Evaluation of Temperature Distribution on Human Skin During Philaser Tattoo Removal

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Abstract

Many difficulties were recorded during laser-assisted tattoo removal. But most of them remain unknown. The recent literatures on laser tattoo removal focuses more on removal methods and systems than on side effects, such as temperature increase over tissue and ideal treatment parameters. This study aims to assess the surface temperature in compliance with eyebrow tattoo removal. The study was carried out for 55 patients aged between 22 and 43 years. The treatment was performed using a Nd:YAG laser (1064nm, Phi laser system) with an energy of 1000 mJ, a frequency of 3Hz, and a spot size of 8mm. The surface temperature of the skin during tattoo removal process was measured with a FLIR thermal camera. The results were analyzed by testing the normal state of distribution. The Shapiro-Wilk and Kolmogorov-Smirnov tests were used. All patients finished the full treatment of three laser sessions to achieve the goal of total removal. After temperature comparison, the results showed a significant influence of skin nature and patients' age on temperature distribution on skin, as for older patients, the energy absorption increased. Additionally, patients with darker skin tones exhibited greater absorption. The benefit of deepening understanding appeared in the Temperature distribution in the tissues of the affected area and the surrounding area during laser irradiation, as it provides a guiding and reference function for the effect of photothermal therapy.

Keywords: Philaser, IR Camera, Laser Skin Interaction, Shapiro-Wilk, Patient Age, Tattoo Removal.

تقييم توزيع درجة الحرارة على سطح الجلد البشري أثناء إزالة الوشم باستخدام PhiLaser

زهراء عامر سلمان ، زياد طارق الدهان ، أحمد رياض الحموي

الخلاصة:

تم تسجيل العديد من الصعوبات خلال عملية إزالة الوشم بالليزر، لكن معظمها غير معروف بشكل جيد. تركز الأدبيات الحديثة حول إزالة الوشم بالليزر على طرق وأنظمة الإزالة أكثر من التركيز على الآثار الجانبية مثل زيادة درجة الحرارة على الأنسجة والمعلمات المثالية للعلاج. تهدف هذه الدراسة إلى تقييم درجة حرارة السطح أثناء إزالة وشم الحاجب. تم إجراء الدراسة على ٥٥ مريضاً تراوحت أعمارهم بين (٢٢-٤٣) عاماً. تم العلاج باستخدام ليزر Nd: YAG 1064nm (نظام فايليزر) بطاقة ١٠٠٠ملي جول، وتردد ٣هرتز، وحجم بقعة ٨ ملم. تم قياس درجة حرارة سطح الجلد خلال عملية إزالة الوشم باستخدام كاميرا حرارية من نوع FLIR. تم تحليل النتائج من خلال اختبار الحالة العادية للتوزيع. تم استخدام اختبار شابيرو ويلك واختبار كولموغوروف-سميرنوف. أنهى جميع المرضى العلاج الكامل من خلال ثلاث جلسات ليزر لتحقيق هدف الإزالة الكاملة. بعد مقارنة درجات الحرارة، أظهرت النتائج تأثيراً كبيراً لطبيعة الجلد وعمر المرضى على توزيع درجة الحرارة على الجلد، حيث زاد امتصاص الطاقة لدى المرضى الأكبر سناً. كما أظهرت المرضى ذوي درجات لون البشرة الداكنة امتصاصاً أكبر. الفائدة من تعميق الفهم ظهرت في توزيع درجة الحرارة في أنسجة المنطقة المتأثرة والمنطقة المحيطة أثناء تعرضها للإشعاع بالليزر، حيث توفر وظيفة إرشادية ومرجعية لتأثير العلاج الضوئي الحراري.

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1. Introduction

Laser tattoo removal uses high-intensity light beams to break up the tattoo ink into tiny particles. These particles are thus naturally eliminated by the human immune system, causing the tattoo to fade over time (Ho, Stephanie & Goh, Chee 2015). In dermatology, fields have developed; the laser have become very important therapeutic tools. (Carroll and Humphreys, 2006; Gold, 1959; Meeman, 1960; Zarit et al., 1961). Lasers have recently been employed in a wide range of procedures, from cosmetic dermatology to dermatology treatment and surgery. Laser irradiation is more reliable and efficient than traditional techniques, with a small wound and rapid healing (Carroll and Humphreys, 2006). The most important aspect of these treatments is the management of overheating and dispersion within living tissue. As a result, the surrounding tissues will experience less unintended thermal damage. Laser tattoo removal is one of the gold standards of these uses, but its effectiveness is influenced by various factors as patients age, skin color, and tattoo age (Zhang et al., 2018). These factors affect the treatment outcome directly. The purpose of this study was to determine the relationship between lasers and tissues in relation to medical applications using recognition of how tissues react thermally to laser radiation. By creating models and simulation tools, prediction and evaluation techniques are proposed in an effort to reduce unwanted side effects from heat damage and serve as a basis for future treatment strategies. (Al Ansari Master 2013). With proof of the wavelength of the laser and how it affects the patient's age and tissue type in the amount of time allotted for heat transfer in the laser-induced heat treatment, the skin layers were systematically examined. The epidermis, dermis and subcutaneous tissue are the three layers that make up the biological structure of the skin (Woodland and Goldsmith, 1991). The temperature gradient within the epidermis, dermis, and outer skin layers affects skin tissue exposed to laser radiation and understanding them is an important part of thermal conductivity. It is necessary to determine the relationship between patient age and operating parameters and the radiation effect on that transfer in area of eyebrows and forehead as it is very close to eyes and brain tissue (Bindu B 2017) Given the complexity of the interactions between the various factors that may be linked to these difficulties, defining best practices is a challenging task. This work employed a number of traditional statistical approaches and strategies to find characteristics that gives safe and efficient results, and decrease tattoo removal difficulties. The outcome was proofed to bring better practices. Lastly, the statistical model that explains how the parameters of laser treatment interact with the skin and builds the system order for processing parameters utilizing boot and gradient enhancement. [Yim, Richard & Haddock 2021].

2. Materials and Methods

Thermal videos and images were recorded using a thermal camera (Type of camera and Company) during the removal of the tattoo from the skin. The video shots were converted into frame sequences (still images at a specific frame rate). Calculating the moment associated with each frame for the value of the frame rate used during the shooting phase. Except for frames that do not have thermal data for the interaction of the laser with the skin (i.e. tires that do not have a laser spot inside). Displaying frames at a fast frame rate is convenient for the user to choose and track the laser spot to target are applied with approximately 10-20% overlap (the spot must be isolated and visible during its lifetime). Depending on the size of the target spot (Pazhoohi, Farid & Kingstone, Alan, 2021).

2.1 Patient preparation

First, the treatment area should be thoroughly cleaned and any remaining makeup or skin products removed with the use of a gentle soap or cleanser that does not irritate the skin. An antiseptic solution is applied to cleanse the skin and reduce the risk of infection. Commonly used solutions include disinfectants containing alcohol or iodine. Any flammable products for cleaning such as isopropyl alcohol should be avoided. Then carefully dry the area with a clean, soft towel to avoid irritation. Local anesthesia of 5% lidocaine cream (LMX-5) and 2.5% lidocaine / 2.5% prelucaine (EMLA) are frequently used under blockage for 45-60 minutes before radiation to reduce patient pain. This layer of anesthetic cream must be completely removed from the surface of the skin before starting treatment.Also, to reduce patient discomfort cool air can be used during therapy, or anesthesia infiltration to cause local nerve block, or even use both of them. During the laser process, all medical staff should wear safety goggles of the specific system wavelength. Additionally, external metal eye shields must be used to protect the patient eyes. (Ortiz AE, Alster TS 2012).

2.2 IR CAMERA

Infrared thermal imaging with FLIR thermal cameras has demonstrated encouraging outcomes in detecting temperature changes on human skin. Unusual temperature distributions that signify wounds, injuries, and illnesses can be detected by these cameras (Kirimtat et al., 2020; Karimat and Krigkar, 2018). FLIR cameras are particularly helpful for patients with darker skin tones (Nelson et al., 2021) and have demonstrated value in tracking temperature variations on the skin caused by internal body temperature fluctuations. High-quality photos are produced by FLIR one (Kirimtat et al., 2020). Specifications of this camera :Thermal Sensitivity: < 0.10°C at 25°C - Temperature Range: -20°C to 250°C (-4°F to 482°F) - Image Resolution: 10,000 pixels (100 x 100) - Sensor Type: Uncooled microbolometer (Focal Plane Array) - Camera Weight: 13 oz (365 grams), making it lightweight and easy to use - Display: 2.8-inch (71 mm) color LCD screen - Field of View: 21° x 21° - Minimum Focus Distance: 0.6 meters (2 feet) - Battery Type: Rechargeable Li-Ion battery, with more than 5 hours of continuous use - Storage: microSD card capable of storing up to 5000 images in JPEG format - Lens Type: Fixed focus lens

- Frame Rate: 9 Hz. These thermal cameras are useful instruments for improving patient monitoring and results in medical settings because of their offline nature and intuitive interface (Nelson et al., 2021).

2.3 PhiLaser

The used lasers system (PhiLaser) has advantage of shorter pulse duration (only 2ns) compared to older version, which has pulse duration of 8ns. This advantage (Quicker by four) characteristic shredded the tattoo particles finer and allowed its removal easier (Filippychev, D.S.2001). This technology is considered one of the newest and best in the world and gives best results with stylish design & maximum efficiency.

The process is carried out by means of portable device to deliver laser pulses to the eyebrow tattoo. This Nd:YAG laser system contains optical-circuit system in the treatment handle, and electric-circuit system, computer system and cooling system in the console. The laser gives wavelength values 1064, 532, and 1320 nm, maximum energy of 2J, 15mJ/cm^2 fluence, and 2ns pulse duration. Also, the pulse frequency can be varied from 1 to 10 Hz. The laser, shots feel like a series of shots or pinches on the skin. The duration of each session depends on the size and color of tattoo, but most cases take only few minutes. After treatment, a soothing gel or cream is applied on area with after care instructions. Patients may experience some redness, swelling, or blistering on treatment area. All these side effects are considered normal and temporary, and they subside within few days to week.

3. Results

In this study, the skin surface temperature of 55 female patients was measured while using a laser to remove tattoos from the eyebrow area. The ages were different ranging from 22 to 43 and with different skin colors, since the FLIR type camera was used to know the thermal distribution of the surface due to the importance and sensitivity of this area (front) the temperature was measured with great accuracy. The PhiLaser (Nd:YAG) 1064nm was used in the removal process with a power of 1000 mJ and a frequency of 3Hz, and a laser spot size of 8 mm. They are applied with an overlap of approximately 10-20%, with the aim of instant bleaching, ten strokes were made per eyebrow, each stroke takes one second of time. The results for temperatures were analyzed by statistical analysis of the distribution of age groups, testing the normality of the distribution. The Shapiro-Wilk and Kolmogorov-Smirnov test was used to determine whether the distribution of the collected data was normal. The following images show a thermal scan with a temperature reading. The scan displays different colors indicating different temperatures, with blue representing the cooler areas and red, yellow, and green indicating the warmer areas, with the hottest areas around the forehead and the cooler areas around the sides. They recorded the highest temperature on the forehead, and the lowest temperature in the cheek area. The temperature of the chin is approximately between these values. It is assumed that the high temperature of the forehead is due to the metabolic activity of the brain. The front is divided into three areas: the left front, the middle front and the right front. This is consistent with (S. Ariyaratnam, J. Rood 1990) findings. To identify sources of temperature variation Measurements. R&R analysis looks at sources of variation in Complete measurement system. takes into account measuring instruments (thermal imaging cameras with accurate performance), Analysts (two researchers with different skills and experience) and samples (in this case 55 patients whose skin surface temperature was measured during laser treatment). The Analysis can be applied if the minimum number of repetitions in each the subgroup analyzed is at least 3 groups, and the distribution of results in each of them the subgroup is not significantly different from the theoretical normal distribution. The normal state of all subgroups was confirmed by the ShapiroWilk test.

Essentially the test statistic W is the square of the Pearson correlation coefficient computed between the order statistics of the sample and scores that represent what the order statistics should look like if the population were Gaussian. Thus, if the value of W is close to 1.0 the sample behaves like a normal sample whereas if W is below 1.0 the sample is non-Gaussian. The original formulation of the W-test [Shapiro SS, Wilk MB].

Skin tones, often called skin tone or cuticles, indicate the actual color of the local skin (black, brown, yellow, white, etc.), Table (1) shows the Skin tone variations. On other hand, Figure (1) shows examples of how the temperature distribution in the infrared photos, the four listed images are for a 25-year age female patient of skin tone 3 at different pulses during the process.

Table (1): Skin tone variations

Number	Name	Color
1	Vanilla	
2	Beige	
3	Almond	
4	Golden	
5	Mocha	
6	Toffee	

By Testing the normality of distribution, the Shapiro-Wilk test and Kolmogorov-Smirnov were used to determine whether the collected data's distribution was normal. The data were found to be regularly distributed by the Shapiro-Wilk test and Kolmogorov-Smirnov.

From the results of statistical analysis, the data are subjected to the normal state test of distribution and are in the form of two important tests. The results ($P > 0.05$) were considered insignificant. The study sample was divided into three age groups, the minimum being at the age of 22 and ending at the age of 43. It should be noted that the selection of the sample was random and natural if the sample number for the age groups was not equal, which was 12, 23 and 21 for the three groups, respectively.

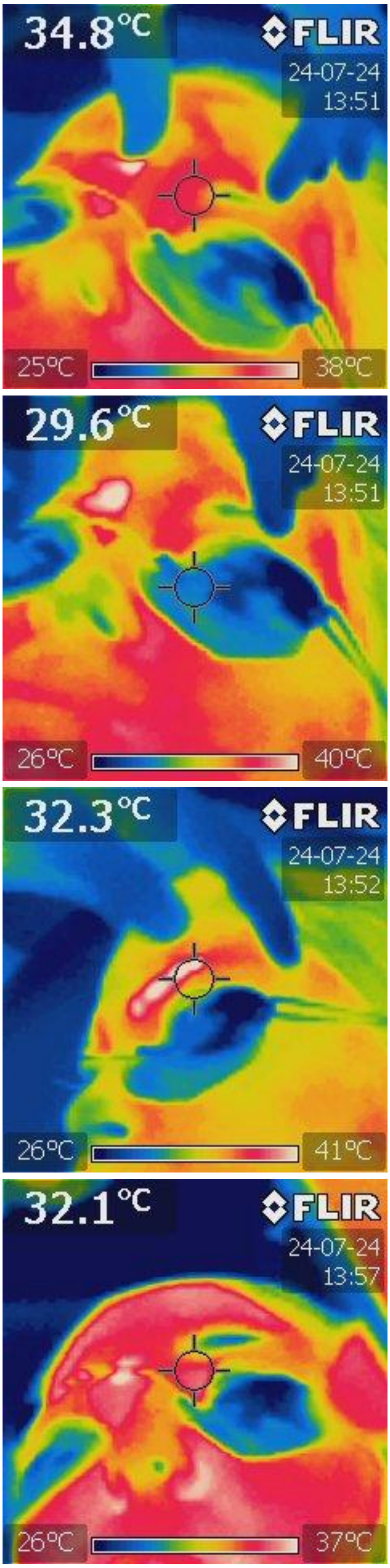

Figure (1): Different infrared photos

Table (2): Statistically analysis for Age ranges distribution in tested samples

Age groups Year	*N*	*Mean*	*Std. Deviation*	*Min.*	*Max*
G1=22-28	*12*	*24.75*	*2.05*	*22*	*27*
G2=29-35	*21*	*31.67*	*2.11*	*29*	*35*
G3=36-43	*23*	*39.74*	*2.34*	*36*	*43*
P value	***0.001 H. Sig***				

According to the results of statistical analysis, Table (2) the study demonstrated that there is a highly significant difference at the p-value of 0.001 between the mean age for the three age groups included in the study.

The current study also found that there were no significant differences in the temperature mean value before starting the tattoo removal process for all age groups under study, which indicates that all participants in the experiment started at an approximately equal temperature, as shown in Table (3).

Table (3): Temperature Before tattoo removal

Temperature Before					
Age groups	***N***	***Mean/C°***	***Std. Deviation***	***Min.***	***Max.***
G1=22-28	*12*	*23.00*	*0.60*	*22.00*	*24.00*
G2=29-35	*21*	*22.24*	*1.30*	*19.00*	*24.00*
G3=36-43	*23*	*22.35*	*1.11*	*20.00*	*24.00*
P value	***0.39 Non sig***				

On the other hand, a large difference was observed in the temperature rates upon completion of the tattoo removal process among the three age groups, as the temperature reached its highest levels in the third age group 40.48 C°, with highly significant differences p-value 0.01, as shown in Table (4).

Table (4): Temperature **after tattoo removal**

Temperature After					
Age groups	***N***	***Mean/C°***	***Std. Deviation***	***Min.***	***Max.***
G1=22-28	*12*	*35.33*	*4.96*	*30.00*	*46.00*
G2=29-35	*21*	*34.14*	*1.82*	*32.00*	*38.00*
G3=36-43	*23*	*40.48*	*6.25*	*32.00*	*53.00*
P value	***0.01 H.SIG***				

The results of the current study proved that there were highly significant differences in the average temperatures of the three groups before and after treatment, but they differed in intensity with the difference in age group, as shown in Table (5) and figure (2).

During this experiment, the temperature was measured during the ten shots, and when comparing the temperature rates between the first and last shots, it was found that there was a significant difference for the three age groups, table (6) figure (3).

Table (5): Temperature mean value before and after Tattoo removing

Temperature Before vs After in each group					
Age groups	***Temp. C°***	***Mean/C°***	***Std. Deviation***	***Min.***	***Max.***
G1=22-28	*Before*	*23.00*	*0.60*	*22.00*	*24.00*
	After	*35.33*	*4.96*	*30.00*	*46.00*
P value	***0.003 H.SIG***				
G2=29-35	*Before*	*22.24*	*1.30*	*19.00*	*24.00*
	After	*34.14*	*1.82*	*32.00*	*38.00*
P value	***0.001 H.SIG***				
G3=36-43	*Before*	*22.35*	*1.11*	*20.00*	*24.00*
	After	*40.48*	*6.25*	*32.00*	*53.00*
P value	***0.0001 H.SIG***				

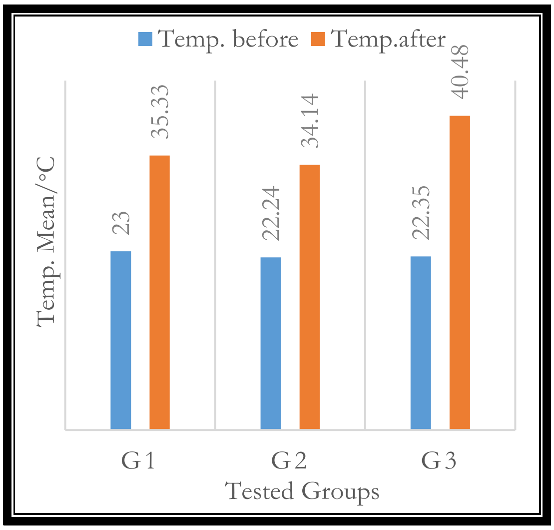

Figure (2): Temperature mean value before and after Tattoo removing

Table (6): Comparative between Shots from 1-10

Shots from 1-10					
Age groups	***Temp .C°***	***Mean/ C°***	***Std. Deviation***	***Min.***	***Max.***
G1=22-28	*Shot 1*	*26.22*	*0.83*	*25.20*	*27.50*
	Shot 10	*39.32*	*4.90*	*35.60*	*49.40*
P value	***0.001 H.SIG***				
G2=29-35	*Shot 1*	*25.38*	*1.81*	*20.90*	*27.30*
	Shot 10	*38.30*	*1.60*	*35.90*	*41.40*
P value	***0.001 H.SIG***				
G3=36-43	*Shot 1*	*25.74*	*1.14*	*23.90*	*27.60*
	Shot 10	*44.24*	*6.52*	*36.00*	*57.00*
P value	***0.0002 H.SIG***				

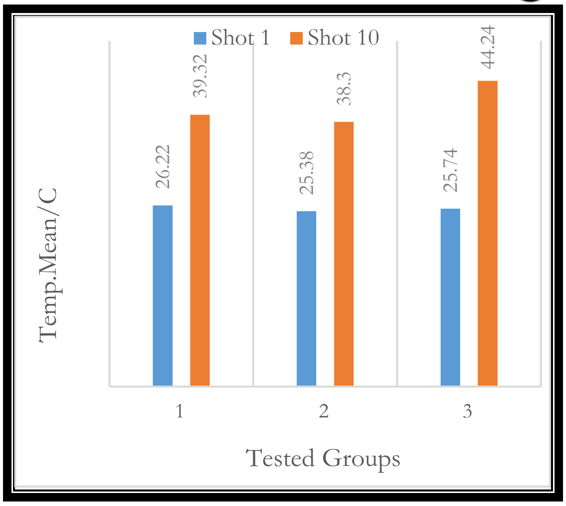

Figure (3): Comparative between Shots from 1-10

4. Discussion

Accurately predicting the temperature range and avoiding heat injury when the skin tissue warms up during treatment is crucial. The statistical analysis's findings indicated that the average age of the three age groups included in the study differed statistically significantly, with a p-value of 0.001. Additionally, the current study discovered that the average temperature before the tattoo removal procedure began did not differ statistically significantly across all age groups, indicating that all experiment participants began at the same temperature. in this study was applied to the temperature range and a thermal camera was also used to monitor the increase in the temperature of the skin tissue. The temperature data displayed by the camera was compared with the standard face temperature. Thus, this approach is more computationally efficient and has a clearer physical meaning. From the temperature range of the treated area and the surrounding skin caused by the increased heat led to the prediction and understanding of the nature of the damaged tissue and the surrounding healthy tissue of the tattoo removed during laser hyperthermia. There are many factors that can affect the temperature range and thermal injury of the skin. that require adjustment of laser parameters. This is evidenced by the strong correlation between laser peak time, energy and spot size with the patient's age and skin color, which has a greater impact on skin tissue temperature and thermal damage. In cases of hyperthermia. In addition, the peak time or heating period can regulate the temperature of the skin tissue to vary within a predetermined range. This is a method that can provide the required level of hyperthermia without causing thermal damage to the skin. The results of this study showed that skin color has an effect on the absorption of the laser beam. In general, data from successful treatments are used to determine parameters such as laser irradiation energy for tattoo removal in laser treatment guidelines. However, in fact, this investigation showed that the results are not only influenced by skin color but also by the patient's age and skin tone. In addition, the effect of laser therapy on thermal conductivity must be taken into account. In addition, when the pigmentation layer that would have received laser treatment reached a higher temperature. The temperature distribution during tattoo removal was captured by the thermal camera. It was observed that the skin temperature of darker skin from the color gamut No. 4 and higher is much higher than other colors after comparing the results. The age of the patient was directly related to the increase. From there, we hope to establish a governing schedule of appropriate temperatures based on the patient's age and skin color, or be approved by medical centers and their staff. Which requires a large number of patients in this case to conduct intensive tests.

5. Conclusion

As the trend of tattoo acquisition increases, the demand for tattoo removal will similarly rise. Nd:YAG laser is a well-established technique against tattoos of different colors, with varying degrees of effectiveness. It can be difficult to treat certain colors, although the results with a laser are promising. Attention should be paid to temperatures and their rise during removal to avoid burns and injuries. In this paper, a relationship of the patient's age to adjust the laser energy by monitoring temperatures has been proven. It needed more energy for greater ages due to the high absorbency to remove tattoo pigments faster and more effectively. Better regulation of the patient's age and skin tone can help ensure safe application and ease of removal.

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