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# Temperature Simulation and Distribution on Human Skin for Different Ages during Philaser Tattoo Removal

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***Abstract*—The causes of laser-assisted tattoo removal difficulties are currently poorly known, and the literature on tattoo removal focuses more on removal methods and equipment than on the ideal treatment parameters, particularly temperature. This study aims to assess the surface temperature in complex eyebrow tattoo removal. This was done for 55 patients aged 22 to 43 years, who were treated with a phi laser (Nd-Yag) 1064 nm in the removal process, with a power of 1000 mJ, a frequency of 3 Hz, and a laser spot size of 8 mm. The surface temperature of the skin during tattoo removal was measured using the FLIR thermal camera. The results were analyzed by testing the normal state of the distribution. The Shapiro-Wilk and Kolmogorov-Smirnov tests were used. A total of 55 people finished full treatment. Three laser sessions were needed on average to achieve the patient's goal (total removal, attenuation for repetition or correction). The results after comparing temperatures showed that the patient's age and skin type have a significant influence on the distribution of skin temperature. As one gets older, the amount of energy absorbed increases. In addition, increased laser absorption is associated with dark skin tones. The benefit of deepening understanding is that it shows temperature distribution in the tissues of the affected area and the surrounding area during laser irradiation, providing a guiding and reference function for the effect of photothermal therapy.**

***Keywords*—Phi laser; IR camera; skin; Shapiro-wilk; patient age; tattoo removal.**

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## I. INTRODUCTION

Laser tattoo removal uses high-intensity light beams to break up the tattoo ink into tiny particles. These particles are then naturally eliminated by your immune system, causing the tattoo to fade over time [1]. In the fields of engineering and dermatology, lasers have become important therapeutic tools [2], [3], [4], [5]. 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 minimal wound and rapid healing [2]. 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 considered the gold standard, but its effectiveness is influenced by various factors. The patient's age, skin color, and tattoo age significantly affect treatment outcomes [6]. The purpose of this study was to simulate the relationship between lasers and tissues in medical applications by recognizing how tissues react thermally to laser radiation. By creating models and simulation tools, prediction and evaluation techniques are proposed to reduce unwanted side effects from heat damage and serve as a basis for future treatment strategies [7]. With proof of the laser wavelength and how it affects the patient's age and tissue type, and the time allotted for heat transfer in 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 [8]. 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 the patient's age and operating conditions and their effect on heat transfer in the skin layers during laser irradiation in this area (forehead), and because of its great importance, as it is very close to the eye area as well as the brain [9]. Given the complexity of the interactions between the various factors that may be linked to these difficulties, defining best practices is a challenging task. In this work, we employ a number of traditional statistical approaches and strategies to identify characteristics that might be more closely linked to the reasons for tattoo removal difficulties, with outcomes that provide proof of possible better practices. Lastly, a statistical model explains how laser treatment parameters interact with the skin and builds a system order for processing parameters using boot and gradient enhancement [10].

## II. Materials and Methods

Import thermal video and images recorded by the thermal camera during laser removal of tattoos from leather and convert them into frame sequences (still images at a specific frame rate). Calculate 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., frames 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 areas, which 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 [11].

### A. *Patient Preparation*

It is important to properly clean the area that will be treated and remove any remaining makeup or skin care products. Avoid cleaning products that could catch fire, such as isopropyl alcohol. Topical anesthetics like 5% lidocaine cream (LMX-5) and 2.5% lidocaine/2.5% prilocaine (EMLA) are frequently used under occlusion for 45–60 minutes because tattoo removal might be difficult for the patient. Before beginning treatment, the anesthetic should be totally eliminated. The use of cool air during therapy, regional nerve block, local lidocaine infiltration, or a combination of these techniques is another way to lessen patient discomfort. During the laser process, all medical staff are required to wear safety goggles that are specific to the wavelength. Additionally, protective goggles or external metal eye shields must be given to the patient. Intraocular metal eye shields should be applied to the patient if the treated area is on the eyelid or close to the orbit [12].

### B. *IR CAMERA*

Infrared thermal imaging with FLIR thermal cameras has demonstrated encouraging outcomes in detecting temperature changes on human skin. These cameras can detect unusual temperature distributions that signify wounds, injuries, and illnesses [13], [14]. FLIR cameras are particularly helpful for patients with darker skin tones [15], and have demonstrated value in tracking temperature variations on the skin caused by internal body temperature fluctuations. FLIR One produces high-quality photos [13]. These thermal cameras are useful instruments for improving patient monitoring and results in medical settings because of their offline nature and intuitive interface [15].

### C. *Phi Laser*

One of the most significant changes of the new laser is the improvement of the pulse duration. While the predecessor had a pulse duration of 8 nanoseconds, our new PhiLaser Type R 2.0 needs only 2 nanoseconds. So, the machine is four times quicker! The shorter pulse shreds the particles more finely and thus allows the immune cells to remove them more easily [16]. Phi Laser enables you to achieve the best laser treatment results. It has the latest technology, stylish design, and, of course, maximum efficiency. There are multiple types, such as Phi Laser Type-R 2.0 and Phi Laser Type-H, suitable for different types of treatment. Depending on the desired application, for example, to remove tattoos or pigment spots, to remove eyebrow tattoos, or to remove hair. Lasers can also be used to clean clogged pores, for intensive exfoliation, or to purify the skin. Treatment is carried out using a portable device that delivers laser pulses to the eyebrow tattoo. The laser will feel like a series of shots or pinches on the skin. The duration of each session depends on the size and color of your tattoo, but most eyebrow tattoos only take a few minutes to treat [17]. After treatment, a soothing gel or cream is applied to the eyebrow, and some aftercare instructions are given. You may experience some redness, swelling, or blistering on the treated area, but these are normal and temporary side effects. They will subside within a few days or weeks.

## III. Results and Discussion

In this study, the skin surface temperature of 55 patients was measured while using a laser to remove tattoos from the eyebrow area. The ages ranged from 22 to 43, and the skin colors varied; since an FLIR camera was used to assess 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 1000mj and a frequency of 3Hz, and a laser spot size of 8mm. They were 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 tests were 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 forehead is divided into three areas: the left front, the middle front, and the right front. This is consistent with findings by [18] to identify sources of temperature variation measurements. R&R analysis looks at sources of variation in the 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 of the subgroups analyzed is at least 3, and the distribution of results in each of the subgroups is not significantly different from the theoretical normal distribution. The normal state of all subgroups was confirmed by the Shapiro-Wilk 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.

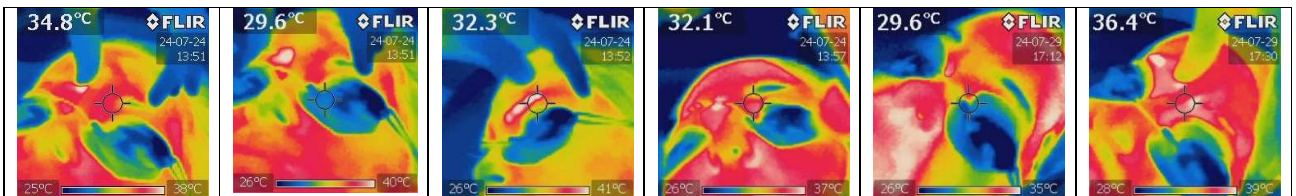
TABLE I
SKIN TONE.

| Skin Tone | |
|---|---|
| vanilla | 1 |
| beige | 2 |
| almond | 3 |
| golden | 4 |
| mocha | 5 |
| toffee | 6 |

Table 2 shows the heat distribution of different ages and skin tones. It shows the close relationship between high temperatures and the patient's age. As shown in Figure 1, the infrared photos.

TABLE II
TEMPERATURES WITH AGE AND SKIN TONES

| Patient No. | SEX | Age | laser energy | Skin tone | Minimum temp. | Maximum temp. | avg |
|---|---|---|---|---|---|---|---|
| 1(A) | female | 25 | 1000mj | 3 | 25 | 38 | 34.8 |
| 2(B) | female | 35 | 1000mj | 4 | 26 | 40 | 29.6 |
| 3(C) | female | 40 | 1000mj | 4 | 26 | 41 | 32.3 |
| 4(D) | female | 25 | 1000mj | 2 | 26 | 37 | 32.1 |
| 5(E) | female | 22 | 1000mj | 2 | 26 | 35 | 29.6 |
| 6(F) | female | 37 | 1000mj | 3 | 28 | 39 | 36.4 |




| 1A | 2B | 3C | 4D | 5E | 6F |
|---|---|---|---|---|---|

Fig 1 The infrared photos [1A, 2B, 3C, 4D, 5E, 6F]

To test the normality of distribution, the Shapiro-Wilk test and Kolmogorov-Smirnov test 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 were subjected to the normal state test of distribution and were tested using two important tests. Results ($P > 0.05$) were considered insignificant. The study sample was divided into three age groups, with the minimum age at 22 and the maximum at 43. The sample selection was random and natural; however, the sample sizes for the age groups were unequal: 12, 23, and 21 for the three groups, respectively.

TABLE III
STATISTICAL ANALYSIS FOR AGE RANGE DISTRIBUTION IN TESTED SAMPLES

| Age groups Year | N | Mean | Std. Deviation | Minimum | Maximum |
|---|---|---|---|---|---|
| **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 in Table 3, the study demonstrated a highly significant difference ($p = 0.001$) between the mean age for the three age groups included in the study. The current study also found no significant differences in the mean temperature 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 4. 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 a highly significant p-value of 0.01, as shown in Table 5.

TABLE IV
TEMPERATURE BEFORE TATTOO REMOVAL

| **Temperature Before** | | | | | |
|---|---|---|---|---|---|
| **Age groups** | **N** | **Mean/C°** | **Std. Deviation** | **Minimum** | **Maximum** |
| **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** | | | | |

TABLE V
TEMPERATURE AFTER TATTOO REMOVAL.

| Temperature After | | | | | |
|---|---|---|---|---|---|
| **Age groups** | **N** | **Mean/C°** | **Std. Deviation** | **Minimum** | **Maximum** |
| **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 Table6 and Figure 2.

TABLE VI
TEMPERATURE MEAN VALUE BEFORE AND AFTER TATTOO REMOVAL

| Temperature Before vs After in each group | | | | | |
|---|---|---|---|---|---|
| **Age groups** | Temp. °C | Mean/C° | Std. Deviation | Minimum | Maximum |
| **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 | | | | |

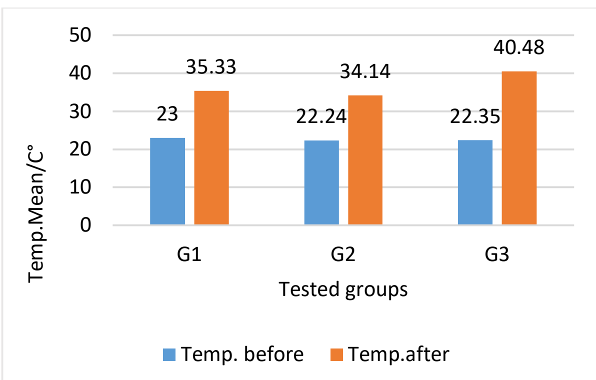



Fig. 2 Temperature mean value before and after Tattoo removing.

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 7, Figure 3.

TABLE VII
COMPARISON BETWEEN SHOTS FROM 1-10.

| Shots from 1-10 | | | | | |
|---|---|---|---|---|---|
| **Age groups** | **Temp .C°** | **Mean/C°** | **Std. Deviation** | **Minimum** | **Maximum** |
| **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** | | | | |

Accurately predicting the temperature range and avoiding heat injury when the skin tissue warms up during treatment is crucial. The statistical analysis found 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 found that the average temperature before the tattoo removal procedure did not differ statistically significantly across all age groups, indicating that all participants began at the same temperature.

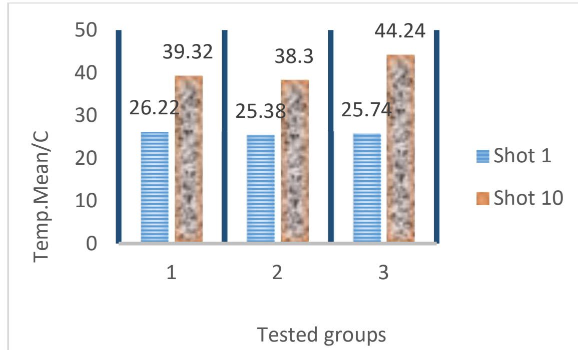



Fig. 3 Comparison between Shots from 1-10.

In this study, the temperature range was applied, 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 were compared with the standard face temperature. Thus, this approach is more computationally efficient and has a clearer physical meaning. 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.

Many factors can affect the temperature range and thermal injury of the skin. These 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 method can provide the required level of hyperthermia without causing thermal damage to the skin. The results of this study showed that skin color affects 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, this investigation showed that the results are influenced not only 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, 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. After comparing the results, it was observed that the skin temperature of darker skin from color gamut No. 4 and higher is much higher than that of other colors. The patient's age 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. This requires a large number of patients in this case to conduct intensive tests.

## IV. 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 laser results 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 and adjusted laser energy by monitoring temperatures has been proven. It required more energy for older patients due to higher 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.

## References


[1] C. Goh and S. Ho, "Laser Tattoo Removal: A Clinical Update," *J. Cutan. Aesthetic Surg.*, vol. 8, no. 1, p. 9, 2015. doi: 10.4103/0974-2077.155066.

[2] L. Carroll and T. R. Humphreys, "LASER-Tissue Interactions," *Clin. Dermatol.*, vol. 24, no. 1, pp. 2–7, Jan. 2006. doi:10.1016/j.clindermatol.2005.10.019.

[3] "Laser (Light Amplification by Stimulated Emission of Radiation) Therapy (LT)," in *Dictionary of Rheumatology*, J. Rovenský and J. Payer, Eds. Vienna, Austria: Springer, 2009. doi: 10.1007/978-3-211-79280-3_646.

[4] R. G. Gould, "The LASER, Light Amplification by Stimulated Emission of Radiation," in *The Ann Arbor Conference on Optical Pumping*, P. A. Franken and R. H. Sands, Eds. The University of Michigan, 1959, p. 92.

[5] T. H. Maiman, "Optical and Microwave-Optical Experiments in Ruby," *Phys. Rev. Lett.*, vol. 4, no. 11, pp. 564–566, Jun. 1960. doi:10.1103/physrevlett.4.564.

[6] M. M. Zaret, G. M. Breinin, H. Schmidt, H. Ripps, I. M. Siegel, and L. R. Solon, "Ocular Lesions Produced by an Optical Maser (Laser)," *Science*, vol. 134, no. 3489, pp. 1525–1526, Nov. 1961. doi:10.1126/science.134.3489.1525.

[7] M. A. Ansari, M. Erfanzadeh, and E. Mohajerani, "Mechanisms of Laser-Tissue Interaction: II. Tissue Thermal Properties," *J. Lasers Med. Sci.*, vol. 4, no. 3, pp. 99–106, 2013.

[8] F. B. Goldsmith, "Coppicing — A Conservation Panacea?," in *Ecology and Management of Coppice Woodlands*, Springer Netherlands, 1992, pp. 306–312. doi: 10.1007/978-94-011-2362-4_16.

[9] A. Bindra, B. Bindu, and G. Rath, "Temperature Management Under General Anesthesia: Compulsion or Option," *J. Anaesthesiol. Clin. Pharmacol.*, vol. 33, no. 3, p. 306, 2017. doi:10.4103/joacp.joacp_334_16.

[10] R. Yim, "Statistical Learning for Best Practices in Tattoo Removal," *SIAM Undergrad. Res. Online*, vol. 15, 2022. doi:10.1137/21s1421325.

[11] F. Pazhoohi and A. Kingstone, "The Effect of Movie Frame Rate on Viewer Preference: An Eye Tracking Study," *Augment. Hum. Res.*, vol. 6, no. 1, Jan. 2021. doi: 10.1007/s41133-020-00040-0.

[12] A. E. Ortiz and T. S. Alster, "Rising Concern over Cosmetic Tattoos," *Dermatol. Surg.*, vol. 38, no. 3, pp. 424–429, Mar. 2012. doi:10.1111/j.1524-4725.2011.02202.x.

[13] A. Kirimtat, O. Krejcar, A. Selamat, and E. Herrera-Viedma, "FLIR vs SEEK Thermal Cameras in Biomedicine: Comparative Diagnosis Through Infrared Thermography," *BMC Bioinformatics*, vol. 21, no. S2, Mar. 2020. doi: 10.1186/s12859-020-3355-7.

[14] A. Kirimtat and O. Krejcar, "FLIR vs SEEK in Biomedical Applications of Infrared Thermography," in *Lecture Notes in Computer Science*, Springer International Publishing, 2018, pp. 221–230. doi: 10.1007/978-3-319-78759-6_21.

[15] Z. Nelson, L. O'Neill, A. H. Fisher, S. D. Kozusko, K. Addagatla, and D. Bird, "Postoperative Detection of Free Flap Congestion in a Fitzpatrick Skin Type VI Patient Using the Flir Thermal Imaging Camera: A Case Report and Literature Review," *Plast. Reconstr. Surg. - Glob. Open*, vol. 9, no. 10S, pp. 127–128, Oct. 2021. doi:10.1097/01.gox.0000799756.22231.87.

[16] D. S. Filippychev, "Computing the Particle Paths in an Open-Trap Sharp-Point Geometry," *Comput. Math. Model.*, vol. 12, no. 3, pp. 193–210, Jul. 2001. doi: 10.1023/a:1012589205469.

[17] L. Hernandez, N. Mohsin, F. S. Frech, I. Dreyfuss, A. Vander Does, and K. Nouri, "Laser Tattoo Removal: Laser Principles and an Updated Guide for Clinicians," *Lasers Med. Sci.*, vol. 37, no. 6, pp. 2581–2587, May 2022. doi: 10.1007/s10103-022-03576-2.

[18] S. Ariyaratnam and J. Rood, "Measurement of Facial Skin Temperature," *J. Dent.*, vol. 18, no. 5, pp. 250–253, Oct. 1990. doi:10.1016/0300-5712(90)90022-7.