable high-power emitters based on 652 nm semiconductor material. [33] Niamtu [34] reported the effectiveness of 532 nm diode-pumped, frequency-doubled Nd: YAG laser for the treatments of facial telangiectasia, some pigmented and minor vascular lesions. Šćepanović et al. [35] developed a multimodal spectroscopy (MMS) instrument based on 830 nm diode laser for exciting tissue through MMS probe and collecting the spectra for the diagnosis of diseases like atherosclerosis and breast cancer. Furthermore, 980 nm diode lasers gained a good degree of acceptance in facial and oral surgery without compromising the health of patients due to efficacy and safety of these lasers. [36] An interesting use of diode laser is in the investigation of

chemical composition of surgical smoke (term used for heat generation causing tissue pyrolysis due to the use of several surgical instruments like high-speed drills and saws, harmonic scalpels, electro knives and lasers). [37]

The VCSEL diode laser emitting at 2.007 nm are being employed in measuring the $^{13}CO_2$/ $^{12}CO_2$ isotope ratio at atmospheric pressure in human breath during the medical practices. [38]

Table 1.1: An overview of diode laser wavelengths for medical applications. [32]

Wavelength (nm)	**Applications**
630 to 635, 652, 668	Medical photodynamic therapy
689, 730	Age-related macular degeneration, Medical
	photodynamic therapy
810±10	Cosmetic, hair removal, dental, biostimulation, surgical, ophthalmology
915	$Yb^{3þ}$: glass fiber laser
940	Varicose vein removal, surgical applications
980±10	Dental, prostate treatment, surgical opthalmology
1064	Hair removal, tattoo removal
1210	Liposuction
1320 to 1380	Surgery
1450 to 1470	Acne treatment, endovenous laser treatment, surgery
1850 to 2200	Acne treatment, surgical substitute for thulium laser

Wilhelm was the first one to describe a new technique in management of peri-anal fistula as a replacement for traditional surgery and to preserve anal sphincters using a radial laser probe (fistula–tract laser closure, biolitec company, Germany). The probe destroys the epithelium lining the fistula and simultaneously obliterates the tract by vaporization and photocoagulation effect. [39]

Due to increased number of patients suffering from complications of PNS surgery, we will use diode laser 1470 nm in this study as an alternative of surgery of PNS because its highly absorbed with water.Fig1.7 for achieving many benefits from laser therapy in management of PNS as easily applied, minimal-invasive technique low recurrence rate, non-toxic, less pain, highly effective for many conditions, patient satisfaction is high, reduce the needs of pharmaceuticals, no drug interactions, quick return to work and daily activity and no known adverse effects.

A process and device for selective photothermolysis of a surgical target and neighboring tissue. The target and the neighboring tissue are heated to about 60° C may reach about 70° C. Then the target is heated to reach the destination point of photocoagulation, preferably by monochromatic light. The heat difference between the coagulating target and the neighboring tissue is sufficiently mild that heat diffusing out of the target does not hurt the neighboring tissue. Diode laser device offer nice advantages over several different lasers as a result of its little size, diode laser additionally provides a large variety of spectrum of beam wavelength that will be employed in multiple medical fields. another privilege of diode laser device; the fiber-optic probe that transmits heat energy in 360c direction homogenously, so it can be used in different locations with good results. [40].

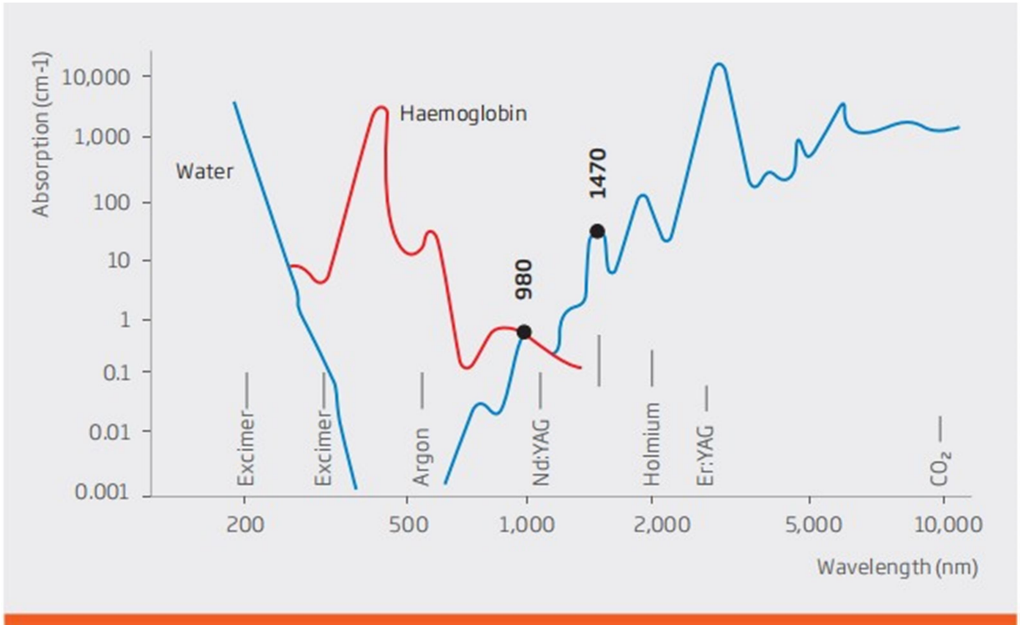


Figure 1.7 absorption spectrum of diode 1470n.[40]

Aim of the study:

To evaluate 1470nm Laser in management of Pilonidal Sinus Disease .

Chapter two

Patients, Materials And Methods

2.1 Introduction:

This chapter includes the criteria of choosing the Patients and their description and also including the materials and the procedure about preparing the patient before the laser treatment and parameters used in the treatment of the patients. In this study twelve patients complained from sacrococcygeal pilonidal sinus disease treated with diode laser 1470 nm in one session as outpatients.

This study was conducted over 6 months from Augustus 2021 to January 2022 in consultation surgical clinic in Baghdad city, Iraq.

2.2 Patient's selection:

Examination of all the patients done to determine their suitability and the inclusion and exclusion criterion depending on clinical and ultrasonography examination for detecting the borders of pilonidal sinus tissue are as following:

2.2.1 Inclusion criteria:

1- Patients with mild infection pilonidal sinus.
2- patients with solitary cavity pilonidal sinus.
3- - patients with sinus in the natal cleft with lateral expansion or an expansion on the medial line itself.
4- Relapsing disease after one or more previous incisions (surgery) performed previously.
5- patients unfit for surgery.

2.2.2 Exclusion criteria:

1- patients with inflammatory bowel diseases complaining of pilonidal sinus disease.

2- patients with immune suppressive diseases and uncontrolled diabetes.

3-Patient on long term chemotherapy and corticosteroid.

4- Patient with peri anal fistula with extension to the natal cleft.

2.3 Patient description:

This prospective study includes twelve patients of PNS diseases with a average age of 33.25±6.75 years suffering from PNS diseases recruited via a surgical clinic . Each patient was getting ready for the procedure after full explanation and discussion regarding the nature of the procedure, the possible advantages, disadvantages and complications expected. Patient description as in table 2.1.

Table 2.1: Patient's characteristics

Patient Gender	Male	Female
Patients No.	8	4
Average Age	24-46	28-37
Prior Abscess	2 patient mild abscess	No
Disease Status	6 primaries	3 primaries
	2 secondaries	2 secondaries
No. of sinuses treated	1 patient /one sinus 3 patients /2 sinuses	1 patient /1 sinus 3 sinus / 3 sinuses
Type of anesthesia	L/A(local anesthesia)	L/A

2.4 Clinical assessment:

2.4.1 Detailed history and physical examination:

-General history which included questions about:

1-Chronic diseases like diabetes mellitus, immune suppressive diseases.

2- Previous medical and surgical history.

3- Neurological and congenital abnormalities.

- Physical examination:

-Inspection of sacrococcygeal region while patient in prone position for any small dimple or large swelling between buttocks or an abscess with draining of blood with or without foul smelling.

-A tuft of hair projects from its mouth.

-Secondary opening may be present at either site of the midline, often far out on to the buttocks or in the perineum

- Any previous scar in the region.

-All patients were examined by the same surgeon and the border of the sinus tissue was marked on skin according to palpation, then injection of methylene blue through the sinus external opening while using a white gauze placed inside the anal canal to assess any connection, then the patient is sent to nearby ultrasonography clinic prior to operation with laser.

-Ultrasonography examination was performed by radiologist with the use of a 7.5 MH linear probe a LOGIQ 5 pro ultrasound scanner (General Electric, USA) according to ultrasonographic evaluation, the margins, extensions, sinus tract, branches and openings of the pilonidal sinus tissue were determined and marked on the patient on a different color with two dimensions measurement of the tract (radius and height).

All scanning was performed by the same radiologist, and power Doppler mode was used when needed, the surface area was calculated using the formula:

$A= 2 \pi r (r + h)$

A= surface area of a cylinder as we can consider PNS tract cylinder in shape.

R= radius h= height or length

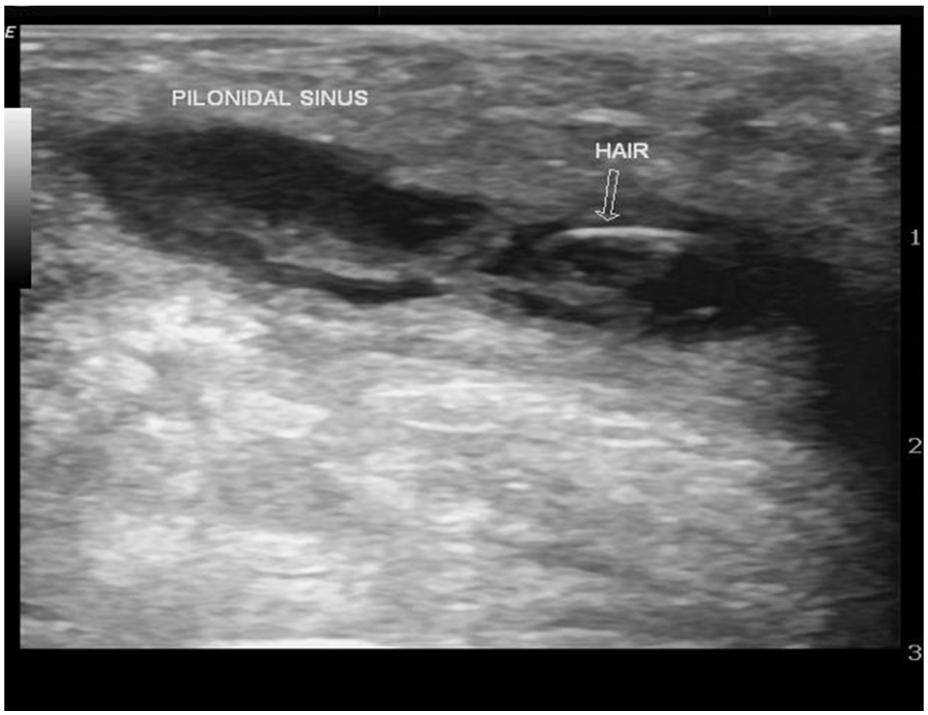


Fig 2-1 Ultrasonic image shows pilonidal opening and tract with hair inside.

-Post operative follow up included an outpatient evaluation at days 15, 30, 45 and 60. A healing time longer than 60 days was defined as delayed healing and necessitated further patient visits.

2.5 Investigations:

1- CBC 2-Hepatitis test 3- Covid 19 (serology test)

4- Blood sugar 5-RFT.

In order to better define the types of patients that may mostly benefit from this procedure we depend on this modified classification.

2.6 Pilonidal sinus disease classification:

Stage 1: Single pit in the midline, no lateral extension.

Stage 2: More than one pit in the midline, no lateral extension.

Stage 3: Midline pit / pits plus lateral extension in one direction.

Stage 4: Midline pit / pits plus lateral extension in both directions.

Stage R: Recurrent PNS following any type of treatment. [41]

2.7 Diode Laser Specification:

The laser machine used in this study is CHERYLAS-45JN diode laser is a surgical and therapeutic device at the cutting age of technology manufactured in China by Wuhan Dimed Laser Technology Co., Ltd.

Its clinical data is the following, as shown in the catalogue

Electrical

Operating Voltage	100V -240V-at1.4A
Frequency	50/60Hz
Main Control	Power Switch
Working Mode	Continuous Operation with Intermittent Loading 5min on 1min off
Disable Control	Emergency Stop Button

Laser

Laser Type	GaAIAs Diode Laser
Wavelength	980nm, 1470nm
Maximum power	980nm 30W, 1470nm 15W
Operation Mode	CW, Single or Repeat Pulse
Pulse Duration	10us-3s
Repetition Rate	0.2Hz-50KHz
Pilot Beam	Red Diode Laser of 650nm, Power<5mW
Control Mode	True Color Touch Screen
Transmission System	Fibers of 400um600um with SMA905 Connector
Spot Size	Surgical Hand piece:600 μm(maximum in contact mode) Therapy hand piece: adjustable Size(15mm/20mm/25mm/30mm)diameter
NOHD	8.7m
Beam Divergence	8-25.4◦ persideangle
Standard Fiber Cable Length	≤ 3m
Dimensions	380(Width)*430(Length)*220(Height)mm
Weight	11Kg
Power Accuracy	± 20%

Fig 2-2 CHERYLAS-45JN diode laser system.

2.8 Treatment parameters:

Diode laser with a wavelength 1470 nm used with the following parameters protocol was:

Power:	8 W
Pulse duration (on):	3 sec
Pulse pause (off):	1sec
Mode:	Repeated

Fig 2.3 Treatment parameters.

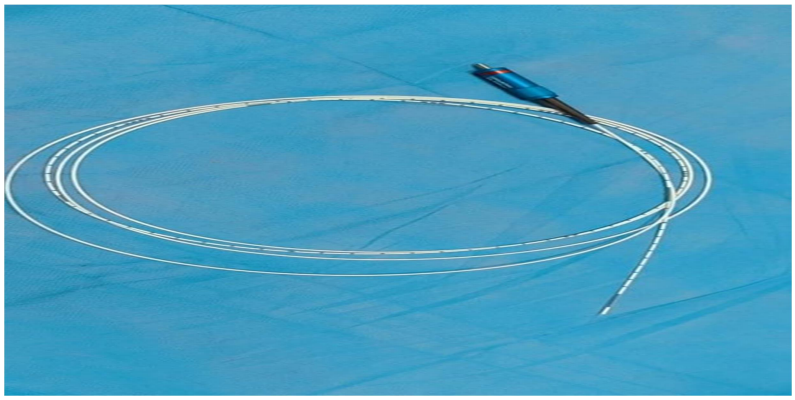


Fig 2.4 Optical radial fiber 600 micrometer used in treatment protocol.

2.9 Safety measures during the procedure:

In this study the laser employed was class IV laser. These types of laser can cause damage with direct intra beam exposure and from specular or diffuse reflections. So, safety measures must be taken to provide protection from energy emissions of these lasers. All persons wear protective glasses appropriate to the procedure to eliminate the risk of eye damage. These glasses are designed with special wavelength and optical density for 1470 nm diode laser. The doctor goggles. (Figure 2.5).

In this research the eyes of the patient were covered with patient eye goggles.

Fig 2.5 The doctor goggle.[42]

2. Mechanism of action:

The heat energy delivered from diode laser through fiber optic probe acts on vaporization of water content of blood (resulting from curettage of the sinus tract after cleaning) leads to photo

coagulation and ablation of sinus tract leads to steaky sensation during exit of the probe from the tract with the obliteration of sinus tract is palpated., Fiber optic probe: Flexible, radially emitting laser fiber that emits laser beams in 360 o .[42]as in fig: 2.6

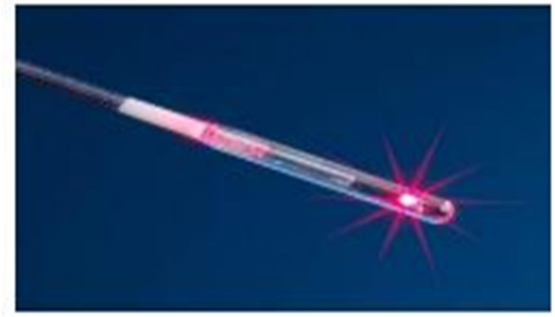


Fig: 2.6 Radialy emitting lasewr fiber baems in 360 degree.[42]

2.10 Procedure:

Laser Pilonidoplasty:

1-The procedure was performed under local anesthesia (Tumescent solution: Lidocaine 2% + diluted adrenaline with normal saline in a concentration equal to a concentration 1/ 100000 buffered with sodium bicarbonate 8.4 %) with maximum dose 4.5 mg / Kg for Lidocaine.

2- patient lying prone.

3-Sterile gauze soaked with 10% povidone Iodine antiseptic solution was applied on the shaved skin of the buttocks and sterile drapes were used to expose the whole natal cleft.

4-The whole sinus tract, pockets and side branches if present were curetted through the midline pits and lateral pits if present by a small Volkmann's spoon to remove hair, debris and unhealthy granulation tissue.

Cleaning of sinus tract from hair debris necrotic tissues as in fig2.7

Care was taken to extract all debris from the sinus to avoid remaining hair and unhealthy granulation tissue after laser pilonidoplasty, which could potentially lead to further acute infection, this is done by curettage of tract and side branches if present.

5- washing the sinus more than one time by saline 0.9% followed by hydrogen peroxide once with curettage more than one time and cleaning by normal saline washing several times to get rid of hair, debris necrotic tissue and unhealthy granulation tissue as in fig. 2.8

6-The 600-micrometer fiber optic probe introduced through the tract till reach the tip of tract then retrograde force in a vary rate of 2 mm /second applying repeated mode and power of 8 W (3 Sec ON 1 Sec OFF)with duty cycle 75%.and power density 10.1watt/cm2. The procedure continuing at this rate till the total fiber out of the sinus. The procedure as in fig. 2.9 a, b.

7-We did laser pilonidoplasty using diode laser 1470 nm (CHERYLAS-45JN TECHNOLOGY), with radial fiber optic probe and the optical output is 15 watts at the distal end, and radially emitting laser fiber that emits laser energy in a 360 degree that ensures homogenous photo thermal destruction of the tract. Each secondary bit needs to be treated with laser energy in the same fashion.

8-The laser energy causes progressive shrinkage of the pilonidal tract and the circular diffusion of the energy by the radial optical fiber facilitate its uniform distribution within the sinus and the tract.. The laser device used and the laser catheter used

9-Finally, cold fomentation and dressing.

10-Time of operative technique: ranged from 20 to 30 minutes with mean of 25.2 ± 5.1 minutes.

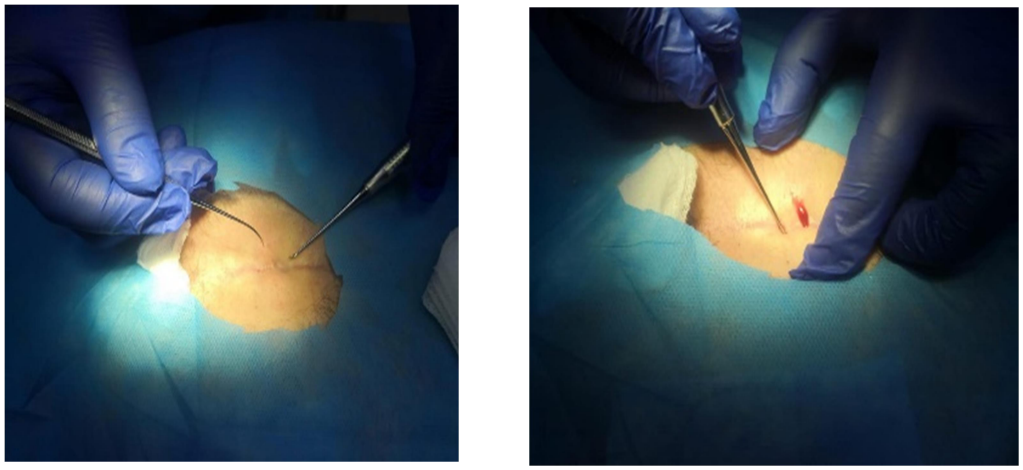
a) b)

Fig(s). 2.7: cleaning of sinus tract from hair, debris and necrotic tissues.

a. Cleaning of sinus tract from debris using currete

b. Washing of sinus tract by hydrogen peroxide.

a- b-



Fig(s). 2.8: curettage of sinus tract to remove unhealthy granulation tissues.

a. Probing of sinus tract after removing of hair and debris.

b. Curettage of sinus tract to remove unhealthy vascular granulation tissues.

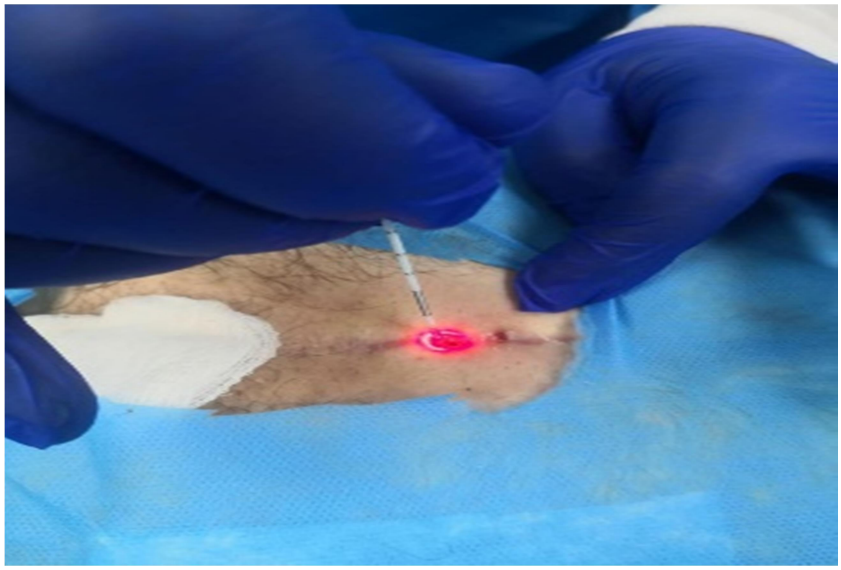


Fig.2.9 a: Laser Pilonidoplasty (destruction of sinus opening)

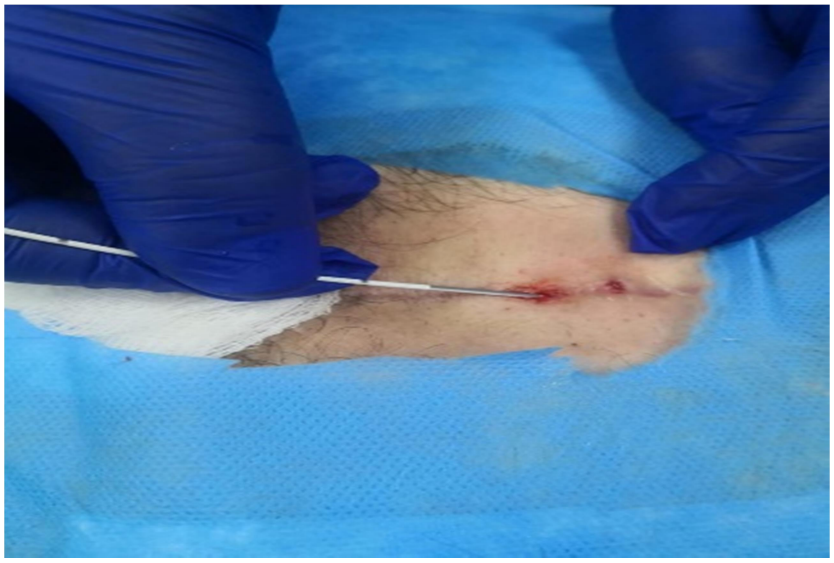


Fig. 2.9 b: Laser pilonidoplasty (destruction of sinus wall).

a- b-

Fig 2-10 pilonidal sinus with abscess

A 37 years old male patient (patient No. 9 according to table 3-1) with multiple sinus tracts laterally extended with small abscess.

(a) immediately after application of laser energy at 1470 nm through the existing sinuses under local anesthesia with total energy (1002j).

(b) result after 5 weeks.

Chapter Three

-Results

-Discussion

-Conclusions

-Recommendations

3.1 Introduction

This chapter presents the results, the discussion to explain these results, conclusion and suggestion about this study.

3.2 Results:

The current study enrolled 12 patients with PNS, male was more common as it represented in 8/12 (67%) while female was found in 4/12 (33%) cases with male to female ratio (2:1).

The average age was (33.25±6.75) years with range (19-46) years, 9 (75%) patients presented with primary and 3 (25%) cases as secondary disease. Abscess were found in 2 (16.7%) of cases, number of sinuses treated range from (1-4) sinuses, the mean time of procedure in total was (34.58± 10.88) minutes while the time of laser emission was (60-90 second), surface area treated was range from (3.9-10.4) cm2, mean healing times was (6.58±1.31) weeks, all these were shown in (table 3.1).

Table 3.1: Characteristics of patients treated and technical details regarding the procedure performed.

No. of patient	Gender	Age/ years	disease status	Prior abscess	Number of sinuses treated	Procedure time/minute	*Surface area/cm^2	Healing time/weeks
1	F	28	*Primary	NO	3	28	4.6	5 weeks
2	M	35	primary	yes	2	24	9.1	10 weeks
3	M	46	primary	NO	2	29	6.2	5 weeks
4	M	19	primary	NO	1	19	3.9	5 weeks
5	F	35	*secondary	NO	3	41	7.8	7weeks
6	M	39	primary	NO	2	33	6.9	6 weeks
7	F	37	primary	NO	1	22	4.7	5 weeks
8	F	34	Primary	NO	3	42	8.1	7 weeks
9	M	37	secondary	YES	3	51	10.4	8 weeks
10	M	29	secondary	NO	3	37	7.9	8 weeks
11	M	31	primary	NO	4	53	9.3	10weeks
12	M	29	primary	NO	3	36	7.8	7 weeks

* Surface area measured depending on ultrasonography results prior to the surgery.

*Primary: PNS with no previous intervention *Secondary: PNS with previous intervention

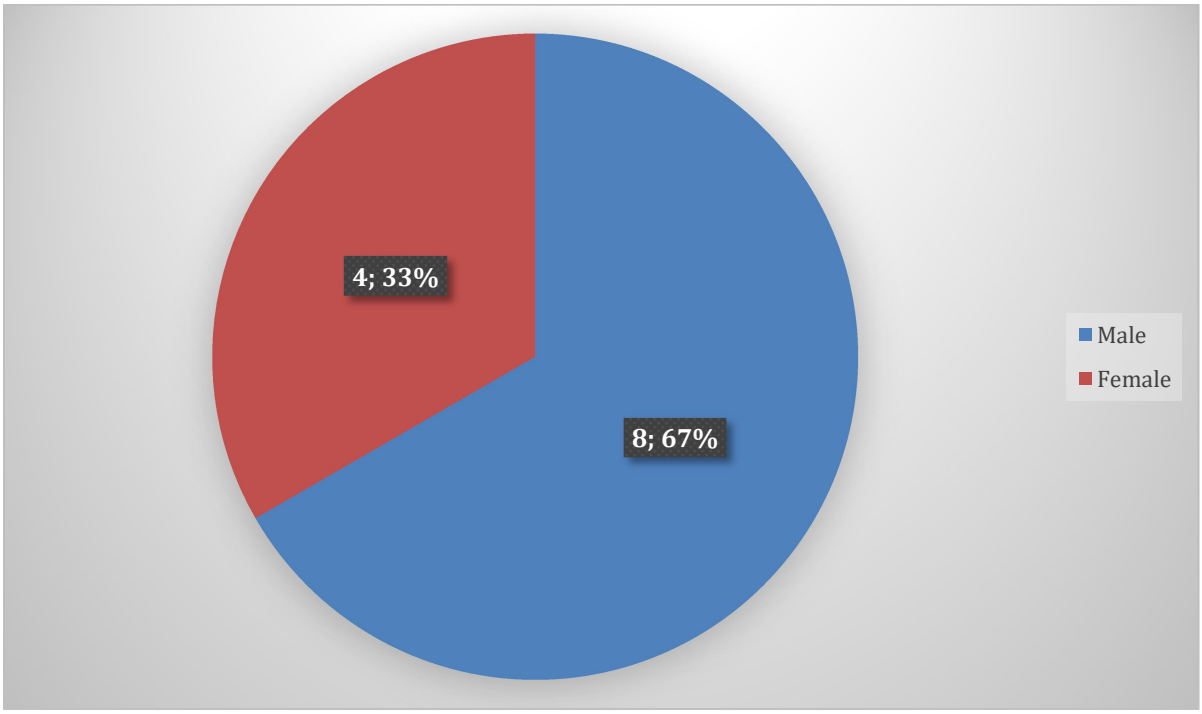


Figure 3.1: Gender distribution

As shown in table 3.2, the post-operative pain was presented in 9 cases and distributed as: 3/9 (33.3%) cases in stage 2, 5/9 (55.6) cases in stage 3, and 1/9 (11.1%) case in stage R (recurrent stage). wound infection happened in one case only (in stage 3), no case detected regarding post-operative hemorrhage, 2 cases were delayed healing more than 60 days. The most common finding in the current study is the immediate return to work; 4 cases in stage 2, 5 cases in stage 3, and 3 cases in stage R.

Table 3.2: summary of post-operative morbidity and immediate return to work in patients treated with 1470 nm diode laser for PNS disease of stage 1-4.

All Patients (n=12)	Stage 1 (n=0)	Stage (2) (n=4)	Stage (3) (n=5)	Stage (4) (n=0)	Stage (R) (n=3)	Total
Post-operative pain	0 (0%)	3 (33.3%)	5 (41.6%)	0 (0%)	1(8.3%)	9 (75%)
Wound infection	0(0%)	0(0%)	1 (8.3%)	0(0%)	0(0%)	1 (8.3%)
Post-operative hemorrhage	0(0%)	0(0%)	0(0%)	0(0%)	0(0%)	0(0%)
Delayed healing (>60 days)	0(0%)	0(0%)	2 (16,6%)	0(0%)	0(0%)	2 (16.6%)
Immediate return to work	0(0%)	4 (33.3%)	5 (41.6%)	0(0%)	3 (25%)	12 (100%)

In the current study the mean time to healing in stage 2 was (45) days with range between (40-50) days, while for stage 3 its needed for 65 days with range between (55-70) days, and stage R needed for 50 days to complete heal with range between (45-55) days. The mean time needed for the complete healing in all patients was (53.3±10.4) days with range between (40-70) days (table 3.3).

Table 3.3: Results of PNS disease treatment of various stages of PNS cyst

	Patients No. (%)	Mean times (days) to complete healing (range)	Patients subjected to second treatment	patients subjected to third treatment (open)	Recurrences
Stage 1	0 (0%)	0	0	0	0
Stage 2	4 (33.3%)	45 (40-50)	0	0	0
Stage 3	5 (41%)	65 (55-70)	0	0	0
Stage 4	0 (0%)	0	0	0	0
Stage R	3 (25%)	50 (55-45)	0	0	0
Mean±SD		53.3±10.4 (40-70)			

Discussion:

Diode laser device offer advantages over several different lasers as a result of its small size, diode laser additionally provides a large variety of spectrum of beam wavelength that will be employed in multiple medical fields. A strong effort has been introduced to find a minimally invasive techniques towards the pilonidal sinus treatment in a few recent years. [43-45]

In the past a conservative technique has been used for treatment of PNS, these methods include destruction by thermal, injection of phenol, radiation that's used locally, and cryosurgery. But these techniques lead to high complications rate so they no longer used for treatment of PNS. [47;48]

Neola B et al, proposed the cleaning of the sinus with a Farrell applicator, thorough removal of hair and debris from the cyst and application of 3% peroxide solution to achieve hemostasis and promote the granulation process. [48]

Meneiro et al, [49] in a published multicenter trial study popularized a minimally invasive method which is endoscopic PNS treatment. Under spinal anesthesia they introduced a video assisted endoscope into the pilonidal sinus and then under direct vision the surgeon removed necrotic material, granulation tissue and hairs. Good clearance of the cavity is the strongest point of this method and it is followed by widening of the external opening to achieve optimal wound drainage and secondary healing. Meneiro et al. [50] complete wound healing rate was high at 94.8%, with a short mean complete wound healing time of 26.7 ± 10.4 days and a recurrence rate of 5%.

Currently, the objectives of the ideal treatment are a simple treatment requiring local anesthesia, minimum hospitalization, quick recovery and return to

everyday life activities, less postoperative pain, a high success rate and low cost. [51] Which is same that revealed by the current study in which quick recovery and immediate return to work after the treatment were happened.

The results of the present study revealed that there is short duration of the treatment (53.3±10.4) minutes, with minimum complications, that is in agreement with that found by many previous studies. Some surgeons have introduced lasers for the treatment of pilonidal sinus based on the initial encouraging results for epilation of the sacrococcygeal region performed by dermatologists. [52-54]

The idea was that the high laser energy could destroy the deep tract systems of the sinus without affecting the overlying skin. Initial reports with Nd-YAG lasers gave encouraging results, with success rates over 70%, shorter duration of treatment, shorter hospital stay, low need for additional surgery (about 7%), minimal discomfort and a low complication rate. [55;57]

Other authors have used a newer type of laser treatment for closure of fistula-in-ano, with a primary healing rate of about 70%. Primary closure of the tract was achieved by a radial laser fiber connected to a diode laser. The laser energy caused shrinkage of the tissue around the fiber, resulting in healing and preservation of continence for such a complex situation. The diode laser delivers energy at 1470 nm, providing an optimal absorption curve in water which is considered to achieve effective protein denaturation and tissue shrinkage. [58]

The present study found that the success rate was (100%) with no recurrence of the disease (PNS) within the period of study and the complication rate was 25% (2 cases as delayed healing and one as wound infection)

Dessily et al, [57]) treated 40 patients with a pilonidal sinus using a radial diode laser probe in order to destroy the sinus epithelium by the delivered energy and achieve obliteration of the tract. The success rate was 87.5%, the recurrence rate 2.9% and the complication rate 10% (two cases of hematoma and two abscesses, all medically treated.

Georgios K. Georgiou 5 patients were treated using diode laser 1470nm with success rate was (100%) as an outpatient basis under local anaesthesia, receiving no antibiotics or painkillers after discharge. At 6 months complete follow-up, no recurrence was documented. energy applied varied between a total of 417 and 1197 J (mean 118 J/ cm of sinus treated) Healing times varied between 3 and 6 weeks (mean 5 weeks) .[58]

A F Pappas et al, Two-hundred and thirty-seven patients (183 male, median age 24 years, range 14-58) suffering from pilonidal sinus were operated on using diodelaser 1470nm. A high healing rate was observed after the first session (90.3%, 214 of 237) with a median healing time of 47 days (range 30-70 days). A second treatment was offered for patients failing in the first session; this was successful in 78.3% (18/23). The duration of the procedure ranged between 20 and 30 min and had limited morbidity (wound infection in 7.2%, [59]

The weakness of the procedure is the blind control of the tracts that may still contain foreign bodies or untreated epithelium. For this reason, in order to reduce the risk of recurrence, careful cleaning of the cavity is deemed mandatory prior to laser treatment.[60]

Conclusions:

The benefits of the PNS treatment by laser diode 1470 nm for patients:

1. Immediate return to usual physical activity.
2. No recurrence of the disease during the period of study,

3- No post-operative hemorrhage.

3. Mild post-operative pain.

Recommendations:

1. large randomized controlled trials are needed to confirm early findings.
2. More period of time for follow up

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الملخص

الخلفية: ناسور العصعص مشكلة شائعة بين الشباب ، تصيب الرجال بشكل شائع بين العقد الثاني والرابع من العمر. قد تظهر على المرضى أعراض المرض الحاد أو قد يعانون من الشكل المزمن للمرض مع إفراز صديدي من واحد أو أكثر من الجيوب الأنفية. الصمام الثنائي الليزر هو جهاز أشباه الموصلات يشبه الصمام الثنائي الباعث للضوء حيث يمكن للديود الذي يتم ضخه مباشرة بالتيار الكهربائي أن يخلق ظروف الليزر عند تقاطع الصمام الثنائي.

الأهداف: تقييم علاج الناسور الشعري بالليزر ديود (نانومتر)

المواد والطرق: أجريت الدراسة الاستباقية على مدى ٦ أشهر من أغسطس ٢٠٢١ إلى يناير ٢٠٢٢ في عيادة جراحية تخصصية في مدينة بغداد ، العراق

النتائج: تم عرض آلام ما بعد الجراحة في ٩ حالات. عدوى الجرح حدثت في حالة واحدة فقط (في المرحلة الثالثة) ولم يتم الكشف عن حالة نزيف بعد العملية ، حالتان تأخر الشفاء أكثر من ٦٠ يوم. النتيجة الأكثر شيوعًا في الدراسة الحالية هي العودة الفورية إلى العمل ؛ ٤ حالات في المرحلة ٢ ، و ٥ حالات في المرحلة ٣ ، و ٣ حالات في مرحلة التكرار. كان متوسط الوقت اللازم للشفاء التام لدى جميع المرضى (٥٣,٣±١٠,٤) يوم ، وتتراوح بين (٤٠-٧٠) يومًا .

الخلاصة: علاج ناسور العصعص بالليزر دايود١٤٧٠ نانومتر: عودة فورية لممارسة الفعاليات الحيوية مع عدم تكرار المرض خلال فترة الدراسة

الكلمة الرئيسية: ناسور العصعص ، ليزر ديود ١٤٧٠ نانومتر ، مرحلة النكس

وزارة التعليم العالي والبحث العلمي

جامعة بغداد

معهد الليزر للدراسات العليا

تقييم الليزر ذو الطول الموجي 1470 نانوميتر في علاج مرض الناسور العصعصي

دراسة

مقدمة إلى معهد الليزر للدراسات العليا بجامعة بغداد عن استيفاء جزئي لمتطلبات درجة الدبلوم العالي في

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١٤٤٣ هـ ٢٠٢٢م