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REVIEW ARTICLE

OPTICAL COHERENCE TOMOGRAPHY AND OPTICAL COHERENCE TOMOGRAPHY ANGIOGRAPHY IN OPHTHALMOLOGY

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Abstract: Optical coherence tomography is a non-invasive method of imagining the anterior and the posterior segment of the eye. It is commonly used in ophthalmic practice to diagnose and monitor various pathologies of the eyeball. Optical coherence tomography angiography (OCTA) is a useful tool to visualize the entire retinal and choroidal microvasculature, allowing the assessment of retinal perfusion without intravenous dye administration.

Keywords: OCT, OCTA, optical coherence tomography, optical coherence tomography angiography

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INTRODUCTION

The first reports on optical coherence tomography appeared in 1990 from the laboratory of Professor James Fujimoto from Massachusetts Institute of Technology [6,7]. Optical coherence tomography (OCT) is a non-invasive imaging method based on optical scanning. It is an interferometric technique that uses near-infrared light. The principle of action of OCT is based on the interferometric measurement of the scattering or reflection of a light beam with low coherence from individual structures of the eyeball [22]. It allows the detailed assessment of the layered structure of the tissue; therefore, this method is called „in vivo optical biopsy" (see Fig. 1).

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In the following years, the OCT developed intensively and number of clinical publications appeared on the use of OCT in various pathologies of the anterior and posterior segment of the eye [1,3,10,12,15,17,18]. OCT is commonly used in everyday ophthalmic practice and is the most frequently ordered examination in the diagnosis of macular diseases such as age-related macular degeneration, central serous chorioretinopathy, epiretinal membrane and diabetic retinopathy (see Fig. 2 and Fig. 3).

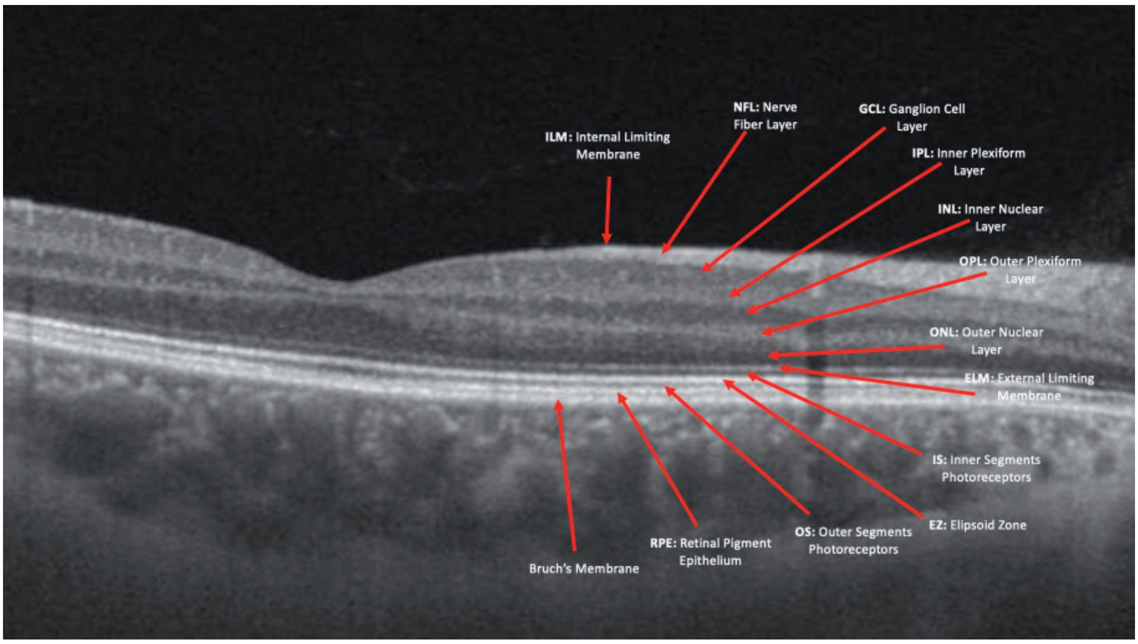

Fig. 1. Normal macula in OCT B-scan.

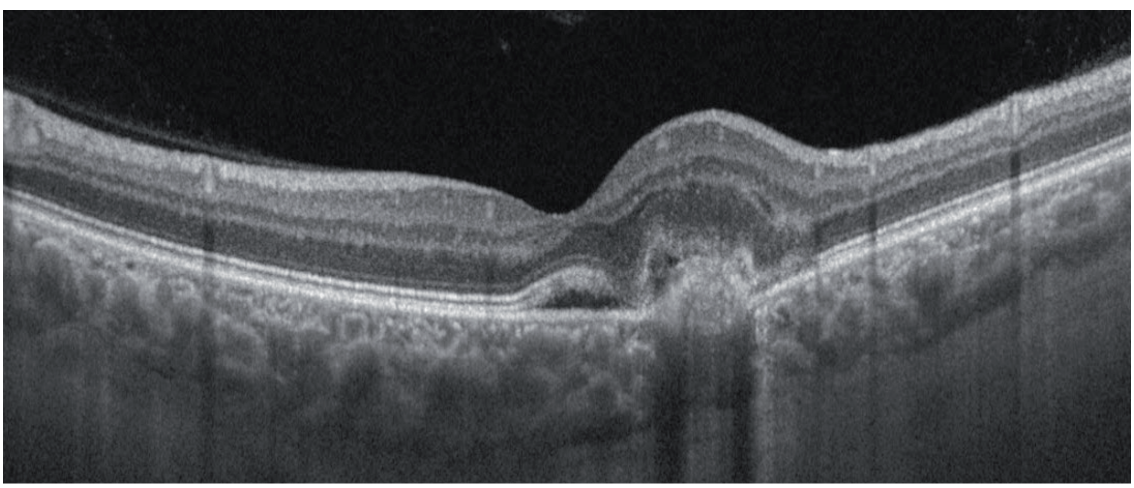

Fig. 2. OCT- B scan shows thickening of the retina, large drusen, subretinal fluid in a patient with AMD.

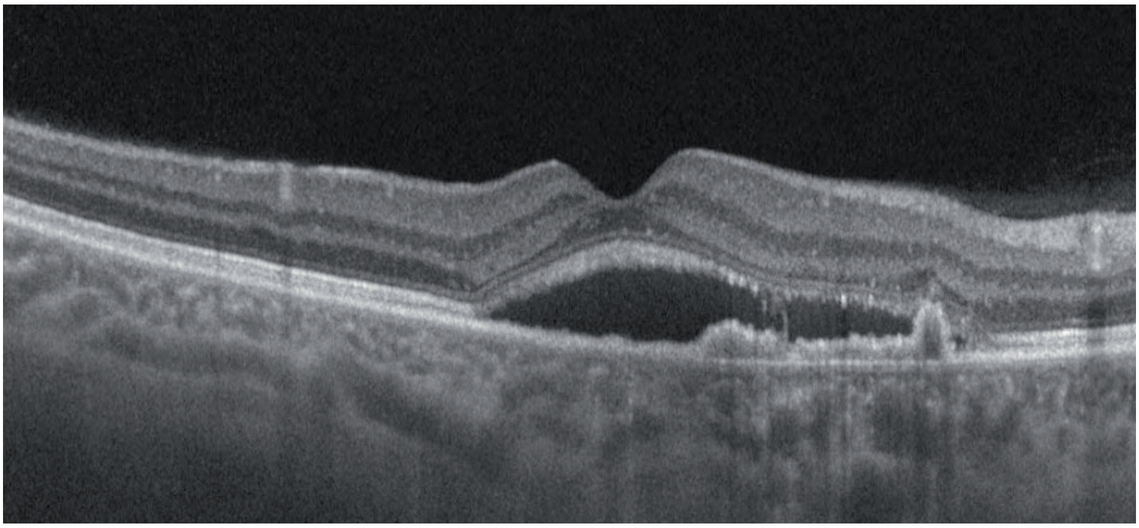

Fig. 3. OCT- B scan shows subretinal fluid in patient with central serous chorioretinopathy.

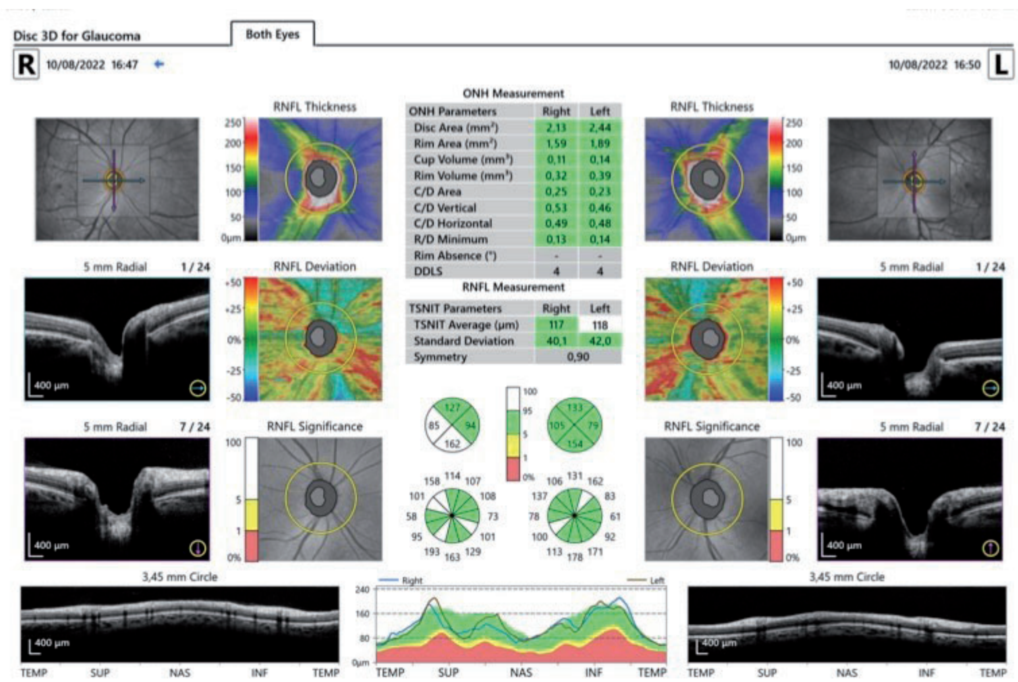

Fig. 4. OCT scan in a glaucoma patient.

Moreover, OCT is being commonly used to diagnose and monitor glaucoma patients. The examination provides assessment of the thickness of the peripapillary nerve fibers, optic disc parameters and thickness of retinal ganglion cells (see Fig. 4).

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Conventional OCT enables a detailed assessment of the structure of the retina but does not allow the assessment of the retinal circulation. Since the 1960s, fluorescein angiography (FA) has been the "gold standard" in retinal vasculature assessment [16]. This method enables visualization of even slight vascular pathologies of the posterior pole and retinal periphery. The main limitation of this technique is the necessity of intravenous dye administration (see Fig. 5).

Optical coherence tomography angiography (OCTA) is a new, non-invasive tool that delivers highly detailed, three-dimensional images of the entire microvasculature of the retina and choroid, providing retinal perfusion assessment without intravenous dye injection [14,19].

OCTA is a development of en face OCT and the latest method that allows visualization of blood

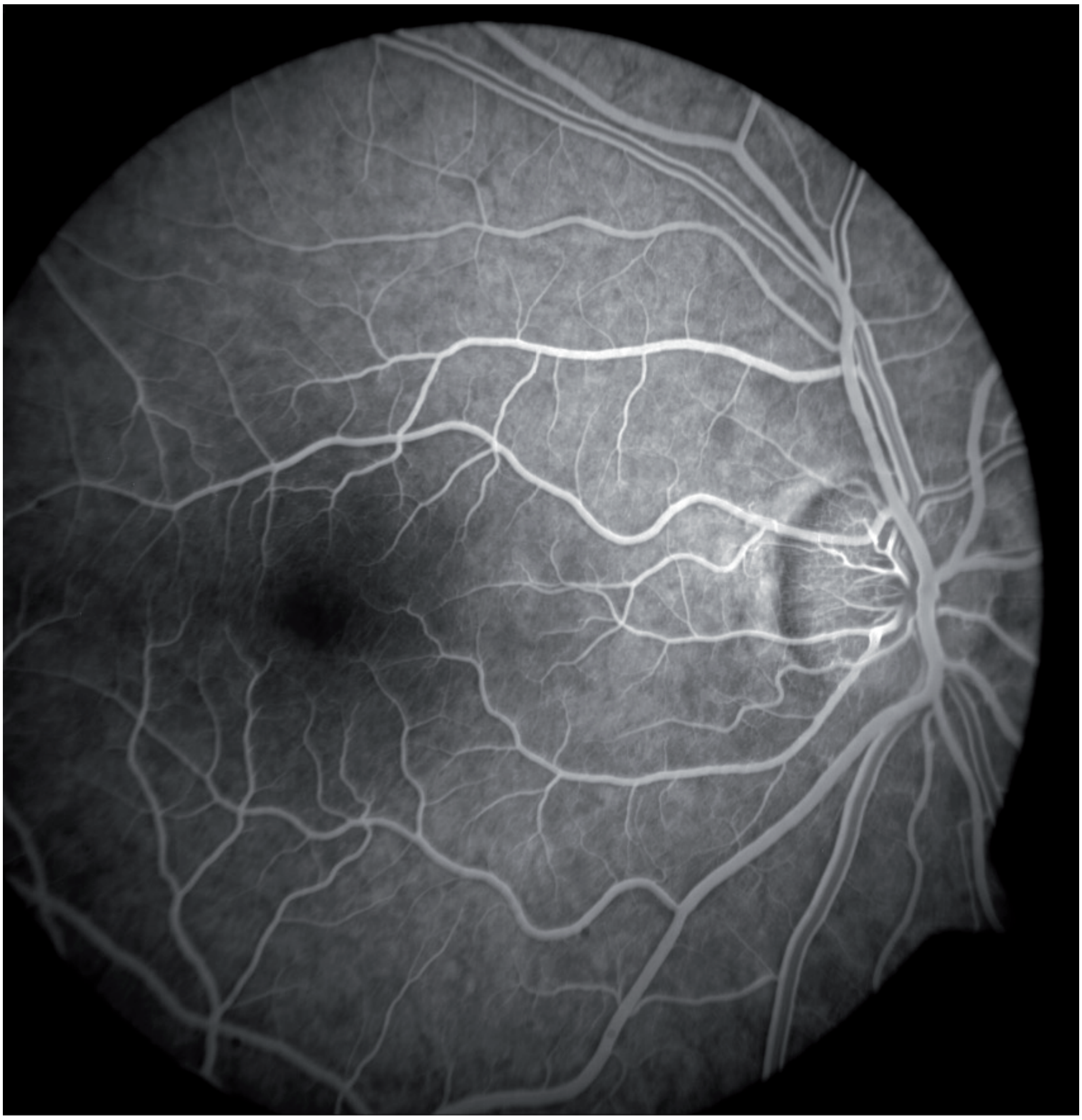

Fig. 5. Fluorescein angiography image showing normal flow in retinal vessels.

flow in the retinal vessels and choriocapillaris. Split spectrum amplitude decorrelation angiography (SSADA) is the basis of OCTA. It identifies the retinal vessels by detecting and measuring the movement of blood cells in the vessels, which allows to distinguish stationary tissue from blood flow [8]. The slowest flow that can be detected is determined by the time between consecutive B–scans. In the case of atrophy or occlusion of the vessels, the flow in the capillaries or choriocapillaris may be below the threshold of sensitivity and is then not visible on angiograms. OCTA enables a histological assessment of the vascular structure of the retina. Blood flow is visible in the superficial vascular plexus, deep vascular plexus, at the level of the outer layers of the retina and in choriocapillaris [20] (see Fig. 6).

Foveal avascular zone (FAZ) is a round capillary-free area within the macula visualized in OCTA scans. The FAZ area in healthy eyes is measured to be about 0.26 mm2 in the superficial plexus and 0.49 mm2 in the deep vascular plexus. Measurements of the FAZ zone using OCTA have been used in patients with microcirculatory deficiency such as diabetic retinopathy. Studies reveled that the FAZ zone increase in diabetic patients (see Fig. 7).

The outer retina is avascular in the healthy eye; hence the layer is most often visible as a homogeneous, dark background (no flow). Vessels in this layer can be observed only in pathological conditions, such as the macular neovascularization (MNV) in wet age–related macular degeneration (AMD) [2]. The layer of normal choriocapillaris exposes appears as a greyish grainy background. In pathological condi-

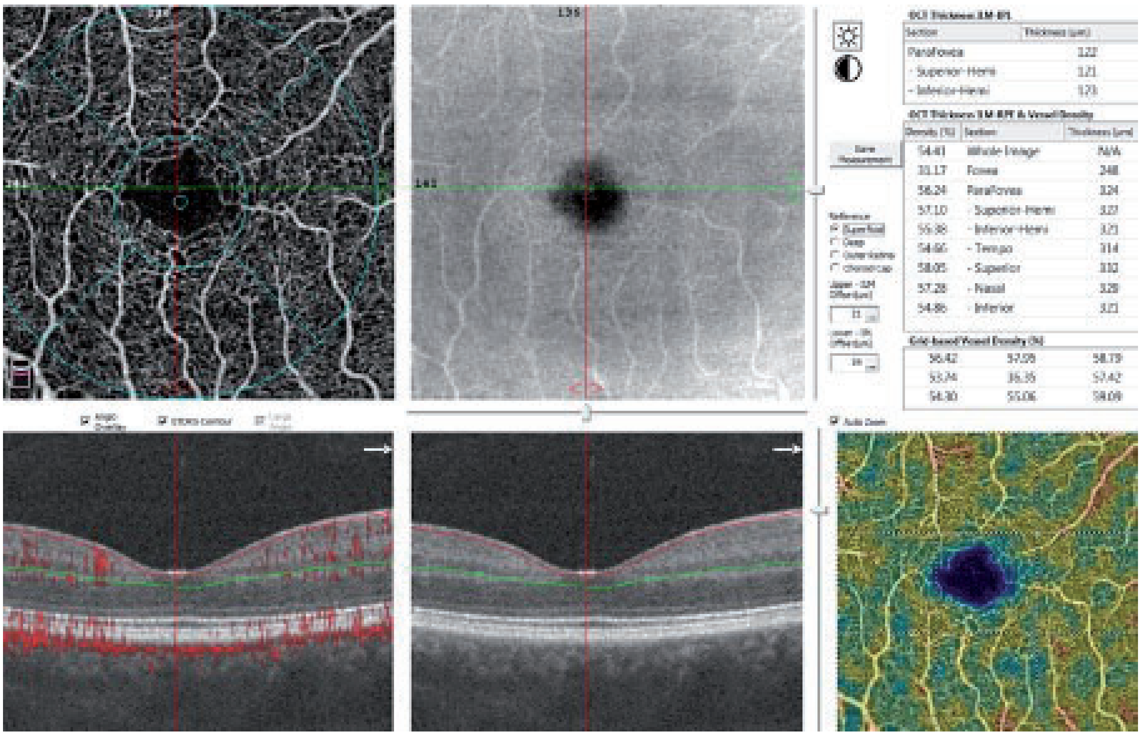

Fig. 6. OCTA assessment of the superficial retinal plexus, including detailed measurement and color map of macular vessel density.

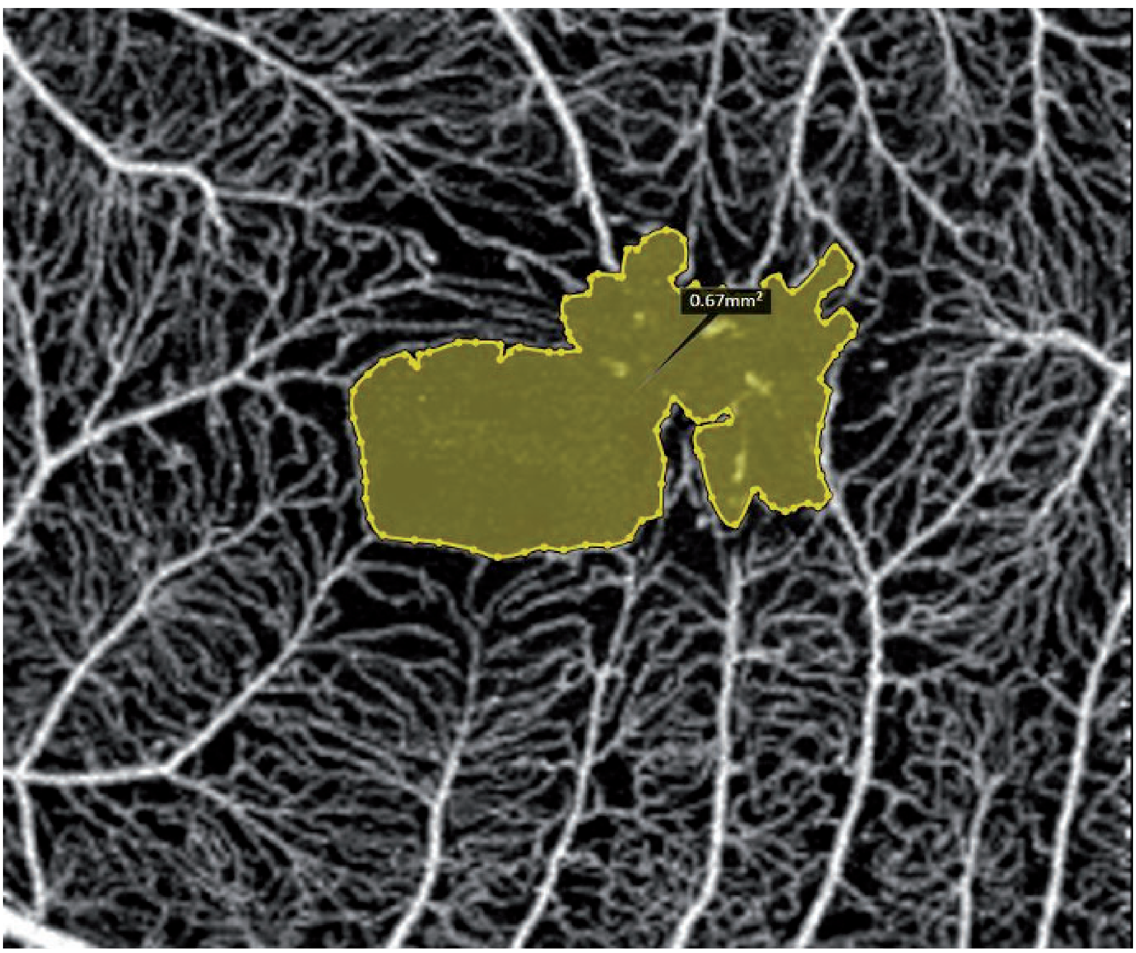

Fig. 7. OCTA showing foveal avascular zone area.

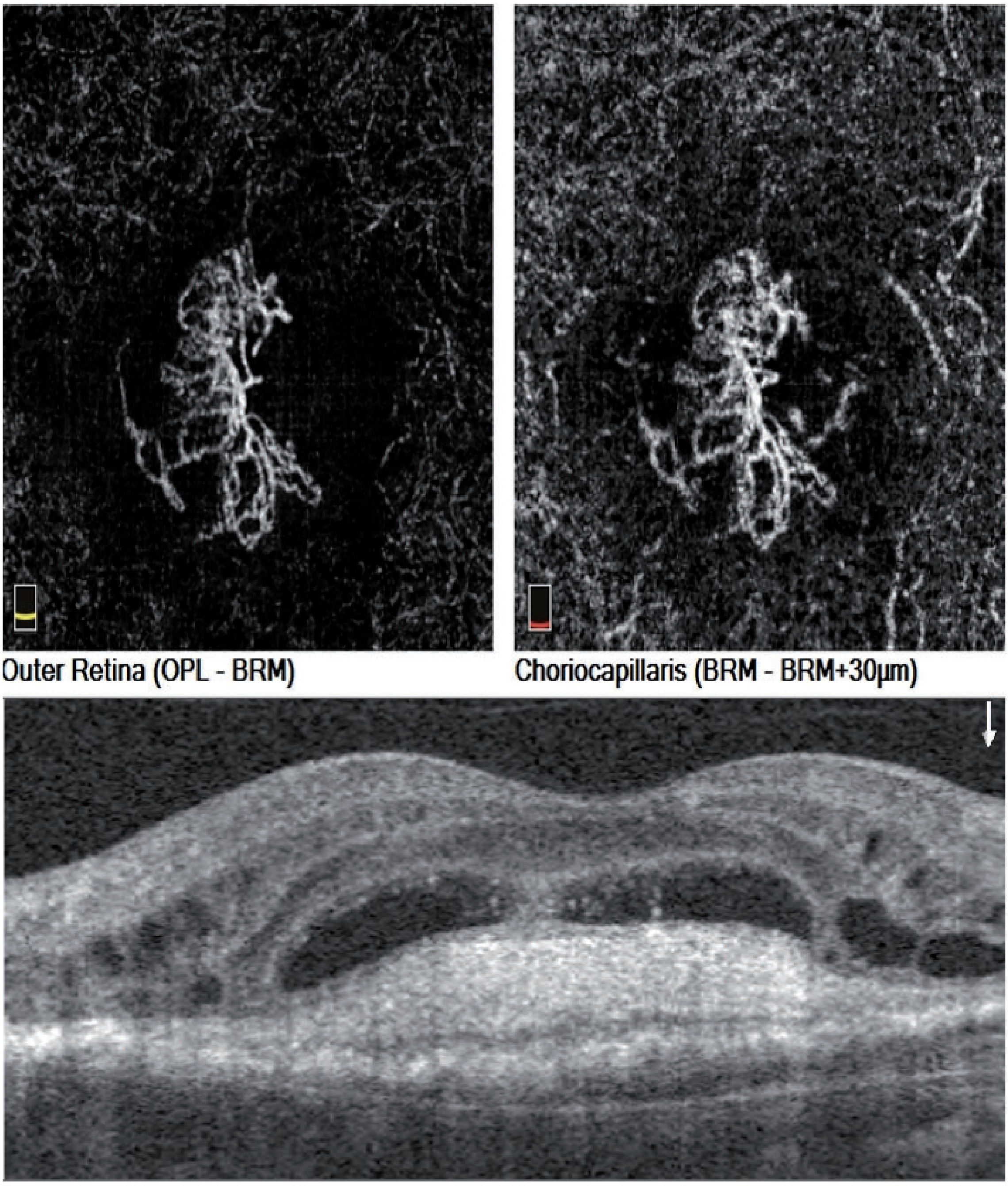

Fig. 8. OCTA image of pathological vessels at the level of outer retina (A) and choriocapillaries (B) in a patient with wet AMD. The OCT B–scan shows thickening of the retina with subretinal and intraretinal fluid and central macular neovascularization.

tions, e.g. choroidal neovascularization, abnormal flow is visible at this level (see Fig. 8).

The main indications for OCTA include age-related macular degeneration, polypoidal choroidal vasculopathy and other causes of choroidal neovascularization such as myopia, central serous chorioretinopathy, angioid streaks and uveitis-related choroidal neovascularization. It is also a useful diagnostic tool in diabetic retinopathy, central retinal vein occlusion, central retinal artery occlusion. Furthermore, OCTA can be used in diagnostics of optic nerve pathologies for example in glaucoma [4,5,11,13]. Pathological vessels have an irregular caliber and course, form waves, bends and loops, so the blood stream may be interrupted. There may be connections between the superficial and deep weaves - shunts, rarely seen in healthy people. The background of the avascular regions is dark and smooth or slightly grainy (see Fig. 9 and Fig. 10).

Fig. 9. OCTA image in a patient with branch retinal vein occlusion- dark areas of ischemia and irregular vessels are visible.

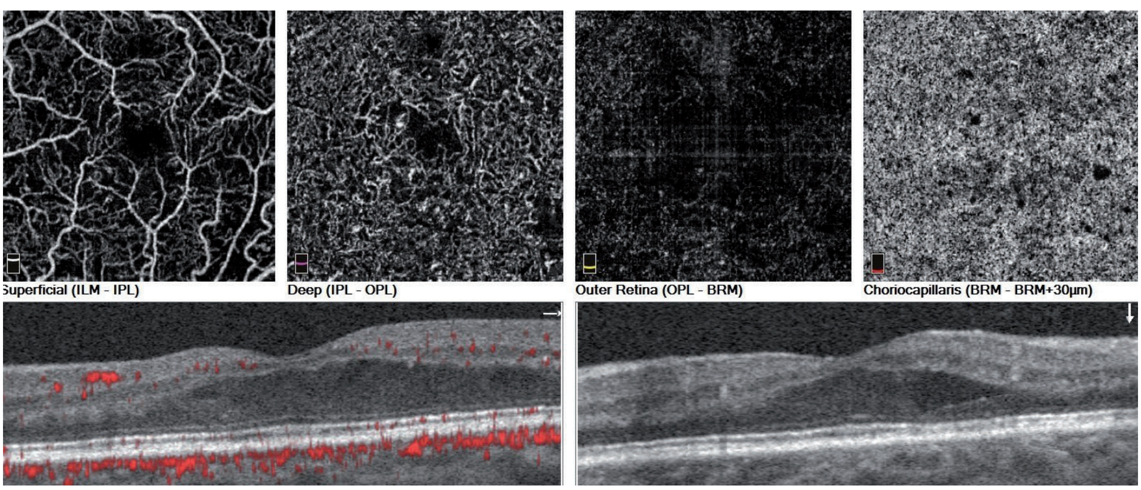

Fig. 10. OCTA image of the non-perfusion areas in superficial plexus and microaneurysms in deep vascular plexus in a diabetic patient. The OCT-B scans show thickening of the retina and intraretinal fluid.

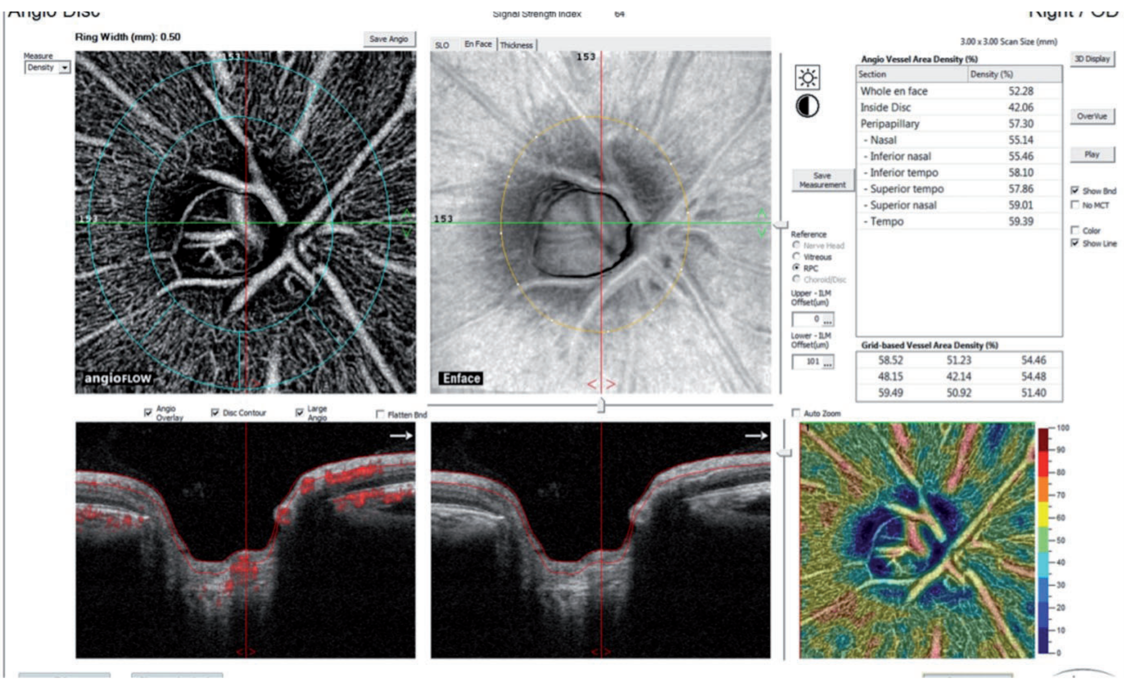

Fig. 11. The optic disc flow disturbance maybe visible even in preperimetric glaucoma.

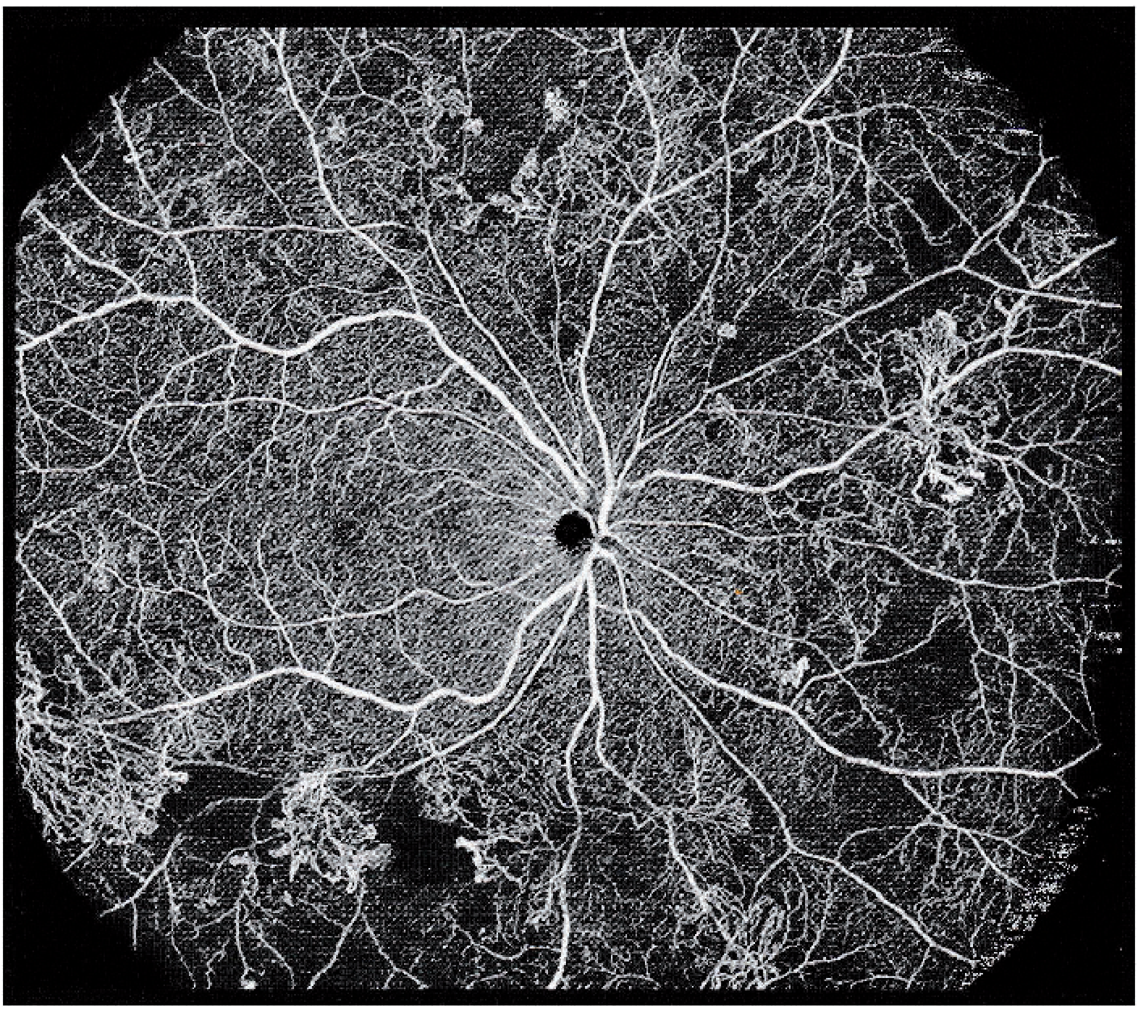

Fig. 12. Wide-field OCTA in a patient with diabetic retinopathy. (Courtesy of Prof. Hirano, MD. PhD. Shinshu Univ).

The possibility of assessing the flow in the vessels of the optic nerve, both the larger ones and the peripapillary capillaries, makes OCTA a technique more and more popular in the diagnosis of glaucoma [9] (see Fig. 11).

OCTA is a part of the routine OCT using Angio Retina scans (for macular flow assessment) or Angio Disc scans (to assess optic disc flow) and takes a few seconds.

OCTA is an irreplaceable tool used to visualize and analyze changes in capillaries and pathological vessels in retinal diseases, glaucoma and other optic nerve neuropathies.

The method limitations are the same as that of standard optical coherent tomography. These include optical media opacities, poor fixation, too narrow pupil or nystagmus.

Moreover, the limitation of typical OCTA macular scans is that it provides visualization only the area of the posterior pole. OCTA scans cannot assess leakages that are typically visualized in fluorescein angiography. Moreover, the method provides limited information about actual blood flow, imagining mainly the vascular structure. In the future we may commonly use wide-field OCTA imaging that shows peripheral vascular changes and provides a wider field of imagining [21] (see Fig. 12).

CONCLUSIONS

OCTA equals simultaneous angiography and high-resolution OCT. It enables early detection of pathologies within the vessels at different levels of the retina. OCTA as a non-invasive and repeatable test is commonly used in ophthalmology even in patients with worse cooperation.

AUTHORS' DECLARATION:

Study Design: Katarzyna Paczwa, Joanna Gołębiewska. **Data Collection:** Katarzyna Paczwa, Joanna Gołębiewska. **Manuscript Preparation:** Katarzyna Paczwa, Joanna Gołębiewska. The Authors declare that there is no conflict of interest.

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