Rapid Skin Profiling with Non-Contact Full-Field Optical Coherence Tomography: study of patients with Diabetes Mellitus Type I

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The skin of diabetic patients has been characterized in a non-contact way with the novel full-field optical coherence tomography microscope followed by an automatic morphology quantification procedure. Results have demonstrated high correlation with reference method.

OCIS codes: (170.4500, 110.4500) Optical coherence tomography, (110.0113) Imaging through turbid media (170.4580) Optical diagnostics for medicine, (170.1870) Dermatology, (040.1490) Cameras, (100.6950) Tomographic image processing; (170.1790) Confocal microscopy; (200.6046) Smart pixel systems

1. Introduction

Self-monitoring of blood glucose is a prerequisite for achieving tight metabolic control in patients with diabetes on intensified insulin therapy [1]. Currently the control of the body glucose is performed in blood samples obtained by pricking the finger. This procedure, considered unpleasant and painful by many diabetic patients, has to be performed several times a day. Thus a reliable method for non-invasive glucose monitoring (NIGM) could present a great relief to millions of patients with diabetes around the world. A number of NIGM approaches based on different physical techniques have been developed and tested in the last two decades and a few are under continued development [2,3]. These approaches are typically based on the biophysical characterisation of skin and underlying tissue. There is a growing awareness that, besides the underlying physiological dynamics of glucose and other metabolites, an understanding of the skin morphology and its variations is essential for the quantitative reproducibility of NIGM methods [2]. A robust and fast method for the acquisition and quantification of the skin structure would be beneficial for the investigation and interpretation of inter-patient differences. Additionally, methodologies that are suitable for the online monitoring of skin morphology could have a great value for the further development of non-invasive *in vivo* measurement modalities.

2. Methods

In this work we present a measurement technique for profiling of the superficial skin layers based on the open space Optical Coherence Tomography (OCT) microscope utilising Smart Pixels technology [4]. A fully automatic processing scheme has been developed that is shown to provide near instantaneous estimates of the clinically-relevant skin dimensions such as epidermal thickness (ET), thickness of the dermal-epidermal junction (DEJ) and

the end of papillary junction or dermal depth. The skin characterisation procedure is performed without contact with imaged area and requires only a few minutes to complete including the time taken for patient arm placement under the microscope measurement head.

The OCT measurements were performed of the dorsal part of the upper arm and validated with reference measurements provided by a commercial Laser Scanning Confocal Microscope (LSCM) VivaScope 1500 from Lucid Inc. (USA) followed by expert-assisted image analysis.

Measurements were performed on 22 patients (13 males and 9 females) with Type I Diabetes Mellitus (age; 41.7±12.7 years; body mass index: 24.2±2.8 kg/m^2; duration of diabetes 19.8±12.8 years; HbA1c: 6.9±0.7%) to enable tissue characterisation to occur within the clinical studies performed by Solianis Monitoring AG.

3. Results

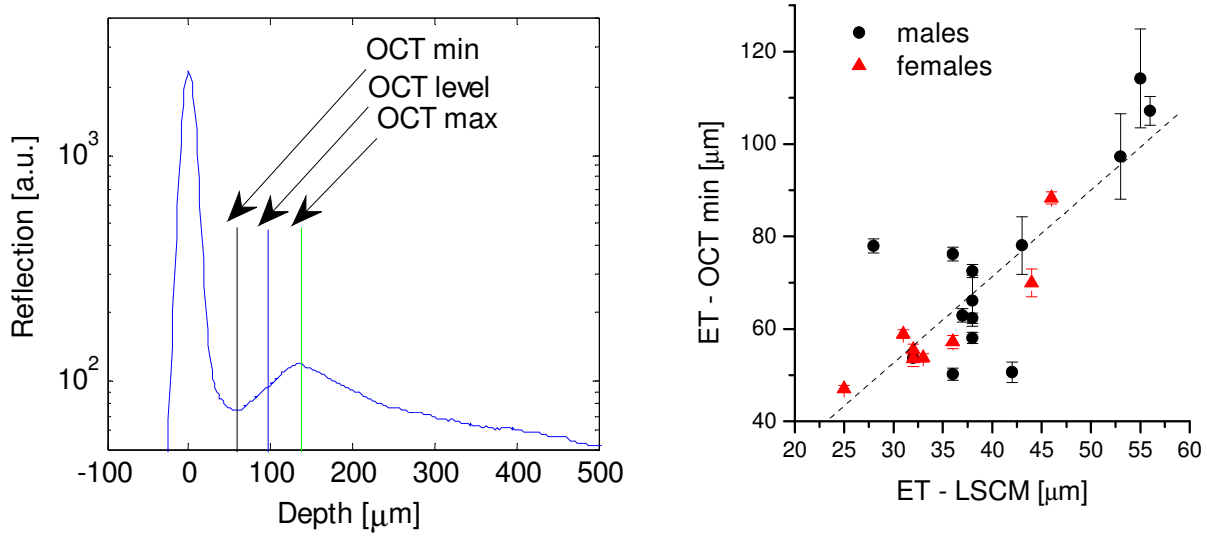

Figure 1 Dimension characteristics of the OCT reflection profile (left) and comparison of OCT min and LSCM based estimation of ET (right).

We have analyzed different dimension characteristics of OCT profile which has been used by other groups for the ET characterisation, like distance from surface (first maximum) to first minimum (OCT min), to the second maximum (OCT max) and to the half level between minimum and maximum (OCT level) (see Figure 1 for illustration). The highest correlation with LSCM ET corresponds to the distance from the OCT min ($r \approx 0.82$, $p < 0.0001$). The OCT max has slightly lower correlation with LSCM ET ($r \approx 0.65$, $p \approx 0.0009$) and is probably related to the dermal depth. We observed a decrease in the dermal depth with age due to the thinning of the DEJ, which agrees with findings of other groups (e.g. Ref. 5). The dermal depth also has a statistically significant correlation with body mass index (BMI). Lower mean values of ET and dermal depth for females (see right graph in Figure 1) can be related to the smaller BMI when compared to males.

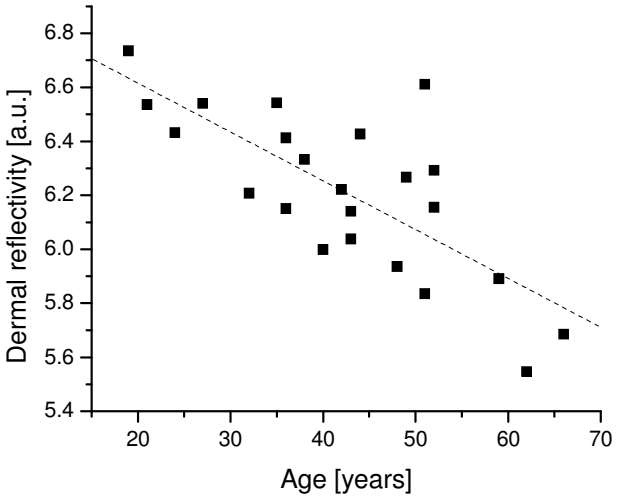

Figure 2 Dermal reflectivity as a function of age.

We have also revealed a high negative correlation of the dermal reflectivity with age ($r \approx -0.75$, $p < 0.0001$), which can most likely be associated with aging. This can be a manifestation of the collagen degradation in the dermal layer due to the exposure to UV light and due to intrinsic aging processes [6].

The obtained results of these 22 patients do not manifest statistically significant correlations of the duration of diabetes with the measured skin morphological properties at the specific body location.

In conclusion, the procedure involving fast data acquisition of the skin layers with parallel OCT microscope followed by automatic quantification of the skin morphology has been developed and validated with a human-assisted LSCM investigation. Correlations with patients' demographic characteristics have been observed.

Currently these findings are being compared to data accumulated by the NIGM system to assess the effect of the skin morphology on its performance.

4. References

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