PROCEEDINGS OF SPIE

SPIEDigitalLibrary.org/conference-proceedings-of-spie

Evaluation of laser treatment response of vascular skin disorders in relation to skin properties using multi-spectral imaging

de Roode, Rowland, Noordmans, Herke Jan, Rem, Alex, Couwenberg, Sharon, Verdaasdonk, Rudolf

Rowland de Roode, Herke Jan Noordmans, Alex Rem, Sharon Couwenberg M.D., Rudolf Verdaasdonk, "Evaluation of laser treatment response of vascular skin disorders in relation to skin properties using multi-spectral imaging," Proc. SPIE 6842, Photonic Therapeutics and Diagnostics IV, 68420B (8 February 2008); doi: 10.1117/12.763288

SPIE.

Event: SPIE BiOS, 2008, San Jose, California, United States

Evaluation of laser treatment response of vascular skin disorders in relation to skin properties using multi-spectral imaging

Rowland de Roode, Herke Jan Noordmans, Alex Rem, Sharon Couwenberg, Rudolf Verdaasdonk
Dept. of Medical Technology & Clinical Physics,
University Medical Center Utrecht, The Netherlands.
Correspondence: r.deroode@umcutrecht.nl

ABSTRACT

There can be a large variation in response between laser treatments of vascular malformations like port-wine stains even in one patient. This could be ascribed to variations in the skin properties like tint (melanin) and perfusion (redness) which will influence the effectiveness of the laser dosimetry.

To obtain a better understanding of the relation between skin properties just before treatment, laser dosimetry and clinical response, a multi-spectral dermatoscope is applied. A sequence of calibrated images is captured from 400 to 720 nm. Images at the treatment laser wavelength (532 nm) show the absorbing structures during laser exposure. Images of different treatment sessions of one patient were matched with dedicated registration software to quantify the results of the laser treatment (change in blood vessels structure, effect on pigment). For feasibility, images were collected from 5 patients and used to determine the optimal wavelength combination strategies. The image matching software gives an objective impression of the improvement, e.g. the clearing of the port-wine stain over time or pigment reactions, which will facilitate the discussion with the patient about the end point of treatment.

The multi-spectral dermatoscope and software developed enables the evaluation of large patient series which will result in objective data to advise the dermatologist on the optimal laser dosimetry in future in relation to the skin properties

Keywords: Dermatoscope, biomedical Imaging, multispectral imaging, dermatology, port wine stain, KTP laser.

1. INTRODUCTION

Vascular skin disorders can be a cause of discomfiture and feelings of social insecurity for patients. Examples of these lesions are: (1) Port wine stains, a local hyper vascularisation of the dermis, (2) rosacea increased vascularisation dermis, often seen as a side effect of medication, and (3) spider naevi, elaborate branching of one small vessel in the skin. Several techniques are being used to treat vascular abnormalities in the skin. Abnormalities can be treated with diathermia using a hyfrecator, intense light (IPL) or laser (Pulsed Dye or KTP lasers) (4,5,6,7,8). To study the effectiveness of each technique, patients are often treated with one modality on one side of the skin and another on the other side. To objectify the differences, medical photos are made which are then judged by observers (4,5). In this study, we want to go a step further in objectifying these differences by using an advanced multispectral dermatoscope which can be repositioned with high accuracy on the same spot on the skin during the entire period of treatment sessions. Pulsed laser therapy has become an accepted method of treatment for vascular skin disorders. The treatment laser emits high energetic light pulses of a wavelength corresponding with the selective spectral absorption of the micro vessels in the dermis. Consequently, the micro vessels absorb the energy of the laser and will be severely damaged. The effectiveness of laser treatments varies and there are many variables that could contribute to the effectiveness, such as wavelength, pulse duration, and fluence on the laser side and skin type, and degree of disorder on the patient side. To accurately asses the effects of laser treatment, we followed the effect of pulsed laser treatment for patients with various

Photonic Therapeutics and Diagnostics IV, edited by Nikiforos Kollias, Bernard Choi, Haishan Zeng, Reza S. Malek, Brian Jet-Fei Wong, Justus F. R. Ilgner, Kenton W. Gregory, Guillermo J. Tearney, Henry Hirschberg, Steen J. Madsen, Proc. of SPIE Vol. 6842, 68420B, (2008) · 1605-7422/08/$18 · doi: 10.1117/12.763288

vascular skin disorders over a period of several months. To obtain detailed information of the skin, a specially developed multispectral imaging system was used in combination with dedicated software to visualize the microvasculature in the treated skin. The unique imaging software enabled the matching and objective comparison of skin images taken at different time point during the treatment at one particular location in the lesion over time.

2. MATERIALS & METHODS

2.1 Time scheme of data acquisition

Pulsed laser treatments of three types of vascular skin disorder were evaluated with spectral imaging (see fig. 1 for time scheme). One patient with a spider naevus was treated once. Two patients with a port wine stain were treated two times and three times respectively. In addition, two patients with rosacea were treated, one two times and one three times. Duration between consecutive treatments was one or two months. Multi-spectral images were taken both just before and just after treatment (~5 minutes).

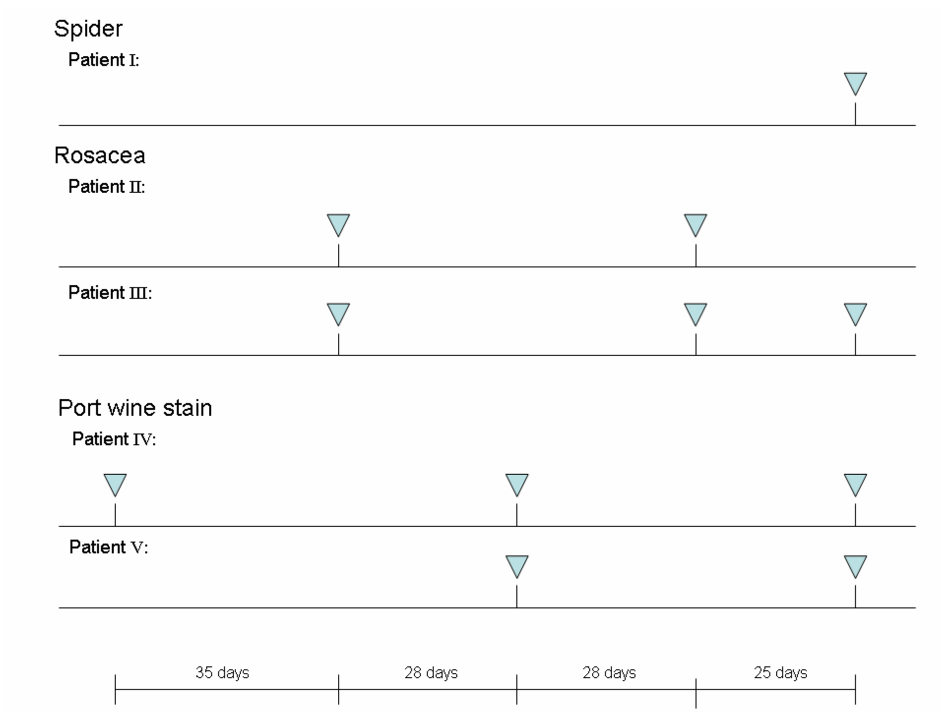

Fig. 1 Time scheme of moments of the pulsed laser treatments at which multispectral images were obtained. The arrow heads indicate the moment of treatment.

2.2 Pulsed laser treatment

The patients were treated with a KTP laser (Versapulse, Coherent/Lumenis, 532 nm). The laser is handled by the dermatologist. Typically, the treatment settings are fluence 13 J/ cm^2, pulse length 30 ms with a spot size of 4 mm. The laser light is irradiated through a sapphire cooling window at 4 degree C which is placed with minimal pressure on the skin at the location of the vascular skin disorder.

2.3 Data acquisition with the multispectral dermatoscope

To obtain an accurate and detailed image of vascular skin disorders before and after treatment, multi-spectral images are recorded of the particular areas of the treated skin. We apply a multi-spectral imaging system as described before[1] (Fig. 2). In summary: the treated area is illuminated by a ring-shaped fiber bundle with polarized light mounted on the camera head of the multi-spectral dermatoscope. The light source is a high power LED (Luxeon 5W White). A Liquid Crystal Tunable Filter (LCTF) (CRI, Cambridge Research International) positioned between lens and camera enables the user to capture a spectral filtered image at any given wavelength between 400 and 720 nm. The filtered images of each wavelength are imaged and captured by a CCD camera. For each measurement, a set of 106 images is obtained within a spectral range of 400 to 720 nm with a step size of 3 nm within a 20 seconds time span.

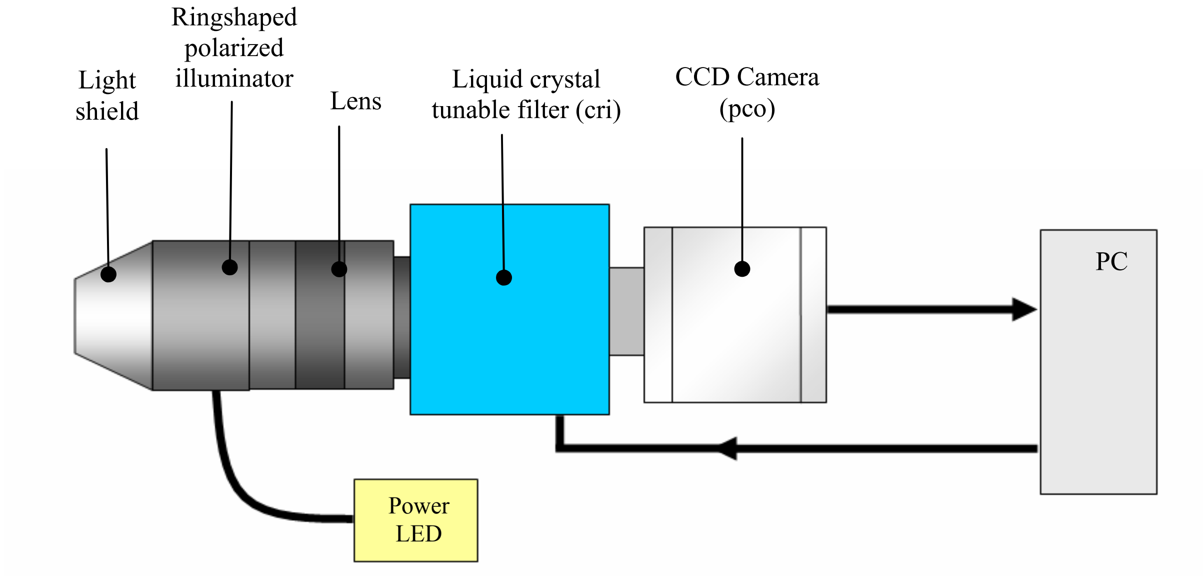

Fig. 2 Schematic overview of the multispectral dermatoscope system.

2.4 Data analysis

Although an effort is made to image the exact same spot of the skin at different time points during the treatment schedule, small differences always remain and can make an accurate comparison extremely difficult. Therefore, dedicated matching software was applied that can perfectly align two images of the same patient taken at different moments [2]. Using this software, images can be compared objectively before and after treatment and differences can be quantified. The vascular lesions can be visualized best at 532 nm. The registered (matched) images can be compared more objectively by an observer or by subtraction and computer analysis.

3. RESULTS

3.1 Spider like naevus

We analysed the effects of pulsed laser treatment on a spider like naevus (patient I, Fig. 3). Multi-spectral images were taken before and directly after the treatment. On the images taken at 532 nm a large difference was observed in the vascular structure. The core of the spider had disappeared almost completely after treatment. In contrast, surrounding micro vessels that were not hit by the laser remained intact. These data demonstrated the effectiveness and specificity of the laser treatment.

Before treatment | Directly after treatment | Subtraction image at 532 nm

Fig. 3 Spider like naevus before and after pulsed laser treatment. Directly after treatment erythema can be seen clearly. Using subtraction of the images at 532 nm, the disappearance of the central part can be appreciated.

3.2 Rosacea

Two patients with rosacea underwent 2-3 pulsed laser treatments. The first patient was given two treatments 56 days apart. By comparing the images of before both treatments, the effect of the first treatment can be assessed. By comparing images made before and directly after treatment, the instant effect is hardly visible. The image taken directly after the treatment usually shows the same vascular structure but the over all image is darker. The darkening is caused by erythema reaction of the skin. When we create ratio images, the difference between before treatment and directly after treatment can be revealed (patient II, Fig. 4). In this case little change was seen in the vasculature shortly after the first treatment. The ratio image of the second treatment, which was applied with higher laser fluence, reveals that a large vessel reacted.

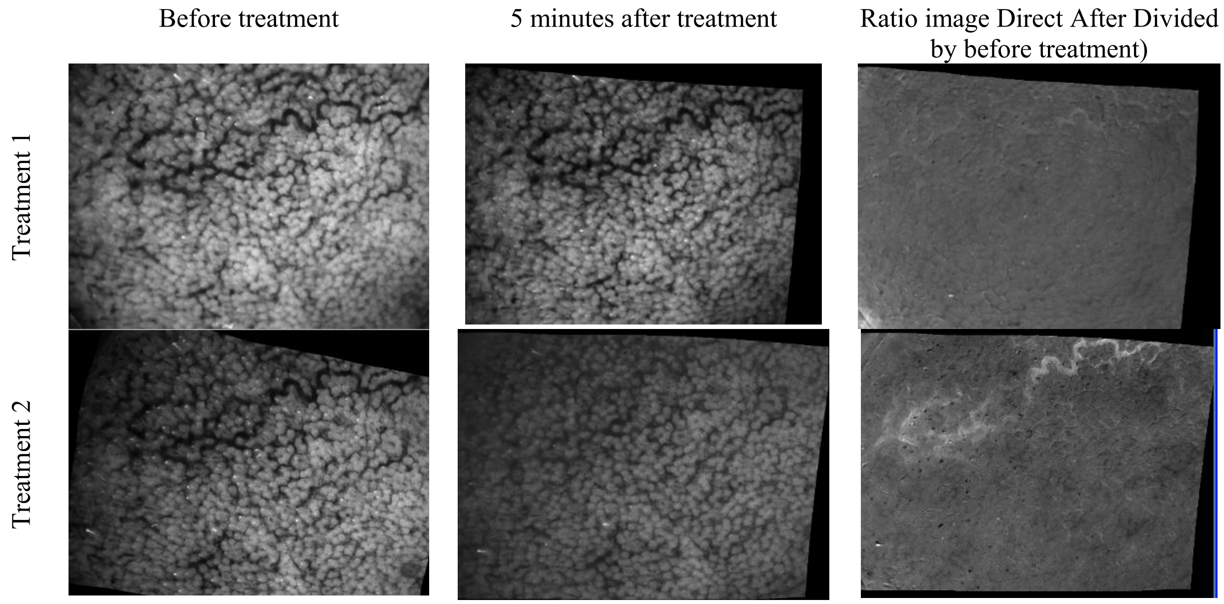

Fig. 4 Results after a low treatment dose (top row), and after applying higher dose for patient II with rosacea. In the ratio image the big vessel was considerably reduced in size after the higher dose.

The change of the spectrum of the responsive vessel seen in Fig. 4 was examined using the pixel spectrometer tool[2]. This tool allows the user to select a pixel, or group of pixels and extract the corresponding spectrum out of the multispectral image. To visualize the spectral change, the ratio spectrum was processed of the surrounding skin tissue and from the responsive vessel. The ratio spectrum shows especially changes in the characteristics of haemoglobin.

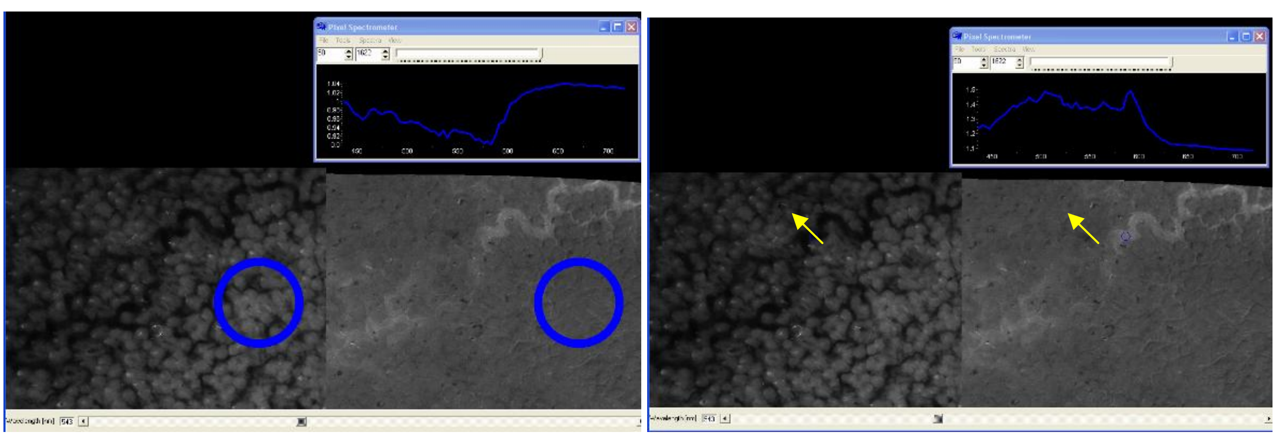

Fig. 5 Patient II with rosacea before and after two sequential treatments. Ratio spectrum shows more blood in the skin shortly after the treatment, caused by erythema, while there is less blood in the large blood vessel.

The second patient with rosacea (patient III), received three pulsed laser treatments with 56 days and 25 days in between, respectively. In contrast to the patient described above, there was a clear reduction in the amount of micro vessels in the treated area. A large reduction in vasculature could be seen after the first treatment of 14 J/cm^2 (Fig. 6). As was seen for the other patient, redness of the skin was a short term effect of the laser treatment. After using a slightly higher setting (16 J/cm^2) the patient developed spots of oedema in the area treated (Fig. 7). Although the treatment caused oedema, the density of micro vessels and the vessel diameters decreased dramatically.

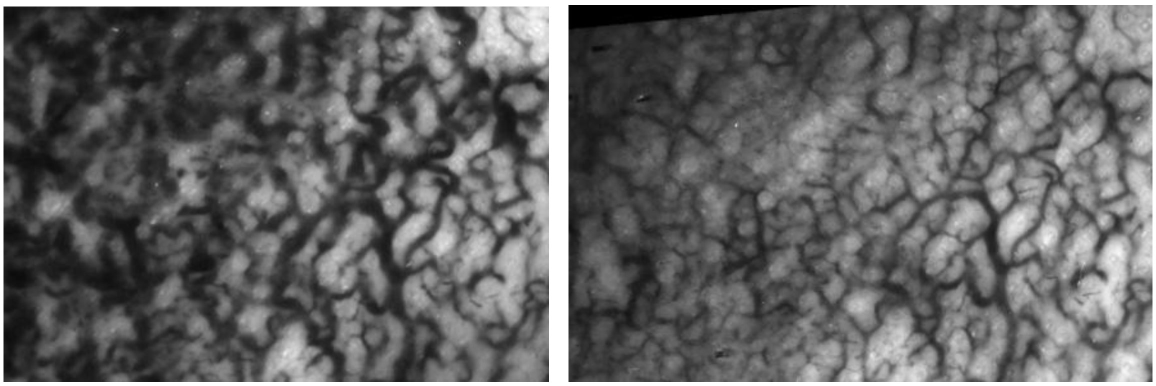

Fig. 6 Clinical result of patient III with rosacea. Images at 532 nm before and after the treatments of 14 J/cm^2. Left before first treatment, right 56 days before the second treatment.

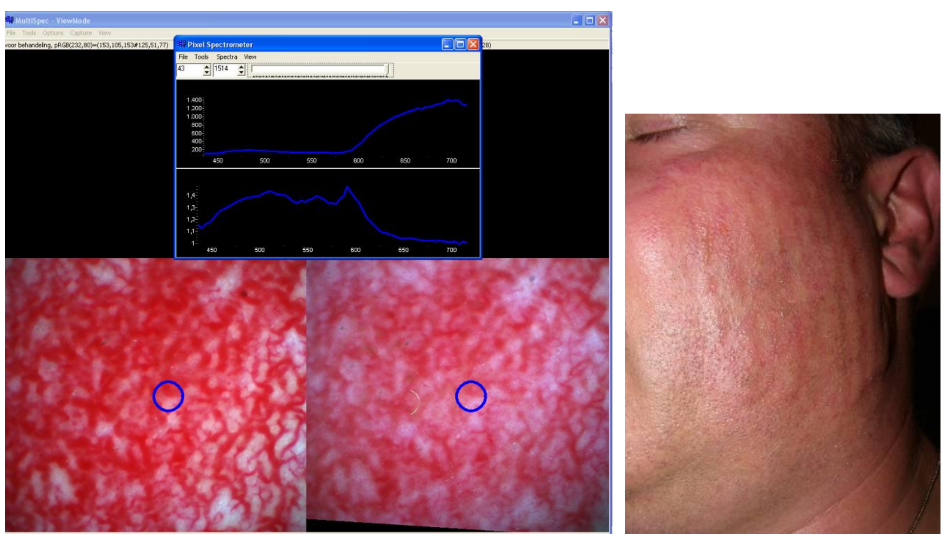

Fig. 7 PixelSpectrometer shows different result shortly after high fluence treatment settings. It seems that the skin already contains less blood directly after treatment. The right photo shows the oedema reaction several hours after the treatment.

3.3 Port wine stains

Two patients with port wine stains underwent consecutive pulsed laser treatments. The first patient (patient IV), was treated three times with 63 and 53 days in between (Fig. 8, Fig. 9).

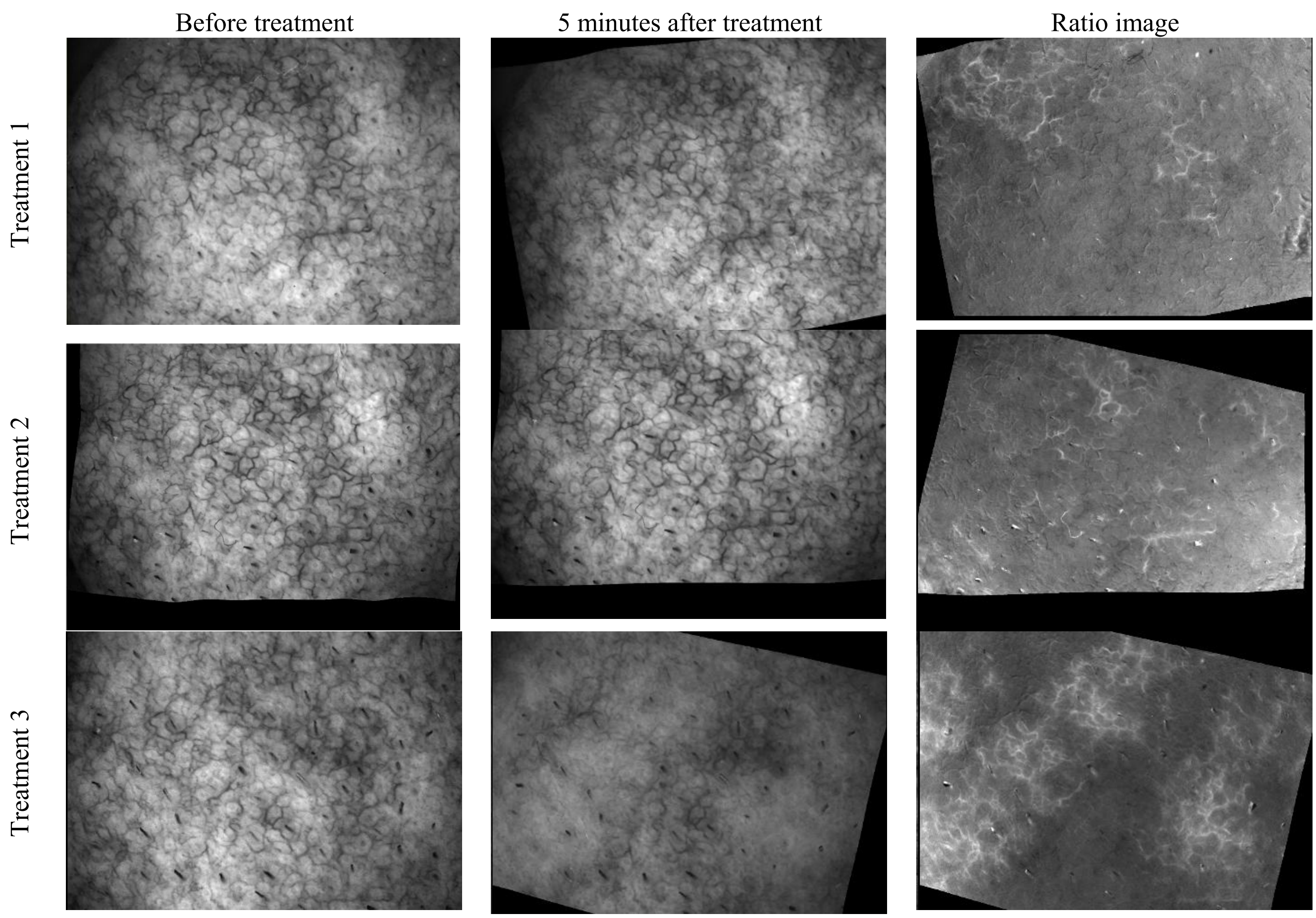

Fig. 8 Ratio spectrum shows no change 63 days after the first treatment of patient IV.

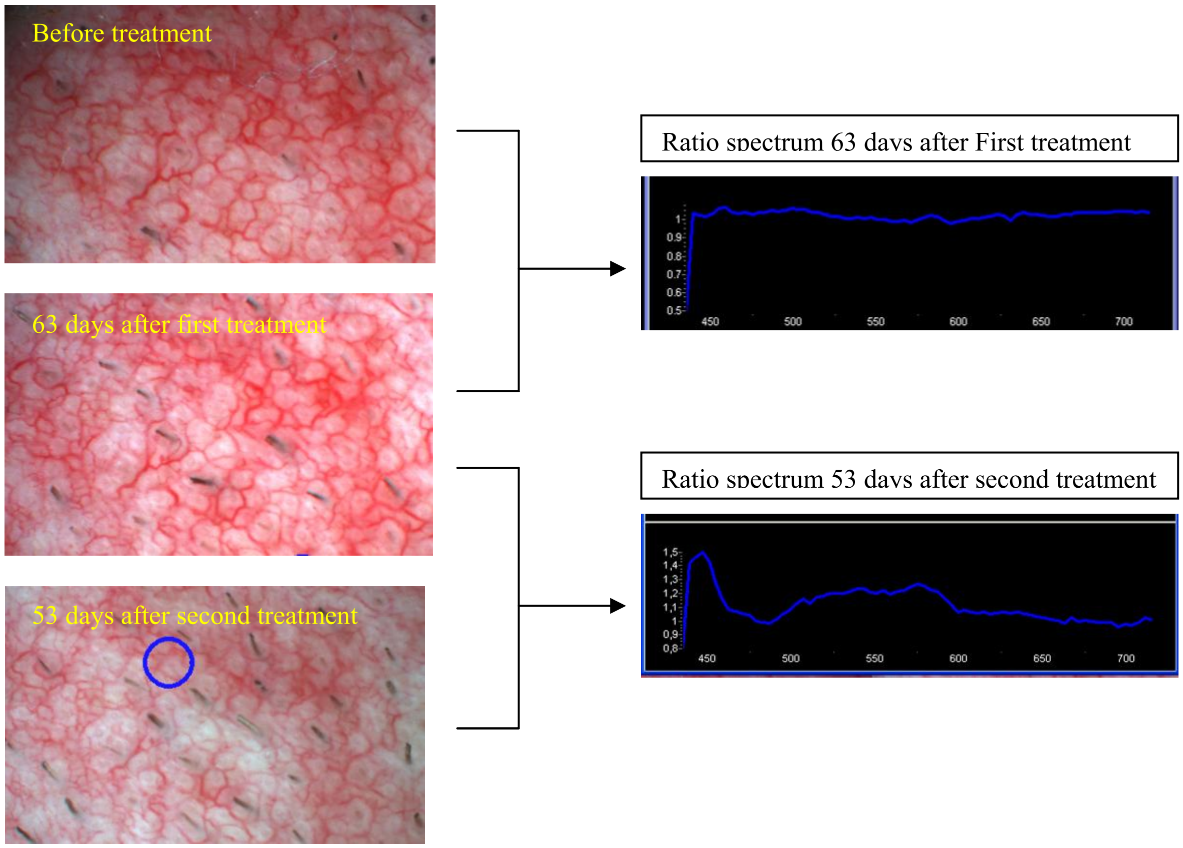

Fig. 9 The ratio spectra show virtually no change 63 days after the first treatment. The ratio spectra show response on the treatment 53 days after the second treatment of patient IV. There is significantly less blood present in the skin.

4. DISCUSSION

In this initial study, the efficacy of the multi-spectral imaging system was examined to evaluate the effect of pulsed laser treatments for various vascular deformations.. The multispectral dermatoscope enables the capture of quantitative images. However, for analysis the registration software is essential. Only the combination of hardware and software gives the capability to obtain the quantitative results to obtain an objective result of the effectiveness of a laser treatment. Potentially, the multispectral imaging can also provide information for optimal treatment in the future after a large group of patients and treatment settings has been analyzed and correlated. These first patient results give a good impression of the capability and additional value of the multispectral dermatoscope for the optimization and evaluation of treatment. The dermatologist now has a tool to obtain an objective measurement of the treatment effect. In this study we have focused on the 532 nm wavelength. However, by collecting more multispectral data sets from patients, more wavelengths of interest need to be examined and more algorithms need to be developed to find potentially indicators for success or failure of the treatment. Already in this small patient population there is a large variation in treatment effect. Some of the parameters like presence of pigment or redness before treatment could be quantified using the multispectral imaging system as indicator for treatment settings and predictor for treatment effect.

A database of multi-spectral images of patients has been developed to store and analyze large data set and will be essential to facilitate data processing. In addition, the data need to be combined with different parameters of the treatment schedule and characteristics of the skin of the patient. When more patients are included in the database, statistical analysis could provide valuable insights in the laser parameters for optimal treatment.

5. CONCLUSION

A multispectral dermatoscopic system combining multispectral images and dedicated alignment software enables analysis of the effectiveness of laser treatments. The potentials for treatment evaluation and optimization of laser settings is already apparent in a small group of patients. The combination of specific wavelengths and development of smart algorithms of dataset from larger patients groups in future, will highly contribute to effectiveness of the treatment of vascular lesions.

REFERENCES

1. H.J. Noordmans, R. de Roode, and R.M. Verdaasdonk, *Development of a multi-spectral imaging system for optical diagnosis of malignant tissues*, Proc. SPIE Int. Soc. Opt. Eng. 5694, 1, 1-8 (2005)
2. H.J. Noordmans, R. de Roode, and R.M. Verdaasdonk, *Registration and analyses of in-vivo multi-spectral images for correction of motion and comparison in time*, Proc. SPIE Int. Soc. Opt. Eng., 6078A-28, 1 (2006).
3. Butler EG 2nd, McClellan SD, Ross EV. Split treatment of photodamaged skin with KTP 532 nm laser with 10 mm handpiece versus IPL: a cheek-to-cheek comparison, Lasers Surg Med. 38(2), 124-8 (2006)
4. Dawn G, Gupta G. *Comparison of potassium titanyl phosphate vascular laser and hyfrecator in the treatment of vascular spiders and cherry angiomas*. Clin Exp Dermatol. 28(6), 581-3 (2003)
5. Kauvar AN, Frew KE, Friedman PM, Geronemus RG. *Cooling gel improves pulsed KTP laser treatment of facial telangiectasia*. Lasers Surg Med. 30(2), 149-53 (2002)
6. Rusciani A, Motta A, Fino P, Menichini G. *Treatment of Poikiloderma of Civatte Using Intense Pulsed Light Source: 7 Years of Experience.* Dermatol Surg. 19 [Epub ahead of print] (2007)