

What is the effect of different skin types on the required dose for photodynamic therapy?

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INTRODUCTION

During the last two decades the use of lasers as a treatment modality has increased dramatically. For most treatments wavelengths between 600 and 1 000 nanometres (nm) are used.

In South Africa, one in six men and one in seven women will get cancer in their lifetime¹. Photodynamic therapy (PDT) is a cancer treatment modality where a photosensitiser (PS) is administered to the patient. The PS accumulates mainly in the cancerous tissue and after a period of time the tumour is irradiated by a laser or another light source. The wavelength is carefully chosen to coincide with one of the absorption peaks of the PS. The energy of the photons is absorbed by the PS and singlet and triplet oxygen is formed inside the cells. This is lethal to the cells and causes cell death.

In order to achieve the desired effect, it is important to supply enough laser light to kill the tumour cells without damaging the healthy surrounding tissue. For embedded tumours this becomes more difficult due to the absorption of light in the first layers before the tumour.

OPTICAL MODELLING

To model the effect of laser light on tissue and tumours, photons are treated as particles that travel at the speed of light until they are scattered and absorbed. The four important parameters are:

- Absorption coefficient (μ_a)
- Scattering coefficient (μ_s)
- Anisotropy (g)
- Refractive index (n)

Photons are traced as they travel through the model and the absorption is evaluated at pre-determined depths into the skin. The skin model used consisted of 4 layers, the stratum corneum, epidermis, dermis and the hypodermis. For any skin treatment modality to be effective in South Africa, it is important to take skin tone into consideration. For the purpose of this work, 5 different skin tones from very light to dark were evaluated. The thickness of the different skin layers are provided in **Table 1**. In **Figure 1** illustrating the optical layout, the light escaping from the model is visible as red spots. The effect of backscattered light exiting the model through the stratum corneum is also visible.

The surface area of the model is 10 mm² and the thickness is 4.965 mm. In all cases, a Gaussian laser beam with a diameter of 0.4 mm and power 10 mW was used. To produce statistically sound results, 785 456 rays were traced for each skin tone model. The total thickness of the model was divided into 300 layers and the average absorption in each layer was evaluated.

Evaluations for two different laser wavelengths were conducted; one is a HeNe laser with a wavelength of 632.8 nm and the other a diode laser with a wavelength of 690 nm. The diode wavelength was selected given the absorption features of a specific PDT PS. Both these wavelengths fall within the "treatment and diagnostic window" for light.

The absorption of light through the total thickness of the model (4.965 mm) was evaluated, but only the first 0.2 mm are shown in **Figures 2** and **3** because the absorption is mainly a feature of the epidermis that is only 0.15 mm thick in this model

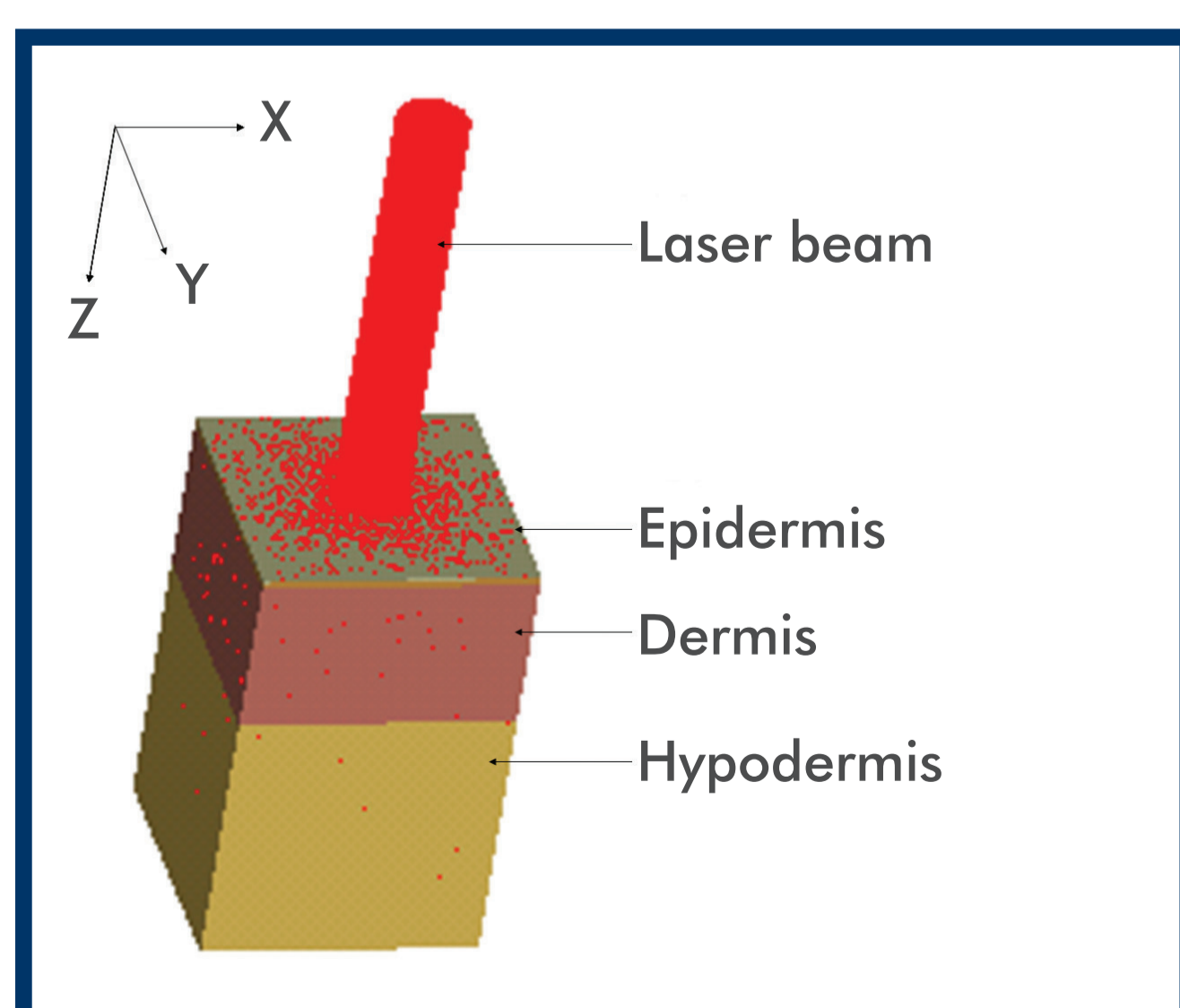


Figure 1: Optical layout showing the different skin layers. The thicknesses of the different layers are given in Table 1

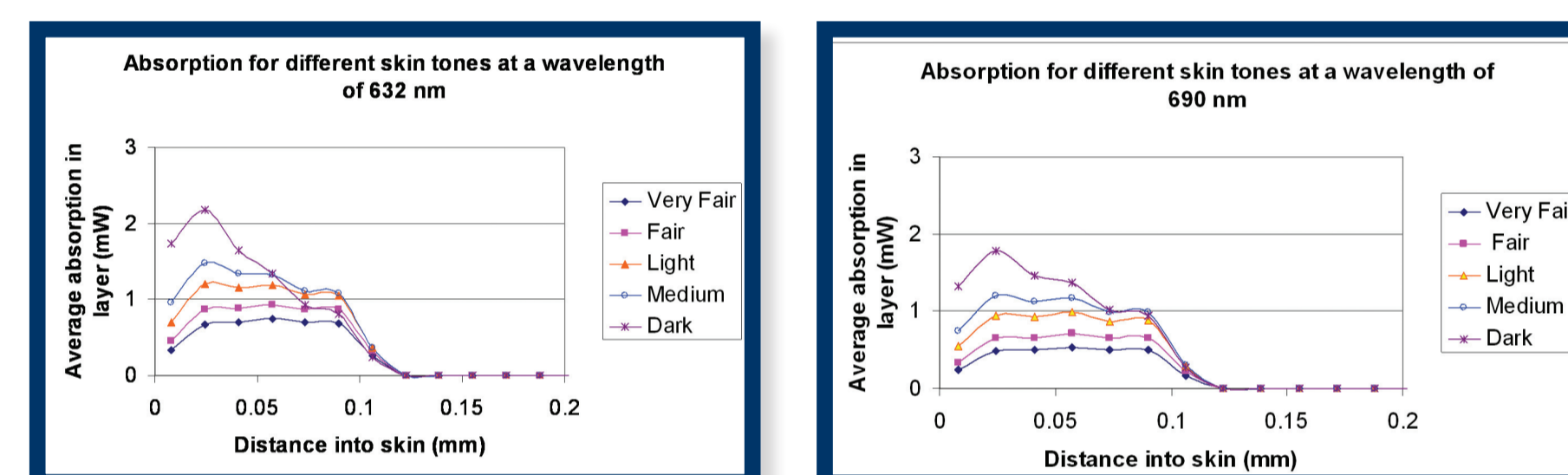
Table 1: Thickness for the different skin layers used

Skin layer	Thickness (mm)
Stratum corneum (SC)	0.015
Epidermis	0.15
Dermis	1.8
Hypodermis	3

RESULTS AND DISCUSSION

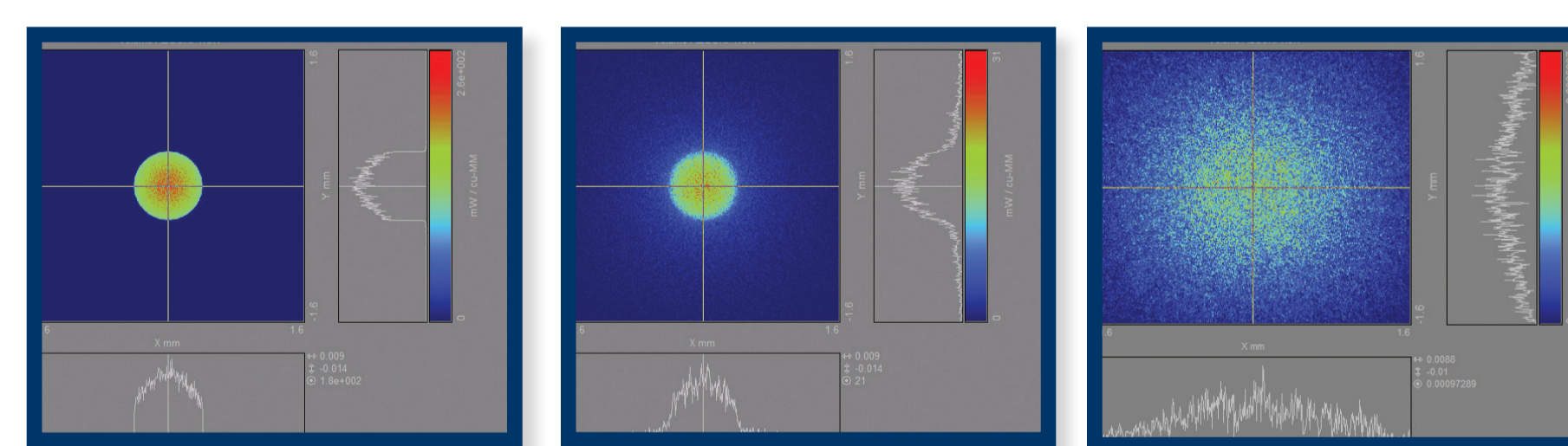
The relative absorption in the first 0.2 mm of the different skin tones at a wavelength of 632 nm are shown in **Figure 2**. **Figure 3** is the results from the 690 nm wavelength. From both **Figures 2** and **3**, the effect of the skin tone on absorption is clear. Comparing the very fair and dark skin, there is at least 3 times more absorption in the epidermis in the dark skin than the very fair skin. If care is not taken during treatment, it is possible to cause unintended damage to the dark skin.

Comparing the different laser wavelengths with each other, the effect is not very dramatic for the two chosen wavelengths, but the results still show that there are differences in the absorption. This should be noted for treatment parameters.



Figures 2 and 3: Absorption in the first 0.2 mm for wavelengths 632 nm and 690 nm respectively

Figures 4-6 shows horizontal (XY in **Figure 1**) cross-sections of the laser beam absorption. The "spreading" of the laser beam as a function of the distance into the skin is clearly visible. The dark skin results are presented here. The colour coding is according to the maximum absorption in each graph. Given the large variance in the absorption values at different depths, it is not possible to display all the graphs with the same maximum colour bar values.



Figures 4, 5 and 6: XY view of the laser beam absorbance at depths of 0.08 mm, 0.1 mm and 1.77mm respectively into the skin

CONCLUSIONS

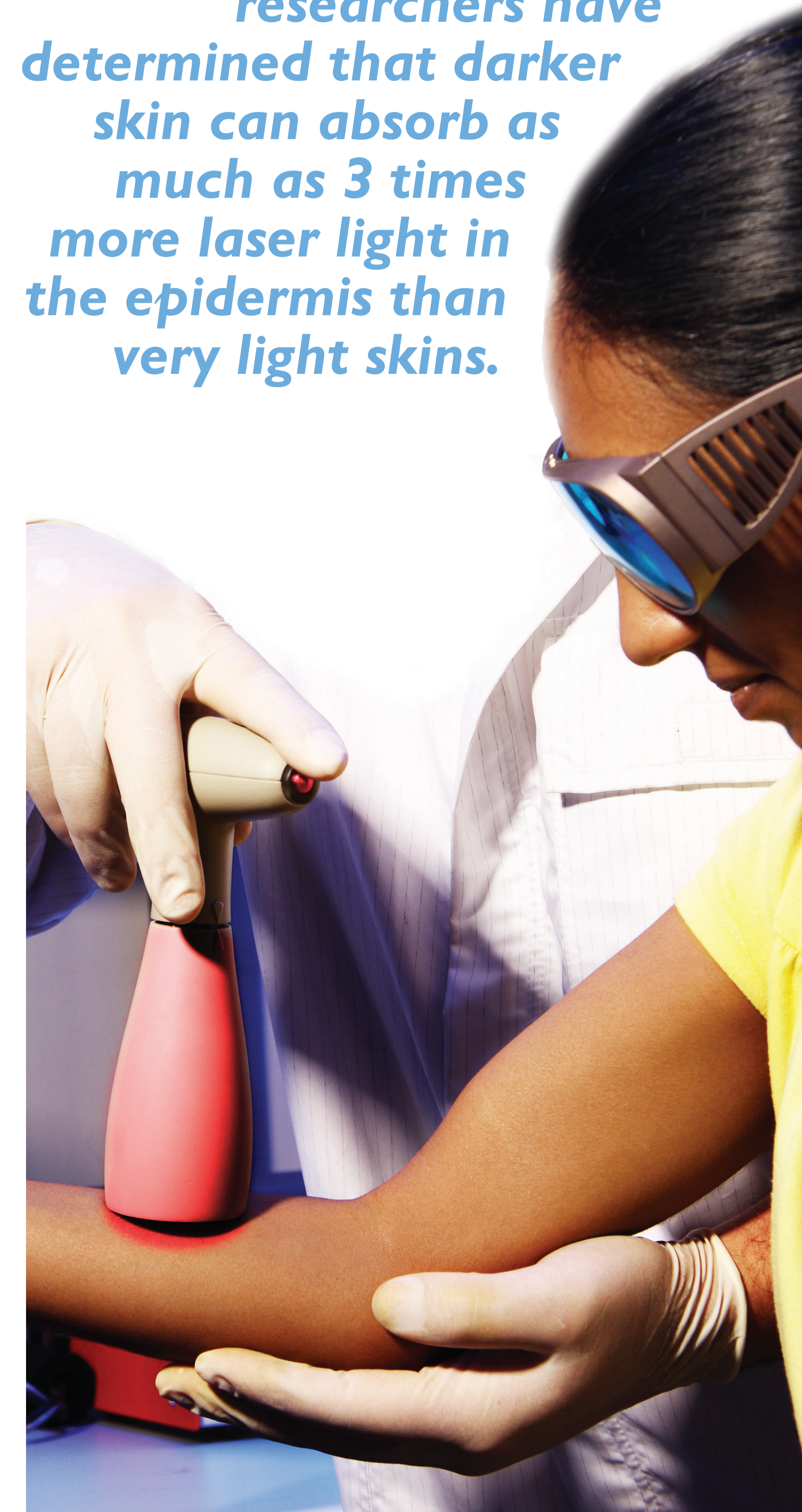
The absorption of light in skin is highly dependent on skin tone. Most of the absorption takes place in the first 0.15 mm into the skin, which is inside the epidermal layer. Light still propagates to deeper levels, but the scattering effect is more pronounced in the deeper levels than the absorption. In dark skin, the absorption can be up to 3 times more than in very fair skin.

Care should be taken to ensure that no harm is done to healthy skin during laser treatments by depositing too much laser energy on darker skin tones. When treatment parameters are specified, it is important to note the amount of light that is absorbed in the epidermis to ensure that enough light will reach the deeper levels where the tumour is embedded.

When comparing the different laser wavelengths it also became clear that although both the wavelengths used are considered to be "red" lasers, measurements of the optical properties at the laser wavelength that will be used for treatment must be conducted. The effect can differ significantly if the evaluations are not conducted at the correct wavelength.

Although the penetration of laser light is a function of the wavelength, the laser wavelength used for a specific PDT treatment is determined by the absorption features of the PS.

Using modelling laser, researchers have determined that darker skin can absorb as much as 3 times more laser light in the epidermis than very light skins.



While this work illustrated the effect of two parameters (wavelength and absorption properties) on the effective dose at different depths into the skin, this is not a completed study. The effect of parameters such as the shape of the input beam and the oxygen concentration in the skin or tumour still needs to be investigated and modelled.

REFERENCES

1. Health 24 - Cancer, Facts and Figures http://www.health24.com/medical/condition_centres