Journal of Neonatal Surgery
ISSN(Online): 2226-0439
Vol. 14, Issue 7s (2025)
https://www.jneonatalsurg.com

OPEN ACCESS

Characterization of Affected Parameters in Laser-Treated Melisma

Nidhal Kadhim Malik [1], Methaq Mutar Mahdi Al-Sultani[2]

[1]University of Kufa, College of Education for Girls.
Email ID: Nidalk.ahussein @student.uokufa.edu.iq
[2]University of Kufa, College of Education for Girls.
Email ID: mithaq.alsultani@uokufa.edu.iq

.Cite this paper as: Nidhal Kadhim Malik, Methaq Mutar Mahdi Al-Sultani, (2025) Characterization of Affected Parameters in Laser-Treated Melisma. *Journal of Neonatal Surgery*, 14 (7s), 91-97.

ABSTRACT
Melasma is a disorder in the regulation of balance mechanisms that control skin pigmentation, leading to excessive melanin production. It is an acquired disorder in melanin formation that results in skin hyperpigmentation.

It always appears as symmetrical brown to grayish-black patches with irregular jagged edges, particularly in sun-exposed areas. Various methods are used to treat melasma, one of which is laser therapy with different wavelengths. In this study, the Spectra VRM III laser with a wavelength of 1064 nm was used. This laser reduces pigmentation by fragmenting the accumulated melanin pigment.

Several factors influence melasma treatment, leading to an increase or decrease in the number of required sessions. Therefore, the objective of this study was to highlight the most important factors affecting melasma treatment. Among these factors are the melasma area and thermal diffusion length. A negative correlation was found between thermal diffusion length and melasma area: as the melasma area increases, the thermal diffusion length decreases, leading to an increased number of treatment sessions. Additionally, the melasma area negatively affects the melanocyte inhibition coefficient, resulting in a higher number of treatment sessions. Regarding the absorbed melanin pigment weight, it increases with the melasma area.

Keywords: *melasma, laser, melasma area, thermal diffuse length, weight of melanin pigment.*

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, originating from the Greek word "milas," is often seen in pregnant women and is 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] and 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, 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 with mixed melasma (a combination of the epidermal and dermal types)[3]. The treatment of melasma is a challenge and can be difficult for its refractory and recurrent nature. A variety of therapeutic approaches include topical formulations[7], oral drugs, 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 quickly improve[8]. There are many studies that have relied on laser melasma treatment [7, 9, 10]. The penetration of laser light into biological tissues depends on the optical properties of the tissues [9, 10]. Therefore, the aim of this study was the effect of melasma area on both the length of heat diffusion, the number of sessions required for treatment, the rate of inhibition of melanin cells and the weight of the absorbed melanin pigment.

2. THEORETICAL PART

The absorption coefficient denoted αa is defined as the probability of photon absorption in a medium per unit length of a path and is given by the following relation:[11]

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

where e.x represents the molar decay coefficient.

The reciprocal of α is indicated by the average absorption length, denoted by Lα, which is given by the following equation:[11]

$L_\alpha = \frac{1}{\alpha}$ ....(2)

The scattering coefficient denoted by αs is defined as the probability of photon scattering in the medium per unit length of a path and is given by the following relation:[11]

$T(x)=\exp(-\alpha_s x)$.........(3)

where x represents the depth of melasma , T permeability of the skin.

The average length of the scatter, denoted by L_S, is given by the following equation:

[12]

$L_S = \frac{1}{\alpha_a + \alpha_s}$............(4)

The absorbed weight of the melanin pigment is denoted by the symbol W_{ma} and is given by the following equation:[12]

$W_{ma} = \frac{\alpha a}{\alpha_a + \alpha_S} * Wm$............(5)

W_m Represents the weight of the melanin pigment.

The length of the optical path, denoted by Lopt, is given by the following equation:[13]

$L_{opt} = \frac{1}{\sqrt{3\alpha a\,(\alpha a + \alpha_s')}}$..............(6)

Where α_a represents the absorption coefficient, α_S the scattering coefficient, α_S' effective scattering coefficient.

The thermal diffusion coefficient D is given by the following equation:[13]

$D = \frac{1}{3(\alpha a + \alpha_s')}$...........(7)

The rate of inhibition of melanin pigment cells is given by the following equation:[12]

$R_{cd} = A * e^{-\frac{EA}{RT}}$...........(8)

Where EA : activation energy is $3.25*10^5$J/mol , T=253K , R=$8.314*10^3$ J/K.mol

A=1/pulse duration

3. PRACTICAL PAR

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 (6 microseconds), 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) Laser Spectra VRM III

4. RESULTS AND DISCUSSION

The optical properties of biological tissues affect the treatment of melasma. In this study, seven cases suffering from melasma were treated, and the patients' data were as follows:

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 melasma	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*2 cm^2
Depth of melisma	0.50cm	0.50 cm	0.40 cm	1.12 cm	0.04 cm	0.06 cm	0.06 cm
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	1064nm
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	13 J/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**

The special equations in the theoretical part are applied using practica data in Table 1, the absorption length L_a was extracted, which represents the distance that light travels inside the tissue before it is significantly absorbed. The scattering length L_s, which represents the distance that light travels before it is scattered due to interaction with the microstructure of the tissue, and the optical path length L_{opt}, which represents the actual distance that light travels inside the tissue before it is finally absorbed. From the results obtained in Table 2, we notice a direct relationship between the thermal diffusion coefficient D, which determines the speed of heat transfer through the tissue, and L_a, L_s, and L_{opt}. While the relationship was inverse between the thermal diffusion coefficient and the weight of the absorbed melanin pigment W_{ma}, because when the effect of thermal diffusion on the tissue increases, it makes the absorption of melanin relatively less.

Table (2) Affected Criteria in Some Cases of Laser-treated Melasma

Caces	L_a(m)	L_s(m)	L_{opt}(m)	D(m^2/s)	W_{ma}(g)
P1	0.851	0.481	0.309	0.111	6.82
P2	0.762	0.479	0.292	0.113	6.67
P3	0.700	0.476	0.288	0.116	4.04
P4	0.658	0.474	0.284	0.120	1.40
P5	0.620	0.471	0.280	0.124	1.09
P6	0.579	0.468	0.277	0.130	0.69
P7	0.543	0.465	0.275	0.136	0.36

The figure (2) shows the relationship between the area of melasma and the length of thermal diffusion with the number of sessions required for treatment. It was found that there is an inverse relationship between the area of melasma and the length of thermal diffusion. The reason is that when the area increases, this leads to an increase in melanin and thus increases heat absorption, which leads to a decrease in the length of thermal diffusion, which leads to an increase in the number of sessions required to obtain satisfactory results.

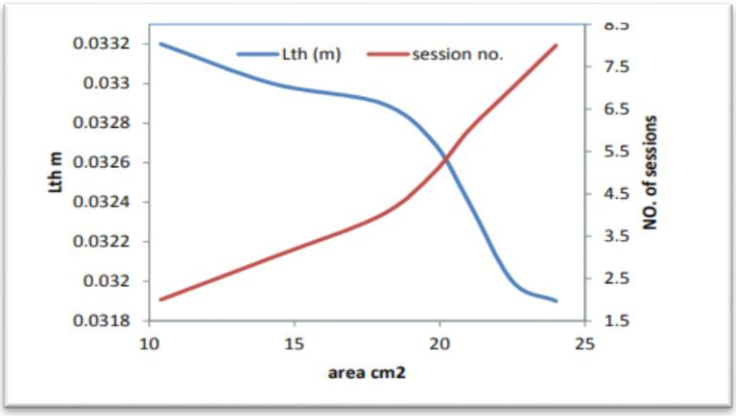

Figure (2) The effect both of thermal diffusion length and Melasma area in NO. Of sessions needed to complete treatment.

Figure (3) shows the relationship between the area of melasma and the rate of inhibition of melanin cells. It was found that there is an inverse relationship between them. The larger the area of melasma, the less inhibition of melanin cells. Therefore, we need more sessions to obtain good results.

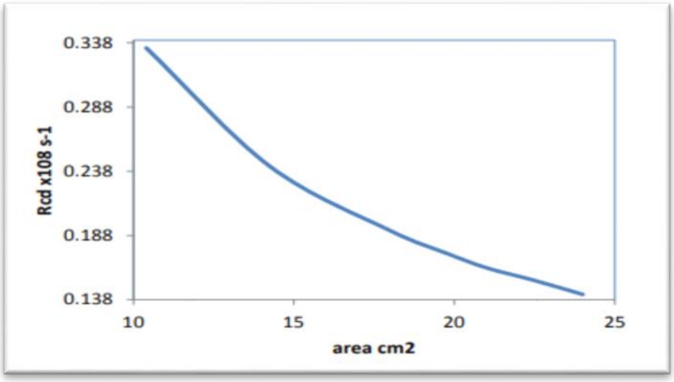

Figure (3) The effect of Melasma area in an inhibition rate of melanocytes

Figure (4) shows the relationship between the area of melasma and the weight of melanin pigment. The results proved that there is a positive relationship between them. The larger the area of melasma, the greater the number of melanosomes filled with melanin in the affected skin, and thus the weight of the pigment increases.

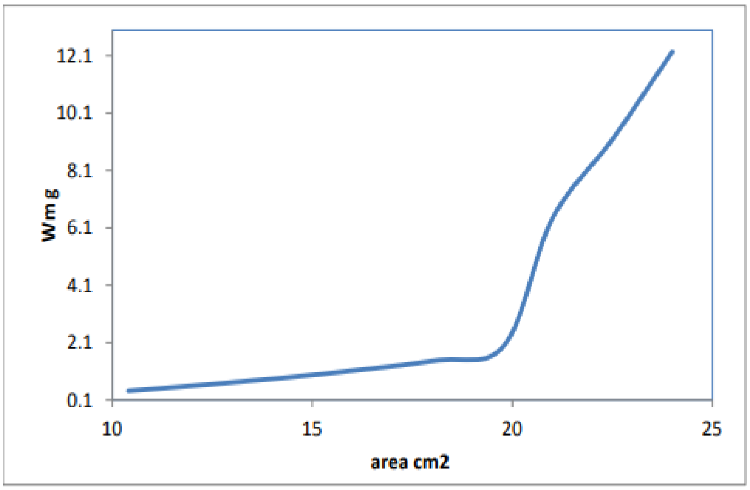

Figure (4) The effect of Melasma area in melanin weight in different cases

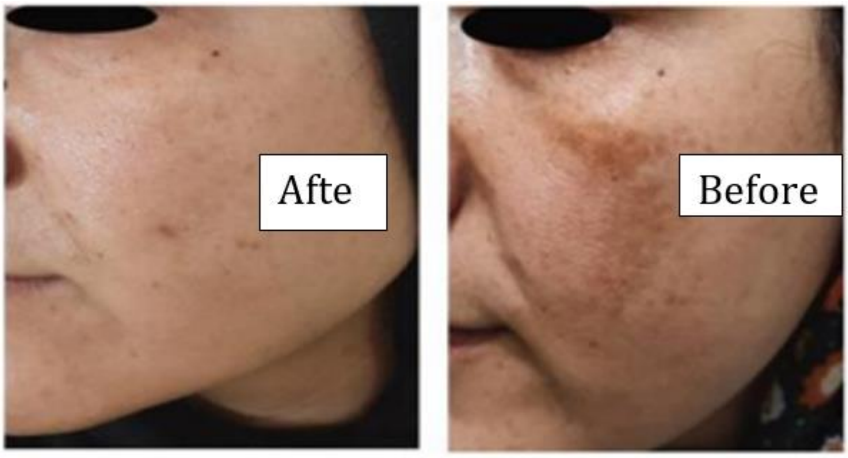

Figure (5) shows pictures of some patients who were treated with laser before and after treatment.

5. CONCLUSION

The study of the relationship of melasma space with the visual and thermal properties of the skin is vital to understanding how the pigmentation responds to various treatments, especially lasers and topical treatments. The relationship between the area of melasma and the length of thermal spread showed that increasing melanin leads to a higher energy absorption, which reduces the length of thermal proliferation, and makes targeting melanosomes more accurate.

On the other hand, the average discordance of melanin cells is associated with the area of melasma, as the largest spaces require more consistent inhibition rates to avoid the variation of pigmentation. Also, the weight of the absorbed melanin dye is directly affected by the intensity of melanin and the depth of pigmentation, which makes the treatments more complicated in the deep costs.

As for the thermal deployment, it plays a major role in the distribution of heat inside the tissues, as it is linked to the weight of the absorbed melanin, which means that the areas rich in melanin absorb the heat quickly, but it limits its spread, which may cause heterogeneous thermal response. In addition, the prevalence factor determines the relationship between absorption length, the length of dispersion, and the length of the optical path, which directly affects the effectiveness of optical and thermal therapy techniques.

Consequently, the deep understanding of these factors allows the development of more accurate therapeutic protocols, where laser energy, the number of sessions, and the type of treatment used according to the physical and chemical properties of costs are controlled, which achieves safer and more effective results.

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