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Predicting the Therapeutic Results of Unwanted Hair Growth with the Alexandrite Laser Device

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Abstract:
The growth of excess hair on the chin, under the neck, near the navel, around the chest, etc. is one of the main disorders that both women and men face. The best, most efficient and least invasive way to remove thick and dark hair is to use a laser. It is important to check the effectiveness of laser in removing unwanted hair after treatment sessions. In this study, the treatment of unwanted hair in the armpit or thigh area in 14 patients was investigated. The participants with skin type I and III were aged 37-27 years and were treated with 755 nm alexandrite laser. Examination of each area (armpit and thigh) was done with a camera system specifically to count the number of hairs at 1 and 3 months after the treatment period. In this study, Monte Carlo modeling was used to estimate the density of excess hair remaining after treatment sessions, and the results showed that the number of excess hair decreased both by Monte Carlo method and manual counting method, and the accuracy rate of the simulation was 75%.

Keywords: Laser, Monte Carlo Simulation, Excess Hair.

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Introduction

Nowadays, in addition to its therapeutic aspects, the removal of unwanted hair has been considered more as a beauty aspect, especially in women (1). The growth of excess hair in different parts of the body causes an inappropriate appearance and sometimes causes the accumulation of pollution and infection and causes skin diseases. One of the ways to remove unwanted hair is to use a laser. In this method, a very concentrated light shines on the hair follicles and the pigments in the follicles absorb the light (4-2). This causes hair loss. One of the most used lasers in the field of body hair removal is the Alexandrite 755nm laser. Alexandrite laser is a type of laser that produces high-energy light through an alexandrite crystal. When the light passes through the alexandrite crystal, a 755nm light beam is produced. This laser can be set in Q-switching mode, which causes the laser to produce a high-energy beam of light in short pulses (5,6). This is what makes it effective on unwanted hair. Laser hair removal is known as the least invasive method to remove ingrown hairs compared to other methods.

Treatment of skin tissue with photoactive materials and light such as nanoparticles and compounds useful in cosmetic, diagnostic and therapeutic applications in mammals such as humans. In particular, embodiments of hair removal with coated metal nanoparticles are presented (7, 8). It is important to investigate the effectiveness of laser in removing unwanted hair after treatment sessions. In this research, Monte Carlo modeling was used to estimate the density of remaining unwanted hair after treatment sessions with 755nm alexandrite laser.

Materials and Methods

The database includes 14participants of laser hair removal treatment. In this research, the treatment of unwanted hair in the armpit or thigh area has been done. People with skin type I and III were in the age range of 37-27years. All of them were treated with 755nm alexandrite laser in three treatment sessions, one month apart from each session. Two treatment areas were selected using commonly accepted parameters for permanent hair reduction as well as a control non-treatment area. Each treatment area was examined with a camera system specifically to count the number of hairs at 1and 3months after the second treatment. The specifications of the laser device used are given in Table 1. For example, the image of the treatment area of one of the subjects, in the first and third sessions of the treatment, can be seen in Figures 1and 2, respectively.

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Table 1: Specifications of the laser device used

Model	Company name (brand)	Wavelength	Spot size	Cooling	Fluence	Pulse width
GentleLase/ Alexandrite laser	Candela	755 nm	18 mm (Diameter)	Cryogen Spray	18 J/cm^2	30 ms

Preprocessing:
Consecutive digital photographs were obtained using the same lighting, patient positioning and camera equipment at the beginning and during the three-month treatment. Hair counting was done manually and final hair marking was done using digital photos of the treatment session and during the final evaluation 3 months after the last treatment. In general, only pre-processing images were matched in terms of size.

Monte Carlo Simulation:
The Monte Carlo method is a computational algorithm that uses random sampling to calculate results. Monte Carlo methods are usually used to simulate mathematical and economic physical systems. In computer science, it is a method that finds the solution by scanning the entire space of the problem. In this research, Monte Carlo modeling was used to estimate the density of residual hair after treatment sessions with 755 nm alexandrite laser. Using the Monte Carlo method, it is possible to properly simulate the propagation of photons in the skin.

Creation and Determination of Photon Step Length:
First, we randomly generate numbers between 0 and 1 by assigning a weight (W) equal to 1 for each photon. Photons are irradiated vertically on the coordinate system. The Monte Carlo procedure is such that after creating a photon, it is important to determine the step length of the photon. This length represents the distance that the photon travels in the tissue, without any interaction. This will be done by sampling from the probability distribution function and as a function of generated random numbers.
Photon movement: after determining the step length of the photon, we start to move it in the drum, this work is done by changing the coordinates of the photon and the vertical angle of the radiation.
Absorption, distribution and destruction of photons: The amount of reduction in the initial weight of photons due to the interaction of photons with the skin is called absorption of photons, which leads to an increase in tissue temperature. A part of the photon is spread, the amount of photon spread is determined using random sampling from the probability distribution related to the

cosine of the angle, which is known as the phase function or the Henyey-Greenstein probability function. The weight of the photon decreases after each radiation and interaction with the tissue and finally reaches zero.

Data Processing:

Simulation and processing operations are done in MATLAB software. Light propagation was simulated using the Monte Carlo method and heat transfer in the tissue was simulated using the finite difference method. The suggested method is to manually count the number of skin surface hairs in the first sessions (as initial information) and then predict the number of unwanted hairs in the next sessions. The images of the treatment area are scanned and divided into equal areas, and then the hairs of each area are counted. An example of the treatment configuration of one of the subjects in the first and third sessions is shown in Figures 3 and 4, respectively. We have used a grading system of hair reduction, assuming zero is less than 25%, one, 25 to 50%; two, 51 to 75%; Three indicates 76 to 90% and four indicates more than 90%. The evaluation of the photos in 1 and 3 months showed that there is a significant decrease in the number of hair (55%) and hair coverage (60%). In order to calculate the predicted performance probability distribution, in MATLAB programming, the input uncertainties have been transferred to the output uncertainties. In the Monte Carlo simulation, the whole system has been executed many times (Realization) around 1000 times (Figure 5). For each realization, all non-deterministic parameters have been sampled, which means that a random value from the specific distribution corresponding to each parameter was selected. Then, this system was simulated with certain input parameters over time. This simulation is done in such a way that finally the efficiency of the system can be calculated. This results in a large number of independent and separate outcomes, each representing a possible "future" for the system.

We consider each area of the skin in at least 6 different states. If each image has two sides, 12 modes are created, which is obtained by dividing the number 6 by 12, and the value 0.5 is obtained. The results of the simulation to predict 6 laser treatment sessions using the initial information of the first session as well as the initial information of the first to third sessions can be seen in Figures 6 and 7, respectively.

Discussion

Excessive growth of unwanted hair in different parts of the body can have deep psychological consequences for people, especially teenagers, and its treatment is necessary to improve the quality of life (9,10). Laser is one of the non-invasive and effective treatment methods that may be used to treat patients with excessive hair growth (5,8). The desire to remove unwanted body hair has become a growing trend in society and the interest in using lasers for this purpose has been strengthened, especially among the young population. Laser systems emit light with a specific wavelength, which is subsequently absorbed by a specific receptor dye or chromophore.

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Factors such as a person's skin type, hair color, medications, concomitant diseases, tissue optical characteristics and absorption coefficient should also be considered for treatment (11-14). Some hormonal conditions such as polycystic ovary syndrome, hypothyroidism, congenital adrenal hyperplasia, Cushing's syndrome, etc. can cause excessive hair growth. Some drugs, such as corticosteroids, hormones, and minoxidil, cause unwanted hair growth. In some diseases, such as psoriasis, lichen planus, vitiligo (leprosy), there is a possibility of lesions at the laser site. In these patients, laser will not have the right effect. In these cases, additional treatments may be needed to control the hormonal status (15,16,1).

In 2017, Campos investigated the effects of using the 755 nm alexandrite laser to remove unwanted hair in Brazilian skin types, including types 3 and 4. 8 subjects participated in this research. The duration of 6 months and 4 treatment sessions was considered. Photographs were taken of the treatment areas before and after the treatment. Before starting the treatment and after the fourth treatment session, the number of unwanted hairs was counted manually and a significant reduction was observed (1). The existence of the covid epidemic was one of the limitations of this study (17).

In 2018, Nistico and his colleagues used a 755 nm alexandrite laser with a sapphire handpiece to remove unwanted hair. 49 subjects with skin type 2 to 4 participated in their research. The laser energy used is between 6 and 8 joules per square centimeter. The treated areas included areas of the face, hands, feet, groin, and armpits. Eight areas of 3 x 2 cm were identified and photographed. Consecutive digital photographs were obtained using the same lighting, patient positioning and camera equipment at the beginning and during the three-month treatment. Hair counting was done manually and final hair marking was done by two independent observers using digital photos before treatment and during the final evaluation 3 months after the last treatment. They used a grading system of hair loss. Zero less than 25%, one 25 to 50%, two 51 to 75%, three 76 to 90% and four more than 90% (2). In 2019, Gold and his colleagues used a mix of 755 nm and 810 nm diode alexandrite lasers to remove unwanted hair. 50 subjects participated in this research, 3 treatment sessions were performed in 6 weeks. The concerned areas were photographed before and after the treatment and the number of removed hairs was counted manually. The treatment results were acceptable (3).

In 2020, Azin Ayatolahi and his colleagues have compared and investigated the effectiveness of the new 755 nm alexandrite diode laser and the traditional 755 nm alexandrite laser. 20 women with skin type 3 and 4 participated in this research. Each person was treated in 6 sessions at intervals of 1 month. Each axilla was selected as the target area for hair counting and other evaluations. Hair was counted before laser and 6 months after the last session using digital photographs. The present study showed that the 755 nm diode laser is suitable for hair removal methods and is as effective and safe as the traditional 755 nm laser (4).

In 2020, Russe and his colleagues investigated the safety and efficiency of the 755 nm alexandrite laser in removing unwanted hair from different parts of the body. The average laser

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energy used by them is 23.8 J/cm2. This study is based on a retrospective data analysis that includes all laser hair removal procedures at Laserzentrum Innsbruck and Instituto di Fotomedicina Centro Medico Teknon Barcelona between 1997 and 2005 and followed up to 2013. As a standardized clinical outcome measure in both clinics, patients and doctors were evaluated in two follow-up intervals. The first follow-up was evaluated at least one year after the final treatment. The second follow-up was evaluated at least 8 years after the final treatment. There was no additional treatment between the first and second follow-up. In the first follow-up, the doctor checked the amount of clearance in the site by comparing the results with the photos taken before the treatment. In the same follow-up, the patient evaluated the degree of cleansing by personal observation as well as the patient's satisfaction. The clearance rate was evaluated in five different groups: 0-25, 25-50%, 50-75%, 75-95% and 95-100% satisfaction from the patient's point of view on a scale from 1 (best) to 5 (worst). it is registered. In the second follow-up, the patients compared permanent or non-permanent hair removal compared to the first follow-up, and the results were acceptable (5).

Many systemic diseases or their treatment require changes in treatment plans. Also, lack of attention and specialized care in dental treatments may cause serious complications and various problems during treatment (18-20). Due to the increase in the number of patients who have chronic medical conditions, as well as the potential risks that treatment can cause, medical consultation before treatment seems necessary (21-23).

In this research, Monte Carlo modeling was used to estimate the density of residual hair after treatment sessions with 755 nm alexandrite laser in order to evaluate the role of the number of treatment sessions in the effectiveness and safety of hair removal using laser. After analyzing the results, we found that the number of unwanted hair has decreased by both Monte Carlo method and manual counting method, and the simulation accuracy rate has reached 75%. It can be said that the combination of experiments and Monte Carlo simulations is a very successful strategy to study the details of hair removal and regrowth. For future research, the following are suggested: 1- In order to increase the reliability of the results, more people should be recorded. In this way, it can be ensured that the studied people did not influence the results and whether the results obtained were a series of general results or not. . 2- The methods of improving Monte Carlo algorithms should be investigated in order to solve the implementation problems in this method if possible. 3- In this project, most of the focus has been on the normal Monte Carlo method, which according to the favorable results of several researchers' studies, it is suggested to study new Monte Carlo methods. 4- Different validation methods as well as different classification methods can be checked in order to classify images in different sessions.

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Figure 1: The armpit area of one of the patients in the first session (skin type I).

Figure 2: The armpit area of one of the subjects in the third session (skin type I).

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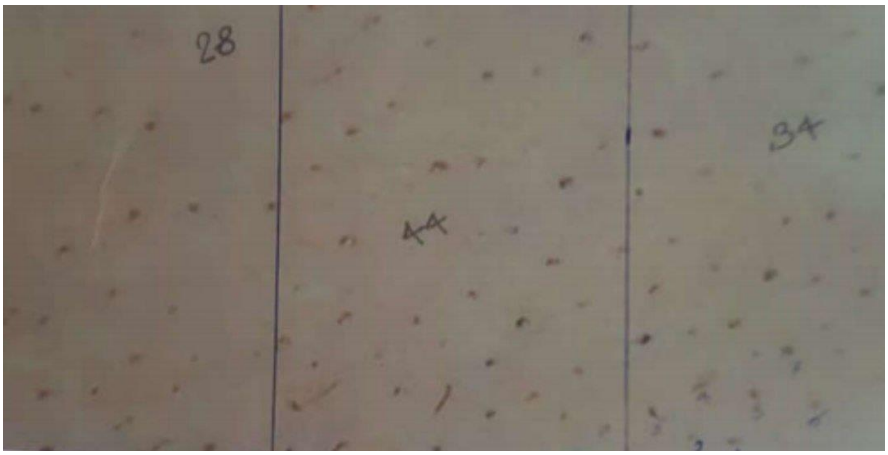

Figure 3 : An example of the treatment configuration of the first session. Two treatment areas and one control area which is the rectangle on the right.

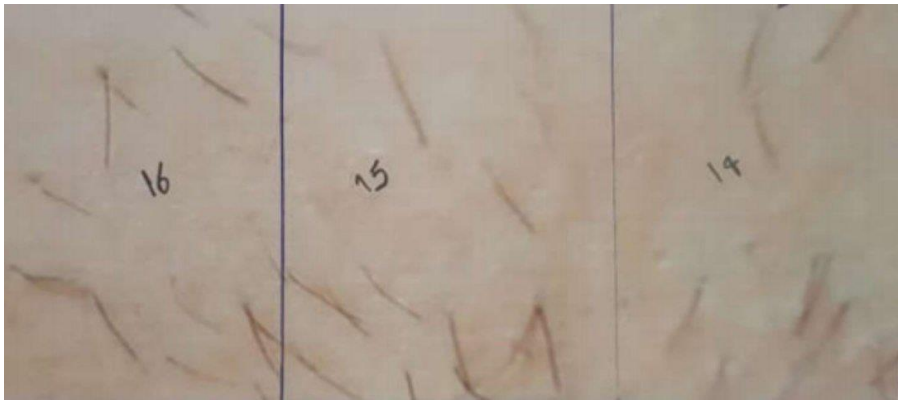

Figure 4: An example of the treatment configuration of the third session. Two treatment areas and one control area which is the rectangle on the right. As can be seen, the number of unwanted hairs in the third session of the laser has decreased compared to the first session.

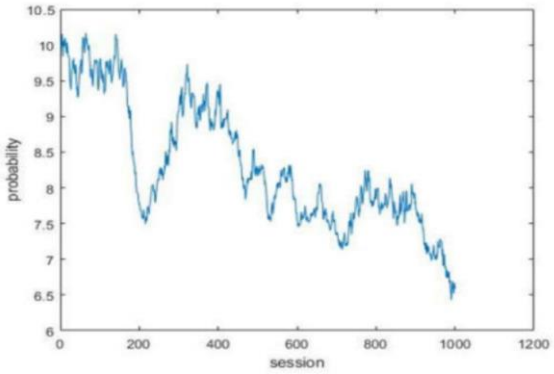

Figure 5: Random simulation using initial information from the first to third sessions

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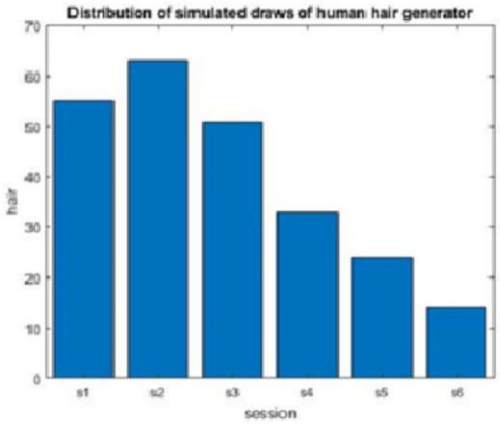

Figure 6: Prediction of 6 laser treatment sessions with the initial information of the first session

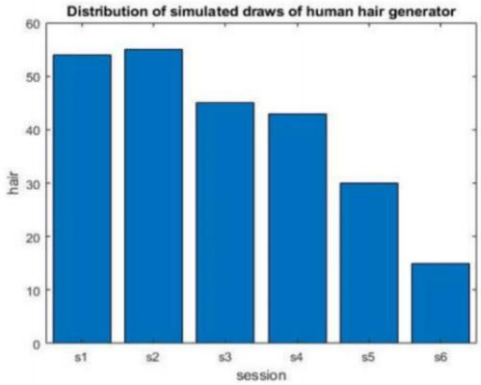

Figure 7: Prediction of 6 laser treatment sessions with initial information of the first to third sessions

