

Study the physical coefficients for some of Melasma cases treated by laser

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Abstract:

Melasma is a common skin condition that results from an imbalance in melanin production. This imbalance causes the appearance of dark, symmetrical patches on areas of the skin that are often exposed to sunlight, especially the face. These patches are usually brown to gray-black in color and have irregular borders. Among the different treatment options available, laser therapy has shown promising results. In this study, the Spectra VRM III laser, which operates at a wavelength of 1064 nm, was used to treat melasma. The laser helps reduce pigmentation by breaking down the excess melanin that accumulates in the skin. The success of laser treatment depends on several physical factors, including the melanin absorption coefficient, the refractive index, and the scattering coefficient. The findings indicate that as melasma becomes deeper in the skin layers, the absorption of the laser energy decreases, which lowers the laser's ability to inhibit melanin production. This leads to the need for more treatment sessions and suggests that deeper melasma cases may require a longer and more complex approach. Understanding how these physical properties interact with laser treatment can help improve outcomes and tailor treatment plans to individual cases.

Keywords : melasma, laser, scattering coefficient, absorption coefficient, melasma depth

1-Introduction:

Melasma is a prevalent pigmentation illness marked by symmetrical, defined patches that range from light to dark brown, often manifesting in sun-exposed regions of the skin, particularly on the face, and sometimes affecting the neck and forearms [1]. This is mostly due to UV exposure [2]. Melasma, a dark brown color, originates from the Greek word "milas" and is often seen in pregnant women, sometimes referred to as a "pregnancy mask" [1]. Studies point to the potential role of many risk factors such as genes, sunlight, age, sex, hormones, pregnancy, thyroid dysfunction, cosmetics, and medications [1], [3], as well as uterine and ovarian illnesses [4]. Melasma can affect individuals of all Fitzpatrick skin types; however, it is more common in darker skin types (Fitzpatrick skin types III to VI) [5]. This condition is more common in women than in

men, although men can also develop it. The pathophysiology of melasma is multifactorial and complex.

Pigmentation is caused by the overproduction of melanin by melanocytes, which are absorbed by keratinocytes and deposited in the dermis[6]. Melasma is classified according to the depth of melanin pigment into epidermal melasma and mixed melasma (a combination of the epidermal and dermal types)[3]. The treatment of melasma is a challenge and can be difficult due to its refractory and recurrent nature. A variety of therapeutic approaches include topical formulations[7], oral drugs, and chemical peeling[4]. Laser therapy is an alternative approach to melasma treatment and may be especially useful for patients with melasma resistant to topical treatment, chemical peels, or when the patient wants to improve quickly[8].

There are many studies that have relied on laser melasma treatment [9], [10], [11]. In this study, the Spectra VRM III Laser with a wavelength of 1064 nm was used due to its ability to penetrate deep into melasma. The optical characteristics of biological tissues determine how much laser light may penetrate certain tissues [9], [10]. The purpose of this research was to examine the relationship between the depth of melasma and physical variables. The study reveals that the depth of melasma reduces the absorption coefficient, resulting in a decrease in the inhibition coefficient of the melanin cell, thereby increasing the number of treatment sessions, and the weight of melanin also increases.

2 - Theoretical part:

The absorption coefficient, represented as (α_a), is defined as the likelihood of photon absorption in a medium per unit length of a route, expressed by the following relation [12]:

$$\alpha_a = \frac{2.303.e.x}{64500} \quad (1)$$

where e.x represents the molar decay coefficient.

The following formula gives the scattering coefficient, which is represented as α_s , which is the likelihood of photon scattering in a medium per unit length of a route [12]:

$$T(x) = \exp(-\alpha_s x) \quad (2)$$

Where (x) represents the depth of the melasma, (T) represents the of the skin .

The effective scattering coefficient is symbolized by the symbol (α'_s) and is given by the following equation [13]:

$$\alpha'_s = \alpha_s(1 - g) \quad (3)$$

Scattering coefficient , (α_s) The contrast factor represents. (g)

The refractive index of the compound melanin is given by the apparent law according to Nelson [14]:

$$N_m = 1.57 + i \frac{\alpha_a \lambda}{4\pi} \quad (4)$$

(λ) represents the wavelength in meters, (α_a) represents the absorption coefficient in m^{-1} .

The absorbed weight of the melanin pigment is denoted by the symbol W_{ma} and is given by the following equation [15]:

$$W_{ma} = \frac{\alpha_a}{\alpha_a + \alpha_s} * W_m \quad (5)$$

W_m Represents the weight of the melanin pigment.

3- Methodology :

Seven women suffering from melasma in different areas of the face such as the forehead and sides of the face were treated, the patients' ages ranged between (27-42) years. These samples were obtained from different centers inside and outside Iraq. After taking the patients' practical data by specialized dermatologists, shown in Table (1), the appropriate laser was determined to treat these cases and the required wavelength was determined. Spectra VRM III Laser with a wavelength of 1064 nm was used. The Spectra Laser device is considered one of the most powerful and best laser skin treatment devices in the world and is the only device in the world approved by the US Food and Drug Administration (FDA) for the treatment of melasma. This is by relying on this device on the ND: YAG laser with great efficiency in treating various skin lesions with different wavelengths depending on the nature of the lesion, which makes the Spectra device clearly preferred and superior to all other types of lasers

available in other dermatology clinics. The Spectra VRM III laser device is also characterized by automatic sensitivity to the size and shape of the lesion, which gives a high margin of safety for treatment with this device, as it preserves healthy skin tissue and directs directly and specifically towards the affected or discolored tissues. This, in addition to the laser beam pattern emitted by the device, the ability to control the energy options that the beam must include (you can choose between four laser beam wavelengths), the short duration of the laser pulse (60 μ s), and its increased power, makes it possible to increase the effectiveness of the device while reducing thermal damage to the surrounding tissues. as this laser is characterized by its ability to target the affected tissues without damaging the surrounding tissues. We directed the laser beam to the affected area with a spot diameter of 6 mm, where the exposure

time was 5 minutes in each session and the time period between one session and another was one month.



Fig.(1): Spectra VRM III

4- Results and Discussion

Based on the experimental data presented in Table (1), and by applying the relevant equations, a relationship was established linking the scattering coefficient and the reduced scattering coefficient with the melanin pigment weight and its refractive index, as shown in Table (2). The table demonstrates a direct correlation between the scattering coefficients and the melanin pigment weight, where both coefficients increase as the melanin weight increases. This is attributed to the fact that the optical properties of melanin—such as scattering and refractive index—are influenced by its concentration and weight within the skin. As melanin concentration increases, the number of particles that scatter light within the skin also increases, leading to enhanced light scattering due to the interaction of photons with a larger number of pigment particles. Furthermore, increased melanin concentration may induce

changes in the skin's optical composition, resulting in a decrease in the melanin refractive index.

The laser parameters used in this study were selected based on a review of relevant scientific literature, as well as clinical expertise in managing melasma cases. The chosen wavelength corresponds to the melanin absorption spectrum, allowing effective targeting of pigmented lesions at various skin depths. Pulse duration and session intervals were carefully adjusted according to tissue characteristics to minimize unwanted thermal effects and prevent irritation or inflammation, while ensuring sufficient absorption in the affected areas. Fitzpatrick skin types were also considered to ensure safety and efficacy across all targeted groups. These settings represent a balanced approach between therapeutic effectiveness and tissue safety, with

recommendations for future studies to further refine parameter selection based on melasma depth and skin type.

This study focused on patients with similar skin types, particularly Fitzpatrick skin type III. As a result, it did not account for variations in skin type, age, or other patient-specific factors that may influence treatment response. While this approach helped reduce variability and isolate the effect of laser parameters, it also limits the generalizability of the findings.

Figure (2) illustrates the relationship between melasma depth, melanin absorption coefficient, and the number of treatment sessions required. An inverse relationship was observed between melasma depth and the absorption coefficient, where the absorption coefficient decreases as melasma depth increases [16]. Although long-wavelength lasers target melanin in the dermal layer (deep melasma), a significant portion of the beam is absorbed by the increasing pigment concentration in the melasma lesion [17], leading to a higher number of treatment sessions needed.

Table (1): Patient data.

Cases	P1	P2	P3	P4	P5	P6	P7
Gender	Female	Female	Female	Female	Female	Female	Female
Age	38	32	27	27	30	42	40
Skin color	IV	III	II	II	II	II	IV
Area of involvement	Side of the face	Forehead	Side of the face	Side of the face	Side of the face	Side of the face	Side of the face
Area of melisma	cm ² 3*8	cm ² 3*5	8*3 cm ²	7*2.5 cm ²	7*3 cm ²	5.7*2.5 cm ²	5.2*2cm ²
Depth of melisma	0.50	0.40	0.30	0.10	0.08	0.06	0.04
Weight of melanin	12.4	9.18	6.42	2.01	1.46	0.87	0.42
Wavelength of laser	1064nm	1064nm	1064nm	1064nm	1064nm	1064nm	1064 nm
Laser energy	13 J/cm ²	13 J/cm ²	13 J/cm ²	13 J/cm ²	13J/cm ²	13 J/cm ²	13J/cm ²
Laser pulse duration	60μs	60μs	60μs	60μs	60μs	60μs	60μs
Number of Sessions	8	7	6	5	4	3	2
Session time	5min	5min	5min	5min	5min	5min	5min
Session interval	1Month	1Month	1Month	1Month	1Month	1Month	1Month
Laser spot radius	6mm	6mm	6mm	6mm	6mm	6mm	6mm

Table (2): The physical coefficients for several of laser treated Melasma cases

Cases	$\alpha_s(m^{-1})$	$\alpha'_s(m^{-1})$	$Nm \times 10^{-7}$	$W_{ma}(g)$
P1	0.903	1.806	0.9945	6.82
P2	0.809	1.618	1.111	6.67
P3	0.713	1.426	1.208	4.04
P4	0.622	1.244	1.256	1.4
P5	0.529	1.058	1.364	1.09
P6	0.414	0.828	1.462	0.69
P7	0.276	0.552	1.559	0.36

$\alpha_s(m^{-1})$: absorption coefficient ; $\alpha'_s(m^{-1})$: effective absorption coefficient
 $Nm \times 10^{-7}$: refractive index of melanin pigment ; $W_{ma}(g)$:estimated absorbed melanin pigment weight

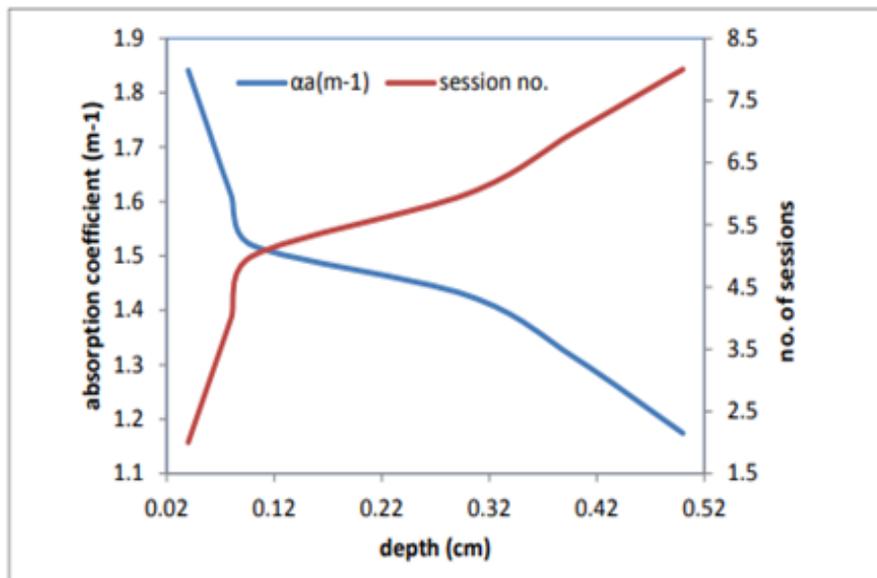


Fig. (2): The effect both of absorption coefficient of laser treated skin and Melasma depth in NO. Of sessions needed to complete treatment

Figure (2) illustrates the relationship between melasma depth, melanin absorption coefficient, and the number of treatment sessions required. An inverse relationship was observed between melasma depth and the absorption coefficient, where the absorption coefficient decreases as melasma depth increases [16]. Although long-wavelength lasers target melanin in the dermal layer (deep melasma), a significant portion of the beam is absorbed by the increasing pigment

concentration in the melasma lesion [17], leading to a higher number of treatment sessions needed.

Although the manuscript identifies an inverse relationship between melasma depth and absorption coefficient, this observation was derived qualitatively based on data trends rather than formal statistical analysis. Given the small sample size and the exploratory nature of the study, statistical verification was limited. While

clinical observations suggest that lower absorption coefficients may be associated with an increased number of treatment sessions, the tissue response to laser treatment is inherently multifactorial. Variables such as laser penetration, session techniques, and individual

variation in skin and tissue properties all play significant roles. Therefore, the relationship between absorption coefficient and the number of sessions should be interpreted within this complex context, and a direct causal link should not be assumed.

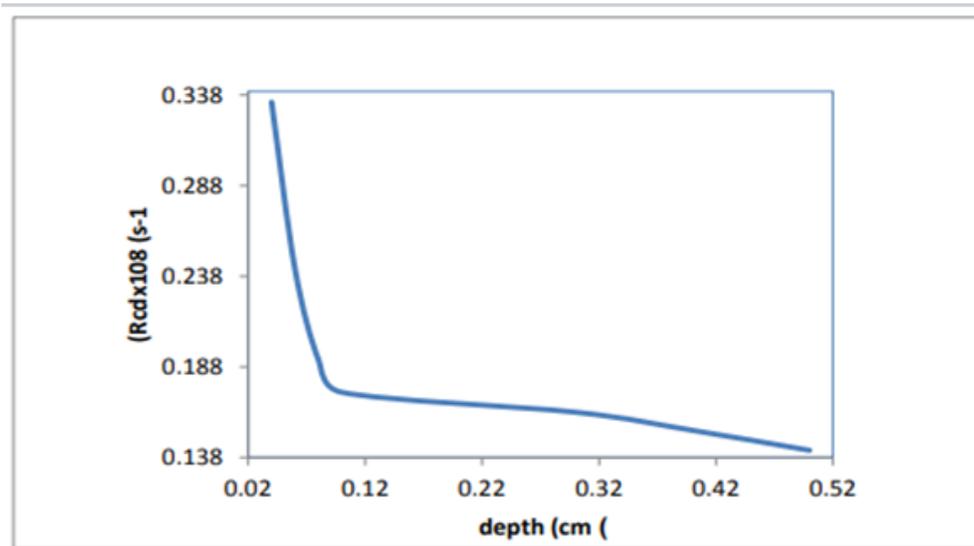


Fig. (3): The effect of Melasma depth in an inhibition rate of melanocytes

The figure(3) shows the relationship between the depth of melasma and the melanin cell inhibition coefficient, showing an inverse relationship between them. The deeper the melasma, the less inhibition the melanin cell is.

The reason is that the deeper the depth, the more melanin cells are in deeper layers of the skin, making it difficult for the laser light to reach them.

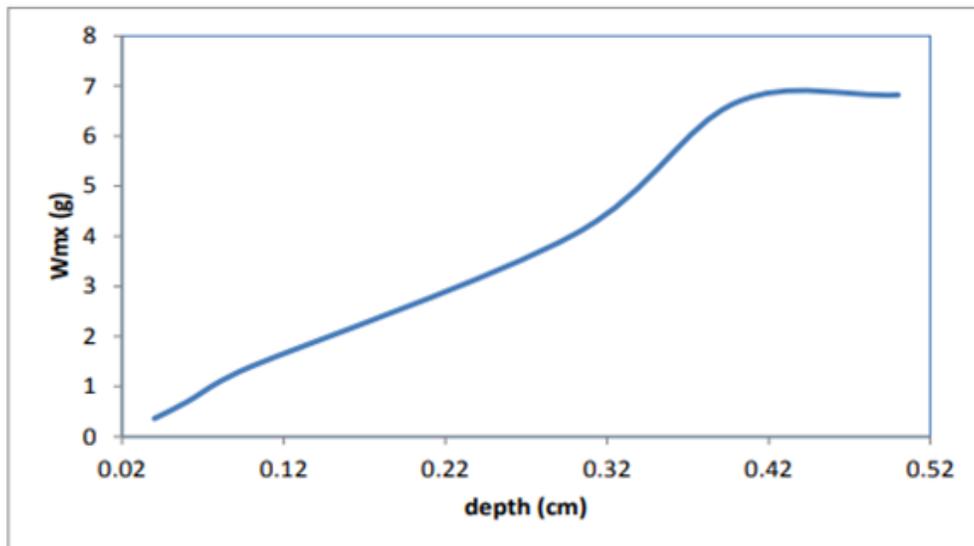


Fig. (4) :The effect of Melasma depth in absorbed melanin weight



Fig. (5): shows pictures of some patients who were treated with laser before and after treatment.

5-Conclusion:

This study highlighted the impact of physical parameters on the effectiveness of laser treatment for melasma, focusing on the role of pigmentation depth in skin response. The findings demonstrated that selecting the appropriate wavelength and optimal number of sessions plays a crucial role in improving treatment outcomes and minimizing potential side effects.

It was also found that deep melasma requires higher wavelengths and more sessions to achieve noticeable improvement, whereas superficial melasma responds better with fewer sessions. Additionally, skin type is a significant factor in determining the ideal treatment protocol, as darker skin tones are more prone to post-inflammatory hyperpigmentation.

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Based on these findings, the study recommends a thorough assessment of melasma depth before initiating treatment and precise adjustment of laser settings according to the condition to ensure optimal results with minimal risks. Furthermore, it underscores the need for further research on skin tissue response to different laser techniques, contributing to the development of more effective and comprehensive treatment strategies for various types of melasma. The study also recommends conducting future research to improve the selection of treatment parameters based on melasma depth and skin type. It further emphasizes the importance of considering individual factors, such as overall skin health and genetic predispositions, when designing treatment protocols to achieve optimal outcome.

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