دراسة مقارنة بين تأثير ليزر الأيربيوم وليزر ثاني أكسيد الكربون على الجلد

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تم استخدام الليزر على نطاق واسع في الجراحة التجميلية ، وخاصة في مكافحة شيخوخة الجلد. ومع ذلك ، ما زال هناك نقص في البحث العلمي والمعلومات الإحصائية المتعلقة بتأثير تفاعل أنسجة الليزر في الجلد الحقيقي ؛ لذلك من أجل الحصول على فهم أفضل لهذه المسألة ، أجرت الباحثة دراسة بما في ذلك Er: YAG و CO2 أساسية باستخدام عدة ليزر تتيح التطورات في تكنولوجيا الليزر إزالة الأنسجة بدقة ، والحد الأدنى من الأضرار الحرارية ، ومع ذلك لم يتم تحديد آليات لتحسين مستحضرات التجميل ؛ إن الاجتثاث وانكماش الكولاجين و ترسب الكولاجين الجديد كلها عوامل تسهم في النتائج السريرية في دجاج مزرعة حية . درسنا الآثار الإجمالية و المجهرية لأجهزة التذرية الحرارية والميكانيكية لوصف آليات فورية و طويلة الأجل في تجديد الجلد. تهدف هذه الدراسة إلى تحديد ومقارنة تأثير أشعة الليزر المختلفة على بنية الجلد كتجربة لفهم كيفية ممارسة الليزر لتأثيراته الطبية في التأثيرات البيولوجية و بالتالي تحديد السلامة بأقل ضرر للجلد . لفترة ، تعرض جلد الدجاج لنوع من الليزر Er: YAG ليزر و CO2 ليزر لفهم كيف يتفاعل كل منهما مع الأنسجة. و تظهر نتيجة الدراسة أن ليزر الإربيوم تمتصه مياه الأنسجة أكثر من ليزر ثاني أكسيد الكربون الذي يخترق الأنسجة أكثر من الليزر الآخر ، ومن الصور التي يمكننا رؤيتها من أعيننا المجردة كيف أن ثاني أكسيد الكربون قد أضر بالجلد من الايربيوم الليزر.

Comparative Study of Interaction with Skin Tissue between The Erbium: Yttrium-Aluminum-Garnet (Er: YAG) Laser and The Carbon Dioxide (CO2) Laser

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Abstract

Lasers have been widely used in cosmetic and plastic surgery, especially in fighting against aging skin. However, there is still a lack of scientific research and statistical information regarding the effect of laser-tissue interaction in real skin. Therefore, in order to gain a better understanding on this matter, a fundamental study has been conducted using several lasers, including the Er: YAG laser, CO2 laser. Advances in laser technology allow for precise tissue removal and minimal thermal damage. However, mechanisms for cosmetic improvement have not been determined. Investigators have suggested that ablation, collagen shrinkage, and new collagen deposition all contribute to the clinical outcome. In a live farm chicken , we examined gross and microscopic effects of thermal and mechanical ablation devices to characterize immediate and long-term mechanisms in skin rejuvenation. This study aimed to determine and compare the effect of different lasers on skin structure as a trial to understand how laser exerts its medical effects in biological effects and thus determine the safety with lowest skin damage. Briefly, the chicken skin was exposed to kind of laser Er:YAG laser and CO2 laser to understand how both of them interact with tissue . Our result shows that, the erbium laser is absorb by the water of tissue than CO2 laser which is has penetrate through the tissue than other laser and from the photos we can see from our naked eyes how the CO2 has damage to skin than Er:YAG laser.

Keywords: Er: YAG laser, Co2 laser , interaction tissue

Introduction:

Both Er:YAG and CO2 devices are commonly used for aggressive skin resurfacing procedures and general surgery application of skin. Each of them has novel tools to be ideal laser system for superficial resurfacing. The erbium: YAG laser is easily absorbed by water, it has wavelength 2.94 µm and since our body contains a lot of water so the depth which it penetrates through the human tissue limited because the high water content in cells.This lasers offer opportunity to produce the laser with a high intensity beam in very short pulse [1]. The effect of laser resurfacing is less powerful with non-ablative laser devices than with ablative fractional laser, although there has been exerting their effects by inducing dermal collagen remodeling while sparing the epidermis with nonablative laser devices [2]. The most function type of non-ablative laser for photorejuvenation is the neodymium-doped yttrium aluminum garnet (Nd-YAG) laser 1064-nm laser [3]. The effects of non-ablative collagen remodeling using the 1064 nm Nd-YAG laser has been reported [4-6]. The effects of long pulsed Nd-YAG laser were evaluated in mice skin, where the collagen remodeling after laser treatment was observed with the change of energy fluence. Only a few investigations have investigated the utility of the long pulse Nd-YAG laser in collagen remodeling production [7]. Histological reports have estimated rejuvenating changes that occur at the dermal level [8]. Reported changes include increase in epidermal collagen, elastic, keratinocytes and glycosaminoglycan . In the clinical studies, there was appearance of facial skin treated in series with a Nd-YAG 1064-nm laser [9]. Theoretically, the effects of reduction in the appearance of rhytids and the improvement in the skin elastically were due to heat deposition into the reticular and papillary dermis stimulating collagen production [10]. The erbium:YAG laser has reputation for being precise, less aggressive and more safety than CO2 laser, though the result of both of them which done on wrinkle treatment or general resurfacing operation it almost the same. Furthermore, the Er:YAG laser has less risk of causing permanent loss of skin pigmentation this might related to the equality of laser itself.

The carbon dioxide (CO2) laser was invented by Patel in 1964 and was widely used in the last twenty years in different areas such as skin diseases, ophthalmology and general surgery. The CO2 laser produces a beam of infrared light with a wavelength of 10,600 nm, the coalitional energy transfer between two molecules which are nitrogen and carbon dioxide leads vibration of carbon dioxide molecule. The laser-active medium in the CO2 laser is a mixture of CO2, $N2$ and He gases, therefore when the gas is electrically discharged, the active medium of the laser is stimulated. This stimulation is done by either direct current or radio frequency stimulation. In direct current stimulation lasers are done between electrodes by gas discharge, whereas the radio frequency stimulated lasers are described by capacitive in coupling of the electrical energy needed for gas discharge [11]. The CO2 fractional laser offers painful reduction through the radiation process which some parameters lead the laser to reduce pain, such as small pulse duration, less spot size, and less exposure period on the skin. In contrast, the CO2 laser has some disadvantages: for example, irradiation of the skin leads to a burning effect, which diffuses to the surrounding area. The CO2 laser is applied for treatment of photoaging appearance, taking away wrinkles and leading to recreation of the dermis via the transmission of the thermal effect [12-14]. The CO2 (carbon dioxide) laser is known for producing greater skin tightening and less bleeding then the Er:YAG laser.The CO2 laser can be used to treat cancer by shrinking or destroying a tumor with heat since has the wavelength of 10.6μm[15]. In medication, the laser commonly used in surgery and treatment procedures on skin, most of ordinary surgery is used like hair removal, skin resurfacing, treating scar, treating pigment and treatment tumor [16]. the CO2 laser has spectra energy in the far infra red portion at wavelength 10,600 nm. The energy of this wavelength is heavily to be absorb by water which is the main chromospheres of cell in living tissue, thus the energy of this laser can used for cutting ablation by means of tissue vaporization[17]. This system of laser has some advantages such as less pain, little of swelling, control of infection and less bleeding which made it use widely in skin treatment[18].The results of laser treatment depend on the immediate interaction of incident light with tissues as well as the subsequent tissue regeneration and repairing. The most factors the interaction between laser and tissue depends on are the color or amount of pigmentation in the skin is very important in determining the amount of damage that will be produce by laser pulse. Second, the amount of substance keratin present in the irradiation region. Third, the characterization of output laser is very important like power, wavelength, pulse duration, etc.

moreover, the reaction the skin to laser play important role which depends on type of skin and exact circumstances [19]. Unfortunately, there were limits data comparing the photo damage differences and change throughout skin between two method treatments. In this present study, we compare the differences in damage pattern; treatment depth and degree of surrounding burn damaging area following treatment with each device are evaluated in side by side cross section photo damage pictures comparison.

Objective:

There are four main objectives for this work as noted below:

1- To compare the effect of different lasers on skin structure as a trial to understand how laser exerts its medical effects in biological effects, and determined the safety mechanisms of using the laser skin treatments.
2- To study the effect of CO2 laser skin treatment using chicken skin.
3- To study the effect of Er: YAG laser on skin using chicken skin as model.
4- To comparative study between both lasers on skin treatments in terms of damages and safety on skin.

Overview on Skin:

The skin covers the whole body and therefore is the large organ of the body. At its most basic role, skin provides an efficient barrier to the outside world. The layers of skin consists of water, as well as boarder keratinocytes which results in varying epidermis thickness around the whole of the human body to provide different levels of protection depending on the body's needs [18, 19]. The epidermis consists primarily of epithelial keratinocytes, but also contains Langerhans and melanocyte cells. The dermis is 300-400 μm thick and is positioned to provide skin with strength, shape, and overall structural completeness. The dermis consists of resident fibroblasts that attach to an extracellular matrix (ECM). When skin is loaded with tension it exhibits a nonlinear concaved stress-strain characteristic. The ramification of this stress-strain curve is that under normal conditions skin is elastic, but becomes stiff when loaded with tension.

Laser Parameters:

The effects of light on skin are due to various degrees of absorption of electromagnetic radiation. The light-tissue interaction effects are due to absorption and excitation of photons. Once the light reaches the skin, part of it is absorbed, part is reflected or scattered, and part is further transmitted. Selective photothermolysis is the basic principle of Light treatment. It consists of matching a specific wavelength and pulse duration to obtain optimal effect on a target tissue with minimal effect on the surrounding tissues. The structures of the tissue that absorb the photons are known as chromorphore. They have different wavelengths of absorption. The energy of the laser is another important parameter of lasers which can be defined as the total amount of energy radiated by an optical source .The continue laser produces a laser output in certain ranges of energy according to its application. The pulse energy is the energy contained in a single pulse. The unit of energy is Joules (J). In pulse lasers, the density is used to determine the energy deposition in a certain area of the target. In a single pulse, the energy density is defined as the energy of the single pulse divide by the irradiated area.

Energy density $= E/A$ (J/cm^2)

The energy density is measured in Joules per square centimeter (Jcm^{-2}). The repetition rate and duty cycle are other parameters of lasers. The repetition rate is defined as the number of pulses per second and it measured in Hertz (Hz) or (S^{-1}).

Apparatus

1. The Carbon Dioxide (CO2) Laser :

The CO2 laser, manufactured by COLE Technology Co. Ltd from China, was used. The laser was modulated into a pulsed continued laser as shown in Figure 1. The power supply is designed for 80 Watt Laser products with wavelength from 35 It's suitable for the laser apply an engraving, cutting or medication equipment. Power is controllable from TTL (20 K Hz or an analog signal 0-5 V). Output is controllable in of the continually or in pulse mode, operating in a single pulse with duration of 1 ms per pulse.

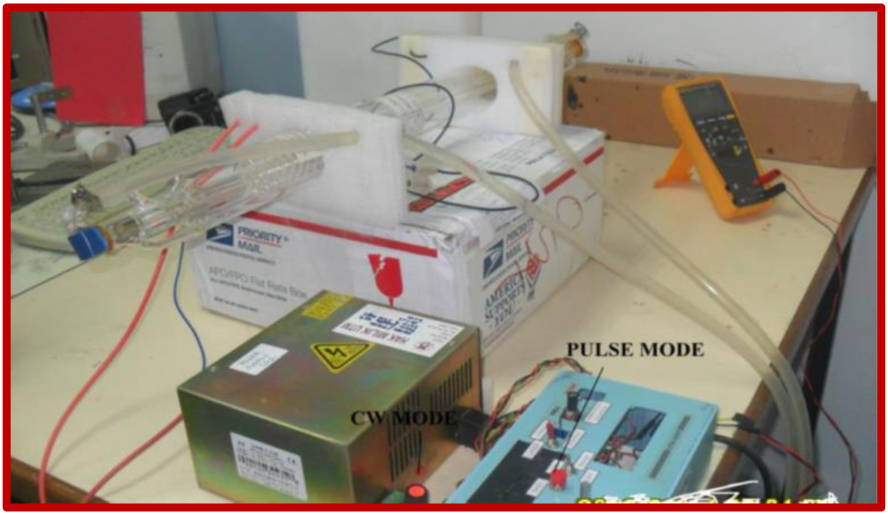

Figure 1: The CO2 laser system

The power of the CO2 laser was measured using a Power Wizard Model PW-250 manufactured from Synrad. Inc. USA. A powermeter was placed at 9 cm from the laser. The distance was chosen so that output beam of the laser has a large diameter at the power meter position. This step protects the power meter sensor from damage caused by excessive power density. The CO2 laser was converted into pulse by using a homemade trigger unit. The input voltage can vary in the range from 1.54 – 4.73 V. 36

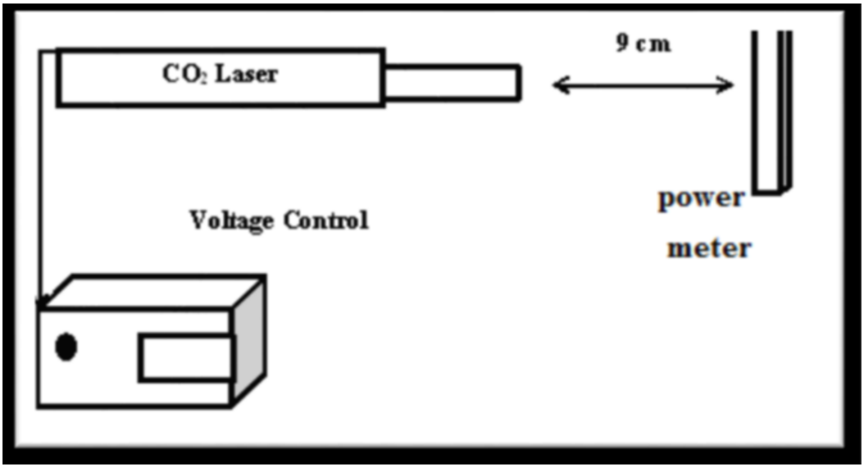

Figure 2: shows a schematic diagram of the experimental setup for a CO laser.

2. The Erbium: Yttrium-Aluminum-Garnet (Er:YAG) Laser System:

The photograph of an Er:YAG laser is shown in Fig. 3. In this work, Erbium yittrium aluminum Garnet (Er:YAG) laser with a wavelength of 2940 nm was employed as a source of treatment. The laser was operated via external trigger unit for a single pulse operation, with pulse duration of 225 ns. The beam spot size is 3 mm. It was manufactured from San Diageo California USA. The laser is operated at a variable voltage in the range of 750-1350 V. An Er 3+ doped YAG crystal rod was used as an active medium in this laser system. Both end-faces of the laser rod were concave, with a radius of curvature of 5 m. Both sides were anti-reflection AR-coated. The laser rod was pumped by a single xenon flashlamp, with typical pump energy of up to 100 J and a repetition rate of 1-12 Hz, housed in a single diffuse cavity LMI 1610. The 39.5 cm-long optical cavity was formed by two flat dielectric mirrors M1, M2 with reflectivity of 85% and 100%, respectively.

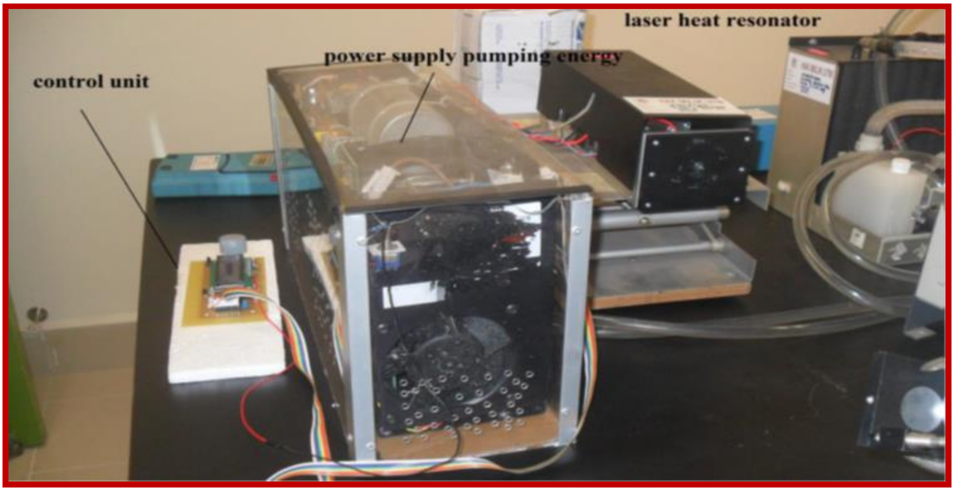

Figure 3: -Er:YAG laser system

Figure 4 shows the schematic diagram of experimental setup used to calibrate output power of the Er:YAG laser. The thermophile sensor was placed at 15 cm from the laser. The distance was chosen so that output beam of the laser has a large diameter at the thermophile sensor position. This step protects the power meter sensor from damage caused by excessive power density. The input voltage can be manipulated in the range of 750-1350 V. The, output laser from the Er:YAG laser was detected via photodetector.

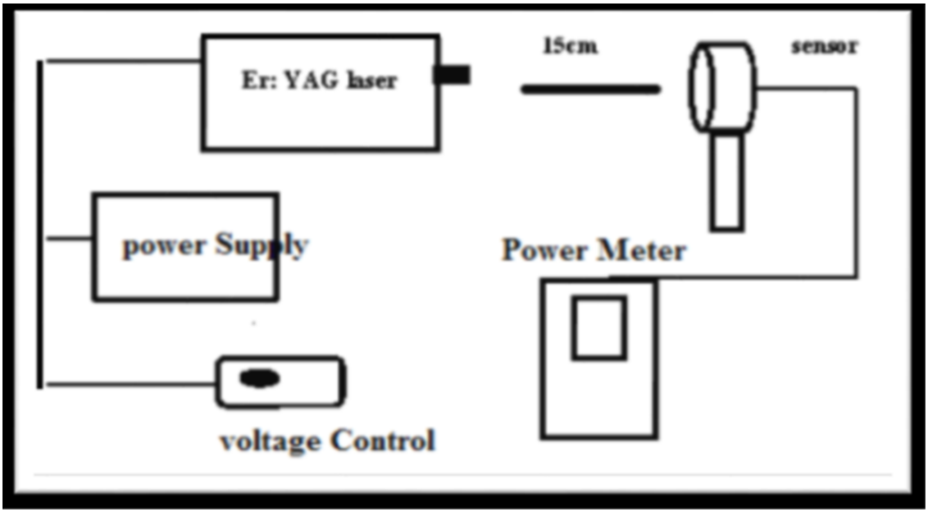

Figure 4 Schematic diagram of Er:YAG laser calibration experimental setup

Materials :

1- The carbon dioCO2 laser with power 3.7W, spot size 3.5 mm and pulse duration 77.8µs.
2- Erbium: Yttrium-Aluminum-Garnet Laser (Er:YAG**)** with energy 162.5 mJ, spot size 3 mm and pulse duration 423ns.
3- The soft tissue samples we use fresh slices of chicken, each with 3-2 mm thickness.
4- CCD camera to capture the effect of laser on skin.

Methodology:

In this study, we will exam both laser systems on chicken skin as animal model to evaluate the difference between two methods. For the Er:YAG laser we used multipulses of laser with energy 162.5 mJ, spot size 3 mm and pulse duration 423nsand CO2 multipulses of laser with power 3.7W, spot size 3.5 mm and pulse duration 77.8µs. The soft tissue samples we use fresh slices of chicken, each with 3-2 mm thickness.Before the samples irradiate to laser we have to weight and should be almost same weight and after expose to laser need to weight too to measure the loss of weight and know how much each laser absorb the water throughout the sample and then take the sample under microscope to measure the depth and damage by software called ImageJ to analysis photo damage and compare with two laser systems.

Result and Discussion

The reaction of the skin to laser radiation in application treatment depends on many parameters. The output characteristics of laser, particularly the wavelength is very important in term of absorption of water since our body contain 90% water. Furthermore, the transmission of radiation through skin varies with the thickness of the different layers of the epidermis and also the location of body. Melanin granules contribute to the absorption and scattering of visible and infra red radiation as well as absorption by ultraviolet radiation.Thesamples we expose to lasers have weight about 4.40 g and their loss of weight varies with type of laser, from result we observe, there losses in weight of samples that expose to Er:YAG laser greater than of samples that expose to CO2 laser. Since the CO2 laser has wavelength in infra red portion in electromagnetic spectrum at 10.600 nm at this wavelength, energy is heavy to absorb by water. The skin burns is the main effect that will be considered. The samples that irradiate with CO2 laser have damage than Er:YAG laser which clearly seen by naked eyes. Since the melanin is response on the skin coloration, there will be some effect on soft tissue. The photothermal effects occur when tissue water absorbs the corresponding wavelength of energy and destruction of the skin causes from the conversion of absorbed energy into heat and transfer to surface of skin and surrounding it. From the cross section photos of samples that exposes to Er:YAG laser we can see the damage through skin due to the absorption of incident laser energy by natural pigmented material found in skin. The area of burning increase as the radiation time increase as well. This burning skin known as the thermal radiation effect where the energy of incident laser is being absorbed by skin and leading the increaseon temperature of exposed skin. This energy in term of heat required for reaction to observe. The exposed skin by Er:YAG laser is shown in figure (6) has burned area which caused by laser. The surface skin is heat up and melted and penetrates through skin. The exposed skin by CO2 is shown in figure(7), this skin cut at normal cross section and this skin likes to be burn after expose due to the water in target tissue absorbs the laser energy, heats up, boils and vaporizes, taking the surrounding tissue with it. Since the carbon dioxide operated in a far infra red spectra region and the waves in this region has ability to remove toxins. When these waves applies on water it being to vibrate and other toxin material released which is useful for body immunization and faster wound healing. By analysis the photos using soft ware we observe that, the depth of CO2 laser through skin greater than Er:YAGlaser. There are three steps in tissue heating upon laser irradiation. The skin is first heated directly within the optical absorption depth. The direct heating is followed by thermal diffusion that indirectly heats the deeper layer tissues. The hottest part of tissue close to the surface is evaporated, in effect reducing the depth of the thermally affected skin layer. If the energy is delivered to the tissue in a very short time can be taken place and long pulsewidth will allow more heat transfer before ablation taken place resulting in greater thermal effect on surrounding tissue, when we take into account the optical penetration depths of the two ablative source, we observe that the Er:YAG laser allows coagulation depth control from 3µm and beyond, while the CO_2 laser limited to larger coagulation depth as shown in table(1).

Table 1: The different depth of laser in skin

Type of laser	Depth
Er:YAG laser	3.59 µm
CO_2 laser	20.77 µm

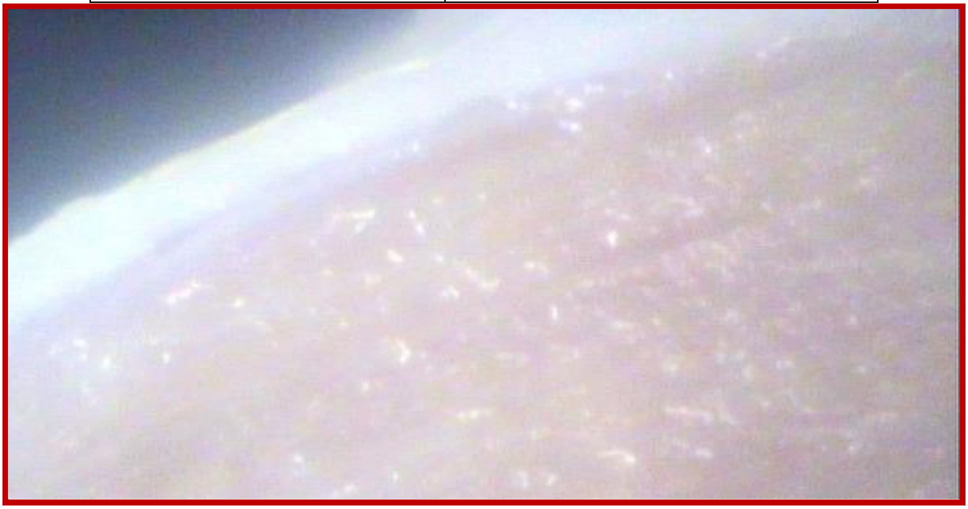

Figure 5: Normal sample of chicken skin

Figure 6: The Cross Section of sample irradiated with Er:YAG laser

Figure 7: Cross Section of Sample Irradiated with CO2 Laser

Conclusion

Based on our objective study, we concluded that, in this study laser-tissue interaction was optimized using macro microscopy images as benchmarks to help us understand the bioeffect of surgical ablation procedures. Here we make compressive study between the Er:YAG laser and CO2 laser and expose both of them on chicken samples to understand how both of them interact with tissue in terms of absorption of water and depths through skin and thermal damage on tissue. From result we observed that, the Er:YAG laser has limited of depth in tissue and high absorption of water than CO2 laser which has high depth in tissue and low absorption of water of tissue than Er:YAG laser butthe carbon dioxide (CO2) laser system induced more damaged area increases with the number of pulses comparative with Er:YAG laser.it is recommended to ensure also that all of the hair is already removed to avoid the laser irradiating the hair instead of the skin. When the Er: YAG laser irradiates skin, the effect it has on the skin can occur as a white colour, which is sometimes not clear with a few pulses; therefore, it is suggested that the irradiated area is taken for histological examination. In addition, it is difficult to use the Er: YAG laser on vivo targets without an arm to assist irradiation of the specific area, especially when comparing the laser system with the CO2 laser. The digital camera used to observe the photodamage

effects by the naked eye should have the same magnification.

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