

Influences of different low level laser power at wavelength 635 nm for two types of skin; dark and light

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Abstract

This study aimed to investigate the different power effects induced by a laser diode at wavelength 635 nm in epidermis layer for dark and light skin. Furthermore, it has been assessed the absorption power per unit volume in both types of the skin. The phantom for two types of skin, dark and light were generated by the ASAP program. Computer modeling is the primary tool to identify optimal laser settings. It was used to deliver the light and propagation multi laser power for two types of skin, dark and light. The power flux distribution and absorption were demonstrated within 0.015 to 0.1 mm in epidermis layer for both skins. The effects of skin types, various power, absorption of optical power per unit volume and fluence were demonstrated and assessed with the principle of medical physics. It is concluded that irradiation with 635-nm laser light applied at low level powers between 2mW, and 20 mW could significantly increase in optical power absorption per unit volume. It was found that, the laser irradiation at 635 nm, at all power used, had a stimulatory effect on epidermis. Furthermore, the result shows that the absorption of power per unit volume for dark skin 2.39 times greatly than the absorption power of light skin.

Keywords: Realistic skin model, low level laser therapy, PDT, simulation, Optical properties of skin.

Introduction

PDT has become more widespread because of advances including shorter incubation times and more applications, including psoriasis, acne and cosmetic skin rejuvenation (Haymo 1986). Laser light absorption by specific tissue targets is the fundamental goal of clinical lasers. The absorption of the photons of laser light is responsible for its effects on the tissue. The components of the tissue that absorb the photons preferentially depend on wavelength. These light-absorbing tissue components are known as chromophore. Frequently targeted chromophore in the skin includes melanin, hemoglobin, and water, as well as exogenous tattoo inks (Lisa et al., 2006, Barun et al., 2007). Low level laser therapy involves applying a low energy laser to tissue in order to stimulate cellular processes and enhance biochemical reactions. Low level lasers are safe, non-toxic and non-invasive (Jan et al., 2001 and Peter et al., 2009). Low -power radiation in the red wavelength is believed to induce prolonged primary photochemical processes, which play an important role in the manifestation of clinical therapeutic effects of quantum therapy in PDT. The most prominent of these effects is improved absorption in skin, which further enhances the therapeutic effect of the low laser level therapy. In addition, low-power radiation via red light has a positive influence on the quantity and quality of endogenous photosensitizers in PDT (Boehncke et al., 1994). Light propagation models are commonly used in medical applications to retrieve biological tissue characteristics by comparing experimental light irradiation measurements and theoretical diffuse reflectance simulation results, but are also used in computer graphics for realistic color rendering of translucent objects (Ying-Ying et al., 2009 and Vincent et al., 2008). Among these methods, ASAP

simulations offer the most accurate approximation of tissue irradiation modeling. In these simulations, each model considers the same statistical approaches of the interaction process between rays and tissue layers.

The choice of a laser system for therapeutic use is based on laser tissue interaction and knowledge of chromophore and molecule that follow laser irradiation of biological materials are important (Kulkarni et al., 1988 and Sheng-Hao et al., 2009). The penetration depth of laser radiation within biological tissues depends on the optical properties of these tissues, namely, on the values of scattering coefficient, absorption coefficient, anisotropy factor, and the separation between the source and the observation point. Laser-tissue interaction mechanisms are a function of wavelength, power, and pulse duration. The penetration depth of the laser light depends upon the optical properties of the tissue at the selected wavelength (Esnouf et al., 2007, Ackemann et al., 2002, Boehncke et al., 1994 and Martin et al., 1989). A biphasic dose response has been frequently observed where low levels of light have a much better effect on stimulating and repairing tissues than higher levels of light. The use of low levels of visible or near infrared light for reducing pain, inflammation and edema, promoting healing of wounds, deeper tissues and nerves, and preventing cell death and tissue damage has been known for over forty years since the invention of lasers (Dhiraj et al., 2001). Low level laser therapy is the application of light to pathology to promote tissue regeneration, reduce inflammation and relieve pain (Igor et al., 2002 and Ying-Ying 2009). Some authors have studied the effects of low-level laser therapy on the viability of skin flaps. The action of low level laser therapy is based on the absorption of the light by tissues, which will generate modifications in cell metabolism (Paulo et al., 2009). Low laser therapy has an increasing popularity as a new therapy for many disorders, in spite of a shortage of objective controlled studies. That means the scientific standardization is imperiously necessary. In most applications the ability of the laser to perform well at elevated laser power was of great interest (Peter et al., 2009). As a result, it was of outmost importance for the skin therapy to be robust enough so as not to degrade due to laser -tissue interaction at high power. In the present work, one try to estimate the effect of absorption dose of laser power (635nm) for different power (2-20mw), and different skin types, dark and light skins. ASAP simulation program 2009 V1R1 use to investigate this work.

Material and Methods

Simulation program

The simulation method by an advanced system analysis program (ASAP) provides a conceptually simple and flexible, yet careful way of illustrating light radiation transfer within a tissue. An ASAP of describing a phantom skin in arbitrary three-dimensional geometry with spatially varying optical properties and tissue anisotropy is presented. We use the realistic skin model (RSM) to explore the effects of laser therapy for optical power measurements of the human skin. In our implementation, the tissue is divided into volume elements (voxels), each of which may have different optical properties. The optical properties of the model include absorption, anisotropic scattering, and the index of refraction

Skin

A phantom realistic skin multilayer continuum model of skin tissue composite has been developed for simulating laser skin interaction. The proposed skin tissue model is composed of three layers with distinct optical parameter properties. These include stratum corneum (0.015 mm), epidermal (0.0875 mm), and dermal layer (1.8 mm). Skin type's variations of the model parameters have been considered.

The skin provides several physiological functions defining this subdivision (from top to bottom): the stratum corneum is a small fraction of the chromophores layer of dead cells at the surface of the skin, the epidermis contains a large fraction of the chromophores of the skin defining the overall skin tone and the dermis contains blood vessels, nerves and structural molecules as shown in Fig.1.

Laser Diode

The spot size of laser light on the target depends of the distance between them, it was 5 mm and diameter of the beam is 0.8 mm. Different irradiation low level power from 2 mW to 20 mW were used, with wavelength 635 nm, has been guided to the skin as shown in Fig.1. Fluence and absorbance of

the laser were measured with VOXEL command. VOXEL in ASAP was used to capture the energy that was lost to absorption within the volume, during this study 1000 000 rays was used to transfer the power from the source to the skin, the total energy absorbed from rays passing through this region was recorded for each of the voxel elements.

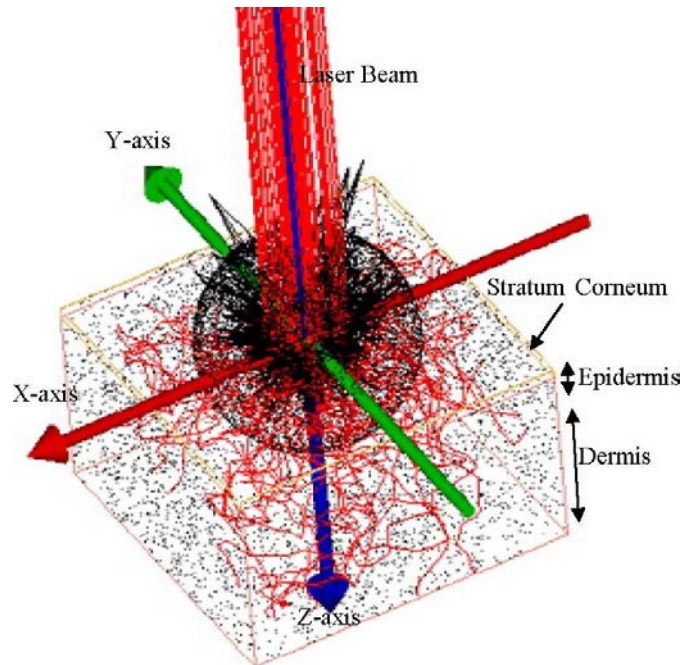


Figure 1: 3D Viewer showing skin parts and laser

Result and Discussion

Figures 2 and 3 are showing the optical power absorption per unit volume as a function of penetration depth for dark and light skins in different powers. When the laser light entered the SC region, at 0.015 mm, most light is transmitted except the small amount of light disappears due to very small absorption, because the concentration of chromophore is low in this region. When the laser penetration depth was approached to the epidermis layer from 0.019 to 0.091 mm, the absorption was increased and optimum peaks appeared and got a maximum absorption intensity, because the concentration of melanin in this layer is to be more, compare with the other layer in the skin, this is correct for both figures.

Figure 2 represents the change of the power absorption dose for the light skin. The top absorption power in epidermis was centered in depth layer 0.03171mm; this is due to the variation of melanin concentration. From this figure, the relation between absorption power and penetration depth in depth layer 0.03171 to 0.091 mm was linear, so the absorption power decreased slowly, depending on the change of the loss power within depth layers. Therefore, one demonstrated that the suitable absorption power to get an affective absorption does to the select depth layer depend on the laser power. Therefore, the physicians should use an appropriate laser power in clinical surgery. Because the absorption dose for each depth layer depend on the suitable laser power as shown in Fig.2, When they need an absorption dose for depth layer (0.091mm) without change on the absorption dose, the 2mw is a suitable dose, for changing absorption dose in same depth layer, 20mw is a suitable. This fact was in agreement with the essential changes in the layer of skin. On the other hand, time exposure is a crucial point because the duration of exposure depends on the penetration depth and the type of diseases treated. The result also has been shown to help decrease the exposure time and reduce power, effectively treating some epidermis disease, and improving the appearance of some skin scars, without damage normal tissue in PDT.

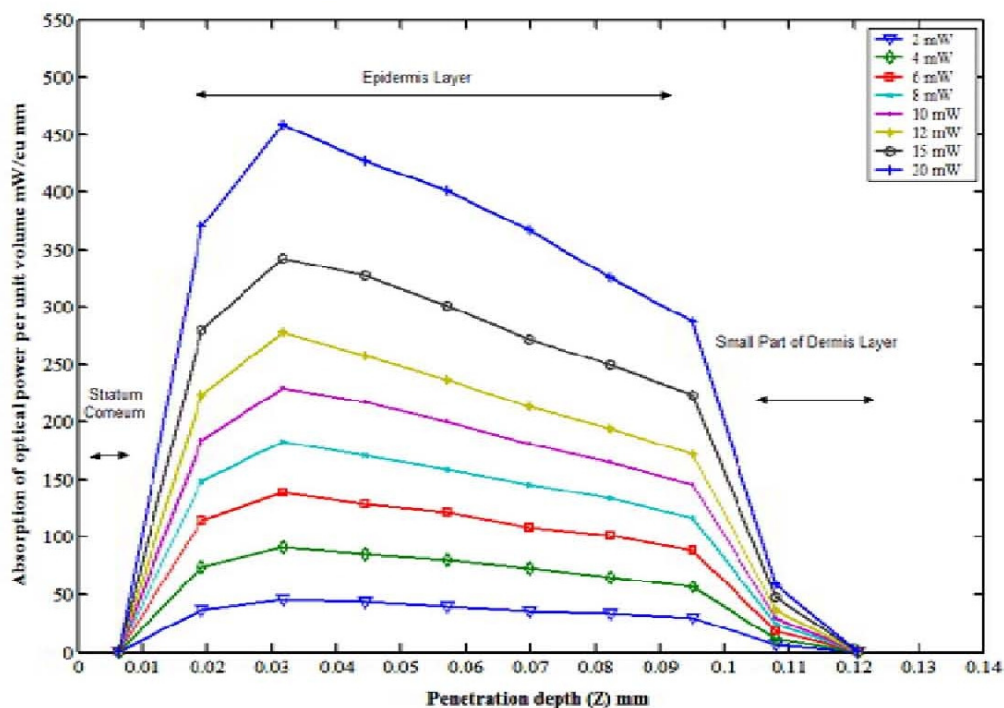


Figure 2: Absorption power per unit volume penetration depth and power dependence for a light skin operating at various low level laser powers.

Figure 3 represents the change of the power absorption dose for the dark skin. The top absorption power in epidermis was ranged over 0.019 - 0.03171 mm depth layer. The absorption dose curve was bending, and the absorption was reduced rapidly especially in the range of layer 0.0317 to 0.095 mm, the reason goes to the high concentration of the melanin comparing with that in light skin. One observed that, the change in the absorption dose for the different low level laser power also depended on the depth layer, but in a different ratio comparing with that mentioned in light skin.

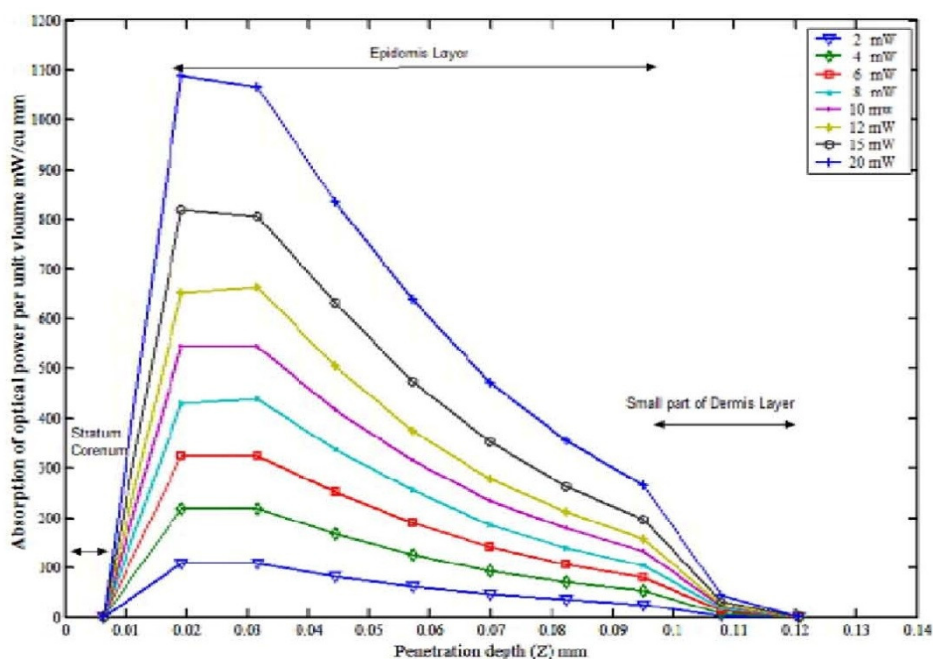


Figure 3: Variation of absorption optical power per unit volume with increasing low level laser power for a dark skin. It is illustrating the absorption power in layers, stratum corneum, epidermis and small part of dermis layer.

The results above approved that the difference in the melanin concentration made a different sensitive skin for absorption dose. So, these results should be taken into account, to assess and get a typical treatment in PDT in skin, and to an effective style therapy. Important information could come from studies of epidermal exposed to elevated power of laser in dark and light skin. The slope of the straight line of Figure 4 was the most important parameters of a laser-tissue interaction and was termed the absorption efficiency of power in epidermis. The absorption of power efficiency, is defined as the amount of increases in signal absorption power per unit increaser of laser power was found to be 55 mW.mm-3/mW and 23 mW. mm-3 /mW for dark and light skin, respectively, at operating wavelength 635 nm. The figure showed a linear dependence between optical power and power absorption dose as given by the equations; (obtained by curve fitting):

$$\text{Abs} = 55 P + 1.2 \text{ ----- (1)}$$

$$\text{Abs} = 23 P + 0.51 \text{ -----(2)}$$

With Abs_{Dark skin} & ABS are the absorption dose for dark and light skin, P is the power of laser diode in mW.

There is a difference between the values first slope and second slope, because absorbance per unit volume changed, due to variance chromophore concentration in dark and light skin. For authenticate our results about absorption dose in light and dark skin, there is a comparison ratio between two slopes of two straight lines. One observed that the ratio was 2.39. It means that, a high concentration of melanin in dark skin make a high absorption dose, and this agreement with that explained in Figures 2 and 3. The result shows that a large amount of the pump light from a laser diode is absorbed in epidermis layer. It seems that the power uptake in epidermis layer for dark skin is 2.39 larger than the power uptake for light skin. So, the differences in melanin concentration should be taken into account for laser therapy in PDT.

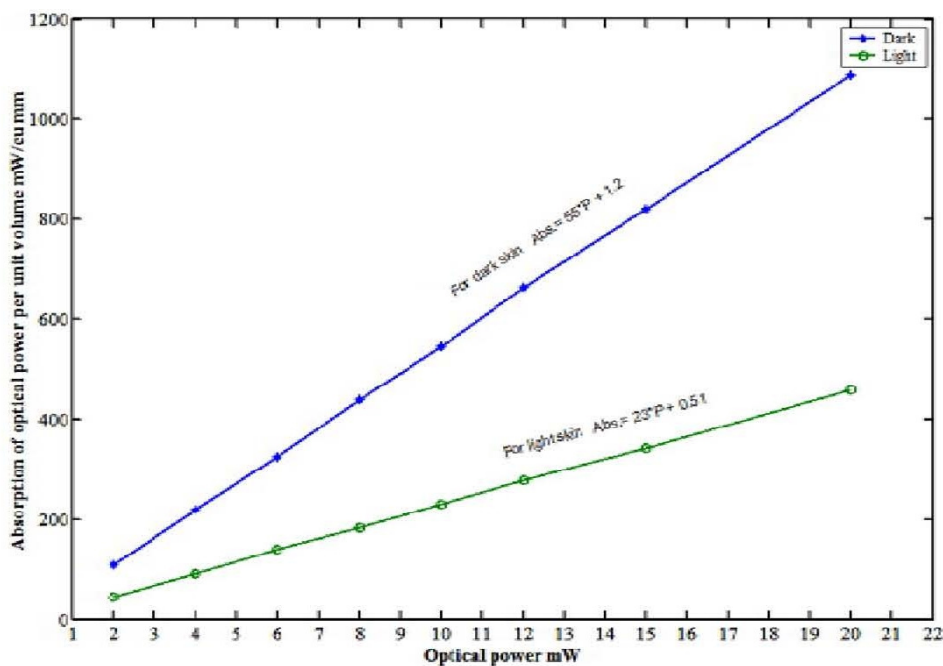


Figure 4: Relation between an optimum absorption of power per unit volume and the laser power, for dark and light skin at the depth Z=0.019 mm to 0.03171mm._

Conclusion

An investigation of the different low level laser power effects induced by a laser diode at wavelength 635 nm in epidermis layer for dark and light skin has been done. There are several differences that have been found between light and dark skin in absorption power when exposed to laser power (635nm). The difference has been appeared clearly in epidermis layer. Computer modeling (ASAP) is an effective method to determine the parameters that are most likely to induce absorption within epidermis in skin. The modeling can be used to study a wide range of parameters that would be practical to test clinical laser therapy in PDT. It is concluded; those irradiations with 635 nm laser light applied at low level laser powers between 2mW and 20 mW, have a crucial role and could be significantly increased in power absorption. Further, an increasing laser power in both types of skin can absorb most of the light in epidermis layer; more absorb means less time need to treatment. One can be estimated that the relative absorption power for 635 nm radiation for dark skin is about 2.39 times bigger than absorption power of a light skin.

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