Republic of Iraq
Ministry of Higher Education and
Scientific Research
University of Baghdad
Institute of Laser for Postgraduate Studies

Recurrence of Chronic Anal Fissure After Laser Surgery Using 980nm Diode Laser

A Dissertation

Submitted to the Institute of Laser for Postgraduate Studies University of Baghdad as Partial Fulfillment of the requirements for the Degree of higher Diploma in Laser in Medicine/General Surgery

By

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2021A.D **1442A.H**

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يَعْلَمْ (٥)﴾

صدق الله العظيم

سورة العلق (الآية ١-٥)

Certificate

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Dedication

For all those who seek knowledge and to my family.

Ala'a Khalid

Acknowledgements

First, my deepest gratitude goes to **Allah** for his unlimited blessing, help, complacency. I wish to express my great thanks to ***Prof. Dr. Hussein Ali Jawad,*** Dean of the Institute of laser for postgraduate studies and ***Asst. Prof. Dr. Basima M.A. Hussein***, Head of Biomedical Applications department for their encouragement.

I would like to express my appreciation and respect to my supervisor ***Dr. Mardukh Sami Abd Ali*** in his role to facilitate my work. My special thanks for my family especially my husband for his scientific and social support.

Great thanks to all the staff of the Institute of Laser for Post Graduate Studies for their kind help and great efforts. Finally, I thank Al- Qimma privet hospital staff and manager.

Ala'a Khalid

Abstract

1.Back ground: -

Laser can now be considered a practical and cost-effective method with specific properties that has been successfully used in a variable range of medical and surgical applications. Chronic anal fissure is one of the most common pathologies encountered in the surgical field which can be treated with laser surgery successfully. In order to maximize healing with minimal damage to neighboring tissues, a combination of laser fissurectomy and lateral internal sphincterotomy using laser diode instead of electro-cautery and manual scalpel was feasible.

2.Aim of study: -

To verify the effectiveness and safety of using 980nm diode laser in fissurectomy and lateral internal sphincterotomy on the incidence of postoperative recurrence of chronic anal fissures.

3.Patients and method: -

This prospective study was conducted for Institute of laser for postgraduate studies from the first of July in 2020 to the end of February in 2021.Eleven women who were complaining of reluctant chronic anal fissure to conservative treatment would undergo to surgery. 980nm diode laser at a power ranges from 5-9 W, continuous mode, and in a contact way, was used in performing fissurectomy and lateral sphincterotomy. To ensure full recovery without recurrence, all patients were followed for at least 3 months by direct clinical review via a series of visits that were determined based on their needs.

4.Result: -

When a diode laser was used to conduct fissurectomy and lateral internal sphincterotomy in effective and minimally harmful doses, there would be reduction in operative time to the range of (15-20min) and recovery period to the range of (10-21) days. No postoperative healing failure or recurrence (0%) had been detected during follow up period**.**

5.Conclusion: -

Laser diode is an effective, less destructive, and safe tool to replace the scalpel and electrocautery in anal fissure surgery. Anal fissure recurrence after surgery can be prevented by combining these above procedures with the use of a minimal laser power that is tolerated by the treated tissue and produces acceptable short- and long-term results.

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List of Abbreviations

Term	Definition
AIDS	Acquired Immunodeficiency Syndrome.
ACLF	Advanced Cardiovascular Life Support
ACPGBI	Association of Coloproctology of Great Britain & Ireland
Ant.	Anterior
ASCRS	American Society of Colorectal Surgeons
BTA	Botulinum Toxin A
CBP	Complete Blood Picture
CO_2	Carbon Dioxide
cm	Centimeter.
CS	Conscious Sedation
CT	Computerized Tomography
CW	Continuous Wave

ECG	Electrocardiography
ESR	Erythrocyte Sedimentation Rate
D	Depth
EUA	Examination Under Anaesthesia
FDA	Food and Drug Administration
GA	General Anesthesia
H	Height
HWG	Hollow Wave- Guides
IAS	Internal Anal Sphincter
IEC	International Electrotechnical Commission
J	Joule
LIS	Lateral Internal Sphincterotomy
LLLT	Low Laser Level Therapy
MAC	Monitored Anesthesia Care
MRI	Magnetic Resonance Imaging

mm	Millimeter
Nd: YAG lasers	Neodymium-doped Yttrium Aluminium Garnet
nm	Nanometer
NA	Numerical Aperture
PCS	Plastic Clad Silica
PDT	Photo-Dynamic Therapy
Post.	Posterior
QSH	AL-Qimma Surgical Hospital
Rh	Rhesus factor
SA	Spinal Anaesthesia
TIR	Total Internal Reflection
TA	Tumescent Anesthesia
W	Width

Chapter “One”

Introduction, and Basic Concept

Chapter one

Introduction and Basic Concept

1.1 Introduction; -

Over the past half century, laser has found its way into ophthalmology, oncology, cosmetic surgery, and many areas of medicine and biomedical research. The possibility of using light in treating illness has been known for thousands of years. The ancient Greeks and Egyptians used sunlight as a therapy and the two ideas were even tied together in mythology, with the Greek god Apollo taking responsibility for both light and healing [1].

The phenomenon of light has had a lot of significance since the beginning of modern science, and our understanding of its physical nature has progressed significantly since then. The behavior of light was explained in the early twentieth century by two main theories: one claimed that light was a particle, and the other claimed that light was a wave. In reality, light is both. This unique property of light what is referred to as wave-particle duality [2].

Lasers have unique properties that make them far superior to sunlight or other light sources for medical applications. Each laser emits light that is coherent and operates within a very narrow wavelength range. They have the potential to be extremely strong. Since the beams can be oriented on such a small area, they have a high-power density. As a result of these characteristics, lasers are now used in a variety of applications [1].

Lasers were first used in medicine in the fields of ophthalmology and dermatology. Leon Goldman showed how a ruby laser, which emits red light, could be used to remove port wine stains, and melanomas from the skin only a year after the laser was invented in 1960. This application based on the ability of lasers to operate at a particular wavelength. Lasers are now widely used in dermatology for things like tumor, tattoo, hair, and birthmark removal [1].

The laser which is an acronym that stands for light amplification by stimulated emission of radiation, is the most important optical invention to be developed in the past 60 years. Its transition from a theoretical idea to tangible applications has provided the means to make optics one of the fastest evolving fields in science and technology today.

In anal surgery, the focus of most surgeons is to choose a suitable method with favorable clinical outcomes in reducing pain and discomfort of the patients. Perianal skin is thin and sensitive, so laser therapy is an innovative treatment for anal lesions [3].

Albert Einstein laid the theoretical foundation for lasers in his 1917 paper regarding his theory of radiation. Einstein theorized that there are three fundamental processes which explain interactions between atoms and light: spontaneous emission, absorption, and stimulated emission. He also predicted the possibility of creating a concentrated, coherent beam of light

However, his work went unexploited for several decades until C.H. Townes and Arthur Schawlow developed a maser, producing light in the microwave range of the electromagnetic spectrum. They proposed aligning two parallel-facing mirrors along the optical axis of the cavity of a preliminary laser model to accomplish this. The mirrors were placed in the cavity to reflect photons at specific frequencies back and forth through the laser's medium. This method uses stimulated emission to create similar photons at a rate that increases as the photons pass through the laser medium. Townes and Schawlow published a paper regarding their idea of implementing parallel mirrors into a laser cavity in 1958.

Gould was the first to publically use the term laser, for "Light Amplification by Stimulated Emission of Radiation" at the June 1959 Ann Arbor Optical Pumping Conference.

In 1960, Theodore Maiman, a Scientist from Stanford University, successfully constructed the first working laser using ruby as the gain medium using the ideas of Townes and Schawlow [1,2].

1.2 Literature review: -

In the past decade, several studies have been carried out on the use of laser for the treatment of perineal lesions however, there is a scarcity of studies on laser treatment of anal fissure.

Fateh Sh., et al. [3], in 2016 stated that laser therapy of acute anal fissure is a simple, non-invasive and with a low rate of complications and relapse. It can be viewed as an effective treatment for patients with anal fissure. However, this procedure has some limitation.

Maheshwari J. [4], in 2018 showed that patients had reduced healing time with no scars following minimally invasive laser sphincterotomy when compared to conservative surgical procedures. There were nil post-operative complications at the follow-up period for 6 months, with minimal bleeding in a few cases following the procedure.

Bernhard Hofer M.d. [5], in 2020 had observed that the use of a diode laser instead of an electroscalpel in anal fissurectomy ensures a better end result, as wound healing begins earlier and the scars become smooth and elastic.

1.3 Overview on anal fissure and its management: -

Anorectal complaints are extremely common; approximately 2-3% of the population have anorectal symptoms at any giving time A basic understanding of principle of applied anatomy and pathology will help to differentiate the patients who need surgical interference from those who can be treated symptomatically [6].

1.3.1. Anatomy: -

The anus is a remarkable structure which has a capability to allow the passage of stools, and it's capable of maintaining continence to gas, fluid and solid. Knowledge of its anatomy is essential if effective treatment is to be instigated for many anorectal conditions [6]. The anal canal can be described in terms of the 'surgical' and 'anatomical' anal canal [7].

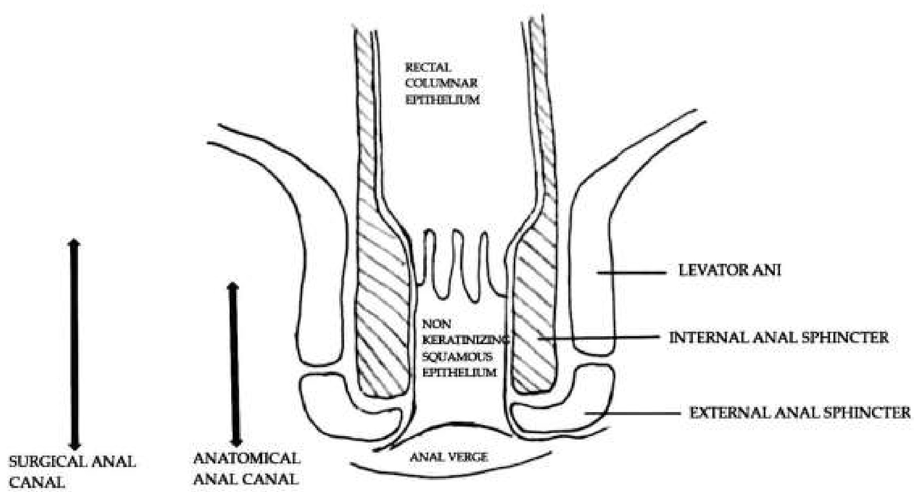


Figure (1.1): Schematic description of anal canal anatomy [7].

The surgical anal canal measures 2-4cm long in the male and slightly shorter in females. It extends from anorectal junction to the anal verge. The anatomical anal canal is about 2 cm long and extends distally from the anal verge to the dentate line proximally. The transition between columnar rectal mucosa and squamous anoderm is marked by the dentate or pectinate line.

The 1- 2 cm of mucosa just above the dentate line shares histological characteristics of columnar, cuboidal, and squamous epithelium and is referred to as the anal transitional zone. AT the dentate line, there is longitudinal folds of mucosa, known as the column of Morgagni, into which the anal cryptogenic glands empty [8].

The anal canal consists of two concentric muscle layers known as the internal and external sphincters. The internal sphincter is a condensation of the circular smooth muscle of the rectum and is a continuation of the circular muscle of the gastrointestinal trac. The autonomic nervous system is responsible of controlling it. The internal sphincter's smooth muscle maintains tone and contributes to resting pressure within the anal canal, so it's crucial for sustaining continence. The gut's longitudinal muscle terminates at the anus as a series of fibrous bands radiating to the perianal skin, and has little effect on perianal disease. The striated muscle of the external sphincter is under voluntary control, being innervated bilaterally by the internal pudendal nerves and the fourth branch of the sacral plexus. The circular muscle tube of the external sphincter blends with the lower part of the levator ani, known as the puborectalis sling. The puborectalis fibres of the levator ani originate from the posterior aspect of the pubic symphysis and pass posteriorly to join the external sphincter. The levator ani muscles themselves are also important in maintaining the relationship of the anus and rectum during defaecation [6]. The anal sphincters and the puborectalis muscle relax during defecation, allowing the anorectal angle to widen and the perineum to descend without overstretching the posterior perineum [7].

1.3.2. Fissure in ano: -

Fissure-in-ano is a common condition characterized by a linear anal ulcer affecting the anal canal below the dentate line from the anal transition zone to the anal verge. There is often little in the way of granulation tissue in the ulcer base. The condition most commonly affects people in their twenties and thirties, with a slight male preponderance. Fissures are most frequently observed in the posterior midline of the anal canal, although anterior fissures may occur in women following childbirth; they are rarely seen in males. Fissures may be acute and settle spontaneously or by medical treatment, but chronic anal fissure is defined as an ulcer that has been present for at least 6 weeks. Owing to failed attempts at healing, there may be a tag of skin at the lowermost extent of the fissure, known as a 'sentinel pile'. At the proximal extent of the fissure there may be a hypertrophied anal papilla. Sometimes fissures will heal incompletely and mucosa will bridge the edges of the fissure. This results in a low perianal fistula and may present years later [6].

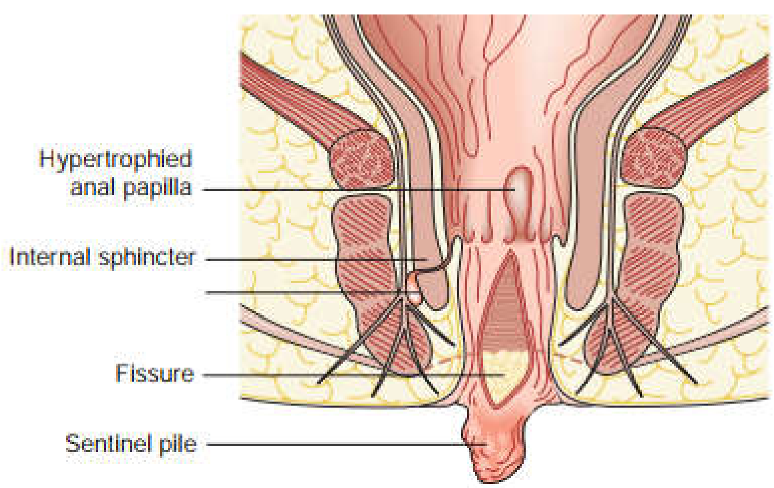


Figure (1.2): Explanatory diagram of chronic anal fissure [10]

1.3.2.1. Etiology: -

Although the majority of fissures are idiopathic (primary), it is apparent that the pathophysiology includes ischemia at the ulcer's base, which is accompanied by anal spasm and a significantly elevated resting anal pressure. Consecutive bowel movements cause more trauma, discomfort, and anal spasm, creating a vicious cycle of anal pain and sphincter spasm, which causes more trauma to the anal mucosa during defecation [6]. This cycle of pain, spasm, and ischemia contributes to development of a poorly healing wound that becomes a chronic fissure [6,7,8]. Nitrous oxide synthase was also found to be intrinsically lower in individuals with fissures in one study [7]. This trauma to the anal canal can happen when its mucosa is over stretched by passing a large stool or hard stool, constipation, repeated diarrhea, childbirth, and anal sex [8]. Secondary anal fissure can occur as a result of inflammatory bowel diseases, AIDS, tumor, tuberculosis, leukemia and poor healing wound following hemorrhoidectomy. Recurrent multiple or unusually extensive fissures affecting areas other than the midline should raise the suspicion of secondary anal fissure [6,9].

1.3.2.2. Clinical finding: -

Patients can present with an acute or a chronic fissure-in-ano. Patients with an acute fissure typically experience severe anorectal pain, particularly during bowel movements, which is characterized as extreme and sharp, and as “passing shards of glass or razor blades.” The pain eases until the next bowel movement.

Because of sphincter spasm, patients with a chronic anal fissure experience intense pain, which is exacerbated during defecation. The initial presenting symptom of fresh bright red blood is rare. Constipation and a straining defecation pattern are common among patients. Painful defecation leads to avoidance of defecation and results in a vicious, self-perpetuating cycle. They tend to eat less to avoid the need for passing stool. Some patients report episodes of diarrhea before symptoms appear. Other patients report pruritus ani, but this is not a typical symptom of a fissure. Sometime, there is mucous discharge [6,7,8,9].

Digital rectal examination is difficult because the patient has an extremely tender anus and is fearful. Often visual inspection with gentle eversion of the anoderm in the posterior midline is all that is required. Physical findings include an approximately 1 cm split in the anoderm in the posterior midline just distal to the dentate line. In chronic fissures, the classic triad may be present: hypertrophy of the anal papilla, anal fissure, and sentinel skin tag. Once an anal fissure has been diagnosed, further examination is very painful, unrewarding, and unnecessary unless the patient is comfortable. More extensive investigations can be performed after the fissure has healed [10]. Severe pain can be induced with digital rectal or proctoscopic examination, so should not be attempted if a fissure is expected or demonstrable in the awake setting. If suspecting a secondary pathology, proctoscopy and digital examination are necessary, this should be done under local, regional or general anaesthesia [7].

1.3.2.3. Investigations: -

If the diagnosis is unclear and the surgeon is unable to see the fissure at the bedside, or a patient who is high risk for colorectal cancer and presents with significant fresh bleeding per rectum, examination under anaesthesia (EUA) with anoscope, colonoscopy and tissue sampling may be needed. Similarly, dependent on findings at EUA, further investigation with endoanal ultrasound, Computerized Tomography (CT) and Magnetic Resonance Image (MRI) scanning may be required [7].

1.3.2.4. Classification: -

Anal fissures are classified on the basis of chronicity and morphological appearance. Acute fissures are defined as those with duration of symptoms of 6 weeks or less. They usually involve only the superficial mucosal layer and the base of the fissure does not have visible internal anal sphincter fibres IAS. They tend to have sharply demarcated, fresh mucosal edges, often with granulation tissue at the base and often they will heal spontaneously. Lindsey et al. proposed a definition for chronic anal fissure as ‘the presence of visible transverse IAS fibres at the base of an anal fissure of duration not less than 6 weeks. The IAS hypertrophies over time and becomes more effective at sustaining the wound open, preventing spontaneous wound healing. Chronic anal fissures have distinct anatomical features, such as the aforementioned visible sphincter fibres at the fissure base along with an anal papilla, sentinel pile and indurated margins [7,8,9].

1.3.2.5. Treatment options: -

Any treatment plan needs to address the following issues: (1) supportive measures, (2) atraumatic passage of stool, (3) pain management, (4) abnormal pattern of defecation, e.g., excessive straining, and (5) decreasing anal sphincter tone and local ischemia in patients with a hypertonic sphincter [7].

1. Supportive measures: - As a first line of care, non-operative management is recommended. Supportive interventions like sit baths, bulking agents, and topical anesthetics and steroids can help nearly half of patients get rid of their symptoms, although there is controversy about its use. As compared to placebo, fiber maintenance therapy is associated with a lower risk of fissure recurrence. [6,7,8,9,10].

2. Atraumatic passage of stool: -Constipation causes straining, which aggravates the symptoms of fissures. Laxatives, stool softeners, and sufficient dietary fiber intake are all recommended. The treatment with fibre supplementation has been associated with increased healing rates, improvement of symptoms, and prevention of recurrence. Fibre absorbs water and forms a viscus and bulky stool, which facilitates peristalsis and makes the stool easier to evacuate, reducing the need for straining during defecation. Stool softeners work by rising the water content of the stool, preventing trauma to the lining of the anal canal during defecation. Mineral oil also aids to facilitate passage of stool without much stretching or abrasion of the anal mucosa, but it is not recommended for indefinite use [6,7,8,9,10].

3. Pain management: - Topical anesthetics, in conjunction with sit baths and the other supportive strategies described above, provide effective pain relief. Analgesics are often needed to keep patients comfortable. Nonsteroidal anti-inflammatory medications, paracetamol, and, on rare occasions, opioid analgesics are required, with the latter requiring the use of a laxative at the same time to prevent more constipation [6,7,8,9,10].

4. Abnormal pattern of defecation: -

Assessment of dyssynergic defaecation and anorectal feedback may be required in patients with excessive straining at defecation. A manual perineum support has been shown to help in patients with defecatory issues. A novel posterior perineal device incorporated in the toilet seat has also shown improvement in pain, constipation, and bleeding symptoms [7].

5. Decreasing sphincter tone and local ischemia: -

Pharmacological and surgical options are available to manage increased IAS tone with associated local ischemia. For chronic fissures, studies have suggested lateral internal sphincterotomy (LIS) has better results as compared to pharmacological agents. The American Society of Colorectal

Surgeons (ASCRS) recommends LIS as the first line of treatment in the selected group of patients with no underlying fecal incontinence of any degree. The available options are discussed below.

a- Pharmacological management: -

Chemical sphincter relaxation is first-line treatment of choice using topical 0.5% diltiazem or nitrates (glyceryl trinitrate 0.2–0.5%) as a cream applied 12-hourly to the anal canal. Headaches can be a dose-limiting side effect especially with topical nitrates, but healing can be achieved in 50–70% of chronic fissures. Other means of reduction in sphincter tone include direct injection of the sphincter with botulinum toxin BTA, which temporarily paralyses the sphincter [8]. Until the relatively recent advent of chemical sphincterotomy as first-line treatment, surgery was the only option. Medical management has a much-reduced incidence of the dreaded complication of faecal incontinence but has a higher recurrence rate (around 50% for medical management as compared to 3–6% for LIS). Medical management does not provide a solution for skin tags, sentinel piles and fibrous polyps. These persist even after symptoms have resolved and can themselves cause bleeding or pain with trauma or can be a cause of faecal soilage. The Association of Coloproctology of Great Britain and Ireland (ACPGBI) recommends supportive treatment for both acute and chronic anal fissures, in combination with a calcium channel blocker for 6–8 weeks. If resistant to treatment, they recommend the injection of 20–25 units of BTA [7].

b- Surgical options:

Surgery still has a major role in the management of patients who have fissures resistant to medical treatment, or who have recurrence. Anal stretching has been abandoned, as it is associated with significant sphincter damage and the risk of incontinence. As per a recent systematic review and metaanalysis of 148 trials, surgical intervention is significantly more effective for chronic anal fissures than medical management, but carries the additional potential risk of incontinence. The main contraindication to surgery for an anal fissure is impaired faecal continence, a condition that might worsen with surgery. This contraindication usually refers to patients who have mild incontinence or are at risk of incontinence due to a compromised sphincter complex, such as multiparous women and the elderly. Patients with chronic fissures and those with acute fissures that is not responding to conservative treatment are also candidates for surgery. No specific preoperative preparation is needed, intravenous antibiotics are not recommended and preoperative enemas can be very painful for the patient and thus should be avoided [7].

- Lateral internal sphincterotomy (LIS): -

It is the most common operation for anal fissure and involves controlled division of the lower half of the internal sphincter at the lateral position (3 o'clock or 9 o'clock with the patient in the lithotomy position). Approximately 30% of the internal sphincter fibers are divided laterally by using either an open or closed technique. Healing is achieved in more than 95% of patients using this technique, and most patients experience immediate pain relief. There is a small but appreciable risk of late anal incontinence following lateral sphincterotomy. This is usually only to gas, but occasionally faecal incontinent [8]. LIS has been shown to result in better quality of life than that following medical therapy. Importantly, LIS also negates any patient compliance issues associated with medical therapy. Due this, LIS can be offered as 1st line treatment for patients with chronic anal fissures and no underlying symptoms of or predisposition to incontinence.

A modified form called a tailored sphincterotomy or fissure apex sphincterotomy involves division of the IAS up to the level of the apex of the fissure and thus it preserves more sphincteric muscle fibres. Two randomized controlled trials have reported a clinically significant reduction in incontinence with fissure apex sphincterotomy as compared the aforementioned traditional LIS. Another described technique is that of the calibrated sphincterotomy. A predetermined anal canal diameter (3 cm) is achieved by transecting the sphincter muscles. Results from a randomized controlled trial show equivalent healing in calibrated LIS and fissure apex LIS, but the incidence of faecal incontinence was higher in the fissure apex LIS group. A recent review using three-dimensional anal ultrasonography to determine the extent of IAS division during LIS in women reported that the safest method is to divide less than 25% of the sphincter, which in women corresponds to less than 1 cm. No incontinence was observed in these patients. It is important to ensure the sphincter is actually divided during LIS [7].

- Anal advancement flap: -

This is a sphincter-saving procedure that has a very low reported incidence of postoperative minor faecal incontinence (0–6%). An anocutaneous (dermal V-Y or house) flap can be used for chronic non-healing fissures in patients with an increased risk of developing faecal incontinence (e.g., older adults, multiparous women, patients with recurrent fissures). This procedure has been shown to have good healing rates (81–100%) [11,12]. Anal advancement flaps have been utilized as a subsequent therapy to LIS or BTA injection resulting in less postoperative pain and improved healing [13].

- Fissurectomy: -

Fissurectomy entails excision of the scarred superficial skin around the anal fissure, chronic granulation tissue, hypertrophied papilla and the skin tag or sentinel pile. This then leaves a base of healthy tissue that will hopefully heal. The wound is either left open or closed primarily. In one clinical trial by Mousavi et al., fissurectomy was considered inferior to LIS.

Fissurectomy has also been performed in conjunction with GTN or BTA injection to treat anal fissures with no recurrence and no sphincter damage on post-operative endosonography. Persistence of hypertrophied papillae, skin tags and polyps often lead to patient dissatisfaction. Removal of hypertrophied anal papillae and fibrous anal polyps should be considered as a part of the surgical procedure. A randomized controlled trial found 84% of patients who had removal of the polyp, papilla or skin tag were satisfied at 2 years postoperatively as compared to only 58% of the control group [7].

ASCRS recommend that LIS may be offered as first-line therapy without prior medical treatment to decrease IAS tone in a selected group of patients. The ACPGBI recommends LIS in cases of failed medical treatment, or of chronic anal fissures in association with a hypertonic anal sphincter. Modifications of the traditional sphincterotomy procedure have shown promising results. Anal advancement flaps can be an option for high-risk patients with IAS hypotonia [7].

- Combination procedures: -

Primary wound healing can be achieved by combining anal advancement flap with LIS or BTA injection providing faster pain relief and potentially providing better functional results. Theodoropoulos et al. found significantly less postoperative pain, faster healing, and fewer incontinence episodes in the tailored LIS plus flap group in comparison to the conventional LIS alone group. Magdy et al. found tailored LIS with V-Y flap produced a superior healing rate, with relatively lesser complications and less rate of recurrence as compared to LIS or anal advancement flap alone. In a randomized controlled trial of 99 patients, the combination of diltiazem and BTA injection was found to be as effective as LIS in patients with chronic anal fissure of the duration of 1 year or less [7].

- Minimal invasive surgery: -

A new approach has been proposed for the treatment of fissure non-responsive to conservative topical treatment or relapsing, based on laser electrocoagulation of the fissure and its margin. By these means, we destroy scarred tissue and give the tissue a chance to heal gradually from the bottom to the top of the anal ulcer of the fissure. All patients experienced immediate improvement and achieved healing of their fissure within one month with no recurrence or any other complication [14].

Following minimally invasive laser sphincterotomy healing time had been reduced with no scar when compared to conservative surgical procedures. There were nil post-operative complications at the follow-up period, with minimal bleeding in a few cases following the procedure [4].

1.3.3. Recurrence of chronic anal fissure: -

Fissures can quickly recur, and a completely healed fissure is more likely to recur after a rough bowel movement or other trauma. Even after the pain and bleeding have subsided, maintaining healthy bowel habits and a high-fiber diet as a lifestyle improvement is critical. If the issue reappears without a clear cause, further investigation might be required. The precise and controlled division of the internal anal sphincter muscle is a highly successful and widely used treatment for chronic and refractory anal fissures, with recorded success rates of over 90%. Recurrence rates after sphincterotomy are exceedingly low when properly performed by a surgeon. Patients undergoing sphincterotomy have much improved quality of life as compared to patients with persistent anal fissures [15].

Approximately 6% of patients have a recurrence of their anal fissure after sphincterotomy. The recurrence rate is higher after a sphincter stretch.

If a patient develops a recurrence after a sphincterotomy, it could be from recurrent disease or from an improperly or incompletely performed initial sphincterotomy.

If a recurrence occurs, medical management should be tried again, but if relief is not achieved, the surgeon must determine if the initial sphincterotomy was satisfactory. Endoanal ultrasonography or palpation during anesthesia may be used to evaluate the patient [16].

Many proctologists, especially those in France, adopted those sphincter-sparing techniques as a standard care for any chronic anal fissure refractory to medical management especially idiopathic non infected chronic anal fissures in a combination with medical and/ or self-manual, pneumonic dilatation of IAS will reduce recurrent rate to that LIS [4,17].

1.4 Basics and Principles of laser: -

1.4.1. Laser operating system: -

Laser operating system has three main components: -

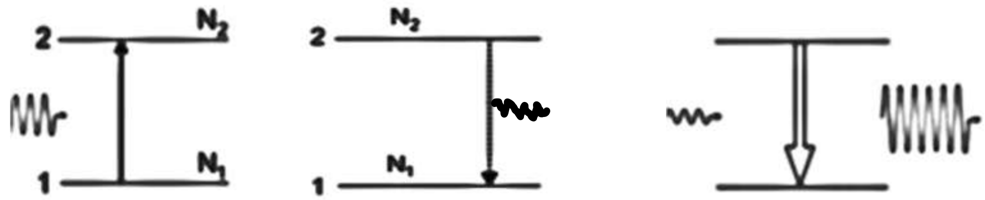
• Active medium (=gain medium = laser medium). The active medium is able to amplify electromagnetic radiation. The active medium, which is situated within a resonator, partially or completely fills the resonator. The characteristics of the laser light emitted will be determined by the laser medium. The laser medium can be solid, liquid, or gaseous.

• Pump system. It pumps the active medium. Methods of pumping are: optical pumping with another laser or a lamp; pumping with a gas discharge; pumping with a current through a semiconductor or a semiconductor heterostructure; chemical pumping. It's the part of a laser system that provides energy to the laser medium. To get laser emission, first we need to produce population inversion. Population inversion is the process of achieving greater number of electrons in higher energy state as compared to the lower energy state.

• Laser resonator. The laser resonator has the task to store a coherent electromagnetic field and to enable the field to interact with the active medium—the active medium experiences feedback from the coherent field. We will describe resonators that consist of two mirrors—one is a reflector of a reflectivity R1 near 1, and the other is a partial reflector serving as output coupler. The output coupling mirror has a reflectivity (R2) that also can have a value near 1 but that can be much smaller; semiconductor lasers can have reflectors with R1 = R2 ∼ 0.3. Each type of laser requires its own resonator design. There is a main criterion concerning reflectivities of resonators: a laser should be able to work at all. Depending on the task of a laser, other criteria can be chosen—for instance, that a laser should have optimum efficiency of conversion of pump power to laser output power [18].

1.4.1.1 Principle of operation at atomic level:

One model in atomic physics describes an atom as a central nucleus of protons and neutrons, surrounded by a cloud of electrons which encircle the nucleus in different orbitals. When appropriate energy is supplied to the atom, electrons can jump from low-energy orbitals (ground state) near the nucleus to high- energy orbitals further away, leading to atomic excitation by the process of energy *absorption.* The absorption of radiation or light occurs only if the energy of incident photon exactly matches the energy difference of the two energy levels.



(a) (b) (c)

Figure (1.3): - (a) Absorption, (b) Spontaneous emission and (c) Stimulated emission [18].

The electrons in the excited state can stay only for a short period. The time up to which an excited electron can stay at higher energy state is known as the lifetime of excited electrons. The lifetime of electrons in excited state is 10^{-8}sec. Thus, after the short lifetime of the excited electrons, they return to the lower energy state or ground state by releasing energy in the form of photons. This type of transition is called *spontaneous emission* in which the electrons move naturally or spontaneously from one state (higher energy state) to another state (lower energy state) so the emission of photons also occurs naturally. Therefore, we have no control over when an excited electron is going to lose energy in the form of light. The spontaneous emission process creates photons that do not flow in the same direction as incident photons. The photons produced in the spontaneous emission process constitute ordinary incoherent light, consisting of a beam of photons with frequent and random phase changes.

When the light energy is supplied directly to the excited electron, incident photon interacts with the excited electron and forces it to return to the ground state. This is called *stimulated emission* which is not a natural process.

In spontaneous emission, the electrons in the excited state will remain there until its lifetime is over. After completing their lifetime, they return to the ground state by releasing energy in the form of light without external stimulation. But, in stimulated emission, the electrons in the excited state need not wait for completion of their lifetime. An alternative technique is used to forcefully return the excited electron to ground state before completion of their lifetime. The stimulated emission process is very fast compared to the spontaneous emission process. This excited electron release energy in the form of light while falling to the ground state.

In stimulated emission, two photons are emitted (one additional photon is emitted), one is due to the incident photon and another one is due to the energy release of excited electron. Thus, two photons are emitted.

All the emitted photons in stimulated emission have the same energy, same frequency and are in phase. Therefore, all photons in the stimulated emission travel in the same direction.

For laser operation the population inversion is required [18]. Electrons in the atoms of the lasing material normally reside in a steady-state lower energy level. When light energy from the flashlamp is added to the atoms of the lasing material, the majority of the electrons are excited to a higher energy level -- a phenomenon known as population inversion. This is an unstable condition for these electrons. They will stay in this state for a short time and then decay back to their original energy state. This decay occurs in two ways: spontaneous decay -- the electrons simply fall to their ground state while emitting randomly directed photons; and stimulated decay -- the photons from spontaneous decaying electrons strike other excited electrons which causes them to fall to their ground state. This stimulated transition will release energy in the form of photons of light that travel in phase at the same wavelength and in the same direction as the incident photon. If the direction is parallel to the optical axis, the emitted photons travel back and forth in the optical cavity through the lasing material between the totally reflecting mirror and the partially reflecting mirror. The light energy is amplified in this manner until sufficient energy is built up for a burst of laser light to be transmitted through the partially reflecting mirror. A lasing medium must have at least one excited (metastable) state where electrons can be trapped long enough (microseconds to milliseconds) for a population inversion to occur. Although laser action is possible with only two energy levels, most lasers have three or more levels.

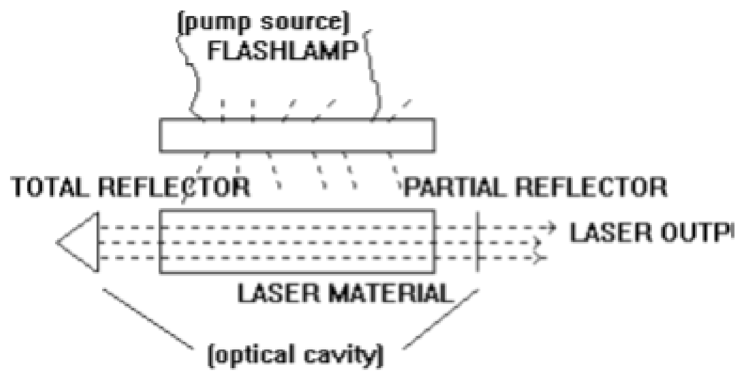


Figure (1.4): Operating laser system [19].

With just two levels, 1 and 2, it is impossible to produce a population inversion. At first, it might seem that it would be possible to achieve this through the interaction of the material with a sufficiently strong electromagnetic wave at definite frequency. Since, at thermal equilibrium, absorption will in fact predominate over stimulated emission. The incoming wave would produce more transitions 1 to 2 than transitions 2 to 1 and we would hope in this way to end up with a population inversion. We see immediately, however, that such a system would not work (at least in the steady state).

When in fact the condition is reached, the absorption and stimulated emission processes will compensate on another. This situation is often referred to as two-level saturation [19]. Therefore, population inversion can be produced using three-level laser or four-level laser. In a three-level laser, the atoms are in some way raised from the ground level 1 to level 3. If the material is such that, after an atom has been raised to level 3, it decays rapidly to level 2 (perhaps by a rapid nonradiative decay), then a population inversion can be obtained between levels 2 and 1. In a four-level laser, atoms are again raised from the ground level to level 3. If the atom then decays rapidly to level 2 (e.g., again by a fast nonradiative decay), a population inversion can again be obtained between levels 2 and 1. Once oscillation starts in such a four-level laser, however, the atoms will then be transferred to level 1, through stimulated emission. For continuous wave (cw) operation it is therefore necessary that the transition from level 1 to 0 should also be very fast (this again usually occurs by a fast nonradiative decay) [19,20].

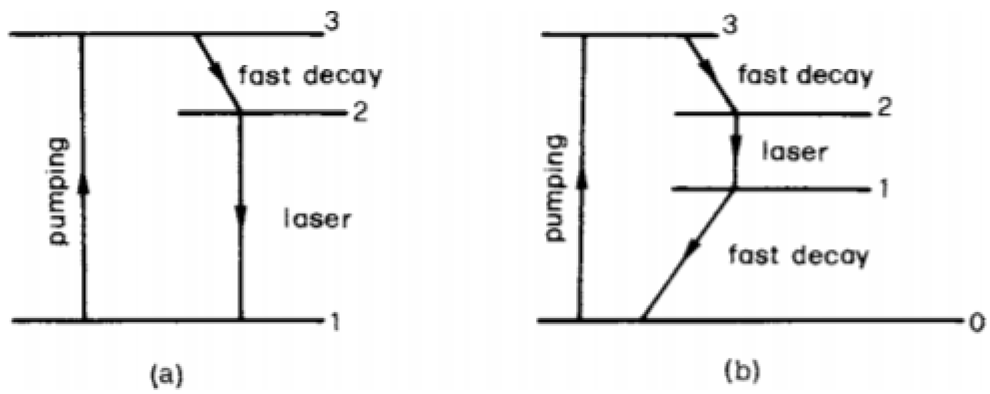


Figure (1.5): (a) three-level laser, (b) four-level laser [19].

1.4.1.2. Properties of laser beams: -

Laser radiation is characterized by an extremely high degree of:

1. monochromaticity,
2. coherence,
3. directionality,
4. brightness.

1.4.1.3. Time Modes of Operation: -

The rate at which energy is delivered distinguishes the various time modes of operation of a laser.

Continuous Wave (CW) lasers operate with a constant output over a set interval. This means that key beam parameters (power output, intensity, etc.) remain constant throughout the beam's duration. Nd: YAG and ruby laser are example of continuous wave laser.

Single Pulsed (normal mode) lasers generally have pulse durations of a few hundred microseconds to a few milliseconds. This mode of operation is sometimes referred to as long pulse or normal mode.

Single Pulsed Q-Switched lasers are the result of an intracavity delay (Q-Switch cell) which allows the laser media to store a maximum of potential energy. Then, under optimum gain conditions, emission occurs in single pulses; typically, of 10^{-8}second time domain. These pulses will have high peak powers often in the range from $10^{6}$to 10^{9} Watts' peak.

Repetitively Pulsed or scanning lasers generally involve the operation of pulsed laser performance operating at a fixed (or variable) pulse rates which may range from a few pulses per second to as high as 20,000 pulses per second. The direction of a CW laser can be scanned rapidly using optical scanning systems to produce the equivalent of a repetitively pulsed output at a given location.

Mode Locked lasers operate as a result of the resonant modes of the optical cavity which can affect the characteristics of the output beam. When the phases of different frequency modes are synchronized, i.e., "locked together," the different modes will interfere with one another to generate a beat effect. The result is a laser output which is observed as regularly spaced pulsations. Lasers operating in this mode-locked fashion, usually produce a train of regularly spaced pulses, each having a duration of 10^{-15}femtosecond to10^{-12} picosecond. A mode-locked laser can deliver extremely high peak powers than the same laser operating in the Q-switched mode. These pulses will have enormous peak powers often in the range from 10^{12}Watts' peak [19,20,21].

1.4.2. Diode laser: -

Diode laser is unique amongst most other laser sources for their wide range of available wavelengths. With wave-lengths ranging from ultraviolet to infrared, diodes have become one of the most powerful laser sources.

Diode lasers are very effective for soft tissue applications including incision, hemostasis, and coagulation [22]. They are used strictly for soft tissue procedures and penetrate 2 to 3 mm or more into soft tissue, depending on the wavelength and tissue biotype. Diode laser wavelengths which are absorbed by pigmented structures are ideal for cutting melanotic or highly vascularized soft tissues and providing hemostasis [23]. Many advantages of the laser in surgery. These include a bloodless operating field, minimal swelling and scarring, and much less or no postsurgical pain. When laser surgical procedures are carried out, the surface produced heals favorably as an open wound, without the need for sutures or surgical dressings. Studies have shown enhanced, faster, and more comfortable wound healing when the diode laser is used [22].

In 1962, Robert N. Hall invented the semiconductor injection laser. Semiconductor lasers utilize a semiconductor as the gain medium. Most of them are electrically pumped laser diodes, where electron-hole pairs are generated by an electrical current in a region where n-doped and p-doped semiconductor materials meet. However, there are also optically pumped semiconductor lasers [24].

- **Overview of Laser Diodes:**

In short, a laser diode is a semiconductor device, whom its conductivity lies between the conductor and insulter, made of two different materials. One a P-material where holes are majority carriers, and an N-material where electrons are majority carriers, sandwiched together. The active layer (light emission layer) sandwiched between the p- and n-type. Clad layers are formed on an n-type substrate, and voltage is applied across the p-n junction from the electrodes. The junction region is actually lightly doped with p-type material and has the highest index of refraction. The n-type material and the more heavily doped p-type material both have lower indices of refraction. This produces a light pipe effect that helps to confine the laser light to the active junction region (wave guide structure). Both edges of the active layer have mirror-like surface. If output is desired from only one end of the device, or if mirrors of higher reflectivity are desired to reduce the threshold for laser operation, the reflectivity may be increased by coating the surfaces with metal films. Optical standing waves may exist between any two of the parallel surfaces of the diode. Two sides are purposely roughened to reduce reflection and prevent lasing "across" the diode cavity. Forward electrical bias, that needs to be a stable, low-noise, transient free current sources, across the P-N junction causes the respective holes and electrons from opposite sides of the junction to combine giving off a photon in the process of each combination. Laser light is a result of stimulated emission produced by electrons giving up their energy through combination with holes in the junction region. Excitation most often is provided by current flow (injection) through the junction, although electron beams can be used in some special cases. The feedback mechanism (cavity) usually consists of the cleaved ends of the diode. Those who know laser theory know what happens when there are photons bouncing around a polished cavity.

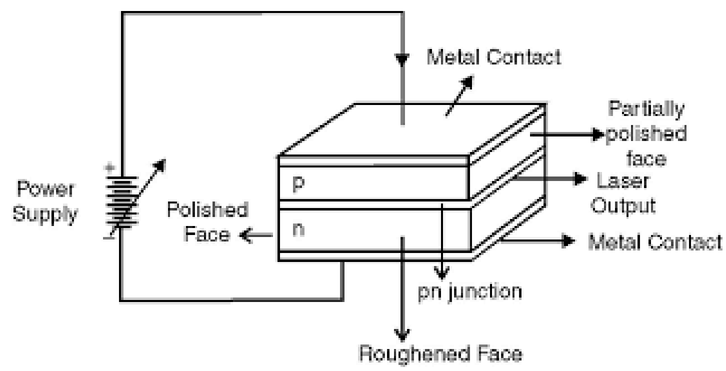


Figure (1.6): Construction of diode laser [19].

The working of a laser diode takes place in three main steps which are: -

1. Energy Absorption

The laser diode consists of a p-n junction where holes and electrons exist. When a certain voltage is applied at the junction, the electrons absorb energy and they transition to a higher energy level. Holes are formed at the original position of the excited electron. The electrons stay in this excited state without recombining with holes for a very small duration of time, termed as "recombination time" or "upper-state lifetime". The recombination time is about a nanosecond for most laser diodes.

2. Spontaneous emission

After the upper-state lifetime of excited electrons, they recombine with holes. As the electrons fall from higher energy level to a lower energy level, the difference in energy is converted into photons that is emitted with energy given by the difference between the two energy levels. This same process is used to produce light in light emitting diodes (LEDs).

3. Stimulated emission

A partially reflecting mirror is used on either side of the diode so that the photons released from spontaneous emission are trapped in the p-n junction until their concentration reaches a threshold value. These trapped photons stimulate the excited electrons to recombine with holes even before their recombination time. This results in the release of more photons that are in exact phase with the initial photons and so the output gets amplified. Once the photon concentration goes above a threshold, they escape from the partially reflecting mirrors, resulting in a bright monochromatic coherent light [19,20,22,23].

1.4.3. Delivery laser system: -

For medical applications, the characteristics of the laser system and the tissue application will govern the choice of delivery system. The most important parts are the beam guide and the target optics. Most lasers have wavelengths in the visible and near-infrared and can be transported by silica fibres. The laser beam can be delivered either by focusing handpieces, bare optical fiber and scanning devices to treat superficial areas or through microscopes, endoscopes and flexible fibres to treat areas almost anywhere inside the human body. The beam properties, transmission and thermal properties can determine the characteristics of delivery system. The delivery of continuous wave or pulsed laser energy, contact or non-contact, will determine the contribution of optical, thermal and mechanical effects to the tissue (25).

There are three types of transmission tools: fibre optic, articulated arm, and the hollow guide. There is also direct fire, when the laser can be held in the hand.

a) Articulated arm: -

Figure (1.7): demonstrates articulated arm [26].

For lasers emitting in the far ultraviolet (known as excimer lasers) or in the far infrared region (e.g., carbon dioxide lasers) or for very short pulses (e.g., nanosecond Nd: YAG lasers) it is necessary to use an articulated arm with multiple mirrors. These articulated arms do not change the beam geometry which remains almost parallel. The technology of articulated arms has progressed recently, and they are stronger than a few years ago. But they are still bulky and cannot be used in a flexible endoscope.

b) Hollow wave- guides

There are two types of hollow guides:

• Rigid hollow aluminium tubes which have the ability to guide the laser light along several tens of cm with very little loss of power. Their exterior diameter varies from about 2 to 5 mm. They are well suited to the use of CO_2 lasers in endoscopy.

• Flexible hollow tubes whose interior is coated with a metallic deposit which reflects a CO_2 laser beam. This technology is less expensive than the articulated arm, and so they are often used with basic CO_2 lasers, with maximum power of 20 W.

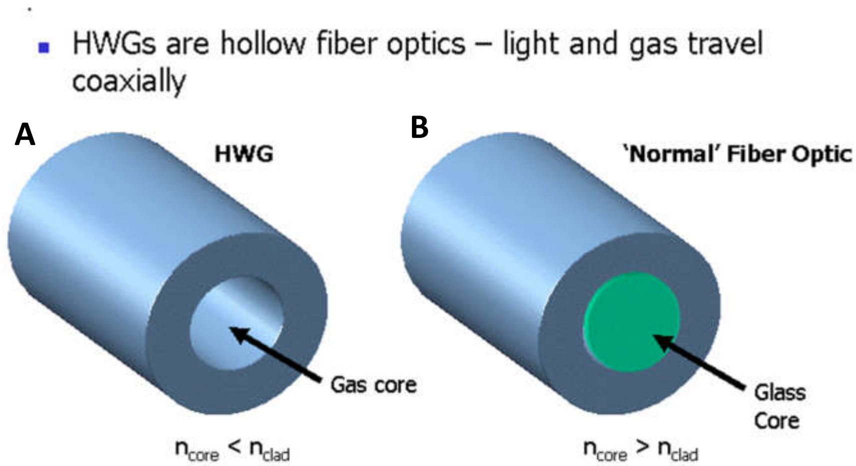


Figure (1.8): (A) Hollow wave guide and (B) fiber optics [26]

c) Direct beam.

If the laser head is made small enough to fit into the hand, the laser can be used by firing direct. Some CO_2 lasers are used in this way with a waveguide [25,26].

d) Fibre optics

Fiber optics play an important role in a number of surgical applications, not all of which involve Lasers. Fiber optic bundles are used to transmit light through both rigid and flexible endoscopes in order to illuminate surgical sites inside the body. In flexible endoscopes a second fiber bundle transmits a view of the surgical site back to the clinician. In laser procedures, a single fiber is used to deliver the energy to cut, coagulate and ablate tissue. This section addresses the application of fibers in delivering laser energy to the surgical site. Optical fibers provide a flexible means of delivering laser energy to otherwise inaccessible areas of the interior body. While fibers provide great utility, in most surgical applications, some of the unique characteristics of laser light can be lost as the energy passes through the fiber. While laser light retains its monochromatic characteristic after passing through an optical fiber, it may no longer be collimated. Light from a fiber can diverge rapidly, depending on the numerical aperture (NA) of the fiber. While fibers can be made of a number of exotic materials for special applications, the vast majority of fibers are made of glass. The diameter of the optical fiber is in between 0.25 to 0.5mm [25,26,27,28].

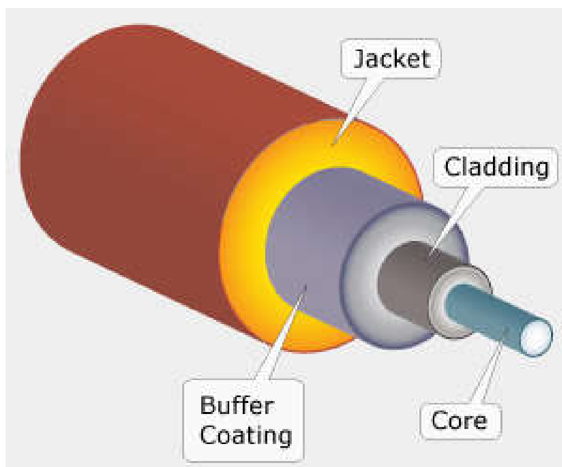


Figure (1.9): The layers of optical fiber [28]

Most fibers consist of three distinct layers: core, cladding, buffer, and jacket. The core transmits the laser energy. The cladding—which has a lower index of refraction—is applied over the core and acts to keep the energy in the core from leaking out through a process called "total internal reflection." The buffer is generally a tough plastic and acts as a protective covering to prevent damage to the fiber as it is passed through endoscopes and similar secondary delivery devices. The two primary types of fibers used are silica/silica, where both the core and cladding are made of glass, and plastic clad silica (PCS). In either case, the cladding material is selected so that it has a lower index of refraction than the core. Total internal reflection (TIR) is a function of the difference between the higher index of refraction of the core material and lower index of refraction of the cladding material. The difference in the indices of refraction creates a mirror like surface at the core-cladding interface. At this interface, a light ray is incident at an angle φ. If φ is greater than a certain critical angle, $φ_c$, all of the incident light is reflected back into the fiber. This reflection obeys the ordinary law of reflection, with the reflected angle equaling the incident angle, in effect, treating the core-cladding interface as a mirror. If the incident angle φ is less that the critical angle $φ_c$, the incident ray partially penetrates the interface in accordance with Snell's law, thereby losing photons to the cladding. As usual, some of the light is also reflected, but not much, so the loss of laser light in the core is significant [27,28,29].

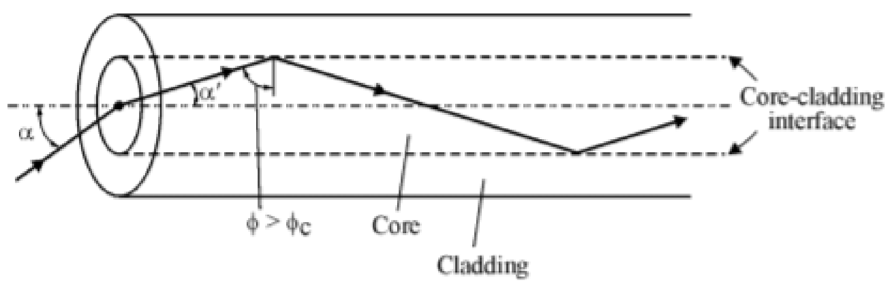


Figure (1.10): The geometry at the core-cladding interface [25].

Once the laser energy has been transmitted through the fiber it can be used in two ways. It can be applied in either a free-beam or a contact mode. Using just the fiber in the free-beam mode, the energy can be directed onto the target tissue without making contact. The spot size applied to the tissue can be varied by adjusting the from the fiber tip to the tissue. Varying the diameter of the spot size dramatically affects the intensity of the incident energy, as we have already seen. Alternately, the light diverging from the fiber can be captured by a lens—or a series of lenses—to recollimated or focus the light for use with a handpiece, microscope, slit lamp, or another secondary device. In the contact mode, the fiber itself or a special tip can be used in contact with tissue [25,26].

Types of Optical Fibers: -

1-The classification based on the refractive index is as follows:

- Step Index Fibers: It consists of a core surrounded by the cladding, which has a single uniform index of refraction. The rays of light propagate through it in the form of meridional rays which cross the fiber axis during every reflection at the core-cladding boundary [27,28,29].

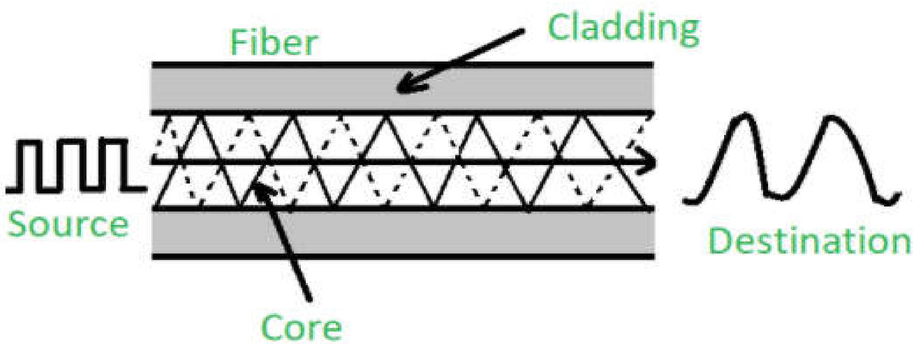


Figure (1.11): Rays'propagation within step index fiber [29].

- Graded Index Fibers: The refractive index of the optical fiber decreases as the radial distance from the fiber axis increases. The core has a non-uniform refractive index that gradually decreases from the center towards the core-cladding interface. The cladding has a uniform refractive index. The light rays propagate through it in the form skew rays or helical rays. It is not cross the fiber axis at any time

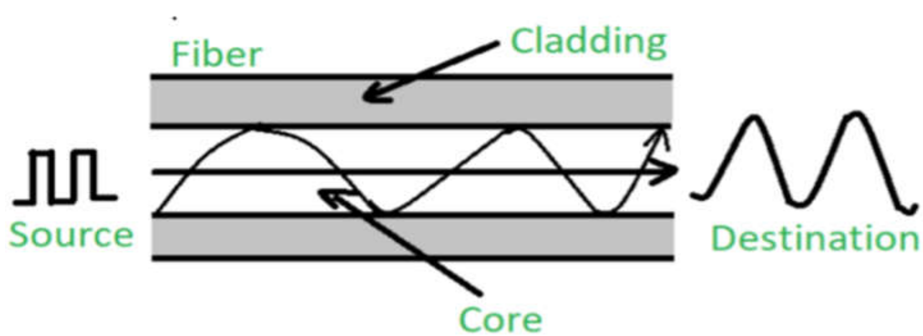


Figure (1.12): Propagation of rays within graded index fiber [29]

2-The classification based on the materials used is as follows:

- Plastic Optical Fibers: The polymethyl methacrylate is used as a core material for the transmission of the light.
- Glass Fibers: It consists of extremely fine glass fibers.

3-The classification based on the mode of propagation of light. (The "mode" in fiber optic cable refers to the path in which light travels) is as follows:

- Single-Mode Fibers: These fibers are used for long-distance transmission of signals. Single mode fiber has a smaller core diameter of 9 microns (8.3 microns to be exact) and only allows a single wavelength and pathway for light to travel, which greatly decreases light reflections and lowers attenuation. Slightly more expensive than its multimode counterparts.

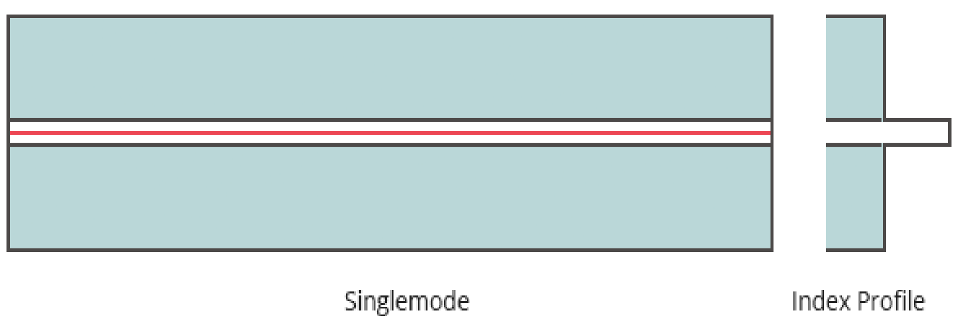


Figure (1.13): Propagation of the rays within single mode fiber [29].

- Multimode Fibers: These fibers are used for short-distance transmission of signals. Multimode optical fiber has a larger core diameter than that of single mode fiber optic cable, which allows multiple pathways and several wavelengths of light to be transmitted. Multimode optical fiber is available in two sizes, 50 microns and 62.5 microns [25,26,29].

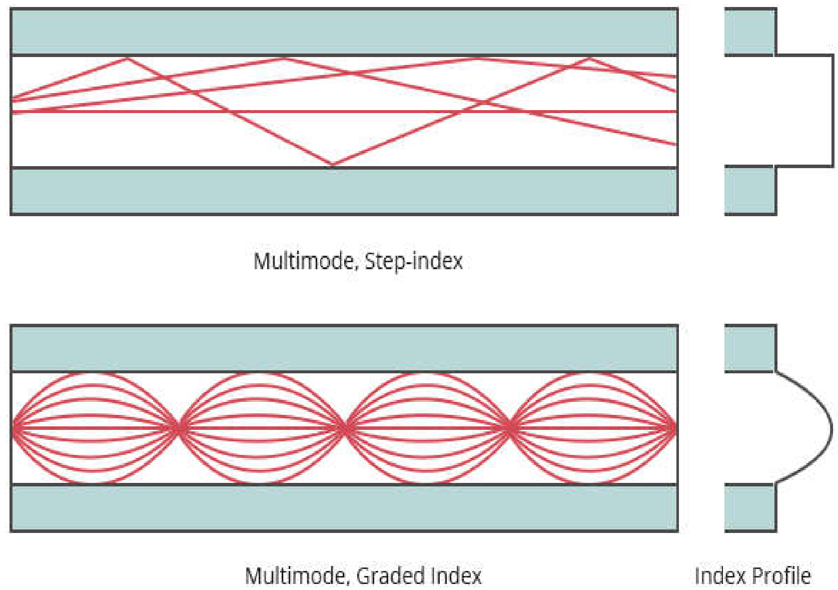


Figure (1.14): Propagation of the rays within multimode fiber [29]

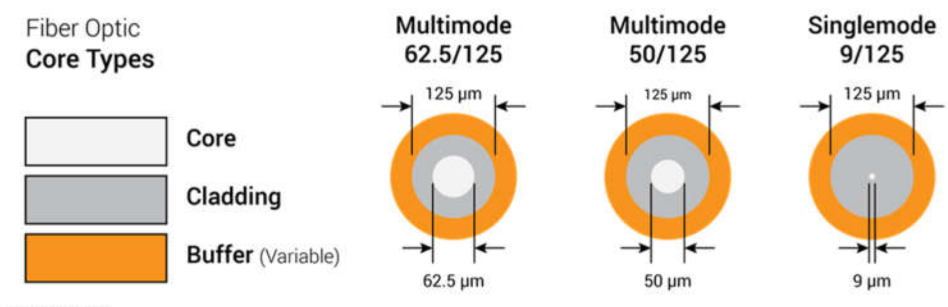


Figure (1.15): Core types of optical fiber [29].

1.4.4. Laser tissue interaction: -

A fundamental understanding of how lasers interact with tissue will enable the physician to choose the most appropriate laser for a given clinical situation. Although the physical laws guiding laser design are vastly complex, the fundamental principles of laser-tissue interaction can be summarized as they are applicable to the clinician [30]. When laser energy is incident on tissue, four things happen: transmission, reflection, scattering, and absorption. Some of the light will be reflected, some will be absorbed at the treatment site, and some will be transmitted into tissues beyond the treatment site. The light must be absorbed by the targeted tissues for the laser to be successful. The extent to which each occurs is determined by the laser wavelength and how the laser energy interacts with the irradiated tissue. The majority of the energy is absorbed in the targeted tissue if the laser wavelength is correctly chosen. Reflection of some of the laser energy simply reduces the laser's efficiency. Any energy not reflected or absorbed is transmitted through and eventually dissipated in the underlying tissues [27].

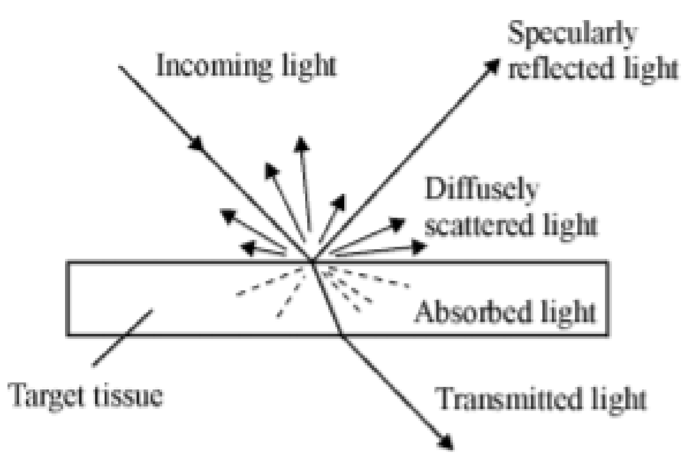


Figure (1.16): Laser tissue interactions [27].

Laser light absorption by specific tissue targets is the fundamental goal of clinical lasers. According to the Grothus-Draper law, light must be absorbed by tissue to produce an effect in that tissue. The absorption of the photons of laser light is responsible for its effects on the tissue. The components of the tissue that absorb the photons preferentially depend on wavelength. These light-absorbing tissue components are known as chromophores. Frequently targeted chromophores in the skin include melanin, hemoglobin, and water, as well as exogenous tattoo inks. Absorption of energy by a chromophore results in conversion of that energy into thermal energy [30].

Since chromophores selectively absorb different wavelengths, the monochromatic aspect of laser light is a crucial property for the application of laser technology in clinical practice. The wavelength of laser light has an effect on the depth to which it can penetrate tissue. Within the visible spectrum, the extent of penetration of laser light increases with increasing wavelength. The depth of the target chromophore as well as the specific wavelength absorbed by that chromophore must be taken into account when one chooses a laser for clinical use.

Scattering is due to the heterogenous structure of tissue, with variations in particle size and the index of refraction between different parts of the tissue determining the amount of scatter. Scattering spreads out the beam of light within the tissue, resulting in radiation of larger area than anticipated. Scattering also limits the depth of penetration because it can occur backward as well as forward. In skin, most scattered light is due to interaction with dermal collagen. In general, the amount of scattering of laser light is inversely proportional to the wavelength of the laser. Longer wavelengths thus penetrate tissue more deeply. An exception to this rule is laser light beyond the mid-infrared region of the electromagnetic spectrum. Laser light with wavelengths above 1300 nm only penetrate superficially owing to the high absorption coefficient of tissue water.

The absorbed portion of the laser radiation can produce photochemical and/or Photothermal effects depending on the wavelength of the laser radiation and nature of the tissue. It can produce fluorescence and this is used in dentistry in diagnosis of initial dental carries that based on spot emission fluorescence [31].

Laser energy is absorbed by the target tissue and the transfer of laser energy, thus causing a tissue interaction (Photobiological Effect) which can be divided according to the laser wavelength into: -

a: Wavelength dependent: like photo thermal and photochemical interactions.

b: Wavelength independent: like photo disruption, and plasma induced ablation [21].

a-Wavelength dependent:

Photochemical reaction: -

Photochemical interaction mechanisms take place at very low power densities (typically 1 Wcm^{-2}) and long exposure times ranging from seconds to CW lasers. In most cases, wavelengths in the visible range are used because of their high optical penetration depths [32]. Derivatives of naturally occurring chromophores or dyes have been used as photosensitizers to induce biological reactions within tissues for both diagnostic and therapeutic applications. Photochemical interactions include photobiostimulation, photodynamic therapy, and tissue fluorescence. In general, most of the molecules of the tissue have their bonding in the ultraviolet frequency region. At shorter wavelengths, tissue components become electronically excited, thus, this (photo excitation) leads to rupture of molecular bonds and formation of molecular fragments. Photochemical reactions generally do not result in a significant rise in temperature. Photochemical effects involved either a change in the course of biochemical reaction due to the presence of an electromagnetic field or photodecomposition due to high energy photons that rupture molecular bonds.

-Photodynamic Therapy: The photodynamic therapy reaction is mediated by exogenous chromophores. At low light intensities, laser energy is absorbed by exogenous chromophore molecules called photosensitizes (photo acceptors). In this case, a specific wavelength of the laser light is used for activation of these molecules or drugs. The light absorbing molecule can cause chemical reactions in the target tissue [32].

- Biostimulation: This process is also known as low energy, low light, soft, cold laser and low intensity, low power therapy is the application of monochromatic light that range from red to infrared wavelengths to stimulate cellular growth factors and improve wound/soft tissue healing. Low Laser Level Therapy (LLLT) was pioneered in Europe and Russia in the early 1960's. Low intensity light energy can promote and upgrade metabolic processes that result in tissue repair and pain relief [21].

Photothermal reaction:

Light energy absorbed by the tissues is transformed into heat energy which then produces tissue effects as in Table (1.1).

Table (1.1): Thermal effects of laser light for different temperatures [33].

Temperature	Biological effects
37°C	Normal
45-50°C	Hyperthermia, Reduction of enzyme activity, Cell immobility
60-80°C	Denaturation of proteins and collagen; Coag-ulation
100°C	Vaporization, Thermal decomposition (abla-tion
>100°C	Carbonization
>300°C	Melting

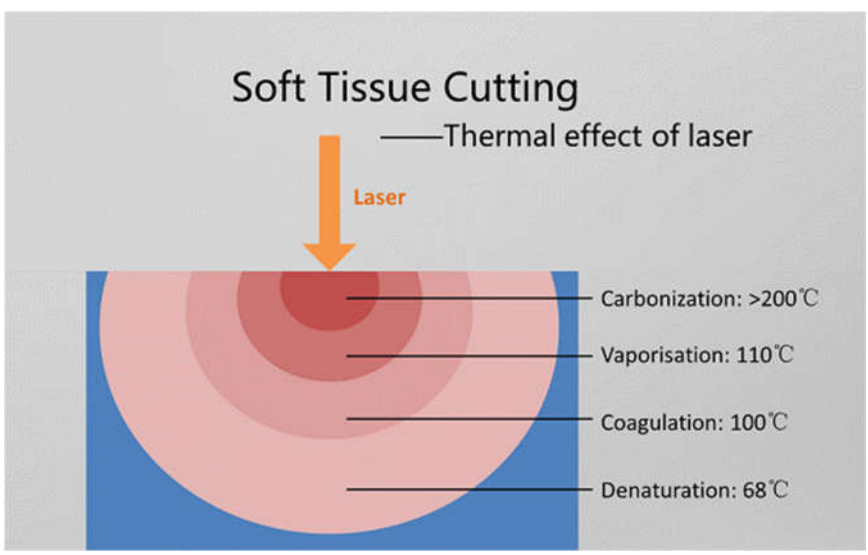


Figure (1.17): Thermal effect of laser [32].

The amount of laser energy absorbed by the tissue largely determines the thermal interaction produced and is in turn dependent on the wavelength of the laser light to a great degree, but also on other parameters such as spot size, power density, pulse duration and frequency, the optical tissues properties, and thermal properties [32].

Laser light is absorbed by tissue chromophores and is converted to heat; this process is accompanied by a local temperature increase, and the heat is conducted to cooler regions. To decrease the transmition of heat and the damage to surrounding tissues a selective photo-thermolysis should be achieved. Selective photothermolysis refers to laser energy absorption by a target chromophore without significant thermal damage to surrounding tissue. To achieve selective photothermolysis, the laser must produce a beam of light with a wavelength absorbed by the chromophore in the lesion. Equally important, the exposure time to the laser beam must be shorter than the thermal relaxation time of the chromophore to prevent the spread of thermal energy beyond the targeted chromophore. The wavelength, exposure time, and fluence of a laser can be tailored to result in selective damage to the lesions without nonspecific thermal damage to the surrounding tissues. Primary cutaneous chromophores targeted by visible light include melanin and oxyhemoglobin. melanin has a broad overlapping absorption band ranging across ultraviolet, visible, and near infrared spectrum with decreasing absorption as the wavelength increases. Water absorbs mainly infrared laser energy. Depth of penetration affects the ability to treat certain chromophores at certain depths with certain wavelengths. For example, the dominant absorption peak for hemoglobin is at 420 nm, but this wavelength only penetrates to the dermal-epidermal junction (100 μm), which would limit use of a laser of this wavelength for cutaneous vascular lesions. The smaller absorption peak of oxyhemoglobin at 577 nm is more useful clinically because of the deeper penetration achieved at this wavelength. The important note to be mentioned that Oxyhemoglobin has three main absorption peaks (418, 542, and 577 nm) [30].

Table (1.2): The relation between the size of chromophore and the thermal relaxation time [30].

Target	Size (ml)	Thermal relaxation time
Tattoo ink particle	1	10 ns
Melanosome	1	1 μs
Erythrocyte	7	20 μs
Epidermis	50	1 ms
Blood vessel	50	1 ms
Ectatic blood vessel	100	15 ms
Hair follicle	200	20 -100 ms

Photoablation reaction: -

Tissue Ablation occurs due to either pressure stress (called thermal decomposition) or volume stress (called ablative photodecomposition). Both of these are termed Photo ablation.

In *thermal decomposition*, the increase in temperature leads to an increase in pressure as water within the cell tries to expand in volume, thereby increasing the pressure within the cells and hence pressure stress. This leads to localized micro explosions and is thus sometimes referred to as a thermo-mechanical effect.

Ablative photodecomposition, meaning that material is decomposed when exposed to high intense laser irradiation. It occurs when the energetic photons of the laser light decompose the molecules by breaking the chemical bonds. In this interaction, photoablation is due to the "volume stress" as a result of bond breaking. The removal of tissue is performed in a very clean and exact fashion without any appearance of thermal damage such as coagulation or vaporization. Photoablation takes place in the intensity range of 10^4-10^{10}W cm^{-2} and interaction time in the range of 10^{-3}- 10^{-10} sec. But the typical threshold values of this type interaction are 10^7-10^8 W cm^{-2} at laser pulse durations in the nanosecond range [32].

b-Wavelength independent mechanisms:

When using power densities exceeding 10^{11} W cm^{-2} in solids and fluids or 10^{14} W cm^{-2} in air, where the pulse duration is in picosecond or femtosecond range, multiphoton ionization of atoms and molecules may occur a phenomenon called optical breakdown occurs. The physical effects associated with optical breakdown are plasma formation and shock wave generation. If breakdown occurs inside soft tissues or fluids, cavitations and jet formation may additionally take place. By means of plasma-induced ablation, very clean and well-defined removal of tissue without evidence of thermal or mechanical damage can be achieved when choosing appropriate laser parameters [21].

Photodistruption (Photo acoustical) interactions: -

These photomechanical interactions, involve fragmentation or disruption of tissue using shock wave. Energy is concentrated in space and time to create optical breakdown or ionization of the tissue, with the formation of plasma at the tissue surface then plasma expansion causing shock wave generation leading to localized mechanical ruptures when the pressure rise is greater than the yield strength of the tissue. If breakdown occurs inside soft tissues or fluids, cavitations and jet formation may also take place [32].

Plasma induced ablation: -

It's a very clean ablation, associated with audible sound and bluish plasma sparking that is caused by ionizing plasma formation [32].

1.4.5. Laser safety standards and hazard classification: -

In spite of their advantages, lasers have definite hazard by causing serious damage on the tissue of both patient and laser operation personnel. Due to this fact, laser users should study the laser hazards and safety precautions [21].

The classification of laser is based upon the beam output power or energy from the laser. Basically, the classification is used to describe the capability of the laser to produce injury to personnel. The higher the classification number, the greater is the potential hazard.

Table (1.3): Laser Classification and requirements [34].

Classification	Logotype	Warning Label Text	Outline of risk assessment
Class I	None Required Max Power <,= 0.39 mW	None Required	Levels of laser radiation are not considered to be hazardous.
Class IIa	None Required (Exposures < 1,000 s) Max power > 0.39 to 1.0 mW	None Required	Levels of laser radiation are not considered to be hazardous if viewed for any period of time less than or equal to 1 x 10^3 seconds.
Class II	CAUTION Max Power <,= 1 mW	Laser Radiation - Do not stare into beam	Levels of laser radiation are considered to be a chronic viewing hazard.
Class IIIa	CAUTION (Irradiance < 2.5 mW/cm^2 Max power <,= 5 CAUTION (Irradiance >,= 2.5 mW/cm^2) Direct Eye Exposure	Laser Radiation - Do Not Stare into Beam or View Directly with Optical Instruments Laser Radiation – Avoid Direct Eye Exposure	Levels of laser radiation are considered to be, depending upon the irradiance, either an acute intra beam viewing hazard or chronic viewing hazard, and an acute viewing hazard if viewed directly with optical instruments.
Class IIIb	DANGER Max Power <,= 500 mW	Laser Radiation – Avoid Direct Exposure to beam	Levels of laser radiation are considered to be an acute hazard to the skin and eyes from direct radiation.
Class IV	DANGER Max Power > 500 mW	Laser Radiation – Avoid Eye or Skin Exposure to Beam	Levels of laser radiation are considered to be an acute hazard to the skin and eyes from direct and scattered radiation.

The following references aid in recognizing laser hazards in the workplace.

Table (1.4) shows sources of laser hazards. FDA stands for Food and Drug Administration in United States. IEC stands for the International Electrotechnical Commission: An "organization that prepares and publishes international standards for all electrical, electronic and related technologies [35].

Table (1.4): Sources of laser hazards [35]

Class FDA	Class IEC	Laser Product Hazard	Product Example
I	1, 1M	Considered non-hazardous. Hazard increases if viewed with optical aids, including magnifiers, binoculars, or telescopes.	▪ laser printers ▪ CD players ▪ DVD players
IIa, II	2, 2M	Hazard increases when viewed directly for long periods of time. Hazard increases if viewed with optical aids.	▪ bar code scanners
IIa, II	2, 2M	Hazard increases when viewed directly for long periods of time. Hazard increases if viewed with optical aids.	▪ bar code scanners
IIIa	3R	Depending on power and beam area, can be momentarily hazardous when directly viewed or when staring directly at the beam with an unaided eye. Risk of injury increases when viewed with optical aids.	▪ laser pointers
IIIb	3B	Immediate skin hazard from direct beam and immediate eye hazard when viewed directly.	▪ laser light show projectors ▪ industrial lasers ▪ research lasers
IV	4	Immediate skin hazard and eye hazard from exposure to either the direct or reflected beam; may also present a fire hazard.	▪ laser light show projectors ▪ industrial lasers ▪ research lasers ▪ medical device lasers for eye surgery or skin treatments

1.4.5.1. Laser hazards effects: -

Laser radiation hazards must be identified and evaluated. Types of laser hazards:

• Eye: Acute exposure of the eye to lasers of certain wavelength and power can cause corneal and retinal burns (or both). Chronic exposure to excessive levels may cause corneal or lenticular opacities (cataracts) or retinal injury.

• Skin: Acute exposure to high levels of optical radiation may cause skin burn; while carcinogenesis may occur for ultraviolet and near ultraviolet wavelengths

• Chemical: Some lasers require hazardous or toxic substance operates (i.e., chemical dye).

• Electric shock: most lasers produce high voltage that can be lethal.

• Fire hazards: The solvents used in dye lasers are flammable. High voltage pulse or flash lamps may cause ignition. Direct beams may ignite flammable materials or a specular reflection from high power Continues Wave (CW) infrared lasers.

• Another hazard involves the potential inhalation of airborne biohazardous materials that may be released as a result of the surgical application of laser. In addition, there are hazards due to excessive noise, and cryogenic coolant [21].

1.4.5.2. Laser safety recommendations and requirements: -

1-Precautions against electrical shock:

Almost all laser systems operate at voltages of dangerous levels. The following should be observed before anyone attempts to work on the circuit:

• The main switch should be turned off before any one handles the circuit connections

• A jumper with an insulated handle should be used to discharge the capacitors before any work is done on the circuits.

• Anyone should not work on the system unless he is familiar with the circuitry and the proper safety precautions.

• For maximum safety, all laser systems should have grounded outlets.

• The circuitry should be covered up when no one is dealing with it [21,36].

2-Precautions against laser radiations: -

a-Eye protection: The human eye is the most vulnerable tissue to all types of laser radiation. The tissue in the retina is susceptible to damage because the lens concentrates and focuses the laser beam on the retina. The retina is surrounded by a thin, dark-brown membrane containing arteries, veins and pigment cells, it would easily absorb radiation. The retina is sensitive to all color wavelength, from the 380 to 900 nanometer spectral range and to some degree to infrared wavelengths beyond 900 nanometers. Within the retinal area, the most critical area for vision is the fovea which is about 1 mm in diameter and contains the highest density of cone cells, resulting in the highest image resolution of the eye. Minimal damage in the peripheral field of the retina may go undetected since the brain compensates, up to a certain point, for small-area vision losses. The fovea is much more susceptible to damage than the para-macular region of the retina. It is necessary for the laser operator to use a protective eye filter because of the back-scatter qualities of the beam. Therefore, the eyes of everyone in the operating room must be protected by safety goggles which should be procured for the specific energy and wave-length of the beam under consideration. For beam control and to minimize direct eye exposure the following precaution to be considered:

• Do not intentionally look directly into the laser beam or at a specular reflection, regardless of its power.

• Terminate the beam path at the end of its useful path.

• Locate the beam path at a point other than eye level when standing or when sitting at a desk.

• Orient the laser so that the beam is not directed toward entry doors or aisles.

• Minimize specular reflections.

•No unauthorized personnel are in the room or area.

•Locate controls so that the operator is not exposed to beam hazards.

•Laser protective eyewear is worn. If you can see the beam through your laser eyewear, you are not fully protected.

•Make sure warning / indicator lights (aiming beam) can be seen through protective filters. All laser users should be trained and familiar with their equipment.

•The individual who moves or places an optical component on an optical table is responsible for identifying and terminating each and every stray beam coming from that component.

•Terminate beams or reflections with fire-resistant beam stop

•To reduce accidental reflections, watches and reflective jewelry should be taken off before any alignment activities begin. Don't wear neckties around Class 4 open beam lasers.

•Enclose as much of the beam as possible.

•When the beam is directed out of the horizontal plane, it must be clearly marked.

•A solid stray beam shield must be mounted above the area to prevent accidental exposure to the laser beam. All laser users must receive an orientation to the laser use area by an authorized laser user of that area.

•The lowest possible / practical power must be used during alignments.

•When possible, a course alignment should be performed with a He-Ne alignment laser.

•Have beam paths at a safe height, below eye level when standing or sitting, not at a level that tempts one to bend down and look at the beam.

• Securely mount the laser system on a stable flat room to maintain the beam in a fixed position during operation and limit beam traverse during adjustment.

• Confined primary beams and dangerous reflections to the optical table.

• Clearly identify beam paths and ensure that they don't cross populated area of traffic path.

• When the beam path is not totally enclosed, locate the laser system so that the beam will be outside the normal eye-level range which is 1.2 to 2 m from the floor. A beam path that exits from controlled area must be enclosed where the beam irradiant exceeds the MPE [Maximum Permissible Exposure].

• Warning signs should be placed on the doors at the entrance to the operating room [21,36].

b-Skin protection: High power laser can cause skin burns and the effect of laser radiation of the skin depends on both the wavelength and the pigmentation of the skin. In visible spectrum range, the skin can reflect much of then while in the infrared region the skin become highly absorbing. The laser injury to the skin may be much less serious than to the eye [21].

c-Airway protection: Inhaled airborne contaminants can be emitted in the form of smoke or plume that generated through thermal interaction of surgical lasers with tissues. Laser plume evacuated device is used, to eliminate laser plume or smoke which is irritant to the pulmonary tree because it is carrying particles of tissue and microorganism. In addition, masks are necessary to use by the medical staff. They act as filters to protect the pulmonary system from the possibilities of an infection by microorganism [21].

1.4.6. Clinical applications of laser: -

In addition to practical usefulness of lasers in the operating room, lasers have a wide range of applications in ophthalmology, lithotripsy, the diagnosis and treatment of various cancers, as well as dermatologic and cosmetic procedures [37].

Table (1.5) shows the various lasers commonly used in medicine along with the wavelength at which they operate, their absorption chromophores, and their clinical applications [37]. LLLT=low level laser therapy. PDT = photodynamic therapy.nm=nanometer

Table (1.5): Laser application in medicine [37]

Laser	Wavelength (nm)	Absorption chromophore	Application
Ruby	694	Pigment, hemoglobin	Dermatology, tattoo removal
Nd:YAG	1,064	Pigment, proteins	Wide applications
Er:YAG	2,940	Water	Surgery
Diode	630–980	Pigment, water (range)	LLLT, PDT, surgery
Argon	350–514	Pigment, hemoglobin	Surgery, PDT, ophthalmology, dermatology
CO_2	10,600	Water	Surgery
Pumped-dye	504–690	Pigment	PDT, dermatology

Because diode laser was used in this study, this section would concentrate on its clinical applications. Most diode lasers operate between the wavelengths of 635nm to 980nm in the near infrared spectrum, and are better absorbed by pigments such as hemoglobin or melanin and, therefore, can coagulate larger blood vessels than a CO_2 laser [38]. Laser-based surgery is an increasingly important in operating theatres. More specifically, diode lasers provide numerous advantages over instrument-based surgery as well as over other surgical lasers. The primary advantage of diode laser is that they offer a wide range of wavelengths, which makes them attractive instruments for surgery [39].

The wavelength range from 630 to 1940 nm enables these lasers to be used in a multitude of ways. Laser diodes in the 630- to 689-nm red wavelength range are used in photodynamic therapy.

Aside from surgery, the wavelengths range between 810 and 980 nm are used for cosmetic applications, hair removal, dentistry, bio-stimulation, ophthalmology and varicose vein removal. The 1064- and 1210-nm wavelengths are used in the cosmetic applications for hair and tattoo removal as well as for liposuction. Laser radiation at 1210 nm is absorbed by adipose tissue, which is depleted. The wavelengths in the infrared range from 1320 to 1940 nm are used for dermatological treatment such as acne removal and for endovenous laser treatment. High-power diode lasers at 1940 nm can be used as surgical substitutes for thulium lasers.

The absorption and coagulation properties of various tissues of the human body differ, and wavelengths can be chosen according to which part of the body is undergoing surgery. In general, laser surgery is used for treating the abdominal organs, including the intestines, esophagus, stomach, colon, liver and bile ducts. Other surgical applications include laser-induced thermotherapy of liver tumors’, esophagotracheal fistulae, colorectal carcinomas, angiodysplasia, erosion of the gastric membrane, colonic polyps, oesophageal stenosis and hemorrhoids. Here, surgical lasers can be used for coagulation, vaporization and cutting [39].

1.4.7. Methods of anesthesia in laser-based therapy:

The methods of anesthesia used in laser-based therapy to help minimize the pain include both noninvasive and invasive procedures. The noninvasive procedures can be divided into topical, cryoanesthesia, and a combination of both. The invasive methods of anesthesia include injected forms (infiltrative, nerve blocks, and tumescent anesthesia) and supervised anesthesia (monitored anesthesia care and general anesthesia).

1-Noninvasive methods: -

a-Topical anaesthesia: -

Topical anesthetics have a proven efficacy in decreasing pain with common dermatologic procedures such as he neodymium-doped yttrium aluminum garnet (Nd: YAG) laser hair removal, Q-switched laser tattoo removal, the discomfort associated with the laser treatment of vascular and pigmented lesions, and the newer methods of superficial skin resurfacing like single pass CO_2 fractional laser, and plasma skin resurfacing. The active targets for topical anesthetics are the dermal nerve fibers. To reach the target, the topical anesthetic must penetrate the thickness of the stratum corneum. Several methods have been used to help facilitate penetration of the topical anesthetic and improve dermal absorption: removal of the stratum corneum with tape stripping; degreasing with acetone; laser ablation of the stratum corneum, occlusion and heat, and iontophoresis, which uses an electrical current to facilitate the passage of ionized molecules through the skin barrier. The duration of their local effect can be modified with the addition of epinephrine, which induces vasoconstriction and slows the effect of the anesthetic's withdrawal. Modifications can also be made to the topical anesthetic preparation to facilitate application to the skin. One example is making a eutectic mixture which allows individual compounds that would normally be solid at room temperature to be combined and be liquid at room temperature, this has been shown to permit higher concentrations to be used safely and to facilitate skin application. Another option is liposomal encapsulation (The active substance is encapsulated in a spherical structured composition of phospholipids) that promotes drug delivery by delivering a greater concentration of local anesthetic to sensory nerves than other formulation.

b-Cryoanesthesia: -

Cryoanesthesia is the use of chilling to provide local anesthesia. It has begun to gain importance in various dermatologic procedures including laser therapy. Cryoanesthesia produces an analgesic effect by cooling the epidermis and provides an additional advantage in laser therapy of thermal protection. This protective effect allows the use of higher levels of therapeutic energy without the risk of damage to the epidermis. In addition, cryoanesthesia has the benefit of decreased post laser side effects (erythema, purpura, and crusting). The types of cryoanesthesia can be subdivided into contact cooling and noncontact cooling. In contact cooling, the medium makes direct contact with the skin on application. Moistening of the skin with cold water and the application of ice or ice packs are some examples. Contact cooling specifically associated with lasers include the sapphire cooling tip hand piece for the long-pulsed Nd: YAG laser, the metal “cooling finger” for the ruby laser, and the sapphire lens for the diode laser. In noncontact cooling, the cold is transferred to the skin by a gaseous medium. Examples include the use of cold sprays, as well as cold air anesthesia. There are also several ways to apply the cold air cooling; according to one study the best approach is to hold the air-cooling nozzle ~3 to 4 inches from the skin as the laser head passes over the skin, with the cold air beam directed at a ~90-degree angle to the laser. Cryoanesthesia can also be used in conjunction with topical anesthesia to amplify the analgesic effect.

2- Invasive Methods of anesthesia: -

a-Injected Anesthesia: -

The injected forms of anesthesia include infiltrative local anesthesia, specific nerve blocks, and tumescent anesthesia. One of the major drawbacks of this method of anesthesia is that it requires needles, which can cause anxiety in patients.

Local anesthesia with infiltration is the injection of an anesthetic solution into the tissue. This provides anesthetic effect, but can cause significant tissue distortion. Types of infiltrative local anesthesia include lidocaine, lidocaine buffered with bicarbonate, or lidocaine with epinephrine. However, because of the volume required a local injection of lidocaine with epinephrine could easily make the patient lidocaine toxic.

To avoid significant distortion, specific nerve blocks can be used; they also provide the advantage of less total volume of anesthetic required and less patient discomfort, but they have the drawback of increased difficulty of administration and complications included transient neurapraxia, vasovagal syncope, and swelling.

Tumescent anesthesia (TA) is a specialized form of injected anesthesia that involves a large volume of dilute anesthetic solutions with lidocaine into the subcutaneous fat compartment resulting in the bulging of targeted areas. Epinephrine and bicarbonate are often added to the solution of lidocaine with normal saline. The epinephrine causes vasoconstriction slowing the absorption rate of lidocaine and producing profound hemostasis. Bicarbonate helps neutralize the acidic nature of the solution, reduces pain during administration, and speeds up the onset of action of lidocaine. The injection into the subcutaneous fat produces less pain and a slower rate of absorption when compared with injection into the dermis, because, compared to the dermis, fat has fewer nerve fibers and is relatively avascular. TA has been used successfully in facial resurfacing procedures and dermabrasion.

b-Supervised Anesthesia

Finally, the most invasive option for anesthesia used in laser resurfacing is supervised anesthesia. This form of anesthesia carries the most risk; therefore, it requires the patient be chosen appropriately, the staff have appropriate training, and the proper methods of monitoring be used. This type of anesthesia is most effective in cases where the patient is reluctant to undergo the procedure with just local or regional anesthesia for fear of pain or awareness of the procedure. This category can be divided into monitored anesthesia care (MAC) and general anesthesia (GA). GA and unconscious sedation are usually appropriate in the hospital or ambulatory surgery center whereas conscious sedation can be appropriate in an office setting if certain parameters are followed.

One form of MAC is conscious sedation (CS): a medically controlled state of depressed consciousness in which protective reflexes are maintained, a patent airway is maintained continuously by the patient, and appropriate responses can be elicited to physical stimulation or verbal command. A way of measuring the level of sedation is the Ramsey Sedation Scale, which is broken down into six levels. Levels 2 and 3 are appropriate for an office procedure, as the patient is cooperative (level 2), or drowsy and able to respond to commands (level 3). Levels 5 and 6 are considered GA, where the patient is asleep and has a sluggish (level 5) or no (level 6) response to stimuli. Some of the agents used in conscious sedation include midazolam, fentanyl, propofol, and ketamine. The supervised methods of anesthesia (MAC and GA) in laser resurfacing if used appropriately can produce rapid sedation, allow patient safety, comfort, and enhance physician efficacy. The main disadvantage is the risk associated with the anesthesia and the increased personnel, equipment, and monitoring required [36,40].

1.4.8. Recommendations for laser surgeries are:

1. Use adequate cover or goggles for team's eyes protection.

2. Presence in the room of the minimum number of people needed for the surgery.

3. Laser equipment operation by qualified professional.

4. Keep room lights on. Pupil with decreased diameter due to higher exposure to light minimizes laser-induced retina injury.

5. Remove jewels. Objects like necklaces, earrings or rings may reflect laser beams and burn other tissues or sites.

6. Maintain laser trigger in the horizontal position below the face level to protect eyes and avoid doing any other task while handling beam-emitting laser pen. Be sure that the stool or chair where the laser operator is sitting is firm. This prevents randomized shots which could cause accidents.

7. Use adequate eye protection (goggles) and be alert not to cause accidental shots and burn other tissues or objects with the laser.

8. Prefer tracheal tubes especially designed for laser surgeries and protect adjacent tissues with gauze moistened with saline solution.

9. Do not use inflammable or potentially inflammable substances, even for cleaning and disinfecting any material used.

10. Decrease oxygen inspired fraction to 0.40 or less during laser use to better prevent combustion; and replace nitrous oxide by nitrogen or helium whenever possible. Nitrous oxide feeds combustion when decomposed, originating oxygen atoms. The decomposition of 2 moles nitrous oxide generates 1 mol oxygen, enough to favor combustion. Helium, due to low viscosity and

better thermal conductivity allows for the use of smaller tubes, which improves operating field and delays ignition.

11. Protect patient's eyes with gauze moistened with saline solution.

12. Fill tracheal tube cuff with methylene blue-containing saline solution to help diagnose cuff rupture.

13-Minimum halothane, enflurane and isoflurane concentrations for combustion in 30% oxygen are 4.75%, 5.75% and7%, respectively [36].

1.5 Aim of study: -

To verify the effectiveness and safety of using 980nm diode laser fissurectomy and lateral internal sphincterotomy on the incidence of postoperative recurrence of chronic anal fissures.

Chapter “Two”

Material and Methods

Chapter Two

Material and Methods

2.1. Introduction:

This prospective study was conducted for Institute of laser for postgraduate studies from the first of July in 2020 to the end of February in 2021. Fourteen patients with reluctant chronic anal fissure had been operated on, but only eleven patients met the criteria that are included in this study which include using the same laser diode in the same hospital and the duration of follow up.

This chapter includes:

1-Patient selection method and parameters.

2-Medical laser system, and surgical instruments.

3-Selection of laser parameters.

4-Details of the laser surgery, and parameters of post-operative evaluation.

5-Safety measures.

2.2. Materials: -

2.2.1. Patient selection's method and parameters: -

This prospective study included eleven patients with symptomatic chronic anal fissures that are reluctant for at least 6 weeks of conservative treatment which was including anal sphincter relaxant (topical nitroglycerin and diltiazem). All of them are female. Their ages range from 25 to 50 years old.

Full general and local examination had been done for all patient in privet clinic. All of them suffer at the time of presentation from persistent pain and unhealed chronic anal fissure inspite of medical treatment prescribed by the doctors. Most of them had previous history of attacks of per anal bleeding and mucus discharge.

Two out of eleven patients had only posterior anal fissures. All of the cases are operated on in Al-Qimma privet Hospital.

All the patients underwent to both fissurectomy, and lateral internal sphincterotomy in the same session at Al -Qimma Surgical Hospital using FOX laser device. Postoperative clinical examinations were performed on all of them for at least three months from the time of healing to ensure complete healing, which usually takes 10-21 days depending on the size of the anal fissure, its skin tag and hypertrophied papilla, and the patient's healing ability. They had also been examined to rule out the possibility of recurrence in subsequent visits. After that we ask them to inform us if the symptoms recur to be re-examined.

Table (2.1) shows no. of cases and their parameters which were including their age and sex, the position of their fissures. Ant. = anterior. Post. = posterior. The place of operations is AL-Qimma Surgical Hospital QSH. The table also shows the types of anaesthesia. GA=general anesthesia, SA = spinal anesthesia.

Table (2.1): Number of cases and their parameters.

No. of cases	Age (years)	Sex	Fissure's sites	Place of operation	Type of anesthesia	Laser diode device's name
1	32	Female	Ant.& post.	QSH	GA	FOX
2	25	Female	Ant.& post.	QSH	GA	FOX
3	32	Female	Ant.& post.	QSH	GA	FOX
4	40	Female	Ant.& post.	QSH	GA	FOX
5	36	Female	Ant.& post.	QSH	GA	FOX
6	47	Female	Ant.& post.	QSH	GA	FOX
7	31	Female	Ant.& post.	QSH	GA	FOX
8	28	Female	Posterior.	QSH	GA	FOX
9	50	Female	Ant.& post.	QSH	GA	FOX
10	40	Female	Posterior.	QSH	SA	FOX
11	30	Female	Ant.& Post.	QSH	GA	FOX

2.2.2. Medical laser system used: -

The FOX laser is a solid-state, class 4 laser device that can be used for a range of medical and surgical applications. A.R.C. Laser, the world pioneer in medical lasers, developed and manufactured the FOX Laser in Germany. It uses optical fiber to deliver 980nm laser light with a maximum power output of 12 watt. The following table (2.2) shows specifications of FOX laser device.

Table (2.2): FOX laser system technical specifications.

Laser type	Diode Parameters
Laser wavelength	980nm.
Laser power output	up to 12watt.
Operated mode	CW, Pulsed, Single.
Pulse width/ adjustable	0.1ms to CW.
Pulse interval	0.1ms to CW.
Beam delivery	Optical fiber through A.R.C. connector.
Display/ control	Color touch screen/ foot switch.
Cooling	Internal, forced air.
Aiming beam	Green 532nm <1mWatt /adjustable.
Power supply	100-240-volt AC or rechargeable battery.
Dimensions (H×W×D)	17.4 cm × 14.2 cm × 16.3 cm.
Weight	1.2 kg. portable

Figure (2.1): FOX laser device.

2.2.3 Equipment used during procedure: -

- Quartz optical fiber as delivery system of FOX laser device.
- Gloves and mask.
- Surgical mosquito and tissue forceps.
- Sterile gauze.
- Surgical sterilization solution (povidone iodine 10%).
- Surgical anoscope.

2.3. Method: -

2.3.1. Preoperative assessment and preparation: -

The assessment of the patient started with a collection of information to fill the case sheet which includes: -Name, age, occupation, chief complaint, systematic review, past medical history, past surgical history, family history and social history.

Case Sheet			
Name:	**Age:**	**Sex:**	**Occupation:**
Chief complaint:			
Systematic review:			
Past medical history:			
Past surgical history:			
Family history:			
Social history:			

General and local examination had been done for all patients. Then, all of them would undergo to routine laboratorial and radiological assessment as shown in figure (2.2). ECG and other tests are done according to the patients' health.

CBP +ESR **Blood sugar level, serum creatinine, blood urea.** **General urine examination.** **Blood group and Rh.** **Corona blood test, HIV and Hepatitis serological test.** **Liver Function Test** **Bleeding Profile.**
Chest X-Ray

Figure (2.2): Routine preoperative tests.

A day before operation, every patient was informed to clean his body, shave the perianal area, take the laxative suppositories at the night of the operation, and fast for at least 8 hrs.

On the day of surgery, all patients should sign the informed consent document for the laser fissurectomy and lateral sphincterotomy procedures that the surgeon has previously described.

2.3.2. Operative procedure: -

A part from one patient who underwent to spinal anaesthesia, all other patients were operated on under general anaesthesia with the usage laryngeal mask airway. The patient was put in lithotomy position and wrapped with disposable towels. Before the operation of laser, we ensure the wearing of protective goggles by the operator and assistance. Under complete sterile condition and after the entry of anoscope, laser fissurectomy and lateral sphincterotomy had been done. Laser fissurectomy includes excision of fissure, its skin tag and hypertrophied papilla with 980nm diode laser using contact bare optical fiber (400µm core diameter) in continuous mode CW and at a power of 7-9 watt. The energy was required for fissurectomy range from 400-700 J and laser exposure time ranges between 5-10 seconds for each cm according to the size and thickness of the fissure, skin tag, and papilla. Lateral internal sphincterotomy had been done by open method at 3 or 9 o’clock using no. 11 surgical blades with 980nm laser wavelength by CW mode and in contact manner, but by using a power of 5 watt, and energy of about 100-150J with exposure time ranges between 3-7 seconds per pass as we cut it in layers which may reach up to12 layers. Some layers need more than one pass especially at their thickened edges so they need totally 50-90 seconds as time exposure for each sphincterotomy according to the thickness of the muscle and its covering membrane. Coagulation of exposed area was achieved by defocus laser beam if required without carbonation or charring. Disposable anal tampon soaked with xylocaine gel was put inside the anus. The operative note was filled for each patient as shown in table (2.3). After recovery from anesthesia, the patient was discharge in the same day of operation with all instructions regarding postoperative care and required medication. To assess full recovery without recurrence, all patients were followed for at least 3 months by direct clinical review via a series of visits that were determined based on their needs. Then, I asked the patient to let me know if any of the previous symptoms resurfaced so that I could investigate them. They don't have to go to the doctor if they don't have any complaint. During a routine visit, the patient's condition was assessed using the satisfaction criteria and a clinical examination.

Grade 0= not satisfied.

Grade 1= moderately (partially) satisfied.

Grade 2= greatly but not fully satisfied.

Grade 3=fully or completely satisfied.

A complete healing usually occurs within 10-21days according to the size of anal fissure and its skin tag, and patient's healing ability. This study was terminated on the first of march, 2021

Table (2.3): Operative notes

Operative notes	
Patient name:	
Age:	
Sex:	
Address:	Occupation:
Record number:	
Date of admission:	
Surgeon's name:	
Assistants' names:	
Anesthetic's name:	
Diagnosis:	
Type of surgical procedure and anesthesia:	
The detail of operation:	
Postoperative treatment and instructions:	
Surgeon signature	

2.4. Safety measures: -

1. All equipment had been sterilized adequately.
2. All surfaces that were sterilized by alcoholic antiseptic solution should be allowed to dry completely. We used non-alcoholic solution like povidone iodin in sterilization of the skin.
3. All inflammable material should be kept away from laser operating area.
4. All staff within operating room wear face masks to avoid hazards of laser plum.
5. Wearing of sterile surgical gloves by working staff prevents the cross transmission of diseases.
6. The laser device and its accessories were carefully handling, and put in standby state when it's not in use.
7. All personals within laser operating area were wearing eye protective goggles that compatible with operating wavelength.
8. Avoidance of the aiming of laser beam directly toward eyes or any reflecting surface was considered.
9. We try to avoid repeated exposure of the same area of tissue to laser beam for a long period of the time to prevent the damage of nearby tissues. Also, the usage of ice-packs could help to reduce the tissues' temperature and inflammatory response.
10. The operating room was adequately ventilated.
11. Warning unauthorized persons from the presence within the laser operating room to avoid unexpected exposure to the laser beam or its reflections.

Chapter “Three”

Results, Discussion and Conclusion

Chapter Three

Results, Discussion and Conclusion

3.1. Introduction: -

At the end of this study which continued for 8 months, the following results had been showed in this chapter. Then, these findings will be discussed and interpreted as much as possible. Some recommendations should be mentioned in this chapter to complete the current study.

3.2. Results: -

The operative time for both laser fissurectomy and lateral sphincterotomy range 15-20 minutes according to the number and the size of fissure, its tag, and papilla.

During the course of postoperative follow-up, seven patients (64%) showed complete epithelization of excised anal fissure bed and healing of the wound of lateral internal sphincterotomy within 14 days, while in the rest four patients (36%) they take place within 14 to 21 days.

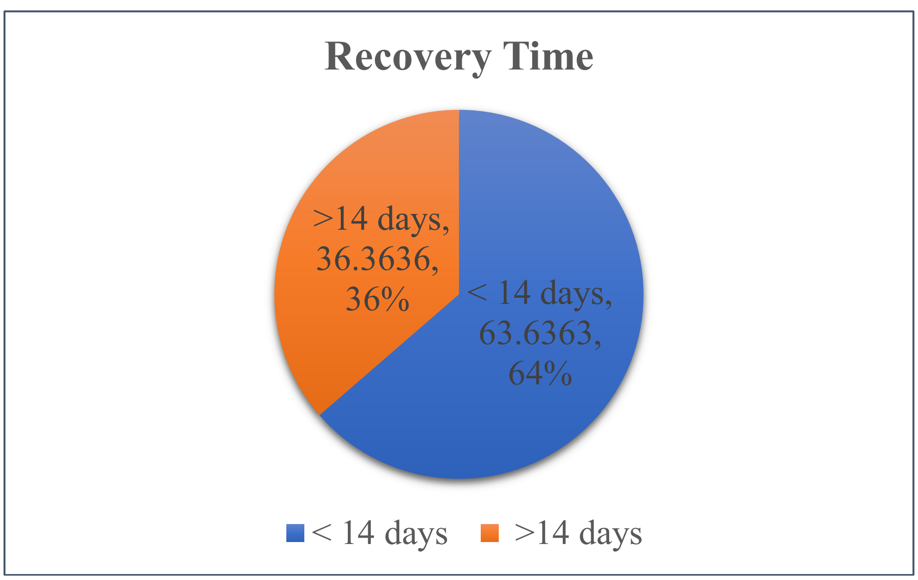


Figure (3.1): The recovery time of the bed of excised anal fissure.

The healing occurs with complete cessation of the symptoms within the recovery time. The closure of the wound of lateral internal sphincterotomy had been achieved within the first postoperative week. Most of the patient returned to their daily activity within one week. Three patients (27.3%) were free of the pain from the 1st post-operative day and completely satisfied. Seven patients (63.64%) became pain free within early ten postoperative days. The pain in only one patient (9.09%) required more than 10 days to subside. This will be demonstrated in figure (3.2).

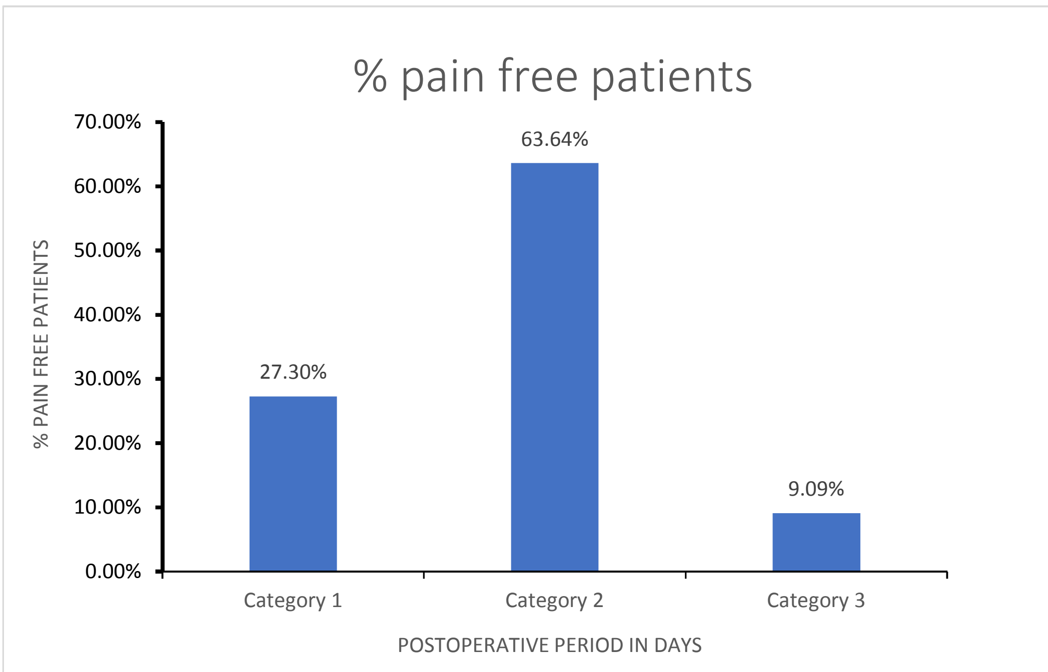


Figure (3.2): Pain free patients in relation to postoperative period.

Patients with no postoperative pain are considered as (category1), patients who were free of pain in < 10 postoperative days (category 2), and the patient was free of postoperative pain in > 10 days (category 3).

During the early three postoperative months of follow up'' after complete epithelization of excised fissure's bed'' by clinical examination, all patients were satisfied and didn't suffer from recurrent of the symptoms or the anal fissure itself on clinical examination. Later on, no one from those patients returns back suffering from recurrent symptoms or any other complication till the end of this study. The rate of healing and cessation of symptoms had no relation with age.

During this study, six patients (54.55%) would be followed up for 8 months, four patients (36.36%) were followed up for 6 months and one patient (9.09%) was followed for four months from the time of healing. The following figure (3.3) demonstrates this.

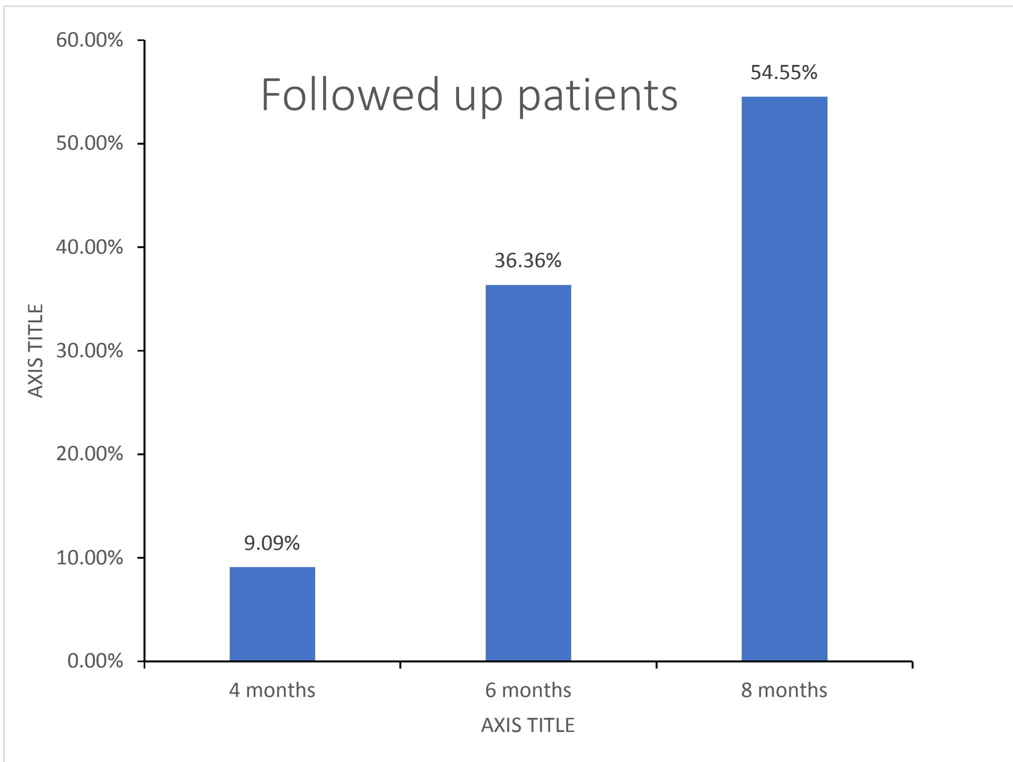


Figure (3.3): The percentage of patients and the duration of their follow up.

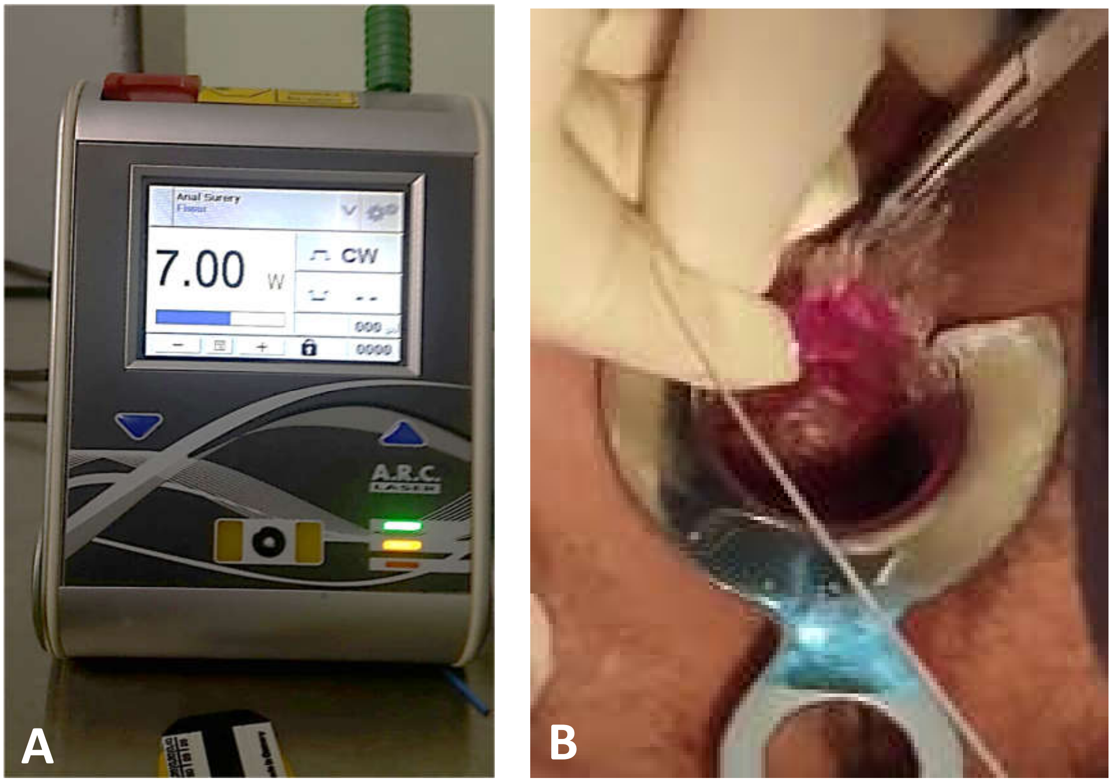
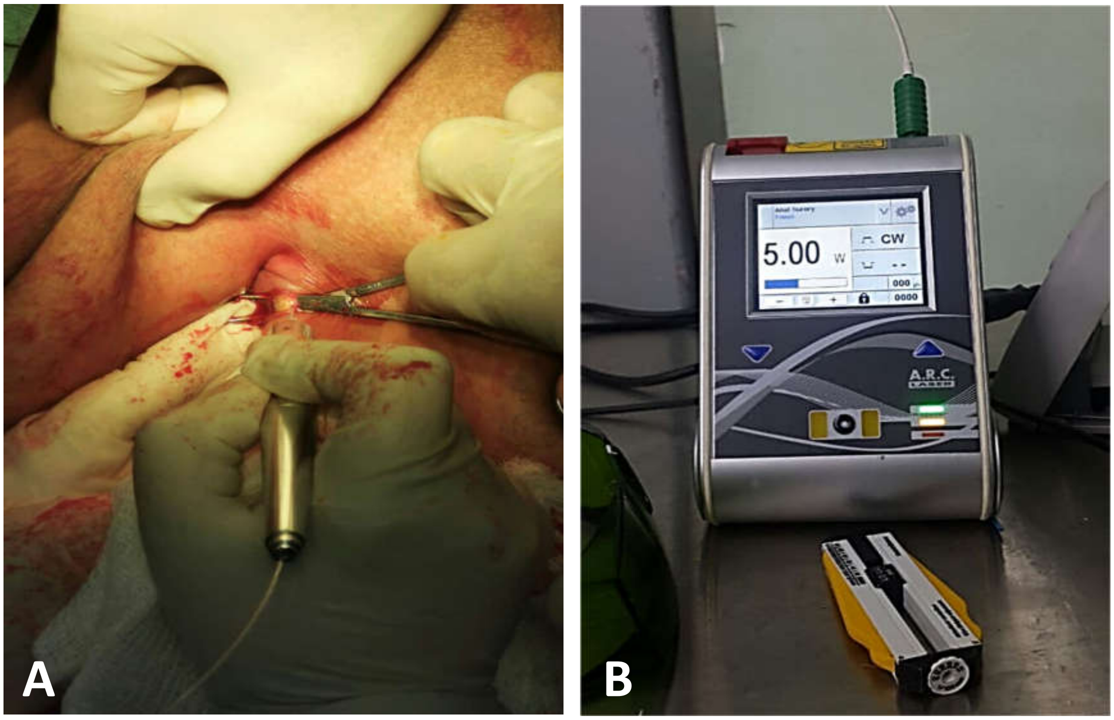


Figure (3.4): Anal fissurectomy (A) using 980nm diode laser (B) delivered by optical fiber which is contact to the tissue.



Figure(3.5): (A) Lateral internal sphincterotomy, (B) using 980nm diode laser.

3.3 Discussion: -

One of the most common pathologies encountered in the surgical field is chronic anal fissure. Anal fissures account for 6.2% to 15% of all visits and 10% of all operations in colorectal units in Australia. Anal fissures account for 10% of visits to colorectal units in the United Kingdom [41]. This reason with the shortage in the available data about the usage of laser diode in different surgical procedures that are available to deal with chronic anal fissure especially lateral internal sphincterotomy are behind the choice of this study. In addition, the recurrence of anal fissure after laser surgery during the period of follow up is one of the issues that hadn't get too much attention in published studies.

The limited number of cases collected was due to the short duration of study, corona pandemic, and the response of the most of the patients to conservative treatment. After explanation of the procedures of different methods of anaesthesia, nearly all the patients preferred to do anal surgery under general anaesthesia because they afraid of being aware during operation and from the local anesthetic procedure itself.

This study used a 980 nm laser diode because it is widely available, lightweight, compact, and easy to handle. It also has good access to the operative area, which aids in the treatment of associated internal hemorrhoids and mucopexy because the laser diode's delivery device is an optical fiber with a length of up to two meters. The use of CW mode facilitates easy adjustment of applied power and better control to the amount and the duration of laser exposure.

A power of 5W was enough to achieve effective and less destructive sphincterotomy through inducing photothermal reaction in the presence of chromophores like hemoglobulin and myoglobulin without carbonation or charring. This will promote early healing with no recurrence. Open method in lateral internal sphincterotomy was chosen to ensure adequate and exact cutting that will overcome the risk of recurrence. To prevent the risk of fecal incontinence, less than 25% which equal to less than 1cm of lateral internal sphincter in women was done. Cianci P.,2018. [7] mentioned that there is no fecal incontinence with cutting of < 25% of the sphincter.

Maheshwari J. [4], 2018. As opposed to conservative surgical procedures, patients who underwent minimally invasive laser sphincterotomy had a faster recovery time and minimal scars. There were few post-operative complications during the 6-month follow-up period. Our findings are consistent with his conclusions.

Fissurectomy by diode laser needs 7-9W to be achieved effectively. This increment in the value of power can be due to deficiency in the amount of target chromophore that present in mucosa and fibrotic edges.

Hussein B.G., Azzawi J.I., et al [42],2020. They noticed that conventional anal fissure surgery has healing range of (14-24) day, whereas laser anal fissure surgery has healing time of (10-15) day. His findings support our results in that healing time ranges between 10-21days. As a result, laser surgery will reduce the amount of time it takes to heal.

Furthermore, in this study no recurrence of the anal fissure was observed during the postoperative follow-up period.

Other studies about laser assisted anal fissure surgery showed a variable percent of postoperative recurrence.

Fateh Sh.H, Shafighi S.D, et al, 2016. [3]. They found “in 6 months’ study” that the frequency of relapses in laser anal fissure surgery was 1.8%, which was lower than in the conventional anal surgery (7.5%). The frequency of reoperation was 3.8% in laser surgery and 13.8% in the conventional surgery.

Many studies using traditional anal fissure surgery can show the difference that will be noticed when we apply laser in the anal surgery regarding the recovery time and the recurrence.

Jensen SL, Lund F, et al, 1984. [43] noticed that 100% healing rate and recurrences 3.3% following sphincterotomy.

Evans J, Luck A, Hewett P.,2001. [44] stated lateral sphincterotomy for chronic anal fissure associated with 97% healing rate at 8th week of follow up and 15.4% recurrence rate.

Finally, single session of formal anal surgery for chronic anal fissure with adequate recovery and minimal tissue trauma is cost and time effective when we compare it by treatment modalities.

3.4. Conclusion: -

Laser diode is an effective, less destructive, and safe tool to replace the scalpel and electrocautery in anal fissure surgery. Although, both laser fissurectomy and lateral internal sphincterotomy causing trauma to the tissue, with the use of laser in these surgeries we can get definitive surgery in a single session with minimal soft tissue injury, and complications when we use laser in these surgeries. Recurrence of anal fissure following anal surgery can be minimized by combination of these procedures with using a minimal effective laser power that can be tolerated by treated tissue and induce acceptable short- and long-term results.

3.5 Recommendation: -

i. Increasing the sample size and length of this clinically applied analysis would produce a successful result

ii. A test group of patients who would be operated on in the conventional manner should be included in the research to show the efficacy of laser surgery.

iii. In the future, we suggest using a different form of laser, such as a diode laser with a different wavelength and/or a different mode, such as pulsed mode with the same or different wavelength, in one or more studies for comparison.

iv. The research could be expanded to include the use of laser in the treatment of acute anal fissures that do not respond to medical treatment or recurrent anal fissures.

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الخلاصة

في الوقت الراهن يمكن اعتبار الليزر احدى الطرق العملية والاقتصادية المستخدمة في العديد من التطبيقات الطبية والجراحية. يعد الفطر الشرجي من الحالات الجراحية الشائعة الحصول التي من الممكن معالجتها جراحيا باستخدام الليزر. ان الجمع بين عمليتي استئصال الفطر الشرجي وبضع العضلة العاصرة الداخلية الوحشية تقلل من خطر رجوع الفطر عند استخدام الليزر دايود فيهما كبديل للكاوية الكهربائية أو مبضع الجراح.

الغرض:

توضيح مدى فعالية ودرجة امان الدايود ليزر ذو الطول الموجي ٩٨٠ نانوميتر عند استعماله في عمليات استئصال الفطر الشرجي وبضع العضلة العاصرة الداخلية الوحشية للشرج في التقليل من حدوث رجوع في الفطر الشرجي بعد هذه العمليات.

العينة وطريقة اجراء البحث:

هي دراسة ترقبيه مقدمة الى معهد الليزر للدراسات العليا. تم اجرائها في مستشفى القمة الجراحي للفترة من الأول من تموز ٢٠٢٠ الى نهاية شهر شباط٢٠٢١. تم اجراء عمليتي استئصال الفطر الشرجي وبضع العضلة العاصرة الداخلية الوحشية لإحدى عشر امرأة كانت تعاني من الفطر الشرجي المقاوم للشفاء بالطرق التحفظية وذلك باستخدام الدايود ليزر ذو الطول الموجي ٩٨٠ نانوميتر وبقوة تتراوح بين ٥-٩ واط وبوضعية التشغيل المستمر. ولغرض التأكد من عدم رجوع الفطر، تم فحص المرضى ومتابعتهم بصورة مستمرة عن طريق زيارات متتابعة للعيادة تحدد حسب حالة للمريض ولمدة لا تقل عن ثلاثة أشهر.

النتائج:

ان استعمال الدايود ليزر في عمليات استئصال الفطر الشرجي وبضع العضلة العاصرة الداخلية الوحشية بالجرع الضوئية المؤثرة وغير المؤذية كفيل بتقليل فترة العملية الجراحية إلى ما بين ١٥-٢٠ دقيقة وفترة الشفاء الى ما بين١٠ -٢١يوما بالإضافة الى الحد من نسب عدم الشفاء ورجوع الفطر الى مستويات متدنية تصل الى الصفر بالمئة (٠%).

الاستنتاج:

يعد الدايود ليزر من الأدوات الفعالة والامنة للاستعمال كبديل لمبضع الجراح والكي الكهربائي في العمليات العلاجية للفطر الشرجي، والتي تسهم في منع رجوع الفطر الشرجي ما بعد اجراء العملية عند استخدامه بقوة تشغيلية فعالة وفي أدنى مستوياتها التي يمكن ان يتحملها النسيج المعالج مع ضمان الحصول على نتائج مقبولة على المدى القريب والبعيد.

جمهورية العراق
وزارة التعليم العالي
والبحث العلمي جامعة بغداد
معهد الليزر للدراسات العليا

رجوع الفطر الشرجي المزمن بعد عمليات الليزر باستخدام جهاز الدايود ٩٨٠ نانومتر

دراسة مقدمة الى معهد الليزر للدراسات العليا / جامعة بغداد/ كجزء من متطلبات نيل درجة الدبلوم العالي في تطبيقات الليزر في الطب / الجراحة العامة

من قبل

الاء خالد أِرحيم

بكالوريوس في الطب والجراحة العامة

دكتوراه (بورد) في الجراحة العامة

بأشراف

د. مردوخ سامي عبد علي

البورد العربي في اختصاص الجراحة العامة

الدبلوم العالي في تطبيقات الليزر الطبية

1442هجري 2021ميلادي