



Sudan University of Science and Technology  
College of Graduate Studies  
Institute of laser



## Effectiveness of Long Pulsed Nd:YAG Laser 1064 in Treatment of Scars

فعالية ليزر الاندياج طويل النبضة في علاج الندوب

A Dissertation Submitted in Partial Fulfillment for the  
Requirement of the degree of Post Graduate Diploma in  
Laser Application in Medicine Dermatology

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استهلال

قال تعالى :

بسم الله الرحمن الرحيم

(قالوا سبحانك لا علم لنا الا ما  
علمتنا انك انت العليم الحكيم)

صدق الله العظيم

سورة البقرة  
الاية (23)

## *Dedication*

*To my mother*

*To the soul of my father*

*To my only sister and only brother*

*I give my work*

*And I wish that Allah bless all of us*

## *Acknowledgement*

*I wish to thank the great contribution of my supervisors Dr. Shaza Mohammed Yousif and Dr. Ali Abdulrahman Saeed Maroof who offered numerous helpful suggestions and corrections.*

*I would like to give special thanks to department of laser, laser technicians in Khartoum Teaching Hospital of Dermatology and Venerology and any one who gave my study its final touches.*

*I am grateful to the staff of the College of Graduate Studies and Institute of Laser in Sudan University of Science and Technology.*

*Finally my thanks to every one who helped me.*

## **Abstract**

This is a prospective clinical descriptive study, aimed to detect the efficacy of and safety of long pulsed Nd: YAG laser (1064 nm) in treatment of scars in some Sudanese patients. The study was performed in Khartoum Dermatology & venerology Teaching Hospital and Institute of Laser in Sudan University of Science and Technolgy. The study was conducted from October 2017-April 2018.

Objectives of this study are to determine efficiency of long pulsed Nd: YAG laser in the treatment of scars, to assess clinical effect of NDYAG laser 1046 in scars treatment and to find possible side effects.

Ten patients (all females) presented with skin scars, they were selected from outpatient clinic in Khartoum Dermatology & venerology Teaching Hospital and other dermatology clinics and were considered as study population. Type of scars (atrophic or hypertrophic), area of scar and skin phototype were took into consideration in this study.

The laser system used in this study was long pulsed Nd-Yag laser 1064 nm. All patients received the same laser parameters of long pulsed Nd-Yag laser. The probe was applied over the scar with a wave length of 1064 nm, energy density of 15 J /cm<sup>2</sup>, pulse duration of 5 sec, 5-mm spot size, 5-Hz pulse rate with covering of all the surface area of the lesion. The frequency of treatment was three sessions of laser with three weeks apart

There is improvement in appearance of scars after the third session in almost all cases, and the study showed that the use of long pulsed Nd-Yag laser in treatment of skin scars is promising.

Further studies with more patients and extended period of time are recommended.

## مستخلص البحث

هذه دراسة سريرية وصفية مستقبلية التدخل، والتي تهدف للكشف عن فعالية العلاج بليزر الاندياج طويل النبضة 1064 نانوميتر في علاج الندوب في بعض المرضى السودانيين.

اجريت هذه الدراسة في مستشفى الخرطوم التعليمي للأمراض الجلدية والتناسلية و معهد الليزر بجامعة السودان للعلوم والتكنولوجيا في الفترة من اكتوبر 2017 حتى ابريل 2018

اهداف الدراسة هي تحديد مدى فعالية ليزر الاندياج طويل النبضة في علاج الندوب وتقييم التأثير السريري لليزر الاندياج في علاج الندوب ومدى احتمالية حدوث اثار جانبية.

عدد المرضى عشرة وكلهم اناث لديهم ندوب بالجلد، وقد تم اختيارهم من العيادة الخارجية لمستشفى الخرطوم التعليمي للأمراض الجلدية والتناسلية وعدد من عيادات الجلدية الاخرى.

انواع الندوب (متضخمة او ضامرة)، ومكانها وفئة لون البشرة كلها اخذت بعين الاعتبار في تلك الدراسة.

تلقى جميع المرضى في هذه الدراسة جرعات متساوية من ليزر الاندياج طويل النبضة 1064 نانوميتر بوضع المجس على كل ندبة بالطول الموجي 1064 نانوميتر، كثافة الطاقة 15 جول بالسنتيمتر المربع، تردد النبضات 5 هيرتز لمدة 5 ثوان مع التغطية الكاملة لسطح الندوب. وكان تردد الجلسات العلاجية مرة كل ثلاث اسابيع بمجموع ثلاث جلسات عند نهاية الدراسة و كان هناك تطور ملحوظ في ملمس ومظهر الندوب بعد الجلسة الثالثة في معظم الحالات.

وقد اظهرت الدراسة ان استخدام ليزر الاندياج طويل النبضة في علاج الندوب هو امر واعد، ويوصى بالمزيد من الدراسات بعدد اكبر من المرضى وفترة زمنية اطول.



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## **ABBREVIATIONS**

ND:YAG      neodymium-doped yttrium aluminium garnet

PDL          pulsed dye laser

# **CHAPTER ONE**

Introduction and Literature review

Objectives

# Introduction and Literature review

## 1.1 Scars

Scarring is the process by which wounds are repaired. Scars are a natural part of the body's healing process. A scar results from the biologic process of wound repair in the skin and other tissues when tissues have been significantly damaged and repaired. Most wounds, except for very minor ones, result in some degree of scarring. Scars can result from accidents, physical trauma or as part of a disease process., skin conditions such as acne, or surgeries ( Sherratt, Jonathan ,2010).

### Formation of scars

Scarring is part of the body's natural healing process after tissue is damage, damage to only the epidermis, the most superficial layer of skin, will not always produce a scar. Scars form when the dermis (deep, thick layer of skin) is damaged (John, Charles, 2012).

When the skin is wounded, the tissues break, this causes a protein called collagen to be released and the body forms new collagen fibers to mend the damage, collagen builds up where the tissue is damaged, helping to heal and strengthen the wound resulting in changes that alter the physical architecture of normal skin ( A.Bernard, Almut ,et al,2005, p.522). The new scar tissue will have a different texture and quality than the surrounding tissue, new collagen continues forming for several months and the blood supply increases, causing the scar to become red, raised and lumpy, in time, some collagen breaks down at the site of the wound and the blood supply reduces. The scar gradually becomes smoother, softer and paler, scars form after a wound is completely healed, although scars are permanent, they can fade over a period of up to two years. It's unlikely they'll fade any more after this time (Gauglitz, Korting ,2011).

Poorly controlled wound healing can result in thick, unsightly scars that cause symptoms, also there is a genetic predisposition in some people to produce thicker, itchy, enlarging scars called keloids( Kelly,2009,28 (2): 71–76).

Scarring in areas of increased skin tension or movement tend to be unsightly ( Sherratt, Jonathan, 2010).

### **Types of scars**(Bernard, Almut ,et al,2005, p.522).

A scar can be a fine line or a pitted hole on the skin, or an abnormal overgrowth of tissue.

#### ***Normal fine-line scars***

A minor wound like a cut will usually heal to leave a red, raised line, which will gradually get paler and flatter over time. This process can take up to two years. The scar won't disappear completely and you'll be left with a visible mark or line. Fine-line scars are common following a wound or after surgery. They aren't usually painful, but they may be itchy for a few months. On darker skin types, the scar tissue may fade to leave a brown or white mark. A pale scar may be more obvious on tanned skin because scar tissue doesn't tan.

#### ***Keloid scars***

A keloid scar is an overgrowth of tissue that occurs when too much collagen is produced at the site of the wound. The scar keeps growing, even after the wound has healed, keloids can be considered to be "scars that don't know when to stop." It is a tough heaped-up scar that rises quite abruptly above the rest of the skin. It usually has a smooth top and a pink or purple color and irregularly shaped . Unlike scars, keloids do not regress over time, they're often itchy or painful, and can restrict movement if they're tight and near a joint.

#### ***Hypertrophic scars***

Like keloid scars, hypertrophic scars are the result of excess collagen being produced at the site of a wound. But not as much collagen is produced in hypertrophic scars compared with keloid scars. Also, unlike keloid scars, hypertrophic scars don't extend beyond the boundary of the original wound, but they may continue to thicken for up to six months.



Hypertrophic scars are red and raised to start with, before becoming flatter and paler over the course of several years. Both of hypertrophic and keloid scars are more common in younger and dark-skinned people.

### ***Pitted or sunken scars***

This kind of scarring occurs when underlying structures supporting the skin (for example, fat or muscle) are lost. Some surgical scars have this appearance, as do some scars from acne or other skin conditions like chickenpox.

Pitted scars, also known as atrophic or "ice-pick" scars, can also occur as a result of an injury that causes a loss of underlying fat.

### ***Scar contractures***

Scar contractures are often caused by burns. They occur when the skin "shrinks", leading to tightness and a restriction in movement.

Some scars result when the skin stretches rapidly, for example (Stretch marks) are narrow streaks or lines that appear on the skin's surface when the deeper layer of skin (dermis) tears. They're often caused by hormonal changes that occur during pregnancy or puberty, or as a result of bodybuilding or hormone replacement therapy. In addition, this type of scar can occur when the skin is under tension (near a joint, for example) during the healing process.

## **Scars treatment**

Scarring can affect both physically and psychologically, a scar, particularly if it's on face, can be very distressing, although scars cannot be completely removed, but most scars will gradually fade and become paler over time, their appearance can be improved to some extent. Methods for improving the appearance of scars include (Roseborough, Grevious, et al, January 2004, . 96 (1): 108–16).

***Laser resurfacing:*** This procedure, similar to dermabrasion, removes the surface layers of the skin using different types of lasers. Newer types of lasers may achieve more subtle results by working on the collagen in the dermis without removing the upper layers of skin. This advancement results in little down time as opposed to traditional laser resurfacing and dermabrasion, which requires a longer recovery.

- **Steroid injections:** A course of steroid injections into a scar may help flatten it. Injections may help to soften the appearance of keloid or hypertrophic scars (Hengge, Ruzicka, et al, 2006, 54 (1): 1–15).
- **Dermabrasion:** This treatment involves the removal of the surface of the skin with special equipment. Dermabrasion is useful to blend in the irregularities of a scar whether it is raised or depressed.
- **Microdermabrasion:** is a much less invasive form of dermabrasion but is minimally useful for very superficial scars.
- **Filler injection:** These treatments can be used to raise sunken scars to the level of surrounding skin. The effects of these injections are only temporary, however, and the procedures may need to be regularly repeated. Newer forms of injectable fillers are now on the market and may be an option for some people.
- **Microneedling:** Many small puncture holes are made into the superficial skin to stimulate collagen production and even introduce collagen stimulators or other products to try to reduce the appearance of scars.
- **Surgery:** Although it will not remove a scar, surgery can be used to alter a scar's shape or make it less noticeable (Tam, Joshua, et al, 2016). Surgery is not recommended in cases of hypertrophic or keloid scarring (raised scars) because there is a risk of recurring scars as well as more severe scarring that results from the treatment (Scarring (PDF), 2016-08-2).
- **Radiotherapy:** Low-dose, superficial radiotherapy is used to prevent recurrence of severe keloid and hypertrophic scarring. This treatment is used only in extreme cases because of potential long-term side effects (Fabbrocini, Annunziata, et al, 2010, 1-13)
- **Topical treatments:** such as vitamin E, cocoa butter cream, and several commercial skin care products sold over the counter may be somewhat effective in helping to heal scars (Elsaie, Baumann, et al 2009, 35 (4): 563–573)
- If scarring is unsightly, uncomfortable or restrictive, treatment options may include (Goodman, 2000, 26 (9): 857–871).
  - topical silicone gel or silicone gel sheets
  - pressure dressings
  - steroids
  - skin camouflage (make-up)
  - surgery

In many cases, a combination of treatments can be used.

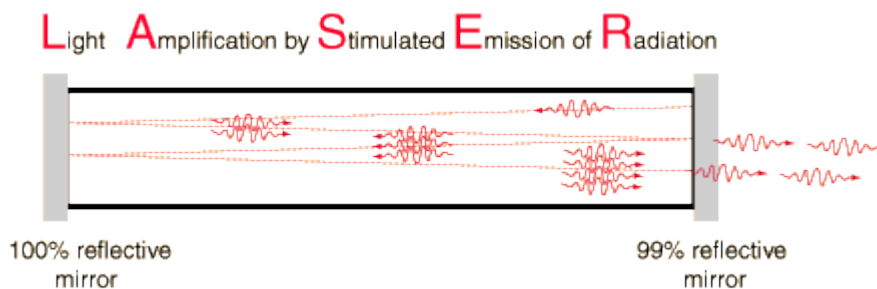
## prognosis of a scar

Scars generally improve in appearance over the first year. So considerations for invasive treatments need to be prudently considered prior to that time ("POST BURN SCAR RELATIVE TO RE-EPITHELIALIZATION"PDF. eplasty.com. 2011).

On the other hand, scarring usually involves tissue contraction, so that it is unlikely that scars that pull or twist other anatomical structures, producing unpleasant results, will improve. These should be treated sooner than later (Fu, Sun ,et al,2005, 118 (3): 186–91).

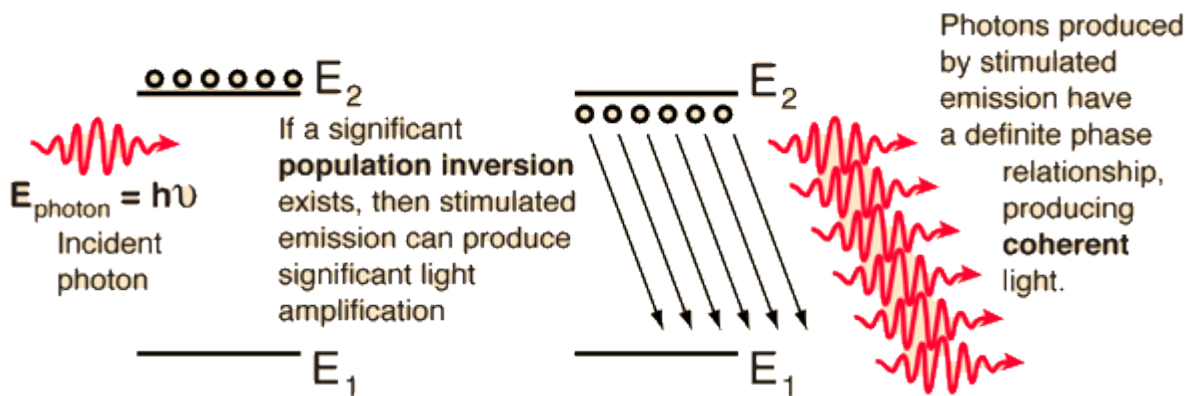
## 1.2 Laser Basics

A laser is a device that emits light through a process of optical amplification based on the stimulated emission of electromagnetic radiation. The term "laser" originated as an acronym for "light amplification by stimulated emission of radiation", The first laser was built in 1960 (Gould, Gordon,1959,p.128)



**Fig 1.1 laser**

The stimulated emission of light is the crucial quantum process necessary for the operation of a laser (laser.com,2008).



**Fig1.2 Stimulated emission**

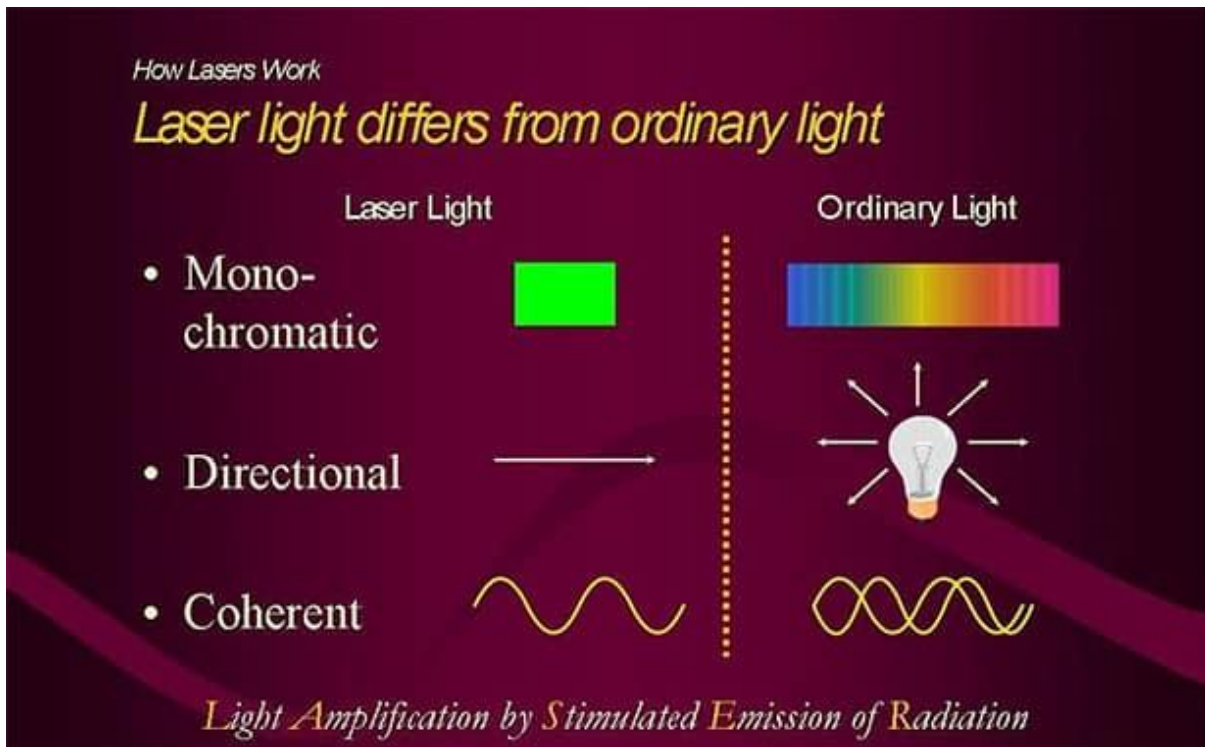
### **Laser Properties**(*Four Lasers Over Paranal [www.eso.org](http://www.eso.org),2016*)

**1. Coherent:** Different parts of the laser beam are related to each other in phase. These phase relationships are maintained over long enough time so that interference effects may be seen or recorded photographically. This coherence property is what makes holograms possible.

**2. Monochromatic:** Laser light consists of essentially one wavelength, having its origin in stimulated emission from one set of atomic energy levels.

**3. Collimated:** Because of bouncing back between mirrored ends of a laser cavity, those paths which sustain amplification must pass between the mirrors many times and be very nearly perpendicular to the mirrors. As a result, laser beams are very narrow and do not spread very much

**4. Directionality:** Laser beam is highly directional, which implies laser light is of very small divergence. This is a direct consequence of the fact that laser beam comes from the resonant cavity, and only waves propagating along the optical axis can be sustained in the cavity. The directionality is described by the light beam divergence angle.



**Fig 1.3 Laser Properties**

Types of laser can be described by: (Paul Hewitt, 2002)

which part of the electromagnetic spectrum is represented:

- Infrared
- Visible Spectrum
- Ultraviolet

the length of time the beam is active:

- Continuous Wave
- Pulsed
- Ultra-short Pulsed

# The Electromagnetic Spectrum

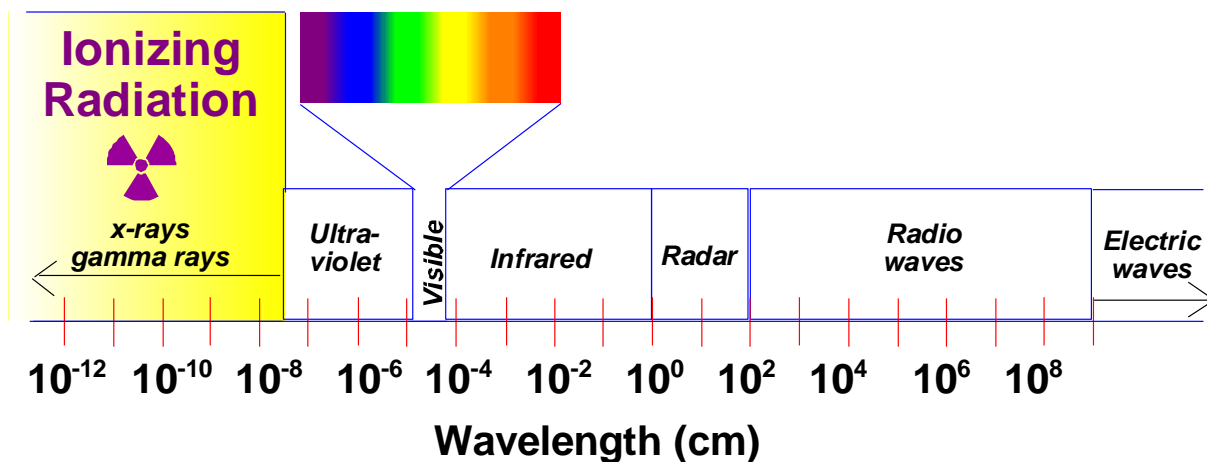


Fig 1.4 Electromagnetic spectrum

## Laser Construction

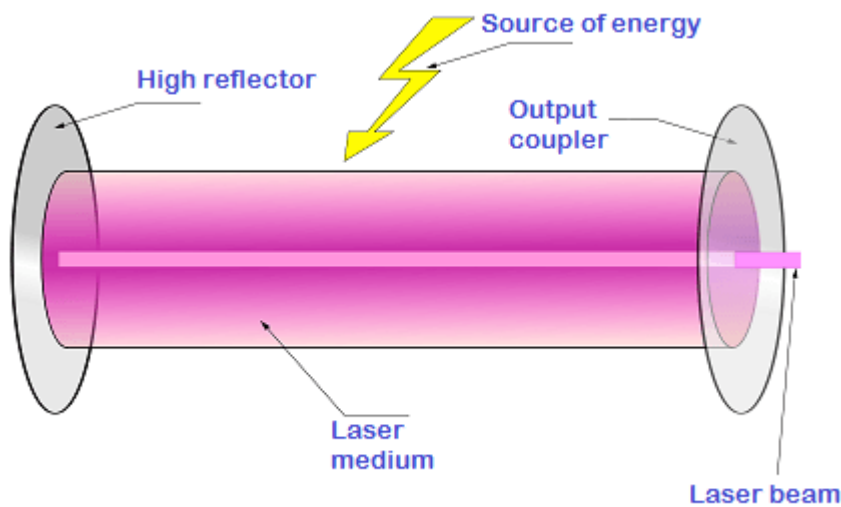
A laser or laser system consists of three important components: a pump source, laser medium and optical resonator (Schawlow and Townes invent the laser,2006).

### *Pump Source:*

The pump source or energy source is 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 (Chu, Steven, et al2003,p. 202).The source of energy supplies sufficient amount of energy to the laser medium by which the electrons in the lower energy state are excited to the higher energy state. As a result, we get population inversion in the active medium or laser medium. Examples of energy sources include electric discharges, light from another laser, chemical reactions, and flash lamps. The type of energy source used is mostly depends on the laser medium. Excimer laser uses chemical reaction as energy source, a helium laser uses an electric discharge as energy source and Nd:YAG laser uses light focused from diode laser as energy source(*"lase"Dictionary.reference.com*, 2011).

Different pump sources are used for different laser mediums to achieve population inversion. Some of the most commonly used pump sources are as follows( Siegman, Anthony ,1986,p. 2).

- Optical pumping
- Electric discharge or excitation by electrons
- Inelastic atom-atom collisions
- Thermal pumping
- Chemical reactions



**Fig 1.5 laser construction**

***Laser Medium:***

The laser medium is a medium where spontaneous and stimulated emission of radiation takes place. Generally, the population of lower energy state is greater than the higher energy state. However, after achieving population inversion, the population of higher energy state becomes greater than the lower energy state, after receiving sufficient energy from source, the electrons in the lower energy state or ground state are excited to the higher energy state (in the laser medium). The electrons in the excited state do not stay for long period because the lifetime of electrons in the excited state is very small. Hence, after a short period, the electrons in the excited state will fall back to the ground state by releasing energy in the form of light or photons.

This is called spontaneous emission. In spontaneous emission, each electron emits a single photon while falling to the ground state, when these emitted photons collide with the electrons in the excited state or meta stable state, it forces meta stable electrons to fall back to the ground state. As a result, electrons again release energy in the form of photons. This is called stimulated emission. In stimulated emission, each electron emits two photons while falling to the ground state, when these emitted photons are again interacted with the meta stable state electrons then again two photons are emitted by each electron. Thus, millions of photons are generated by using only a small number of photons (Paul Hewitt, 2002).

If we use electrical energy as energy source then a single photon or few photons (which are produced spontaneously) will produce large number of photons by stimulated emission process. Thus, light amplification is achieved in laser medium. Laser medium is also known as active medium or gain medium

The laser medium will determine the characteristics of the laser light emitted.

There are many types of lasers available for research, medical, industrial, and commercial uses. Lasers are often described by the kind of lasing medium they use - solid state, gas, dye, or semiconductor.

Solid state lasers have lasing material distributed in a solid matrix, e.g., the ruby or neodymium-YAG (yttrium aluminum garnet) lasers. The neodymium-YAG laser emits infrared light at 1.064 micrometers.

Gas lasers (helium and helium-neon, HeNe, are the most common gas lasers) have a primary output of a visible red light. CO<sub>2</sub> lasers emit energy in the far-infrared, 10.6 micrometers, and are used for cutting hard materials.

Excimer lasers (the name is derived from the terms *excited* and *dimers*) use reactive gases such as chlorine and fluorine mixed with inert gases such as argon, krypton, or xenon. When electrically stimulated, a pseudomolecule or dimer is produced and when lased, produces light in the ultraviolet range.

Dye lasers use complex organic dyes like rhodamine 6G in liquid solution or suspension as lasing media. They are tunable over a broad range of wavelengths.



Semiconductor lasers, sometimes called diode lasers, are not solid-state lasers. These electronic devices are generally very small and use low power. They may be built into larger arrays, e.g., the writing source in some laser printers or compact disk players (Siegman, Anthony ,1986,. p. 2).

***Optical Resonator***(Siegman, Anthony ,1986,. p. 2).

The laser medium is surrounded by two parallel mirrors which provides feedback of the light. One mirror is fully reflective (100 % reflective) whereas another one is partially reflective (<100 % reflective). These two mirrors as a whole is called optical resonator. Optical resonator is also known as optical cavity or resonating cavity.

These two mirrors are given optical coatings which determine their reflective properties. Optical coating is a thin layer of material deposited on materials such as mirror or lens. Each mirror is coated differently. Therefore, each mirror will reflect the light differently. One mirror will completely reflect the light whereas another one will partially reflect the light.

The completely reflective mirror is called high reflector whereas the partially reflective mirror is called output coupler. The output coupler will allows some of the light to leave the optical cavity to produce the laser's output beam.

When energy is supplied to the laser medium, the lower energy state electrons in the laser medium will moves to excited state. After a short period, the electrons in the excited state will fall back to the ground state by releasing energy in the form of photons or light. This process of emission of photons is called spontaneous emission. Thus, light is produced in an active medium by a process called spontaneous emission.

The light generated within the laser medium will bounce back and forth between the two mirrors. This stimulates other electrons to release light while falling to the ground state. Likewise, a large number of electrons are stimulated to emit light. Thus, optical gain is achieved.

This amplified light escapes through the partially reflecting mirror. The process of stimulating electrons of other atoms to produce light in the laser medium is called stimulated emission.

The light in the laser medium is reflected many hundreds of times between the mirrors before it escape through the partially reflecting mirror. The light escaped from the partially reflecting mirror is produced by the stimulated emission process. Hence, this light will travel to large distances without spreading in the space.

## **Laser Safety** (Safety of laser products,2007)

### ***Laser Hazard Classes***

#### ***Class 1***

This class cannot produce a hazardous beam because it is of extremely low power, *Or* because it has been rendered *intrinsically safe* due to the laser having been completely enclosed so that no hazardous radiation can escape and cause injury.

#### ***Class2***

These lasers are visible light (400-760 nm) continuous wave or pulsed lasers which can emit energy greater than the limit for Class I lasers and radiation power not above 1 mW.

This class is hazardous only if you stare directly into the beam for a long time, which would be similar to staring directly at the sun.

Because class 2 lasers include only visible wavelengths, the ***aversion reaction*** will usually prevent us from permanently damaging our eyes. The ***aversion reaction*** refers to our tendency to look away from bright light.

#### ***Class3a***

This class of intermediate power lasers includes any wavelength.

Only hazardous for intrabeam viewing.

This class will not cause thermal skin burn or cause fires

#### ***Class3b***

Visible and near-IR lasers are very dangerous to the eye.

Pulsed lasers may be included in this class.

This class will not cause thermal skin burn or cause fires.  
Requires a Laser Safety Officer and written Standard Operating Procedures.

### ***Class4***

These high-powered lasers are the most hazardous of all classes.  
Even a diffuse reflection can cause injury.  
Visible and near-IR lasers will cause *severe* retinal injury and burn the skin.  
Even diffuse reflections can cause retinal injuries.  
UV and far-IR lasers of this class can cause injury to the surface of the eye and the skin from the direct beam and specular reflections (Laser safety manual. California Institute of Technology,1998).  
This class of laser can cause fires.  
Requires a Laser Safety Officer and written Standard Operating Procedures.

### ***Non-beam hazards:***

refer to anything other than the laser itself that can create a hazard(Kenneth,2006).  
This type of hazard includes (Laser safety guidelines, 2004, University of Virginia)

- Electrical Hazards
- Fire Hazards
- Laser Generated Air Contaminants (LGAC)
- Compressed Gases
- Chemical Hazards
- Collateral and Plasma Radiation
- Noise

## **Neodymium YAG laser**

- Nd:YAG (neodymium-doped yttrium aluminium garnet) is a crystal that is used as a laser medium for solid-state lasers.
- The triply ionised neodymium [Nd(III)] dopant (ie a substance added in minute amounts to another pure substance to alter its conductivity), typically replaces a small fraction of the yttrium ions in the host crystal structure, since the two ions are of similar size.
- The neodymium ion provides the laser activity in the crystal.
- Nd:YAG laser has a wavelength of 1064 nm and has the capability to reach deeper layers of skin tissue than other types of lasers.

- In Q-switched mode, Nd:YAG produces 2 wavelengths, one in the infrared range (1064 nm) and a second beam of 532 nm wavelength which is useful for superficial skin lesions. Q-switching refers to the

technique of making the laser produce a high intensity beam in very short pulses (Yariv, Amnon,1989,pp. 208–11).

neodymium YAG laser works by emitting a wavelength of high energy light, which when focused on a certain skin condition will create heat and destroy diseased cells (Walter,1965, p. 507).

The following skin disorders can be treated with Nd:YAG laser beams.

***Laser surfacing and scars treatment:***

Laser resurfacing is a skin resurfacing procedure that uses a laser to improve the appearance of skin or treat minor facial flaws by removing layers of skin. Laser resurfacing can be done with:

- **Ablative laser.** This is a wounding laser, which removes thin layers of skin. Types of ablative treatments include the carbon dioxide (CO<sub>2</sub>) laser and the erbium laser.
- **Nonablative laser.** This is a nonwounding laser, which stimulates collagen growth and tightens underlying skin. This includes many types of lasers like 1064 Nd-Yag and IPL (Walter,1965, p. 507).

Another type of laser resurfacing, fractional photothermolysis (Fraxel), is available in ablative and nonablative forms. Although nonablative laser resurfacing is less invasive and requires less recovery time, it's less effective than is ablative laser resurfacing (Koechner,1965, 251–64).

Nd:YAG lasers target water in the dermis to stimulate collagen synthesis showed modest efficacy after 3 to 6 treatments in improvement of atrophic and acne scarring (Jacob,2001, 45:109-17).

Also because 1064 nm neodymium-yttrium-aluminum-garnet (Nd:YAG) laser reaches more deeply than many of other lasers, it is increasingly being used to treat deep vascular diseases such as hypertrophic scars (Riveria ,2008, 59:659-76) and keloids It has been suggested that it acts by suppressing neovascularization in these pathological scars, which are characterized by vessel overgrowth that results in nerve fibers and collagen in the reticular layer of the dermis(Akaishi, Koike, et al. 2012,12).

***Vascular lesions:*** (Dover,Arndt, 2000, 26:158–163).

- Spider and thread veins in the face (cheek, temporal region, nasal dorsum, forehead) and legs.
- Vascular birthmark (capillary vascular malformation)
- Varicose veins
- Facial veins
- vascular tumour

The laser light pulses target red pigment (haemoglobin). Typical settings employed for the treatment of facial veins include a 50 milliseconds pulse duration, and fluence (ie output energy) of 150–250 J/cm<sup>2</sup> (measured in Joules per centimetre squared) (Civas , Koc, et al. 2009,35:1933–1941).

***Pigmented lesions:***

Nd:YAG laser can be used to remove brown age spots (solar lentigines, freckles, [naevus of Ota](#), [naevus](#) of Ito, mongolian spots, Hori naevus and café-au-lait-[macules](#).

Light pulses target melanin at variable depth on or in the skin. (Lasers in Medical Science. 29: 823–29)

***Hair removal:***

The longer-pulse (millisecond) 1064-nm Nd:YAG laser system has been shown to be more effective in safely removing hair than has the Q-switched (nanosecond) Nd:YAG system, light pulses target the hair follicle, which causes the hair to fall out and minimises further growth.. (Lasers in Medical Science. 29: 823–29)

***Tattoo removal:***

Blue, grey and black tattoos can be removed with a Q-switched Nd:YAG laser (1064 Laser treatment involves the selective destruction of ink molecules that are then absorbed by macrophages and eliminated. (Lasers in Medical Science. 29: 823–29)

***Onychomycosis.***

***Other uses of neodymium YAG laser:*** Nd:YAG lasers have also be used to improve wrinkles in photo-aged skin (Lasers in Medical Science. 29: 823–29)

laser procedure preparations (Laser safety manual. California Institute of Technology,1998)

***It is important that the correct diagnosis has been made by the clinician prior to treatment, particularly when pigmented lesions are targeted, to avoid mistreatment of skin [cancer](#) such as melanoma.***

- The patient must wear eye protection (an opaque covering or goggles) throughout the treatment session.
- Treatment consists of placing a hand piece against the surface of the skin and activating the laser. Many patients describe each pulse feeling like the snapping of a rubber band against the skin.
- Topical anaesthetic may be applied to the area but is not usually necessary.
- Skin surface cooling is applied during all hair removal procedures. Some lasers have built-in cooling devices.
- Immediately following treatment, an ice pack may be applied to soothe the treated area.
- Care should be taken in the first few days following treatment to avoid scrubbing the area, and/or use of abrasive skin cleansers.
- A bandage or patch may help to prevent abrasion of the treated area.
- During the course of treatment patients should protect the area from sun exposure.to reduce the risk of postinflammatory pigmentation.

### **side effects of neodymium YAG laser treatment** (Kenneth,2006 )

Side effects from Nd:YAG laser treatment are usually minor and may include:

- Pain during treatment (reduced by contact cooling and if necessary, topical anaesthetic)
- Redness, swelling and itching immediately after the procedure that may last a few days after treatment
- Rarely, skin pigment may absorb too much light energy and blistering can occur (this settles by itself)
- Changes in skin pigmentation. Sometimes the pigment cells (melanocytes) can be damaged, leaving darker (hyperpigmentation) or paler (hypopigmentation) patches of skin. Generally, cosmetic lasers will work better on people with lighter rather than darker skin tones
- Bruising affects up to 10% of patients. It usually fades on its own
- Bacterial [infection](#).

**Objectives:**

- 1) To determine efficiency of long pulsed Nd: YAG laser in the treatment of scars.
- 2) To assess clinical effect of NDYAG laser 1046 in scars treatment.
- 3) To find possible side effects.

## **Chapter two**

### Patients and Methods



## **Research Methodology**

### **Study design:**

Prospective clinical descriptive study.

### **Study area:**

The study was performed in Khartoum Dermatology & venerology Teaching Hospital and Institute of Laser in College of Graduate Studies in Sudan University of Science and Technolgy.

### **Study Period:**

The study was conducted in October 2017-April 2018.

### **Study population and sample size:**

The study was performed on 10 patients with skin scars, scar type either atrophic (including acne scars) or hypertrophic, skin phototype and region of scar in body are considered in this study.

Patients are collected from the outpatient of Khartoum Dermatology and Venerolgy Teaching Hospital and other dermatology clinics.

### **Inclusion criteria:**

Any patient present to the outpatient clinic with scars if he/she accepted.

**Exclusion criteria:**

- 1- Isotretinoin use within the previous six month.
- 2- active cutaneous bacterial or viral infection in the area to be treated.
- 3-history of keloid formation scarring.
- 4-ongoing ultraviolet exposure, pri or radiation therapy to treatment area.
- 5-collagen vascular disease.
- 6-recent history of chemical peel and dermabrasion.

**Data collection:**

Data sheet was designed and filled for each patient to record personal history, duration, scar type, site of scar, Fitzpatrick skin type, and follow up results after 3,6 and9 weeks according to improvement of texture(smoothness), pigmentation and erythema based on investigator assessment, patient satisfaction and photographs which are taken before and after treatment.

**Laser system, procedures and parameters:**

The laser system used in this study was long pulsed Nd-Yag laser 1064 nm (Cynosure Acclaim device, entered market in1991 , its head office in USA).

Preoperative preparations and skin conditioning in case of facial scars by using evening kligman formula, morning sun block 6 weeks before treatment and antibacterial soap washing twice before laser treatment were done.

Intra operative safety measures were considered

All patients received the same laser parameters of long pulsed Nd-Yag laser. The probe was applied over the scar with a wave length of 1064 nm, energy density of 15 J /cm<sup>2</sup>, pulse duration of 5 sec, 5-mm spot size, 5-Hz pulse rate with covering of all the surface area of the lesions.

The frequency of treatment was three sessions of laser three weeks apart.

Follow up and evaluation was done according to improvement of texture(smoothness), pigmentation and erythema according to investigator assessment and patient satisfaction based on quartile scale as follows: (1=0change, 2=<25%change, 3=26%-50%change, 4=51%-75%change, 5=>75% change) and photographs which are taken before and after treatment.

### **Ethical consideration:**

Patients included in this study informed about the possible postoperative appearance of the treated area, possible pigmentation changes and need for post operative care, side effects, hazards of laser therapy.

**Data analysis:**

Data collected and analyzed using SPSS 22 programm.

# **Chapter three**

## Results

### 3.1 Results

The ten patients are females who have atrophic scar (including acne scars) and hypertrophic scars.

Skin tone and area of scar are taken into consideration in this study.

The treatment was three sessions of laser three weeks apart.

All patients had the same number of sessions.

Follow up and evaluation was done according to improvement of texture(smoothness), pigmentation and erythema according to investigator assessment and patient satisfaction based on quartile scale as follows: (1=0change, 2=<25%change, 3=26%-50%change, 4=51%-75%change, 5=>75% change) and photographs which are taken before and after treatment.

Results were analyzed at the end of treatment .

The treatment was well tolerated by all patients with minor short term complications (swelling, erythema and itching) in some patients.

**TABLE 3.1:** Follow up Subject and investigator evaluation of scar appearance at 3, 6 and 9 weeks post treatment.

Pt. No.	Patient assessment			investigator satisfaction		
	After 3 weeks	After 6 weeks	After 9 weeks	After 3 weeks	After 6 weeks	After 9 weeks
1	2	3	4	2	3	4
2	3	4	5	3	4	5
3	2	3	3	2	3	3
4	3	4	4	3	4	4
5	2	3	4	3	4	4
6	2	3	3	3	4	4
7	1	2	3	2	3	4
8	2	3	3	2	3	4
9	2	3	4	2	3	4
10	2	3	3	2	3	3

Subject & investigator evaluation based on quartile scale as follows:

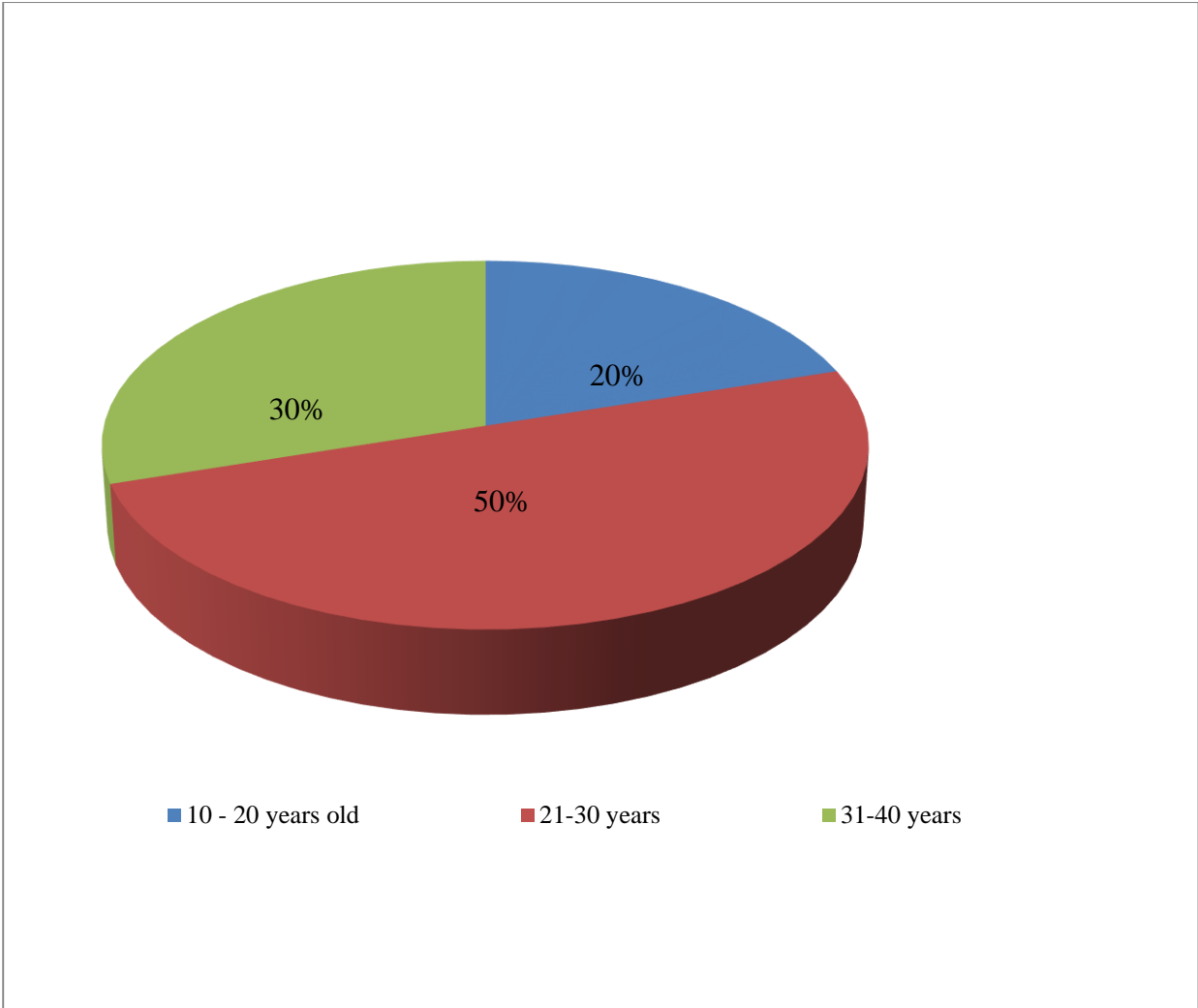
1=0change, 2=<25%change, 3=26%-50%change, 4=51%-75%change, 5=>75% Change

**TABLE 3.2:** Average subject and investigator evaluation of texture(smoothness), pigmentation, erythema and overall satisfaction with appearance at 9 weeks post treatment.

<b>Texture</b>		<b>pigmentation</b>		<b>erythema</b>		<b>overall satisfaction with appearance</b>	
patient	investigator	patient	investigator	patient	investigator	patient	investigator
3.5	4	3.5	3.9	4	4	3.6	3.9

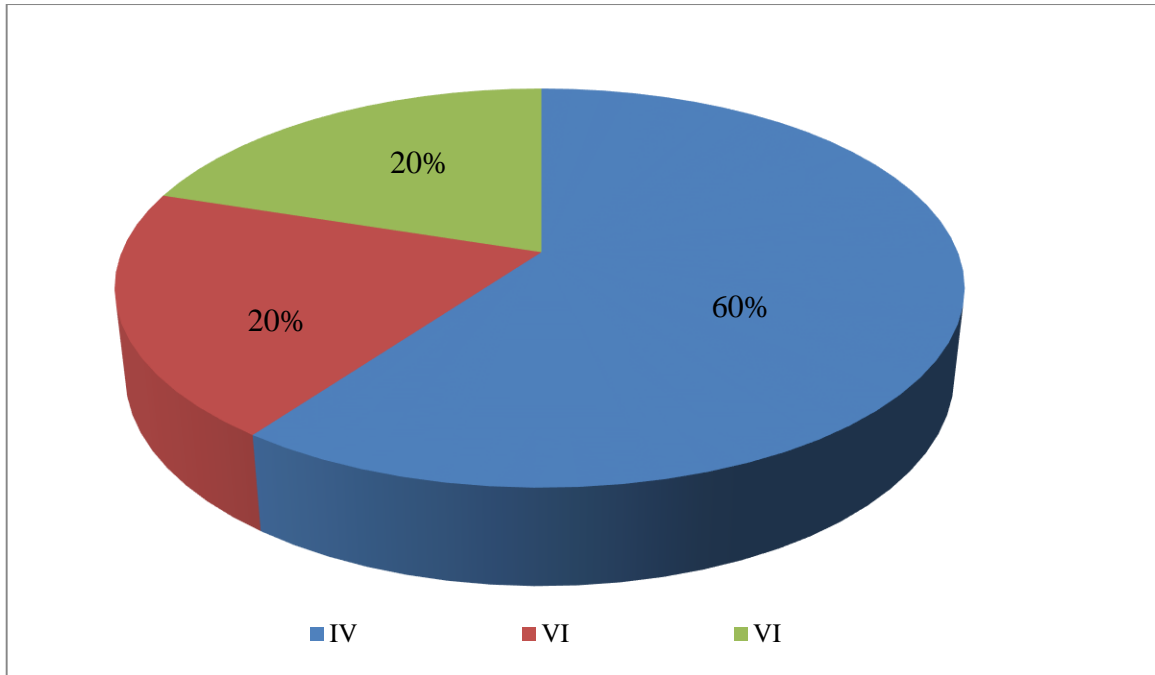
Subject & investigator evaluation based on quartile scale as follows:

1=0change, 2=<25%change, 3=26%-50%change, 4=51%-75%change, 5=>75%  
Change

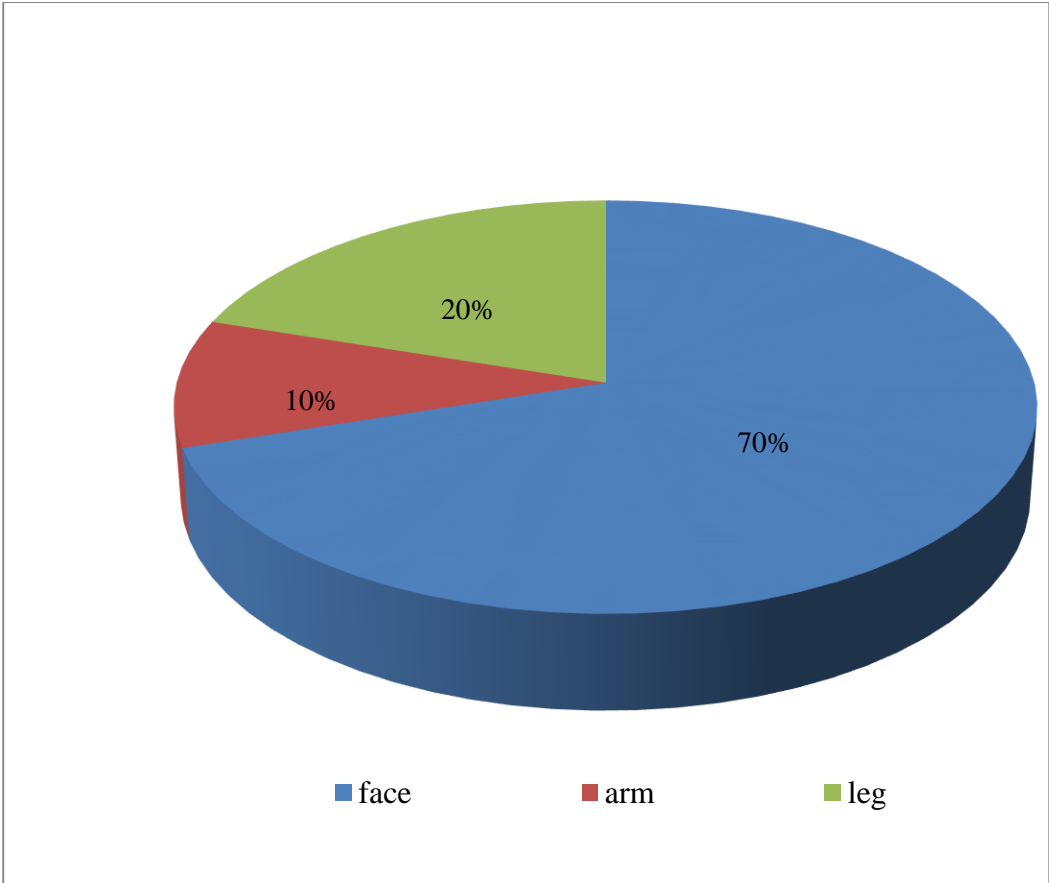


**FIGURE 3.1:**Age distribution of subjects in the study

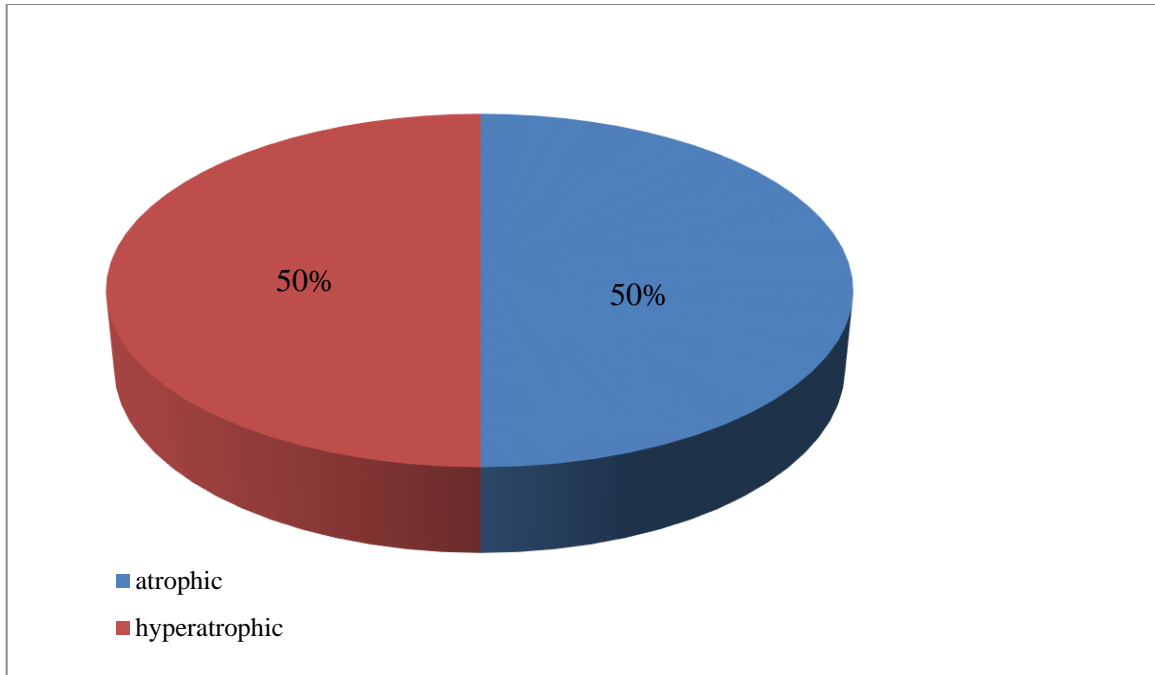




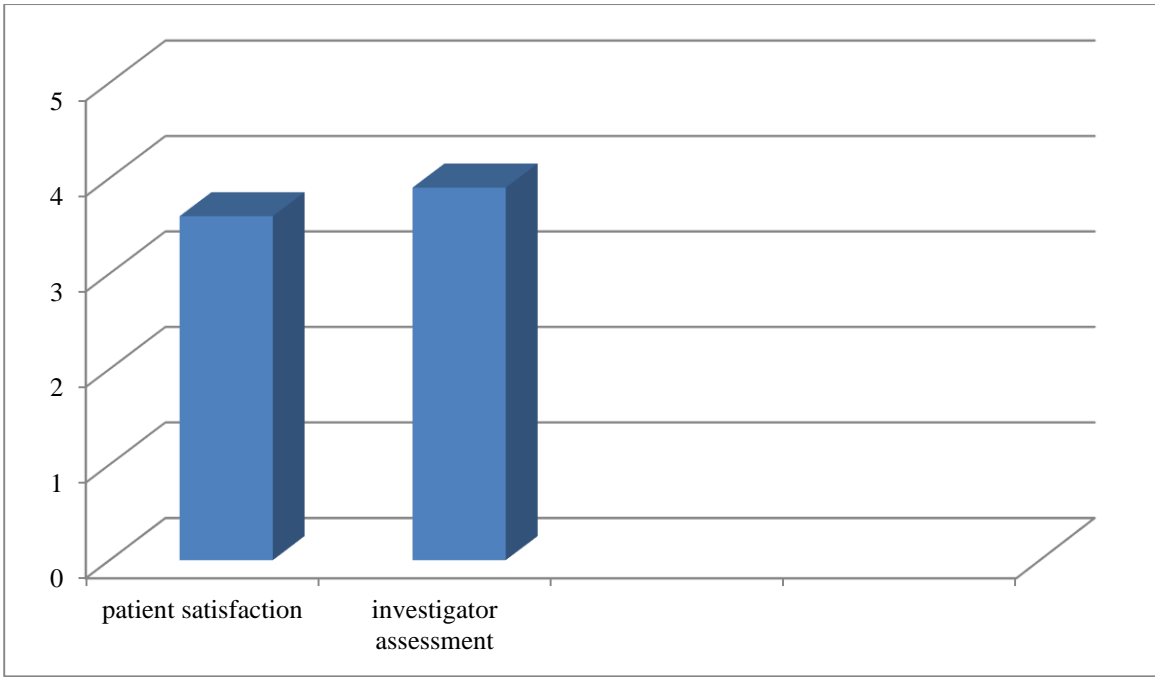
**FIGURE 3.2:** Skin phototype distribution of subjects in the study



**FIGURE 3.3:** Area distribution of subjects in the study

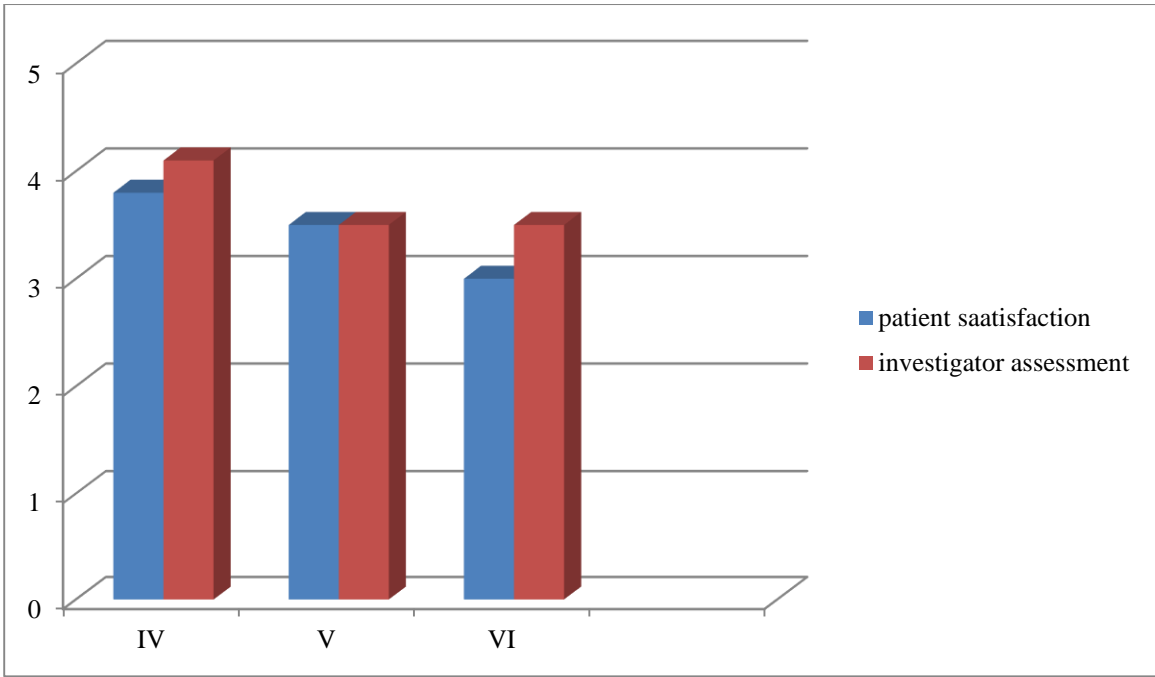


**FIGURE 3.4:**Types of scars in the study



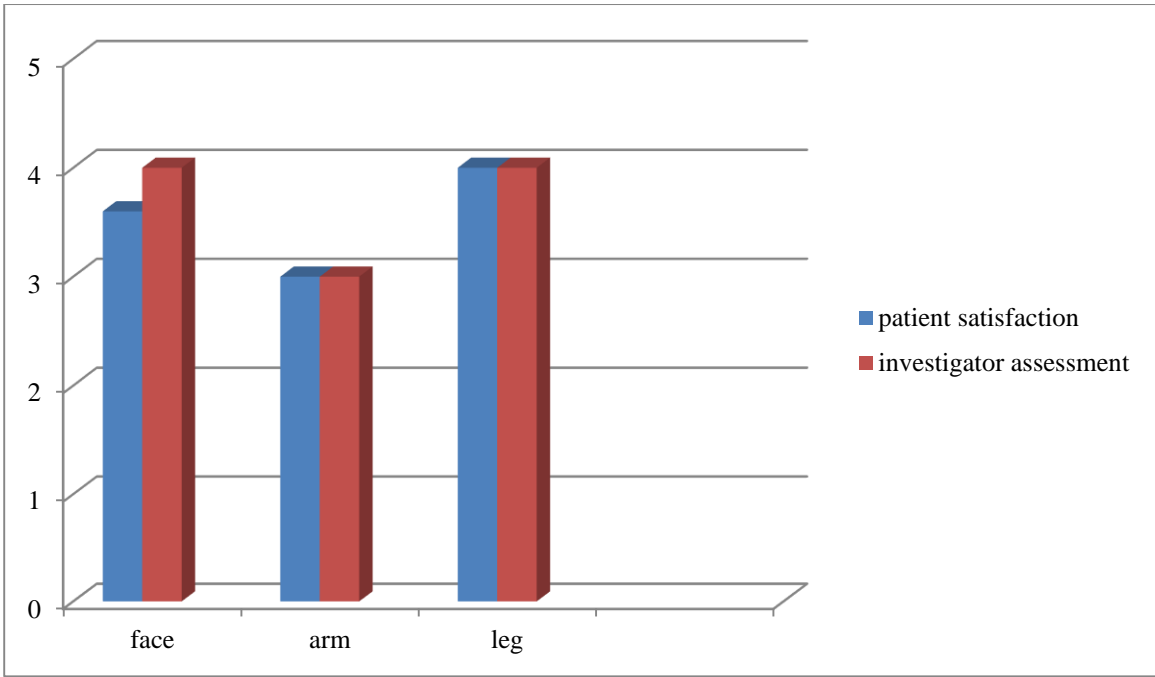
1=0change, 2=<25%change, 3=26%-50%change, 4=51%-75%change, 5=>75% change

**FIGURE 3.5:** Average improvement in all patients after 9 weeks of therapy



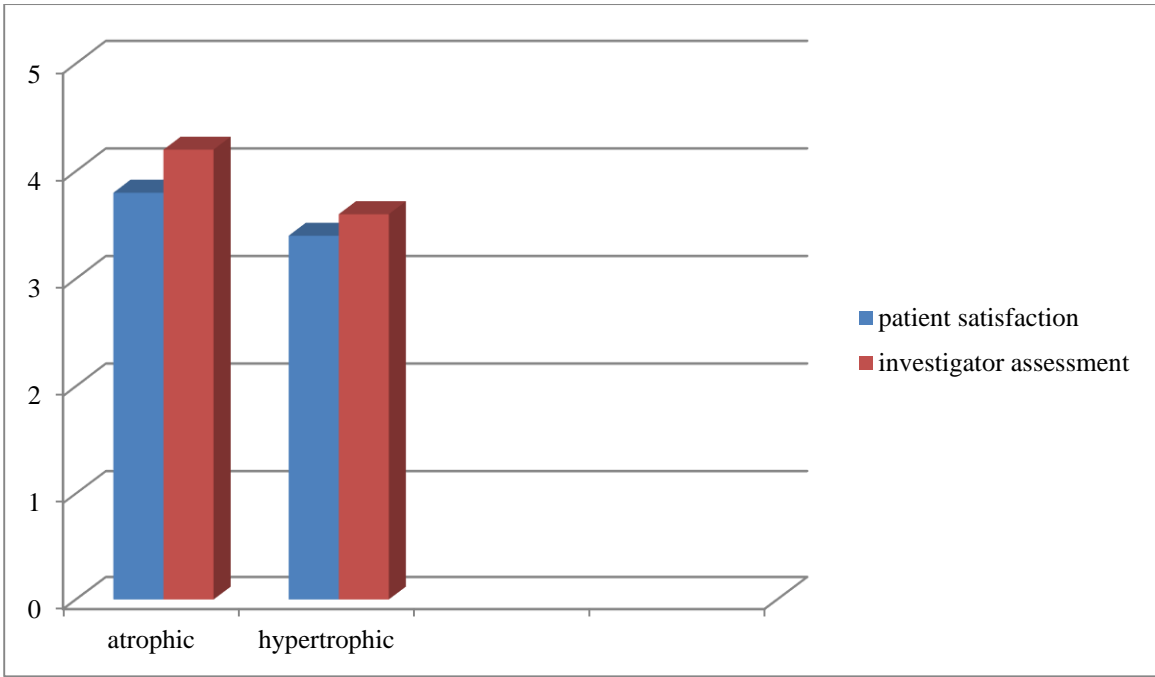
1=0change, 2=<25%change, 3=26%-50%change, 4=51%-75%change, 5=>75% change

**FIGURE 3.6:** Average improvement in patients after 9 weeks of therapy according to skin tone.



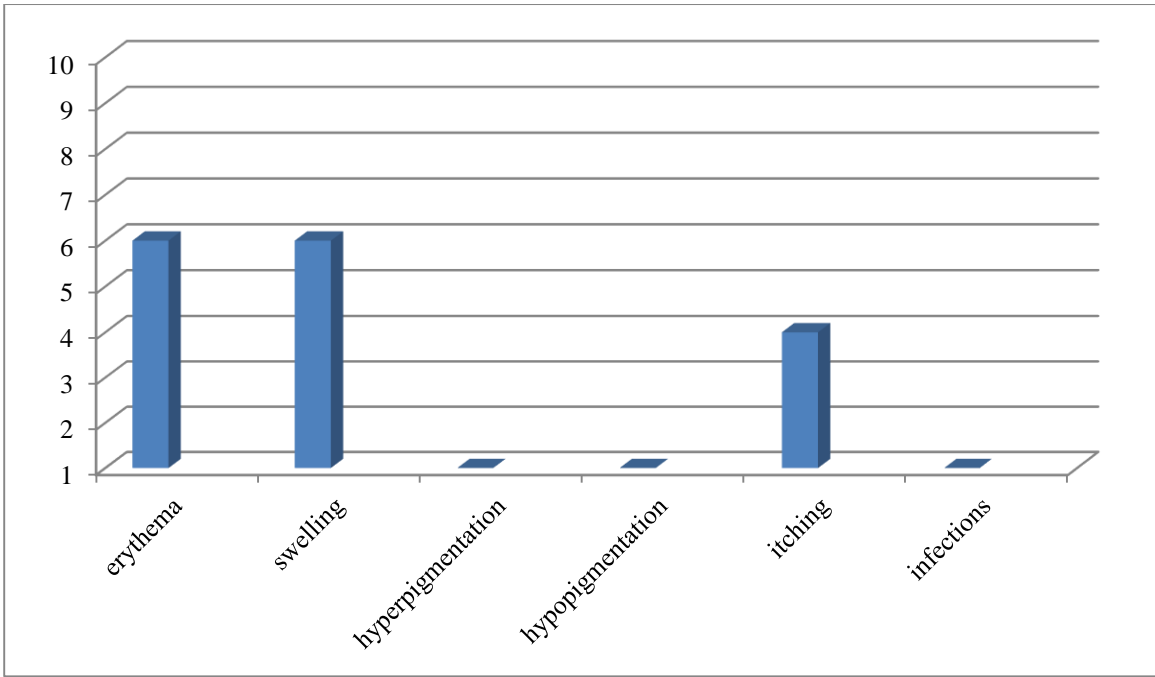
1=0change, 2=<25%change, 3=26%-50%change, 4=51%-75%change, 5=>75% change

**FIGURE 3.7:** Average improvement in patients after 9 weeks of therapy according to scar area.



1=0change, 2=<25%change, 3=26%-50%change, 4=51%-75%change, 5=>75% change

**FIGURE 3.8:** Average improvement in patients after 9 weeks of therapy according to scar type.



**FIGURE 3.9:** complications among patients.



# **Chapter four**

Discussion,

Conclusion,

and recommendations

**Discussion:** Laser cosmetology is used for a variety of aesthetic procedures, one of them is scars removal. Over the past decade, advances in laser technology have allowed dermatologists to improve the appearance of scars and wrinkles and to remove benign skin growths using both ablative and nonablative lasers ("laser".Reference.com,2008).

CO<sub>2</sub> laser, PDL and other therapies modalities such as steroid treatment, hyaluronidase injections, and cryosurgery were tried for the ablation of keloids and hypertrophic scars (Alster, Williams ,1995,345:1198).

Originally invented in the 1960's Nd:YAG lasers are among the most common and widely used class of laser,Nd:YAG lasers are frequently used for the treatment of scars and other cosmetic applications(Riveria ,2008, 59:659-76).

Nd:YAG Lasers generally produce an infra-red laser (1064 nm), It works primarily by heating the water molecules in the treatment area.When used at low power, infra-red lasers are used to stimulate cells by heating them up, but not enough to kill them. When used at high power, infra-red lasers can destroy (ablate) the target tissue very quickly.Ablative laser therapy with Nd:YAG Lasers is a popular technique to resurface the skin and treat scars by removing scar tissue, Infra-red lasers like Nd:YAG can be quite effective in penetrating deeper into skin and tissue at repairing deep scars (Riveria ,2008, 59:659-76).

The limited penetration depth of some lasers like PDL may also cause resistance to further treatment because of the optical absorption and scattering in the epidermis and dermis at a depth of about 1–2 mm thus, deeper vessels may be selectively treated with the 1064 nm Nd:YAG laser Indeed, due to its deeper penetration and lower absorption by hemoglobin, the 1064 nm Nd:YAG laser has proved to be a much more useful light source for the treatment of deep or thick lesions than the traditionally used shorter wavelength sources (Alster, Williams ,1995,345:1198).

Sudanease study of short pulsed non ablative 1064 Nd:YAG nm for acne scars treatment in dark skin type done on 2011 supported the use of it as a safe effective treatment (Badawi MD, Mohamed A.tome ,et al, 2011).

A study done in Brazil about efficacy of 1,064-nm Nd:YAG Laser for Treating Atrophic Facial Scars 2007 showed that 1,064 nm Nd:YAG laser is a safe and effective nonablative method for improving atrophic scars, even in darker skin (Raquel, Walter, 2007, Pages 1470–1476).

One Japanese study showed that Nd:YAG laser is effective in hypertrophic scars improvement which responded significantly to 1064 nm Nd:YAG laser treatment( Koike, Sachiko, et al, 2014. P272).

This study focuses on the response of atrophic and hypertrophic scars (keloids scars are not included in this study) to long pulsed Nd-Yag laser.

All patients are females have skin csars for years.

50% of patients are in the third decade, the rest are 10-20 years old and 30-40 years old.

Majority of patients (60%) are skin tone type IV, the others are skin tone type V and VI.

Seven patients in this study had face scars, three of them were hypertrophic and four were atrophic,one patient had hypertrophic scar on arm, and two patients had leg scars, one was an atrophic scar and the other was hypertrophic.

Regarding type of scars in this study 50% of scars were atrophic including acne scars, and 50% were hypertrophic.

Atrophic scars showed better and faster response than hypertrophic scars.

One patient with atrophic acne scar showed 75% improvement after the third session.

Face and leg scars showed more improvement than arm scar after therapy, and skin tone type IV showed the better response. The study showed that after three sessions with three weeks interval there was average change in whole appearance in all patients by (26%-50%).

Minor short term complications (swelling and erythema) were seen in six patients, and itching in four patients.

**Conclusion:**

The study showed that Nd-Yag laser therapy can be a promising treatment for skin scars.

Results show noticeable improvement can reach 50% improvement of scar appearance.

It is well tolerated with no complications at all or short term complications like erythema.

Response is rapid compared with other topical treatments.

**Recommendations:**

Because of limited number of patients and short duration of study duration further studies are needed to determine the efficacy of Nd-Yag laser in treating skin scars.

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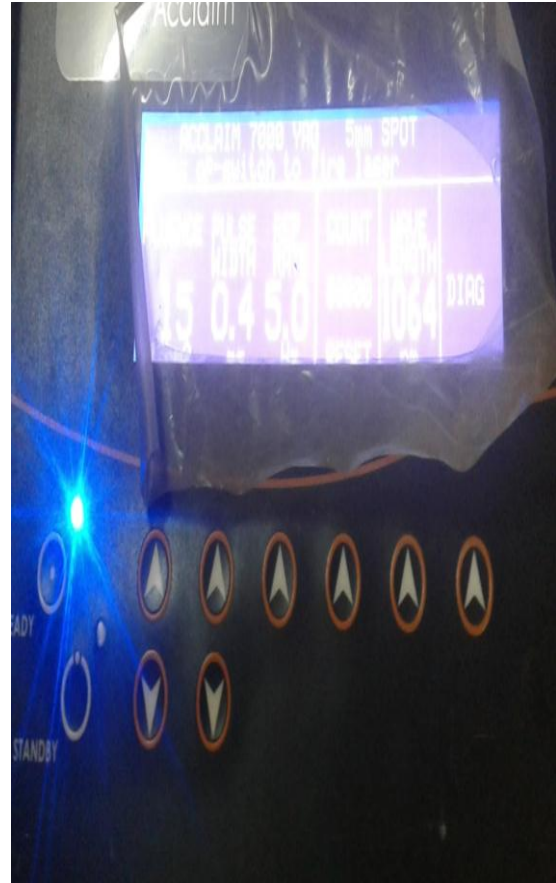
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# Appendices

## **Appendix 1: photos**



Nd yag laser



Parameters used in this study



Cooling system



goggles





Before



After

Acne scars before and after treatment



Before

After

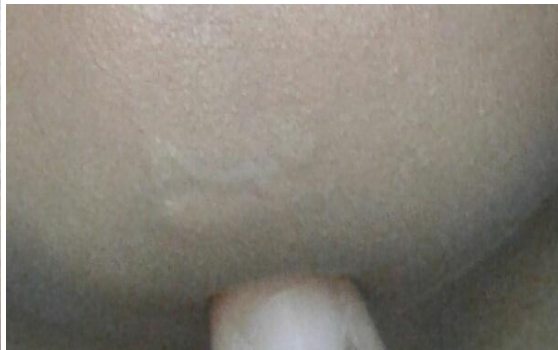
Acne scars before and after treatment



Before



After 3 weeks



After 9 weeks

Chin hypertrophic scar before and after treatment





Before



After

Burn hypertrophic scar on arm before and after treatment

## **Appendix 2: Data Sheet**

## Data sheet

Serial NO:

--	--	--	--

### Personal data:-

1/Name:.....

2/Gender:

Male

female

3/Age:

4/Residence:

5/Origin :

6/Occupation:

7/Telephone NO:

### Duration of acne scars:

Days  weeks

Months  years

### Clinical examinations:

#### Types of scars

Hypertrophic

atrophic

#### Site of the lesion

face  neck

trunk  leg  arm

**Fitpatrick skin type:**

1  2  3  4  5  **6**

**Complications**

Swelling

Erythema

Hyperpigmentation

Hypopigmentation

Itching

Infection

Hypertrophic scars

**Improvement and follow up:**(scale as follows; 1=0% change, 2=<25%,3=26–50%, 4=51–75% and 5=>75%.)

**Subject and Investigator Evaluations of:**

**Scar appearance at 3,6 and 9 weeks Post-Treatment  
Texture(smoothness), pigmentation, erythema and Overall Satisfaction  
after 9 weeks**

**3 weeks post-procedure**

Patient satisfaction

Investigator assessment

**6 weeks post-procedure**

Patient satisfaction

Investigator assessment

**9 weeks post-procedure**

Patient satisfaction

Investigator assessment