The application of optical coherence tomography for the morphometric and dynamic assessment of anterior segment structures in healthy, forme fruste and keratoconic eyes

Introduction: In keratoconus, there are many morphometric changes of the cornea, including its thinning, increased curvature, high irregular astigmatism, which in turn lead to a significant decrease in visual acuity. An important aspect is the detection of the disease at a very early stage. Currently, there are many methods of imaging the geometry of the cornea, which enable the detection of keratoconus, monitoring the progression of the disease, as well as the used treatment. An important supplement to diagnostics is the assessment of corneal dynamics, which determines the conduct of its proper geometry and function.

Aim: Morphometric assessment of the anterior segment in normal, forme fruste and keratoconic eyes using commercially available optical coherence tomography (OCT) devices and evaluation of the clinical usefulness of a prototype swept-source optical coherence tomography (SS-OCT) with an air-puff system for the assessment of corneal dynamics.

Material and methods: A 96 eyes were included in the study, including 50 normal eyes, 15 forme fruste eyes and 31 eyes with early to moderate keratoconus. The patients underwent a full ophthalmological examinations with corneal tomography (MS-39, CSO, Italy), optical biometry (IOLMaster 700, Zeiss, Germany) and measurement of the dynamic properties of the cornea using the prototype SS-OCT with the air-puff system.

Results: The eyes with keratoconus had the highest simulated keratometry with a mean value of 46.2 ± 2.85 D ($p<0.001$). Significantly higher values of maximum curvature of the anterior and posterior corneal surfaces were also observed for keratoconic eyes ($p<0.001$). Central corneal thickness (CCT) was significantly lower in eyes with keratoconus, with a median of 499.0 μm (470.5-520.0) ($p<0.001$). In the case of the central and minimal thickness of the corneal epithelium, lower values were observed in eyes with keratoconus compared to normal eyes ($p<0.001$). Total corneal aberrations were significantly higher in keratoconic eyes ($p<0.001$). The prototype SS-OCT with the air-puff system used to assess corneal dynamics showed high compatibility with commercial devices for biometric parameters, such as CCT, anterior chamber depth (ACD) and axial length of the eye (AL). Maximum corneal displacement was greatest in eyes with keratoconus and its mean value was 1.07 ± 0.11 mm ($p<0.001$). In addition, eyes with keratoconus achieved a higher velocity of corneal apex displacement in two extremes and the time between the velocity extremes was longer ($p<0.05$).

Conclusions: In eyes with keratoconus, there is the increase in corneal curvature, decrease in the thickness of the cornea, and the increase in total aberrations. Tissue stiffness decreases, therefore the dynamic parameters of the cornea are changed: maximum corneal displacement, velocity and time between two extremes of velocity increase. The prototype SS-OCT with the air-puff system enables the assessment of corneal dynamics while maintaining high compliance in the biometric data obtained with commercial devices. It does not allow differentiation of forme fruste eyes from healthy eyes.

Keywords: cornea, keratoconus, keratometry, biomechanical properties, dynamics of the cornea, optical coherence tomography