DAMAE MEDICAL
see beyond appearances

DERMOCOSMETIC BOOKLET

All LC-OCT publications

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IMAGES COURTESY OF

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INTRODUCTION

General Optics

INTRODUCTION TO LC-OCT PRINCIPLE

Line-field confocal optical coherence tomography for high resolution non invasive imaging of skin tumors

A Dubois, O Levecq, H Azimani, D Siret, A Barut, M Suppa, V Del Marmol, J Malvehy, E Cinotti, P Rubegni, JL Perrot

LC-OCT combines the principles of time-domain optical coherence tomography and confocal microscopy with line illumination and detection using a broadband laser and a line-scan camera. LC-OCT images reveal a comprehensive structural mapping of skin at the cellular level down to a depth of ~500 µm. LC-OCT has been applied to the imaging of various skin lesions, in vivo, including carcinomas and melanomas. LC-OCT images are found to strongly correlate with conventional histopathological images.

Journal of the European Academy of Dermatology and Venereology, May 2021, doi: 10.1111/jdv.17078.

OVERVIEW OF LC-OCT

Dual-mode line-field confocal optical coherence tomography for ultrahigh-resolution vertical and horizontal section imaging of human skin in vivo.

J Ogien, O Levecq, H Azimani, A Dubois

LC-OCT is a technique for ultrahigh-resolution imaging of human skin in vivo. LC-OCT allows horizontal andvertical section images. A quasi-identical spatial resolution of 1 µm is measured for both B-scans and C-scans.The images are acquired in both modes at a rate of 10 frames per second. The user can switch between the twomodes by clicking a button. In vivo cellular-resolution imaging of human skin enables the possibility to navigatewithin the skin tissues in real time.

Biomedical Optics Express, February 2020;11(3):1327-1335. doi: 10.1364/BOE.385303. eCollection 2020 Mar 1.

INTRODUCTION TO 3D-IMAGING

Line-field confocal optical coherence tomography for threedimensional skin imaging

J Ogien, A Daures, M Cazalas, JL Perrot, A Dubois

This paper discusses advancements in LC-OCT allowing 3-dimensional image acquisition, in real-time with control of depth and lateral positions. Utilizing a portable probe with a button and scroll wheel for mode control, the device employs a supercontinuum laser and high numerical microscope objective to achieve an isotropic spatial resolution of 1 µm. Three-dimensional images have a field of view measuring 1.2 mm × 0.5 mm × 0.5 mm (x × y × z), with skin tissue images demonstrating the technology's potential in dermatology applications.

Frontiers of Electronics, 2020, DOI: 10.1007/s12200-020-1096-x

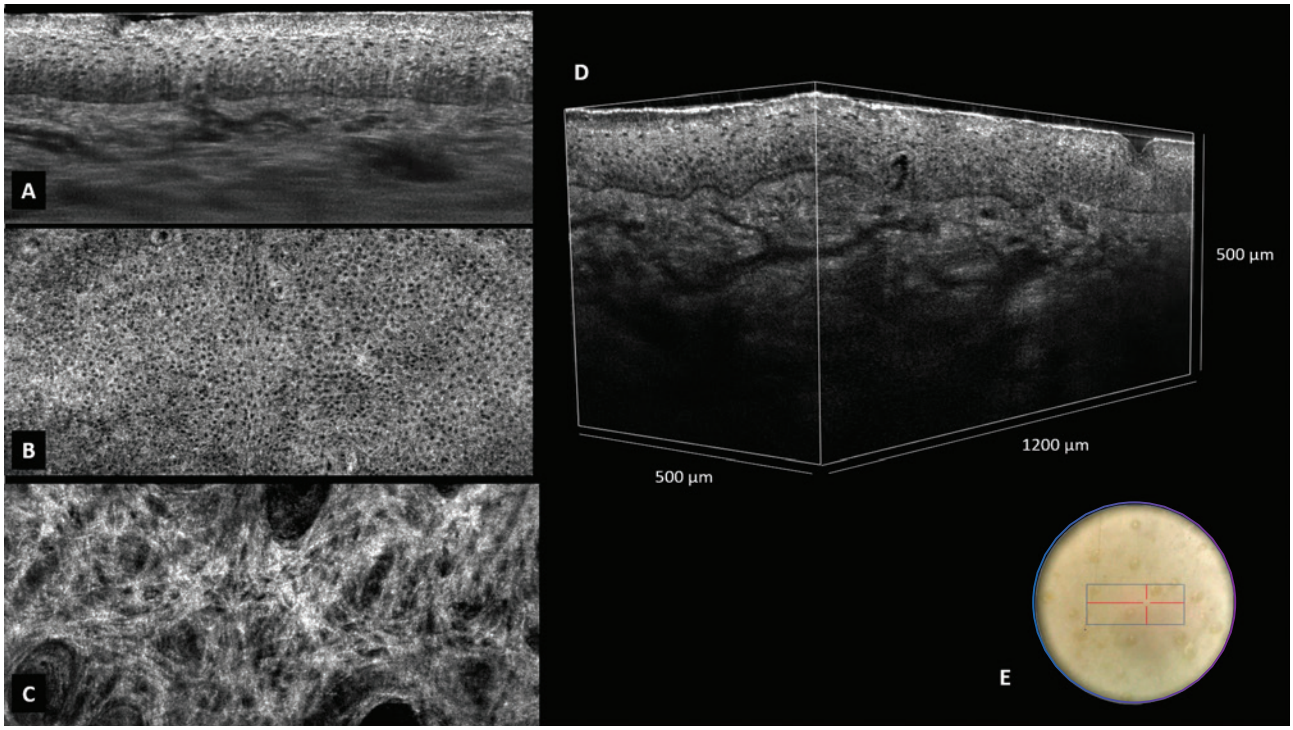
LC-OCT INCLUDING AI

Line-Field Confocal Optical Coherence Tomography (LC-OCT) for Skin Imaging in Dermatology

F Latriglia, J Ogien, C Tavernier, S Fischman, M Suppa,JL Perrot, A Dubois

LC-OCT is a non-invasive imaging technique that combines principles of optical coherence tomography and reflectance confocal microscopy to produce cell-resolved skin images enabling easy access to any skin area for detailed examination. LC-OCT is particularly valuable in dermatological research for high value skin metrics as well as for understanding inflammatory or infectious diseases at a cellular level. Additionally, new AI-driven deep learning algorithms enhance the analysis of LC-OCT images, significantly advancing diagnostic accuracy and therapeutic follow-up in both clinical practice and dermocosmetic research.

Life (Basel). 2023 Nov 28;13(12):2268. doi: 10.3390/life13122268. PMID: 38137869; PMCID: PMC10744435.



Visualization of the skin through the LC-OCT device.

- **A** 2D vertical LC-OCT view. All the different structures of the skin appear: the stratum corneum (SC), the epidermis, the dermoepidermal junction (DEJ) and the dermis (from top to bottom).
- **B** 2D axial LC-OCT view in the epidermis
- **C** 2D axial LC-OCT view in the dermis
- **D** 3D stack
- **E** Surfacic image of the skin. The blue rectangle represents the location of the 3D visualize.

AI for quantification of the skin

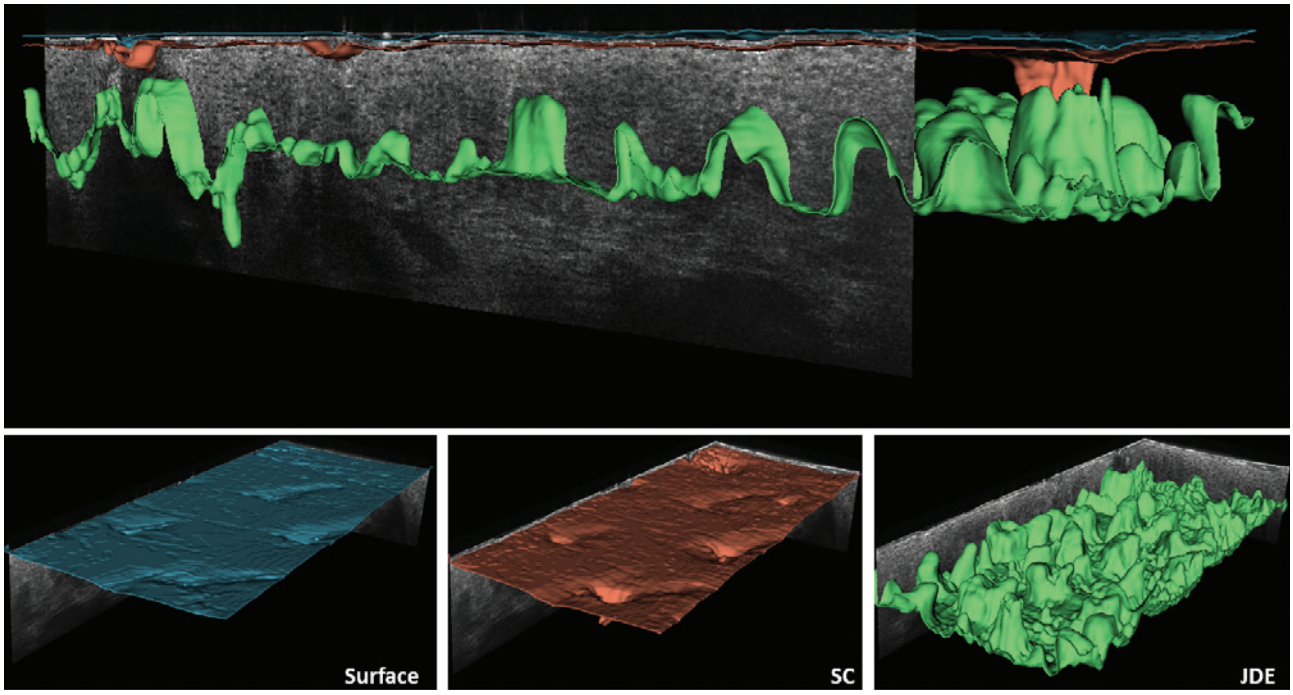
SKIN LAYER SEGMENTATION

Artificial intelligence-based PRO score assessment in actinic keratoses from LC-OCT imaging using Convolutional Neural Networks

JR Thamm, F Daxenberger, T Viel, C Gust, Q Eijkenboom, LE French, J Welzel, EC Sattler, S Schuh

A Convolutional Neural Network (CNN) was trained on more than 3,500 healthy skin LC-OCT images, including several phototypes and body areas, and fine-tuned with more than 450 AK lesions to automatically segment skin layers (surface, stratum corneum and DEJ). Based on the segmentations, enabling the computation of the epidermis thickness and the DEJ undulation, another CNN model was trained (on 237 AK images) to quantify the PRO score, achieving significant agreement (75%) with experts' visual consensus, particularly in PRO II grading (84.8%) (tested on 76 images).

Journal of the German Society of Dermatology: JDDG, vol. 21, no. 11, 2023, pp. 1359–68, https://doi.org/10.1111/ddg.15194_g.



Visualization of the different layers of the skin in 3D

- Surface
- junction between the epidermis and the stratum corneum
- dermoepidermal junction

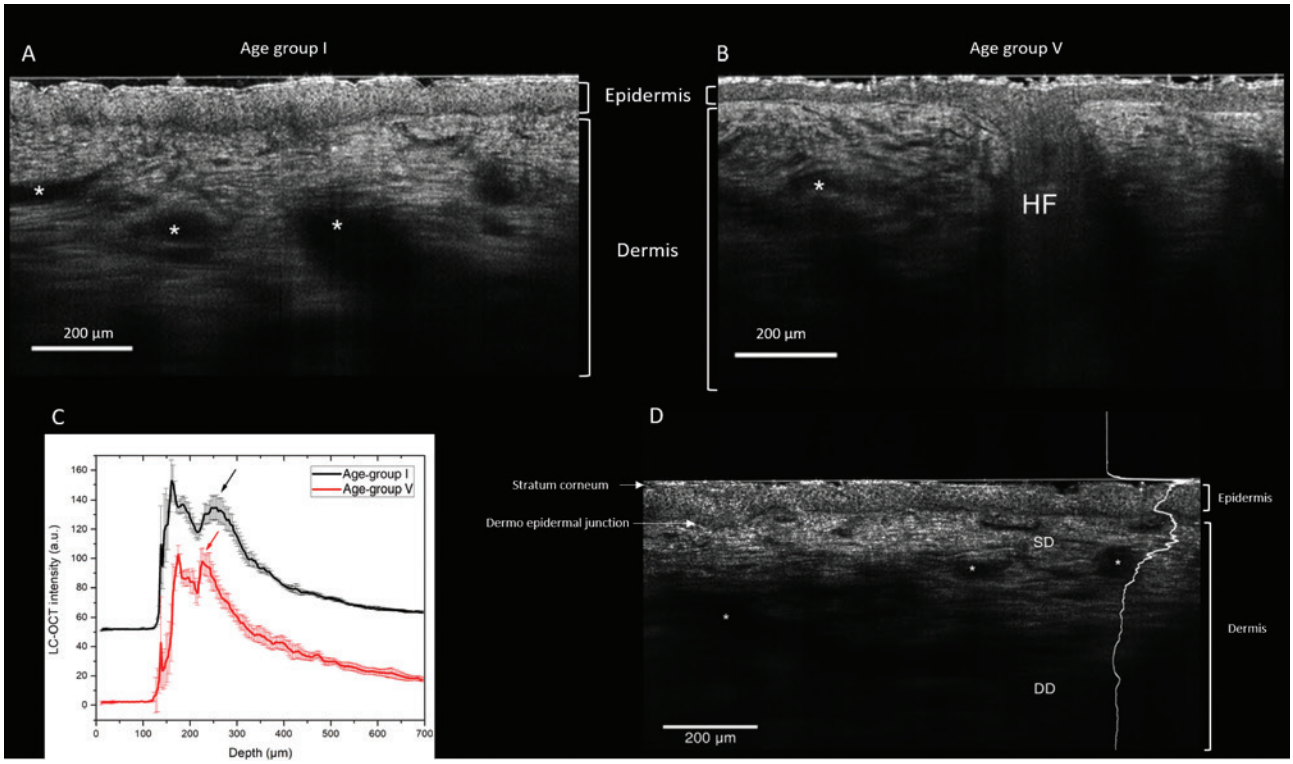
SUPERFICIAL DERMIS THICKNESS

Comparison of Line-Field Confocal Optical Coherence Tomography Images with Histological Sections: Validation of a New Method for in Vivo and Non-Invasive Quantification of Superficial Dermis Thickness

M Pedrazzani, J Breugnot, P Rouaud-Tinguely, M Cazalas, A Davis, S Bordes, A Dubois, B Closs

This study aimed to validate a new method for quantifying superficial dermis thickness by comparing LC-OCT images with histological sections and assess age-related changes in superficial dermis. 37 healthy Caucasian female, aged between 22 to 69 years old, were imaged on the cheek. Results demonstrated that LC-OCT allows visualization and quantification of the superficial portion of the papillary dermis thanks to the intensity profile and revealed a consistent decrease in thickness with age across different age groups.

Skin Research & Technology. 2020; 26: 398–404.



Application of LC-OCT to the measurement of superficial papillary dermis thickness across aging. Annotated LC-OCT images acquired on the cheek of representative volunteers of a group aged between 22 and 27 years old

A and a second group aged between 61 and 69 years old

B

HF hair follicle

* blood vessels

C LC-OCT intensity depth profiles of volunteers from:

—— Group I

—— Group V

⇨ the contributions of the superficial dermis in the intensity profiles

Each curve is the average of data from four volunteers. For greater readability, the curve of age-group I was translated vertically.

D Annotated LC-OCT image acquired on the cheek of a 22 year old volunteer

SD superficial dermis

DD deep dermis

* blood vessels

The white line on the right side of the image corresponds to the intensity profile:

- 1st maximum peak indicates the SC
- 1st minimum peak indicates the DEJ

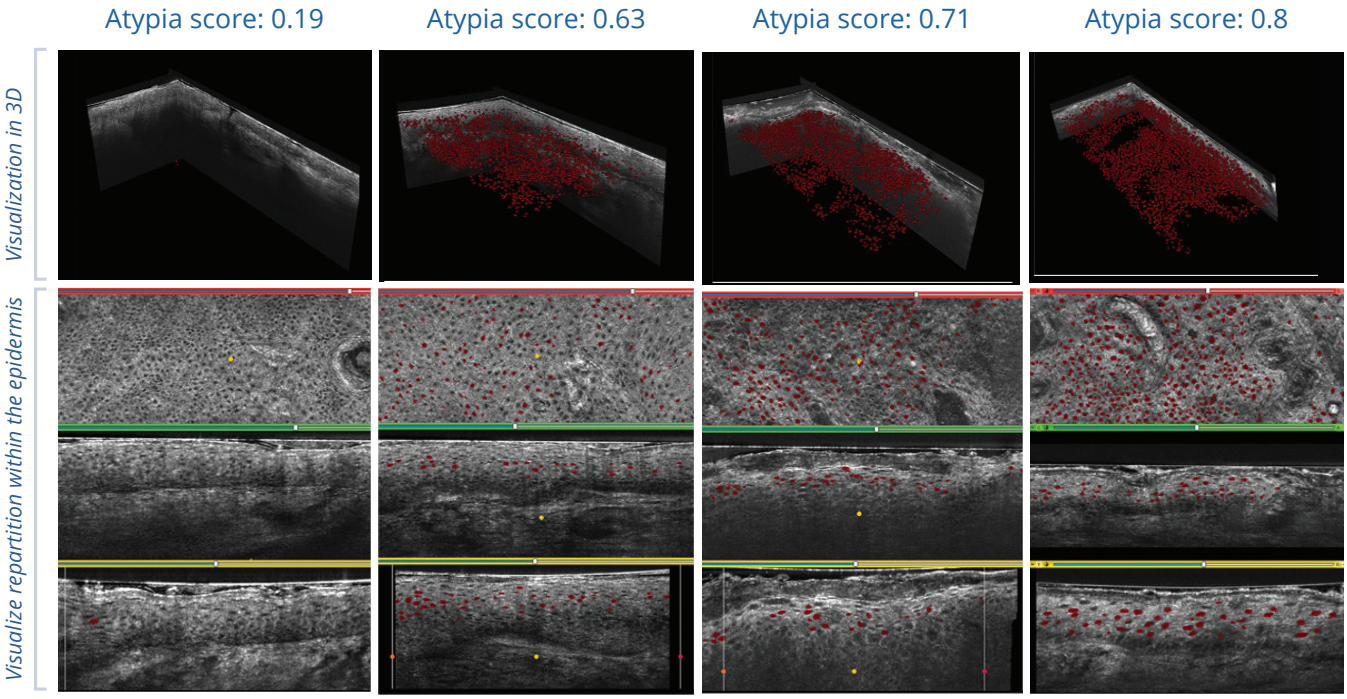
KERATINOCYTE ATYPIA

Non-invasive scoring of cellular atypia in keratinocyte cancers in 3D LC-OCT images using Deep Learning

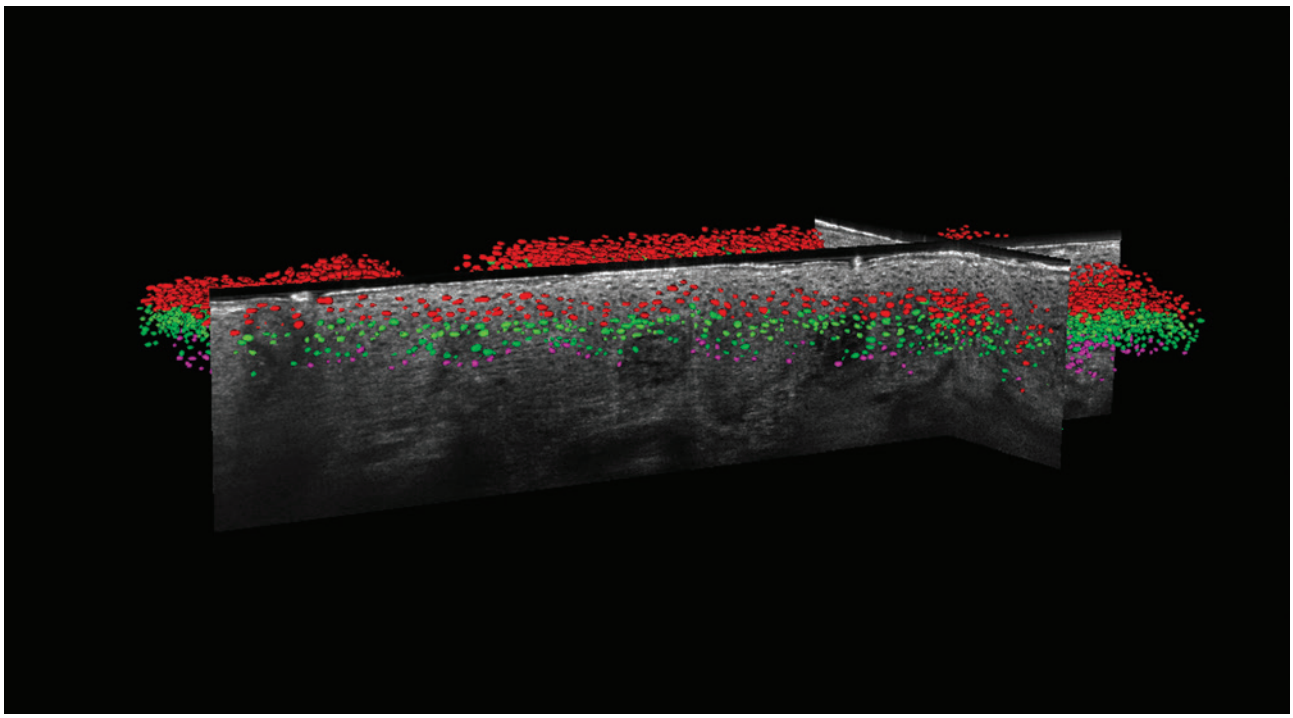
S Fischman, J Pérez-Anker, L Tognetti, A Di Naro, M Suppa, E Cinotti, T Viel, J Monnier, P Rubegni, V Del Marmol, J Malvehy, S Puig, A Dubois, JL Perrot

LC-OCT allows a non-invasive 3D approach to objectively define and quantify cellular metrics. From the keratinocyte (KN) nuclei segmentations, features with simple biological understanding as the surfacic density, the volume or the compactness of KN nuclei can be computed. The atypia is a more complex metrics which can be defined and quantified using Deep Learning. Depending on the approach, the definition of atypia can vary. The best method achieves AUC scores over 0.965, outperforming medical experts (AUC 0.766), and defines high atypia by big cells surrounded by cells with heterogeneous sizes. In clinic, this metrics offers precise monitoring and assessment of skin lesions and treatment effects without invasive procedures.

Scientific Reports, vol. 12, no 1, Art. no 1, January 2022, doi: 10.1038/s41598-021-04395-1.

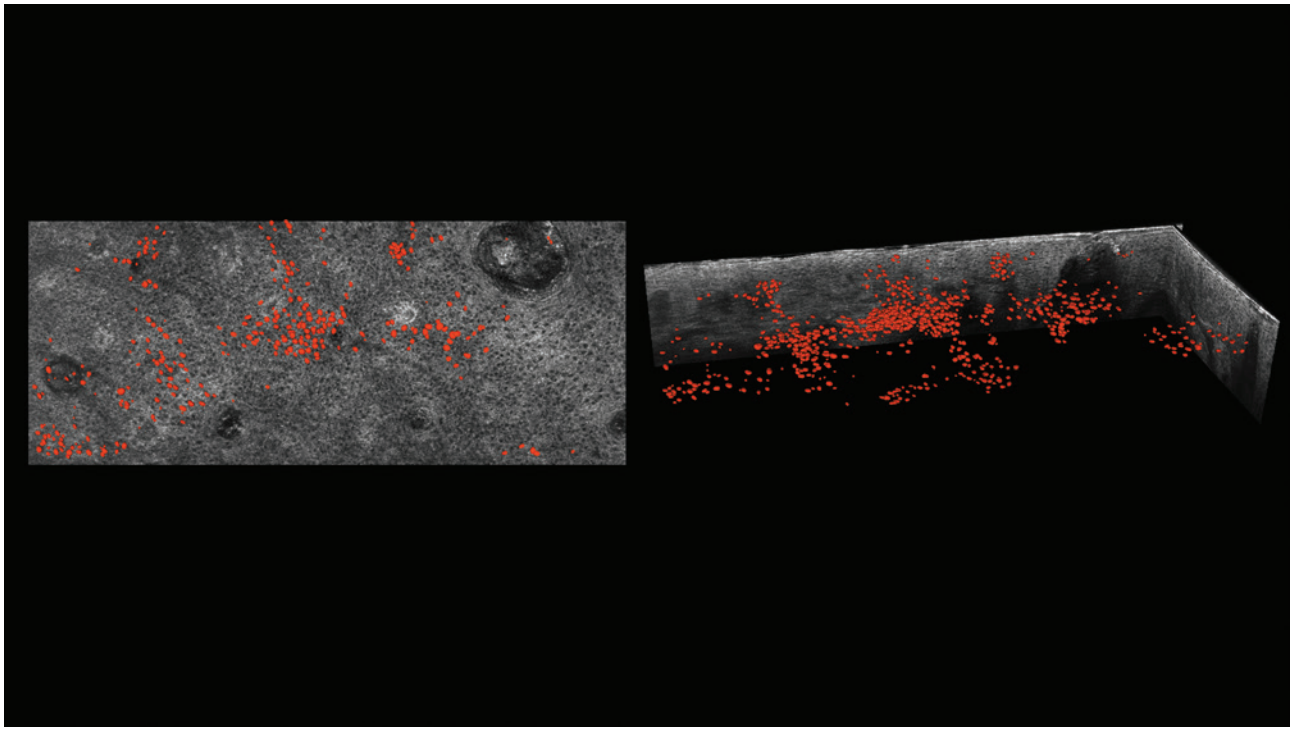


Isolation of cell with the highest atypia score.



3D visualization of the keratinocytes based on their maturation stage

- More matured keratinocytes (localized at the top of the epidermis)
- Middle maturation keratinocytes
- Most immature keratinocytes (localized near the basal layer)



3D visualization of the KN with the highest atypia score on skin with keratose actinitic

- keratinocytes with the highest atypia score

APPLICATIONS

Skin Aging

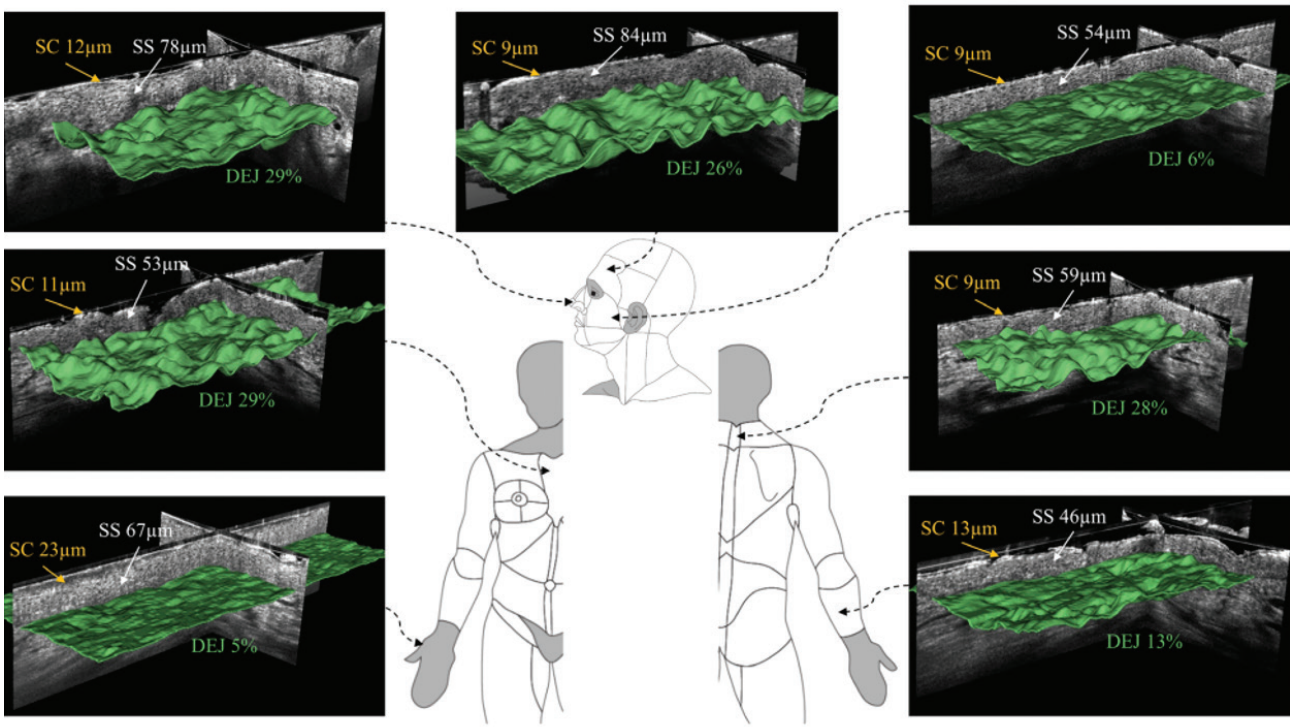
ANATOMICAL VARIATION & AGING

Line-field confocal optical coherence tomography as a tool for three-dimensional in vivo quantification of healthy epidermis: A pilot study

J Chauvel-Picard, V Bérot, L Tognetti, C Orte Cano, M Fontaine, C Lenoir, J Pérez-Anker, S Puig, A Dubois, S Forestier, J Monnier, R Jdid, G Cazorla, M Pedrazzani, A Sanchez, S Fischman, P Rubegni, V del Marmol, J Malvehy, E Cinotti, JL Perrot, M Suppa

LC-OCT offers real-time, high-resolution, in-vivo 3D skin imaging enabling epidermal 3D topography characterization and quantification. This pilot study quantified epidermal metrics using 3D LC-OCT, imaging seven body sites for each of 8 female participants, including younger and older volunteers with skin type II. Epidermal metrics, including thicknesses of epidermis/stratum corneum, dermal-epidermal junction undulation, and keratinocyte nuclei volume, varied across body sites, with evidence of keratinocyte maturation observed in vivo. Combining LC-OCT with artificial intelligence enables quantification of skin microanatomy, offering insights into aging processes and epidermal disorders, with anticipated clinical and research applications.

Journal of Biophotonics, 2022, 15(2), e202100236. https://doi.org/10.1002/jbio.202100236



Representation of the JDE on different body sites

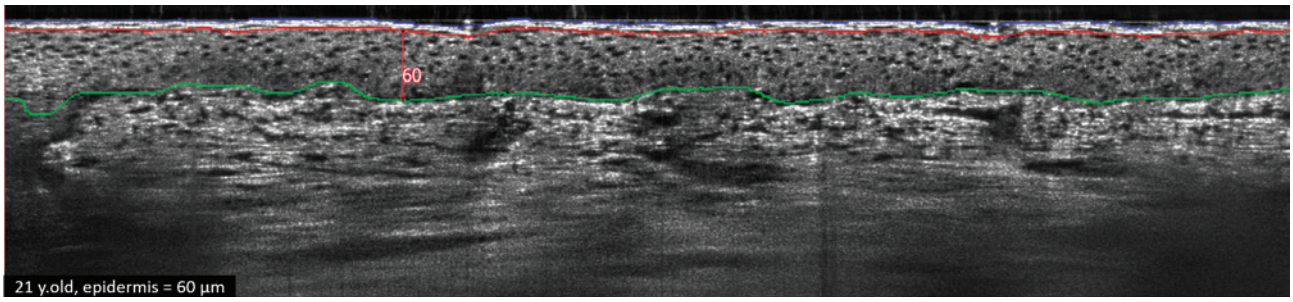
SKIN AGING BIOMARKERS

Line-field confocal optical coherence tomography coupled with artificial intelligence algorithms to identify quantitative biomarkers of facial skin ageing.

F Bonnier, M Pedrazzani, S Fischman, T Viel, A Lavoix, D Pegoud, M Nili, Y Jimenez, S Ralambondrainy, JH Cauchard, R Korichi

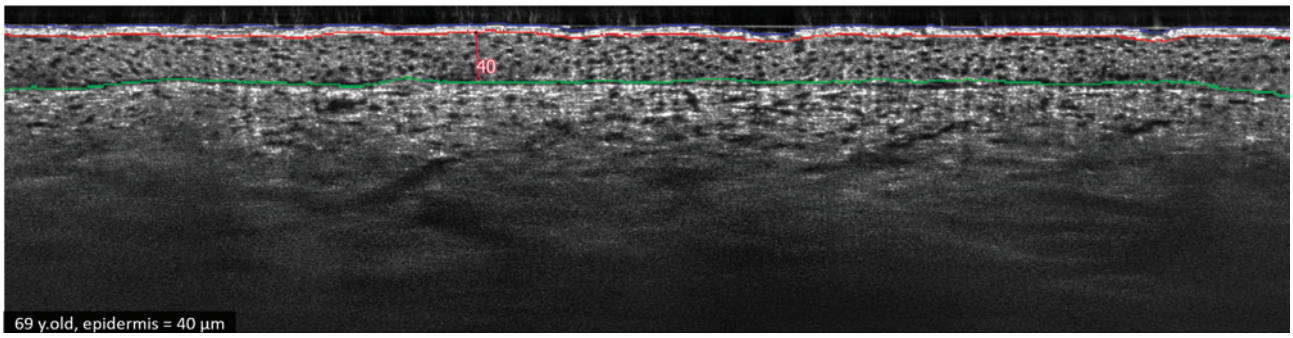
This study aimed to enhance biomarkers of ageing for low phototypes (I and II). Hundred healthy Caucasian female participants, from 20 to 70 years olds, underwent LC-OCT imaging of the temple, the cheekbone and the mandible. The thicknesses of the stratum corneum and the viable epidermis, the dermal-epidermal junction (DEJ) undulation, and the keratinocyte (KN) density, shape, and size were quantified for each areas. Results showed that ageing came with thicker stratum corneum (temple and mandible) and flatter epidermis (mandible), and a higher atypia for KN nuclei.

Scientific Reports, August 2023;13(1):13881. doi: 10.1038/s41598-023-40340-0. PMID: 37620374; PMCID: PMC10449778.



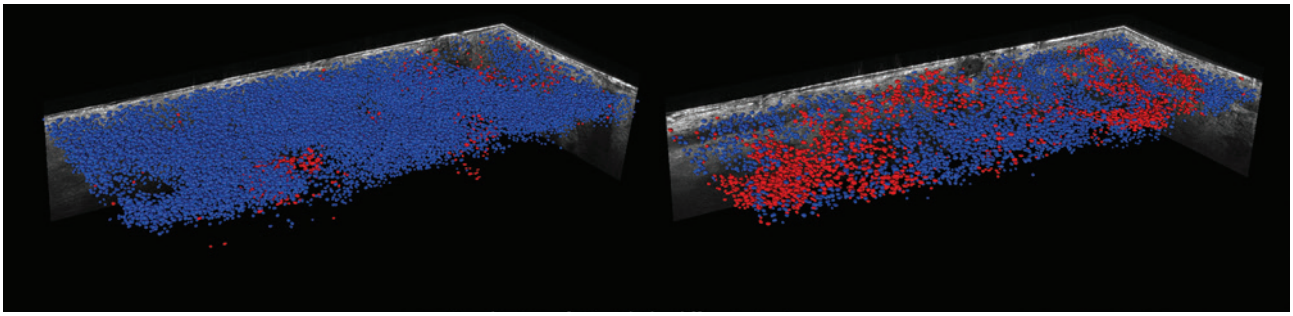
2D vertical LC-OCT view of a young skin (21 year-old) Epidermis thickness: 60 µm

- Surface of the skin
- Junction between the stratum corneum
- Dermoepidermal junction



2D vertical LC-OCT view of an old skin (69 year-old) Epidermal thickness: 40 µm

- Surface of the skin
- Junction between the stratum corneum
- Dermoepidermal junction



3D visualization of keratinocytes in young skin (21 years-old).

- keratinocytes without atypia (the lowest score)
- keratinocytes with the highest atypia score

3D visualization of keratinocytes in old skin (69 years-old).

- keratinocytes without atypia (the lowest score)
- keratinocytes with the highest atypia score

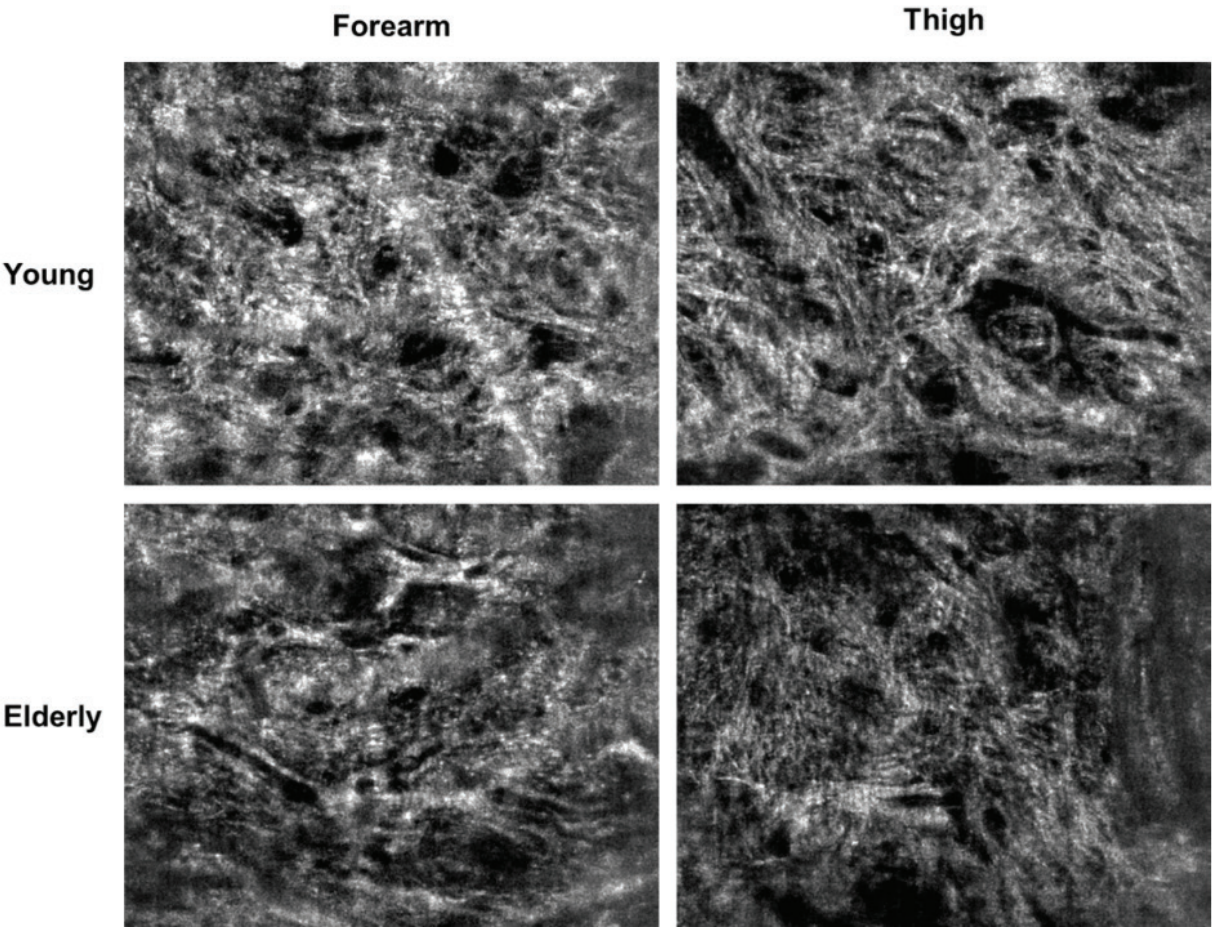
DERMIS THICKNESS & FIBERS

LC-OCT Imaging for Studying the Variation of Morphological Properties of Human Skin in Vivo According to Age and Body Area: The Forearm and the Thigh.

M Ayadh, MA Abellan, S Figueiredo, M Pedrazzani, E Cohen, A Bigouret, H Zahouani

LC-OCT offers high-resolution vertical and horizontal section images, facilitating full 3D skin volume visualization in vivo skin imaging providing detailed insights into tissue evolution. The study, conducted on 42 caucasian volunteers across two age groups (20–30 years old and 45–55 years old), aimed to quantitatively characterize skin morphology variations with age on the forearm and the thigh. Results indicate age-related reductions in skin layer thickness, with papillary dermis thickness correlating with fiber density. Furthermore, aging contributes to flattening of the dermal-epidermal junction, particularly evident in the forearm. These findings contribute to understanding skin mechanics and may inform skin reconstruction models considering age and body area variability.

Dermis, Journal of Dermatology, 2022: Volume 2, Issue 1 DOI: https://doi.org/10.35702/Derm.10002



Horizontal images taken by LC-OCT of the skin of the forearm and the thigh for a young volunteer and an elderly volunteer. These images show the state of the fiber network for skin for both body areas. It can be seen that the fibers of the forearm and the thigh are oriented differently. For the young volunteer, the fiber network seems denser than that of the elderly volunteer.

Dark Spots

BRIGHTENING PRODUCT EFFICACY

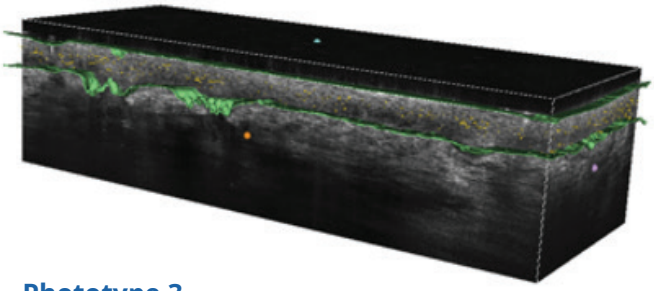
Skin dark spot mapping and evaluation of brightening product efficacy using Line-field confocal optical coherence tomography (LC-OCT)

R Jdid, M Pedrazzani, F Lejeune, S Fischman, G Cazorla, S Forestier, Y Ben Khalifa

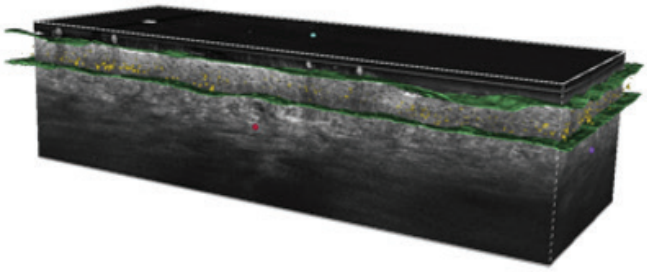
LC-OCT was used to investigate treatment effectiveness of facial dark spots. Twenty-six Asian female volunteers, aged 29 to 65, applied a skin-brightening cosmetic product twice daily for 2 months. LC-OCT analysis revealed varying dark spot morphologies, with younger volunteers exhibiting slight DEJ deformities and older volunteers displaying more pronounced patterns. Application of the brightening product resulted in a statistically significant reduction in melanin density within spots and their surrounding areas, as well as an increase in brightness and decrease in redness. These findings underscore LC-OCT's utility in characterizing dark spots and evaluating skin brightening products, offering insights for dermatological advancements.

Skin Research & Technology, February 2024; 30:e13623. https://doi.org/10.1111/srt.13623

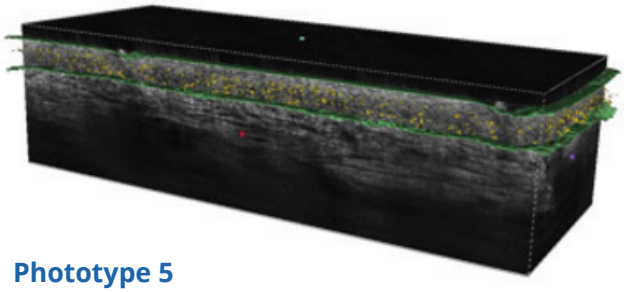
Phototype 1



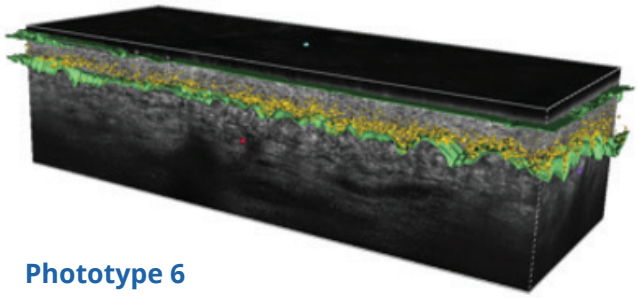
Phototype 2



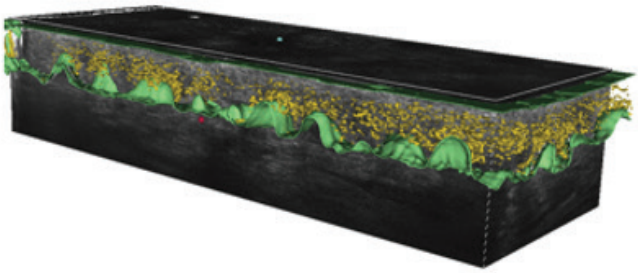
Phototype 3



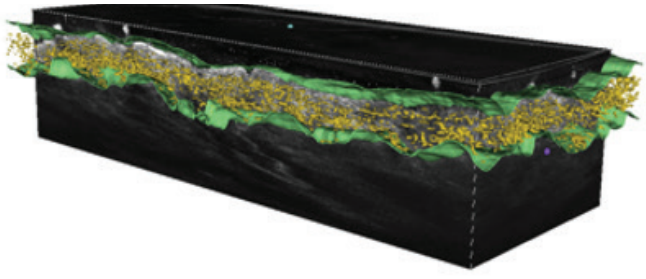
Phototype 4



Phototype 5



Phototype 6



Representation of the difference in density of melanin based on different phototypes

- *Segmentation of the melanin*
- *Representation of the different layers of the skin: the surface of the skin, the junction between the epidermis and the dermis; the DEJ (from top to bottom)*

INFLAMMATORY DISEASE TREATMENT MONITORING

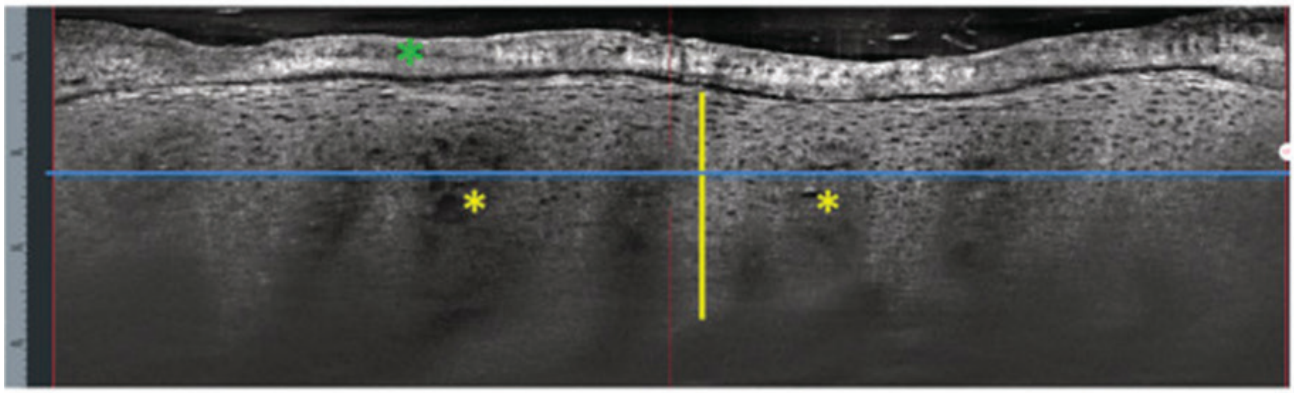
ATOPIC DERMATITIS

Atopic dermatitis on dermocorticoids: visualization and LC-OCT quantification of changes in epidermal morphology and keratinocyte nuclei

H Le Blay, E Raynaud, E Rieux, G Rolland, S Bouayadi, A Saussine, M Jachiet, JD Bouaziz, B Lynch

This study examineD the morphology of the different skin layers, along with the maturation process of keratinocytes, that play crucial roles in barrier function and are affected during atopic dermatitis (AD) flare-ups. Using LC-OCT non-invasive imaging and quantitative measurements (stratum corneum and epidermis thickness, dermo-epidermal junction rippling, volume, and atypia of keratinocyte nuclei) 5 patients with atopic dermatitis were examined, with observation of 4 lesional areas and adjacent healthy regions, while tracking epidermal morphology and cell maturation on days 0, 7, and 14 postdermocorticoid administration. Results showed increased epidermal thickness and dermal-epidermal junction corrugation by 30% and 50%, respectively, in lesional areas compared to healthy ones, with highly variable stratum corneum thickness. Additionally, keratinocyte nuclei volume was 20-30% larger, with doubled nuclear atypia in lesional zones.

Annales de Dermatologie et de Vénéréologie - FMC,Volume 3, Issue 8, Supplement 1,2023,Pages A183-A184,ISSN 2667-0623, https://doi.org/10.1016/j.fander.2023.09.213.



Plaque psoriasis seen in a vertical LC-OCT section.

- ✱ Thickening of the stratum corneum
- ✱ Hypo-refractive, elongated dermal papillae containing dark canalicular structures
- | Thickening of the viable epidermis with elongation of the rete ridges

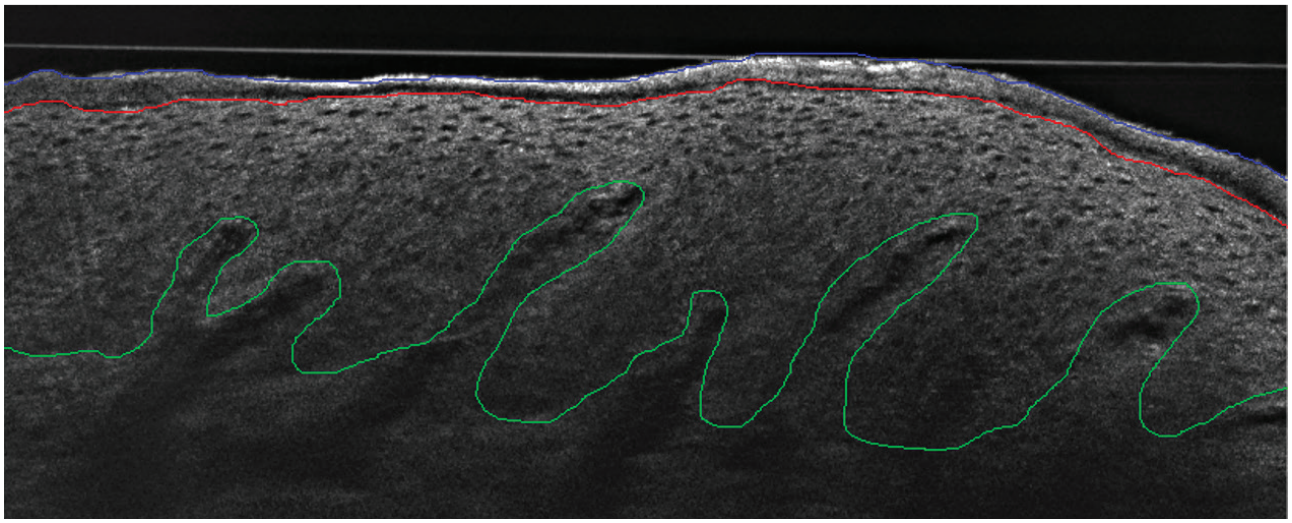
PSORIASIS TREATMENT MONITORING

Line-field confocal optical coherence tomography coupled with artificial intelligence algorithms to identify quantitative biomarkers of facial skin ageing.

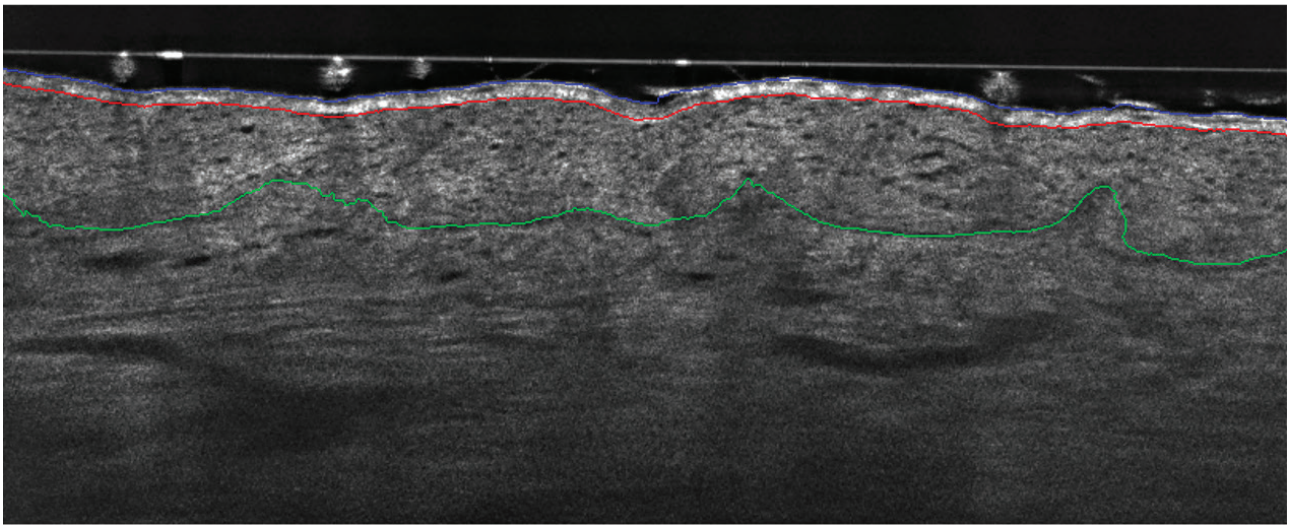
C Orsini, E Trovato, G Cortonesi, M Pedrazzani, M Suppa, P Rubegni, LTognetti, E Cinotti

LC-OCT offers rapid and non-invasive examination of the epidermis and upper dermis, enabling digital interpretation and measurement of high-resolution images on a cellular level. LC-OCT shows potential for monitoring psoriasis during treatment, providing a precise objective severity assessment. LC-OCT imaging of plaque psoriasis lesions from 17 patients before and after 8 weeks of treatment revealed reductions in microscopic criteria such as stratum corneum thickness and living epidermis thickness as well as dermo-epidermal junction undulation. LC-OCT, especially when coupled with artificial intelligence, can non-invasively monitor psoriasis treatment response, offering a promising tool for precise therapeutic monitoring.

Journal of the European Academy of Dermatology & Venereology, February 2024;38(2):325-331. doi: 10.1111/jdv.19568. Epub 2023 Oct 17. PMID: 37823360.



2D vertical LC-OCT view of the skin before the application of a treatment cream for psoriasis.



2D vertical LC-OCT view of the skin after the application of a treatment cream for psoriasis.

The difference of thickness of the skin layers and the undulation of the JDE are highlighted.

— Junction between the stratum corneum and the epidermis
— Dermoepidermal junction

MISCELLANEOUS STUDIES

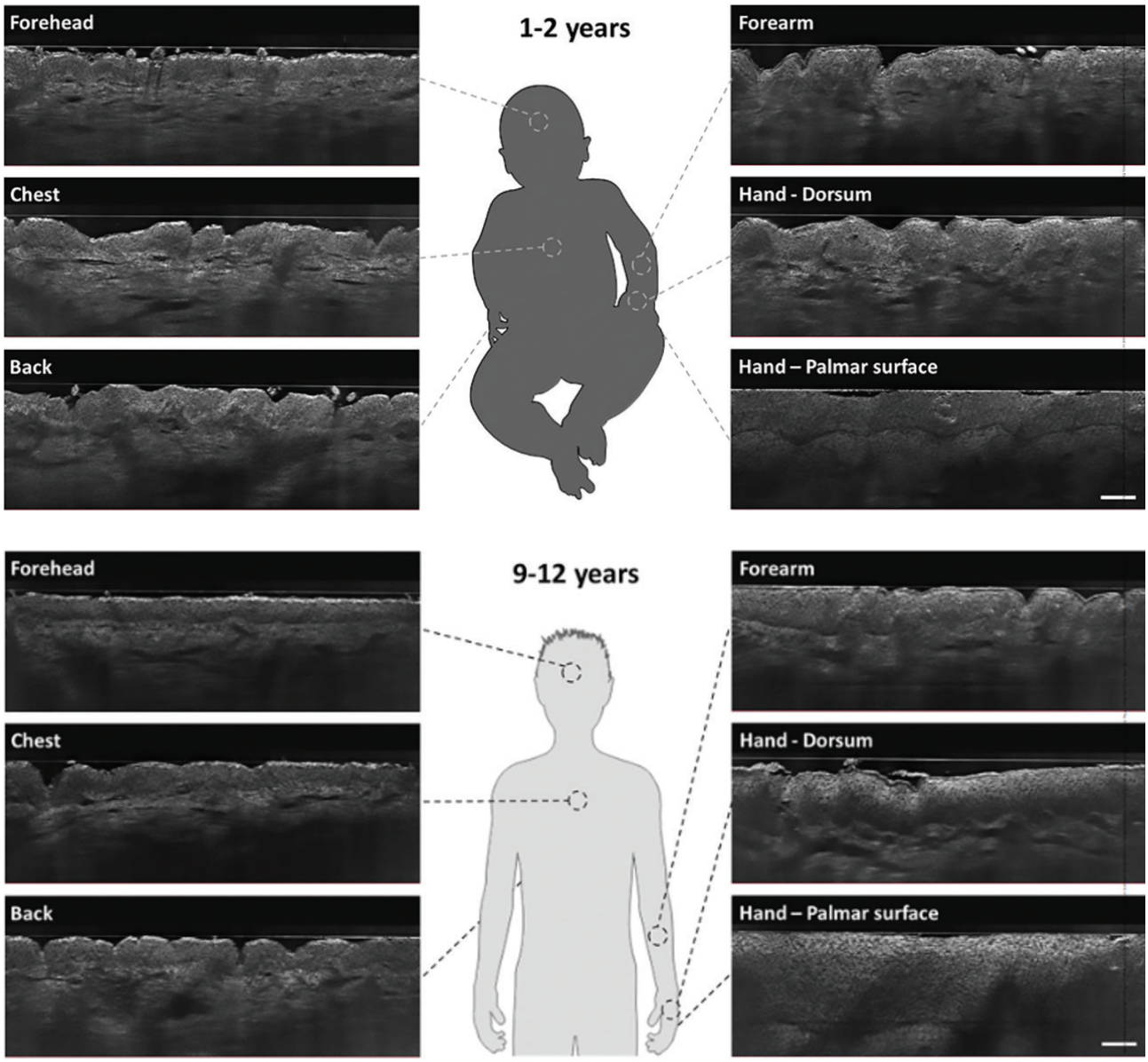
PEDIATRIC SKIN

In vivo evaluation of skin of children with LC-OCT: An objective assessment.

S Del Río-Sancho, C Gallay, S Ventéjou, S Christen-Zaech

The main objectives of this study were (1) to assess the feasibility of using LC-OCT in pediatric patients and (2) to evaluate changes in skin structures in children over time using this method. LC-OCT images were collected from six different body regions (forehead, forearm, chest, back, dorsum of the hand, and palmar surface) in six age groups ranging from 0 to 16 years. LC-OCT is a non-invasive imaging method that can be easily used in children to document changes in the skin over time. It has the potential to be a valuable tool for diagnosing superficial skin disorders and reducing the need for invasive procedures in the pediatric population.

Journal of the European Academy of Dermatology and Venereology, September 2023 ;37(9):1897-1905. doi: 10.1111/jdv.19163.PMID: 37147895.



Representation of the difference of thickness of the skin layers based on the body sites and age (in a pediatric population).

DERMAL MATRIX ASSESSMENT

Utilizing deep learning for dermal matrix quality assessment on in vivo line-field confocal optical coherence tomography images.

J Breugnot, P Rouaud-Tinguely, S Gilardeau, D Rondeau, S Bordes, E Aymard, B Closs

This study aimed to automate dermal matrix quality assessment directly from LC-OCT images to study photo-aging. LCOCT measurements on 57 volunteers' faces were used to train a deep learning model, achieving an accuracy score of 0.83. The model effectively detected greater dermal matrix alterations in older and photo-exposed subjects, suggesting its potential in dermatological and cosmetic research.

Skin Research & Technology, January 2023;29(1):e13221. doi: 10.1111/srt.13221. PMID: 36366860; PMCID: PMC9838780.

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