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# Red Diode Laser in the Treatment of Epidermal Diseases in PDT

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***Abstract*—**The process of laser absorption in the skin during laser irradiation was a critical point in medical application treatments. Delivery the correct amount of laser light is a critical element in photodynamic therapy (PDT). More amounts of laser light able to affect tissues in the skin and small amount not able to enhance PDT procedure in skin. The knowledge of the skin tone laser dependent distribution of 635 nm radiation and its penetration depth in skin is a very important precondition for the investigation of advantage laser induced effect in (PDT) in epidermis diseases (psoriasis). The aim of this work was to estimate an optimum effect of diode laser (635 nm) on the treatment of epidermis diseases in different color skin. Furthermore, it is to improve safety of laser in PDT in epidermis diseases treatment. Advanced system analytical program (ASAP) which is a new approach in investigating the PDT, dependent on optical properties of different skin color was used in present work. A two layered Realistic Skin Model (RSM); stratum corneum and epidermal with red laser (635 nm, 10 mW) were used for irradiative transfer to study fluence and absorbance in different penetration for various human skin colors. Several skin tones very fair, fair, light, medium and dark are used to irradiative transfer. This investigation involved the principles of laser tissue interaction when the skin optically injected by a red laser diode. The results demonstrated that the power characteristic of a laser diode (635 nm) can affect the treatment of epidermal disease in various color skins. Power absorption of the various human skins were recorded and analyzed in order to find the influence of the melanin in PDT treatment in epidermal disease. A two layered RSM show that the change in penetration depth in epidermal layer of the color skin has a larger effect on the distribution of absorbed laser in the skin; this is due to the variation of the melanin concentration for each color.

***Keywords*—**Photodynamic therapy, Realistic skin model, Laser, Light penetration, simulation, Optical properties of skin, Melanin.

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## I. Introduction

PDT is a form of cancer treatment. It is a photochemical process that shows a complex interaction between fluence, photosensitizer concentration and oxygen concentration. Low fluence rates cause more damage than high fluence rates for the same total fluence. [1-2]. PDT is based on the ability of light to cause chemical changes in human tissue. The choice of continuous wave diode laser for PDT is determined by two main factors: the absorption spectrum of the photosensitizers and the wavelength and penetration depth of the light. The first and most widely used class of photosensitizers in PDT is the porphyries, which absorb light maximally in the Soret band ranging from 500 and 635 nm [3].

The light distribution in the tissue depends on the tissue optical properties of various tissue layers at the laser wavelength and on the thickness of those layers. The total problem of light propagation in tissue is referred to as tissue optics [4]. Development of optical methods in the modern medicine for the area of diagnostics, therapy and surgery has stimulated for the investigation of an optical property of various biological tissues. Since the efficacy of laser treatment depends on the photon propagation and fluence rate distribution within irradiated tissues. The skin is the most important tissues for photodynamic therapy of cancer and other diseases [5].

Laser's radiation, is commonly used in dermatology, which accounts for the attention paid to practical aspects of the interaction between radiation and human skin and to the problem of selective absorption and depth of radiation penetration into the skin. As a wavelength increases into the visible and near-infrared optical region of the spectrum, radiation penetrates more deeply into the skin [6]. The knowledge about skin physiology of specific sub-populations leads to an increase in specific therapeutic options, for example, for sensitive skin and ethnic groups. The understanding and quantification of racial differences in skin functions are important for the treatment and prevention of skin diseases and skin care [7].

Human skin color varies significantly between individuals dependent on race, sun exposure and age. Normal skin color originates in the presence of specific chromospheres such as melanin, hemoglobin, bilirubin and carotene. However, scattering due to the inhomogeneous distribution of lipids, water and proteins within each cell, as well as the random distribution of cell also has a very important impact on the visual appearance of skin [8-9].

The phenomena of transmission, reflection, scattering and absorption are very important parameters in laser tissue interaction. Transmission refers to the passage of light through a tissue without having any effect on that tissue or on the properties of the light. Reflection refers to the repelling of light off the surface of the tissue without an entry into the tissue. Scattering of light occurs after light has entered the tissue. Scattering is due to the heterogeneous structure of tissue, with variations in particle size and the index of refraction between different parts of the tissue determining the amount of scatter. Scattering also limits the depth of penetration because it can occur backward as well as forward. In general, the amount of scatterings of laser light is inversely proportional to the wavelength of the laser. Longer wavelengths thus penetrate tissue more deeply [4, 10]. In this study, one tries to estimate the effect of power absorption per unit volume of laser (635nm) wavelength, power (10 mw), for different types of skin; fair, very fair, medium, light and dark skins. The ASAP simulation program (2009.V1R1) was used for done this work.

## II. Methodology

### A. Preparation of realistic skin model

The tissue phantom, realistic skin model (RSM), a bio toolkit interactive script for the advanced systems analysis program from Berault Research Organization was used to create realistic tissue phantoms for investigating optical properties of skin as shown in Fig.1. The stratum corneum is the outermost layer of the skin and its thickness is 0.015 mm, the water is majority chromophore in this layer, a small amount of beta carotene and protein are also present. Epidermal layer thickness is 0.0875 mm; Melanin is the majority chromophore in this layer, although water, beta carotene and protein are distributed in this layer. Area of the surface phantom tissue was 10 $mm^2$. Chromophore in stratum corneum and epidermis are modeled within RSM, for various skin types.

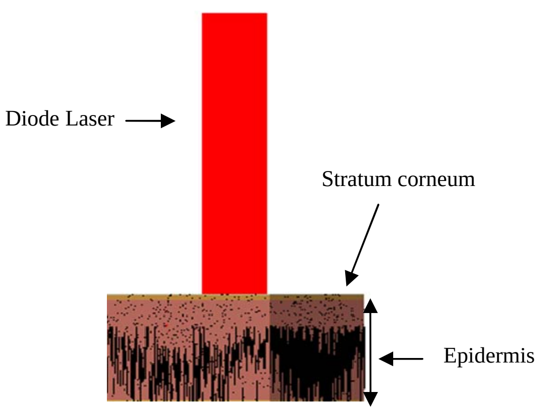


Fig. 1 Realistic skin model (Stratum corneum and Epidermis)

### B. Diode laser source:

The skin is illuminated with red laser diode (635 nm, radius of the beam is 0.4 mm, 10 mw), and the simulating red light is continuously delivered to the entire. Skin, creating Gaussian beam profile with the fluence and absorbance of the laser is measured with VOXEL command. A VOXEL element can be described as a three-dimension (3D) pixel, its major advantage over its two-dimension (2D) counterpart; it can measure the energy of rays passing within the 3D border of it from any direction.

## III. Results and Discussion

Fig.2 represents the fluence rate spectra in the framework of the presented model in the 635 nm wavelength. One observed that the fluence rate of laser radiation reduces clearly after being transmitted through an epidermis sample of human skin tissue, because the variation of the skin layer contains, the significance of fluence rate decrease with an increase of the skin penetration depth, depending on the thickness of epidermis and melanin concentrations. So, most laser radiation was absorbed within the epidermis of skin, at wavelength of 635 nm.

On the other hand, one observed that the distribution of chromophore concentration for very fair skin is different than the other skin type; this is due to the different location of melanin concentration in epidermis layer.

Photodynamic therapy-induced damage increases with increasing fluence, but is independent of the irradiance; this is clear as shown in Fig.2. In fact, insufficient penetration of the light is the main possible reasons for the less favorable results in PDT in skin.

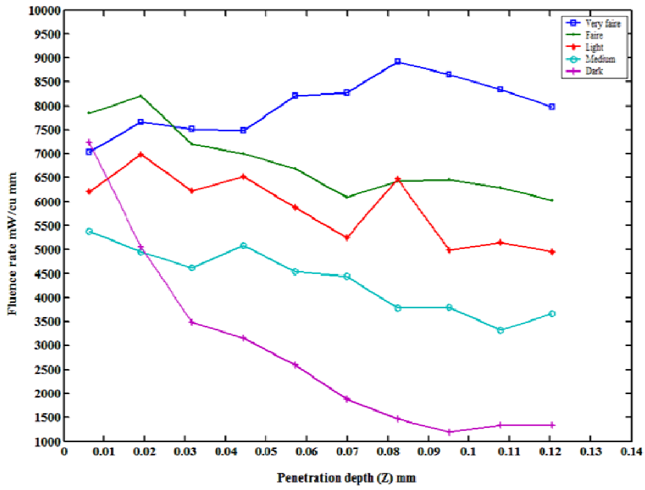


Fig.2 Fluence rate measure in the different penetration depth for various human color skins, the laser was 5 mm far from the tissue, emits 10 mW of wavelength 635 nm.

The result shows that the knowledge on the penetration of optical radiation and color skin are very important parameters in PDT. In that point, one can select an optimum dose for each type of skin, as shown in Fig.3. This figure is important to find the absorbance along a Stratum corneum and epidermis layer, its shows that the laser power injected to the skin, minimum absorbance are happened in the stratum corneum at 635 nm and maximum absorbance of light were happened in epidermis layer. For the epidermis layer when the depth of penetration increases, the absorption of the power per unit volume is reduced, so when the laser reaches to the dermis layer, the change in absorbance is rapidly down at Z=0.1 mm as shown in Fig.3.

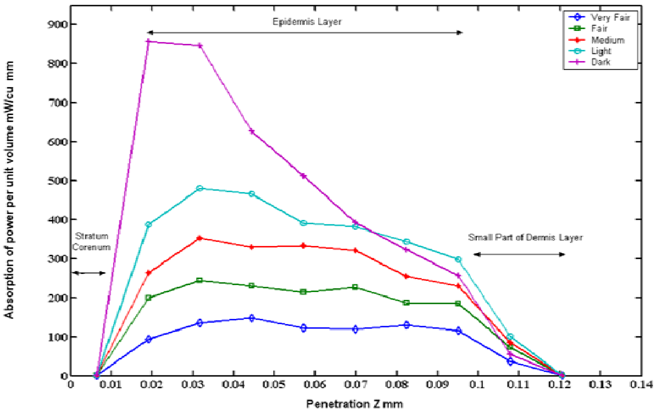


Fig. 3 Variation of absorption in optical power density with penetration depth, for different human skin color.

An absorption event in various penetration depths in an epidermis layer is between 0. 019 mm to 0.0875 mm, and this was done for all types of human skin, as shown in Fig.3. The absorption of optical power distribution in penetration depth for the types of human skin color is different, and therefore, influences the amount of laser light reaching the treatment area, as shown in Fig.3. Both the skin tone and the penetration depth of the epidermis have an influence on the amount of laser light that is absorbed in that layer.

From the above result, one observed that the optical properties of the skin and its parameters are the essentials in PDT treatment. For these reasons, one attempted to describe the penetration of laser light into individual skin layers from different human skin colors, and to compare absorption of power in each color skin. Melanin concentration showed significantly different optical power absorption, and the measurement of laser light absorption in dark skin was higher than the absorption with other skins, because of the different histological structure.

Also, it was demonstrated that the ratio of absorption light penetrating the individual skin layers in dark skin color are more than another skin color as indicated in Figs.3&4,, which is a crucial factor for selecting the power incident. Accurate information about light penetration in tissue is important for possible application of the diode laser in the therapy of PDT.

The transmission of optical radiation in human skin depends on many individual factors different for each skin layer. In general, part of the light is reflected after it reaches the skin and part of the light penetrates into deeper layers, where it may be either scattered or absorbed according to the optical properties of the tissue.

In order to assess the effects of laser therapy on skin colors, Observations were made on the five types of skin. As show in Fig.4 a significant differences were found in the chromophore content of the five skins. There appeared to be a decrease in the absorption of power laser in the (medium, light, fair and very fair) as compared to dark skin. The most important absorption was observed at the depth between 0.01903 mm and 0.04439 mm for skin in different color. This finding indicates that skin color has a great role in laser therapy. Indeed, the dark skin had larger melanin content than the other skins. The result shows that the dosage of laser therapy chosen for the skin in PDT was based on a color of human skin. On the other hand, the result demonstrated that the laser diode has an optimum dose in that region and needs an optimum time to therapy. So, the differences in melanin concentration should be taken into account for laser therapy in PDT.

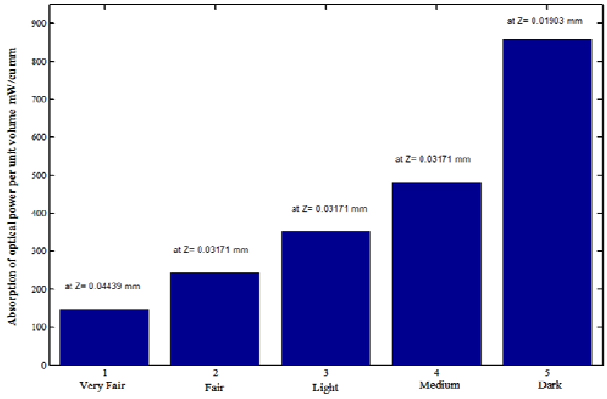


Fig.4: Optimum power absorption per unit volume for each color skin at different position of epidermis layer.

The ASAP program is dependent on the validity of the optical parameters. When the true value of the chromophore concentration in the epidermis low, then small amount of light will reach the epidermis, this is clear in both types of skin very fair and fair, if the chromophore concentration of epidermis was more compare with the above types of skin, so a lot of amount of laser will reach the epidermis as has been shown in skins of medium, light and dark respectively. This finding indicate that, there appeared a strong differences in the absorption of power laser in the dark, light and medium as compared to very fair and fair skin.

The influence of the side effect of laser to surrounding tissue and normal tissue are critical, due to a small amount of laser energy deposited into the skin, also with greater amounts of laser energy the damage in tissue occurs. This is an essential subject in laser safety in PDT; it was shown that the PDT is sensitive with the human color skin in laser -tissue interaction. The result proves that the knowledge of skin colors for a patient in PDT an essential factor.

Importance of optical properties can be estimated from wavelength of 635 nm of variance human skin; epidermis, melanin can influence the amount of light and limit the therapeutic significantly. In this study, the result demonstrated that the skin tone has an essential role for therapeutic and the physician should be careful to select the power in each type of human skin.

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