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Penetration Depth of 635 nm Laser Light Into the Biological Tissue

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Abstract

Optical parameters of the target tissue are important to know for all kinds of phototherapy. In photodynamic therapy, for example, the knowledge of the penetration depth for the light is needed in order to ensure that the optical energy received by the tumorous tissue. In the present study, the optical penetration depths of 635 nm laser light in chicken breast tissue have been measured by using 11 tissue samples with different thicknesses between 3.0 mm and 8.0 mm. Transmitted light intensities through the tissue samples have been measured for the optical powers of 200 mW, 450 mW and 650 mW. Measurement results for each power value have been analyzed according to the Beer-Lambert law. Optical penetration depths have been found to be 5.98±0.47 mm, 5.88±0.36 mm and 5.94±0.37 mm for 200 mW, 450 mW and 650 mW optical powers, respectively. These results show that the optical penetration depth of the light in biological tissue does not depend on its optical power.

Key words: PDT, Laser, Tissue optics, Penetration depth

1. Introduction

In medical diagnostic and treatment area, the usage of electromagnetic radiation of different wavelengths has been increased. Photodynamic therapy (PDT) is one of the cancer treatment method. In PDT, laser light at specific wavelength is used together with a kind of drug containing photosensitizer molecules in order to destroy tumor cells in tissue [1]. After the photosensitizer molecules absorb the light, the energy is transferred into molecular oxygen and singlet oxygen and some radicals are created. Singlet oxygen is known as extremely electrophilic. Therefore, it may oxidize electron-rich double bonds in biological molecules. In PDT, the singlet oxygen is assumed to be the key cytotoxic agent that leads to the death of targeted tumor cells [2].

Although there are various photosensitizers available for PDT, ALA-5 is one of the extensively used ones since it can be used also in Photodynamic Diagnosis (PDD) for detecting cancer nests [3]. The fluorescence emission spectrum of active ALA-5 has a peak at the wavelength of 635 nm [4]. That is why, 635 nm laser light has been preferred in PDT and PDD in which ALA-5 is used.

For a successful PDT treatment, the optical dose received by the target tissue have to be determined accurately. For the determination of correct dose in PDT, penetration depth of the light into the tissue is one of the important parameters. There are exist many studies in the literature indicating the experimental results for the penetration depth of the light of different wavelengths in various tissue types (see, for example, [5-7]).

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In this study, the optical penetration depth in chicken breast tissue has been determined by using 635 nm PDT laser system. The experiments have been repeated for the optical powers of 200 mW, 450 mW and 650 mW.

2. Materials and Method

The experimental setup that is used to measure the optical penetration depth in this study is shown in Figure 1.

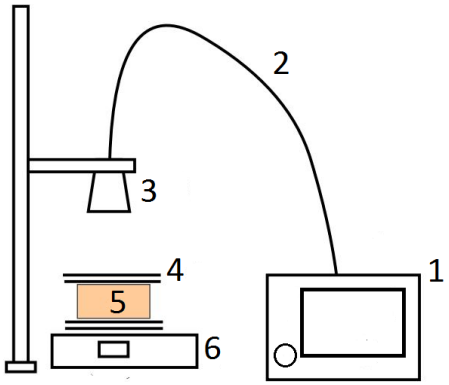

Figure 1. Experimental setup; 1) PDT laser device, 2) Optical fiber, 3) Collimator, 4) Microscope slide, 5) Tissue sample, (6) Array power meter

PDT laser system produce a stable optical wavelength of 635 nm with a maximum optical power of 1.5 W [8]. The wavelength measurement result of the device is given in Figure 2. Although, the device was designed to be run in three different radiation modes (continuous, pulse and burst-pulse), it has only been used in continuous mode for this study. In order to obtain a parallel light beam, the device has been connected to a collimator by using an optical fiber.

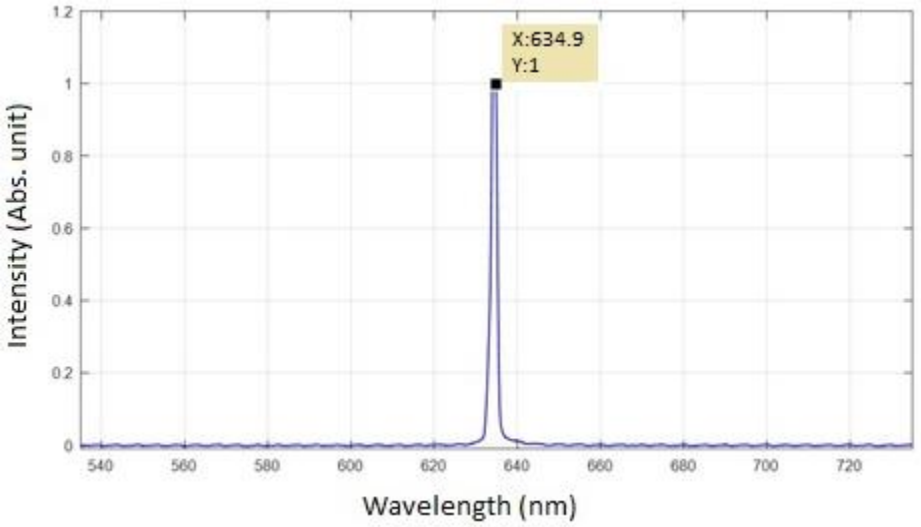

Figure 2. Wavelength spectrum of PDT laser device

For the experiments, chicken breast tissue have been used. For this purpose, raw chicken breast tissues have been kept in the room temperature for 25 minutes, and then skin and fatty parts have been removed. 11 tissue samples with different thicknesses from 3.0 mm and 8.0 mm have been prepared and each one has been placed between two microscope slides.

An array power-meter with an active area of 1.2 cm^2 has been used in the experiment. The optical power of the transmitted light through the samples have been measured together with the one through the empty slides by using the power-meter. The same procedure has been repeated for the optical powers of 200 mW, 450mW and 650 mW. The transmittance for each sample has been calculated by dividing the power of the transmitted light through the sample to that for empty slides. The results are discussed in the following section.

3. Results and Discussion

Transmittances of the 635 nm light with three different optical powers are shown in Figure 3 as a function of tissue thickness.

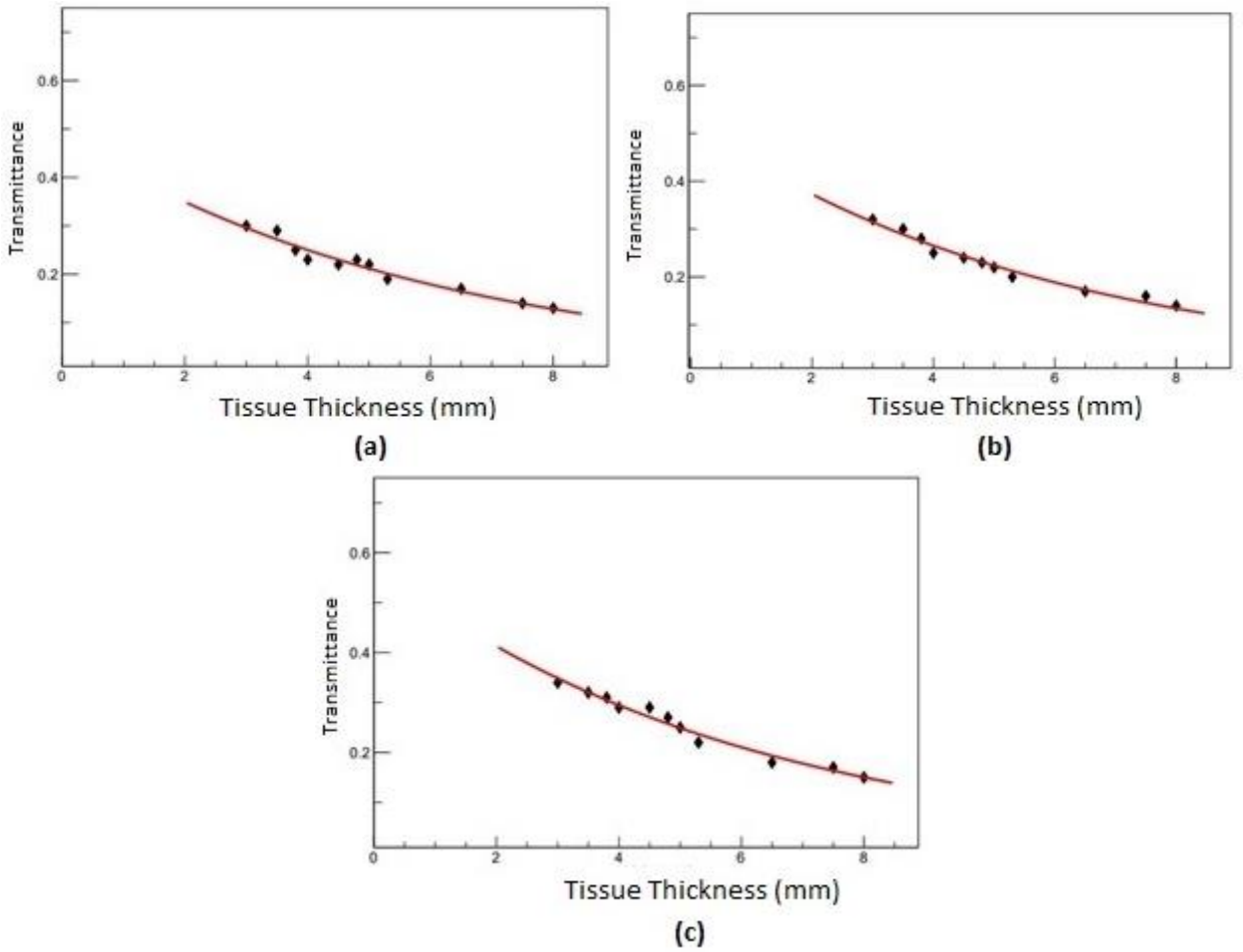

Figure 3. Transmittance as a function of tissue thickness for optical powers of (**a**) 200 mW (**b**) 450 mW (**c**) 650 mW

As it can be seen in the figures, there is an exponential relationship between the transmittance and the thickness of the tissue. This relationship is expressed by Beer-Lambert law. Transmittance (*T*), which is the ratio of the intensity of the transmitted light (*I*) to that of the incident light (I_0), is given by the equation ;

$$T = \mathrm{I}/I_0 = e^{-\mu d} \qquad \text{Eq. (1)}$$

In which, μ represents the attenuation coefficient and *d* is the tissue thickness. The depth at which the transmittance inside the tissue equals to "1/*e*" is defined as penetration depth (δ). Then, the transmittance can be written as;

$$T = e^{-d/\delta} \qquad \text{Eq. (2)}$$

In order to obtain the penetration depths, the graphs given in Figure 3 have been fitted to the function of $e^{-x/\delta}$ and get the fit parameter of δ. Red lines in the figures represent the fit curves. It has been determined that the optical penetration depths for chicken breast tissue at 635 nm are 5.98±0.47 mm, 5.88±0.36 mm and 5.94±0.37 mm respectively. Based on this finding, it can be concluded that the optical penetration depth of the light in biological tissue does not depend on its optical power.

4. Conclusions

In this study, the penetration depths of 635 nm laser light with different optical powers in chicken breast tissue have been measured. Collimated transmittance through each of the samples has been determined and the penetration depth have been obtained by analyzing the measurement results according to Beer-Lambert law. For 200 mW, 450 mW and 650 mW optical powers, the optical penetration depths have been found to be 5.98±0.47 mm, 5.88±0.36 mm and 5.94±0.37 mm respectively. These results show that the optical penetration depth of the light in biological tissue does not depend on its optical power.

Acknowledgments

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