THE EXAMINATION OF THE CANINE EYE WITH OPTICAL COHERENCE TOMOGRAPHY

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Abstract: Advances in veterinary ophthalmology in recent decades are primarily due to the development of eyeball examination techniques. One of the most advanced, non-invasive, non-contact, and high-resolution techniques is optical coherence tomography (OCT). With this technique, cross-sectional, *in vivo* images are provided, bringing new insights into the examination of eyeball structures. This technique complements the information provided by the clinical and paraclinical ophthalmic examination. Due to the structural complexity of the eyeball, the imaging examination plays an important role in diagnosing various ocular pathologies and monitoring these pathologies after interventional actions. This study aimed to present and apply this new method of eyeball examination in veterinary medicine for the diagnosis and monitoring of ocular disorders. The objectives of this study were to present the functioning elements, the working method of the tomograph, and the technique of examining the eye in dogs, as well as the analysis and interpretation of the changes found on the image obtained. The biological material used in this study consisted of 18 dogs of different ages and sexes. Eyeball examination was performed using the IVue-100 optical coherence tomography. The results are presented in the form of OCT images of normal and pathological aspects of the eyeball identified in the dogs consulted such as keratoglobus, corneal ulcer, corneal edema, retinal cyst, retinal edema In conclusion, examination of the eyeball with optical coherence tomography (OCT) is a highly accurate technique for observing the physiological or pathological condition of the eyeball.

Keywords: optical coherence tomography, cornea, iridocorneal angle, retina, non-invasive

INTRODUCTION

Veterinary ophthalmology is an increasingly in-demand and growing field due to the growing number of pets and owners' concern for their welfare. Ophthalmological consultation encompasses an increasing number and variety of techniques to examine the visual analyzer, the eyeball, and its appendages (Charles et al., 2020).

Optical coherence tomography (OCT) is a relatively new optical imaging technique in biomedical optics and medicine. OCT performs high-resolution cross-sectional imaging of internal microstructures of biological tissues by measuring backscattering echoes of light (Hirano et al., 2001). Pathological changes can be visualized in situ and in real-time with a resolution of 1-15µm, with one or two magnitudes more accurate compared to the ultrasound technique. Images are constructed by measuring the magnitude and echo lag time. Cross-sectional images are made by multiple axial measurements of the time shift of the echoes, called axial scans or A-scans, and by cross-sectional scanning of the incident light beam, resulting in a two-dimensional data set representing the optical backscatter on the cross-section of the examined tissue. The obtained images or B-scans can be displayed in two ways, one false color, in which the machine assigns different colors to the examined structures, assigning a more intense color to structures with an increased density, or

they can be displayed in different shades of grey, similar to ultrasound images. The OCT technique can also be used to obtain three-dimensional images, for which the machine obtains volumetric data sets through cross-sectional sequential images by scanning the incident light beam in a special pattern, from top to bottom in linearly arranged points and on a set of parallel lines. The three-dimensional data obtained are extensive concerning the volumetric structure and can be manipulated similarly to those obtained by magnetic resonance imaging or computer tomography (Dexler and Fujimoto, 2015).

Originally designed to examine the retina and optic nerve, optical coherence tomography is now also used to examine the anterior segment of the eyeball. Examination of the anterior and posterior segments of the eyeball is an important part of ophthalmic imaging.

The major advantage of this technique is the provision of high-precision images, and the limitations of the technique are its low penetration capability in cases where the media through which the light beam passes are not fully transparent. The similar morphology of the eye in all vertebrates and the way it reacts to various traumas allows comparative ophthalmology to treat a wide range of eye conditions in different animal species in the same way (Maggs et al., 2018). The way the visual analyzer evolves is that when animals see an object in the environment they can differentiate it in the following aspects: brightness, color, motion, depth, and texture (Maggs et al., 2018; Martin, 2013; Spalton et al., 2004).

MATERIALS AND METHODS

The biological material used in this study was a number of 18 dogs of different ages and sex that were ophthalmologically examined. Eyeball examination was performed using the IVue-100 optical coherence tomograph manufactured by Optovue Inc, Fremont, CA, USA. The OCT examination aimed to identify pathological changes in the cornea, iridocorneal angle, iris, and retina in the patients under study.

For each patient brought to the consultation, a clinical examination form was filled in, in which general information, anamnesis, present condition of the animal, evolution sheet, and epicrisis were written. After the general examination of the patient, the ophthalmological examination will be carried out, which follows the following steps: a physical examination of the eyeball, measurement of intraocular pressure with the Tonovet device; measurement of tear production with the Schirmer test; examination of the eyeball with the retinophotographer, which can be used to examine the surface of the cornea and the fundus (retinal surface). Examination of the fundus with the classic ophthalmoscope, directly or indirectly, is done after prior dilation of the pupil with Tropicamide. Fluorescein testing is recommended in cases of suspected corneal trauma or injury, which can be described in detail by OCT examination or eyeball ultrasound. This working protocol can be adapted, depending on the specific eyeball condition.

Examination of the cornea, iridocorneal angle, and retina was performed using the IVue-100 optical coherence tomographer manufactured by Optovue Inc, Fremont, CA, USA. Eyeball examination with the OCT machine is performed with the patient in the quadrupedal position on a consultation table placed in front of the machine.

Depending on the patient's degree of taming and docility, they will be tranquilized or anesthetized. A minimum of two people are required to perform the restraint: an assistant who positions and holds the dog in a correct position in front of the machine, the dog must remain still, and a clinician who manipulates the machine and enters the data and settings into the OCT machine's software. For corneal examination, the corneal adaptor must be attached, and no adaptor is attached to the retina.

RESULTS AND DISCUSSION

The presentation of the optical coherence tomography examination technique in eyeball examination requires viewing images obtained by this technique on an eyeball whose cornea, iridocorneal angle, and retina show no pathological changes (Figure 1; Figure 2. and Figure 3.). The thickness of the cornea is not uniform over the entire surface, and the assessment of thickness differs depending on the measurement method. Based on post-mortem measurements corneal thickness or pachymetry has been estimated in dogs to be between 450 µm - 550 µm in the central area and 550 µm - 650 µm in the peripheral area, and based on ultrasonographic measurements its pachymetry has been estimated in adult dogs in the central area to be approximately 560 µm (Gelatt et al., 2013), and in a study carried out at the veterinary practice "Kiséri Állatorvosi Rendelő" in Szentes, Hungary, the corneal thickness ranged from 568µm-574 µm (Marietta Máté, 2017). Corneal thickness differs significantly according to age, and within the same age group, it differs according to sex, being thinner in females compared to males (Martin, 2013). In dogs and cats, the difference between the two diameters is small, hence the cornea appears circular in these species, unlike in ungulates where the difference between the two diameters is much larger (Gelatt et al., 2013; Kanski and Bowling, 2015; Spalton et al., 2004). In cats, the average thickness is estimated to be between 546 µm - 578 µm (Gelatt et al., 2013). The corneal measurement is based on a corneal map that shows the measured values automatically and assigns different colors depending on the thickness. At the same time, the top of the image indicates the accuracy of the image obtained, assigning a certain percentage of image quality, the red color indicates that the image obtained does not meet the required quality standards, and the green color indicates that the image obtained is of good quality. The images obtained by us fell into the category of quality images, all of them being of adequate quality.

The healthy cornea appears as a relatively homogeneous, layered structure, differentiating epithelial, stroma, Descemet membrane, and endothelial layers (Récsán and Nagy, 2018). The iris and the iridocorneal angle can be visualized with the OCT machine. During the examination of the iridocorneal angle it is possible to assess its condition, i.e. whether it is closed or open, and to trace the edges of the elements contributing to the angle formation in order to measure the value of the angle. The importance of the iridocorneal angle lies in the fact that it contains the structures through which aqueous humor drains.

The OCT machine allows in vivo, cross-sectional visualization of the structure of the retina and optic nerve, which is the main purpose for which it was designed. For retinal examination, the device is used without attaching the corneal adapter to allow the device to record images directly with the retinal lens. With the help of the ophthalmoscope and the ultrasound scanner, flat images of the retina are obtained. The

major advantage compared to these methods of retinal examination is that this method complements the information provided by these methods by providing structural details of the different retinal layers, and assessing retinal thickness. OCT examination makes it possible to identify early retinal degenerative processes in cases where the overall image captured by ophthalmoscope or ultrasound is relatively normal.

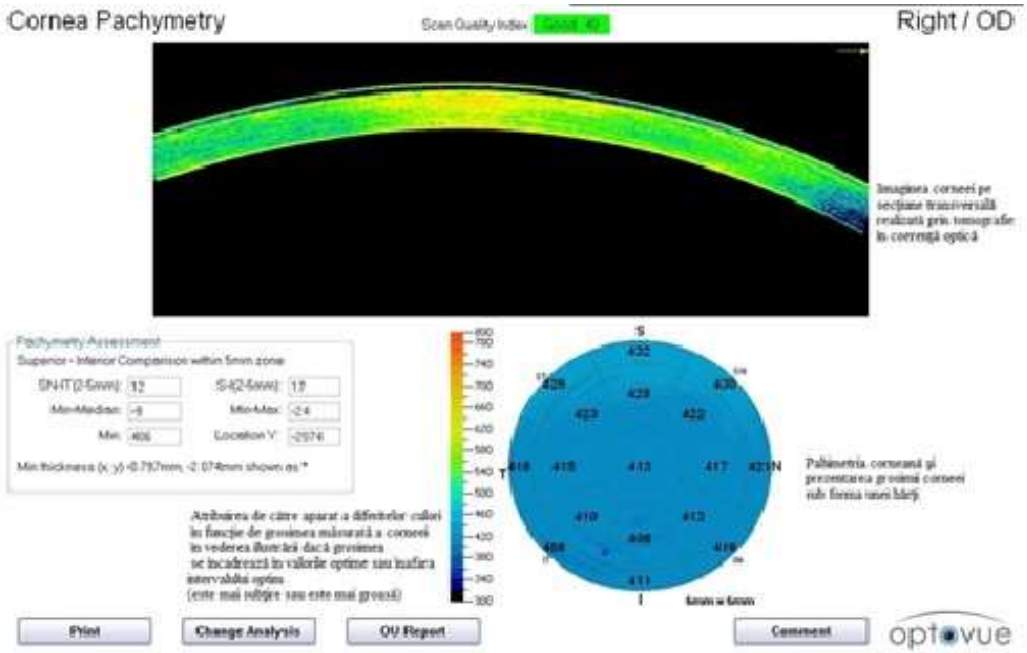

Figure 1. OCT image - cornea without pathological changes, with pachymetry within normal limits

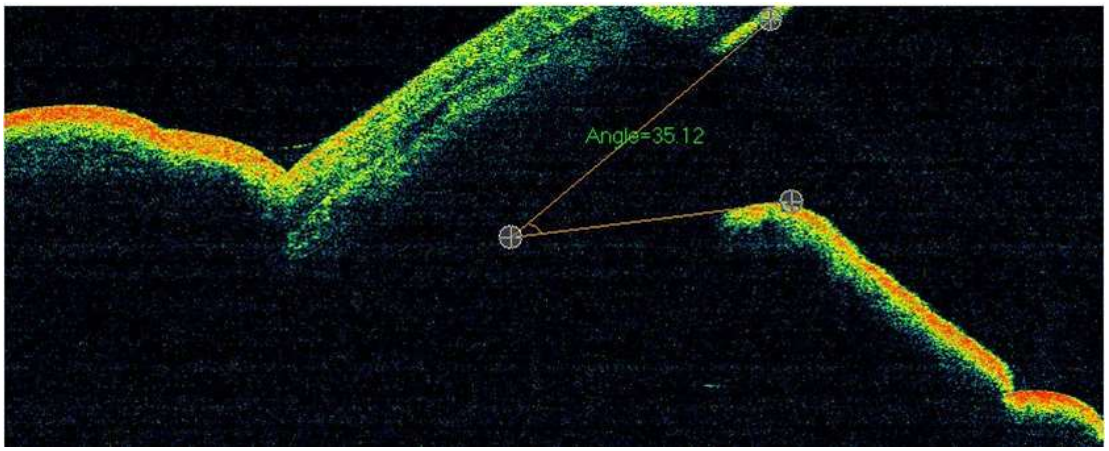

Figure 2. OCT image - open iridocorneal angle with angle value measurement

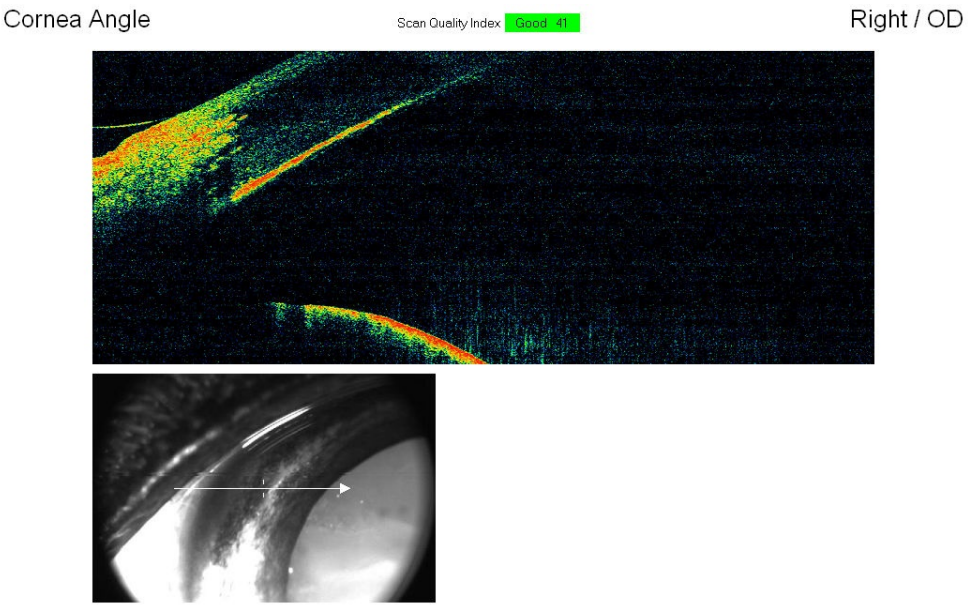

Figure 3. OCT image - open iridocorneal angle identifying with the white arrow the area where the image was taken

The images obtained are presented in two display modes: grey-colored images where changes in smoothness are more visible (Figure 4.) or false-colored images (Figure 5.) where the colors are automatically assigned by the camera according to the thickness and thickness of the layers.

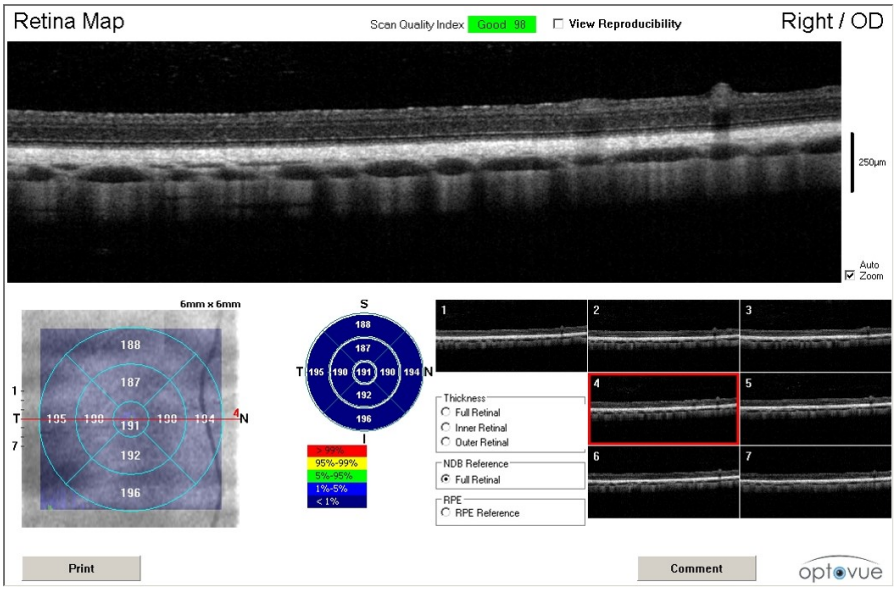

Figure 4. Grey-stained OCT image with finer details visible - normal retina

Out of the total of 18 dogs studied whose eyeballs were examined by optical coherence tomography, 11 cases were selected as relevant for this study. Pathological changes in the cone (corneal edema and ulcer), in the iridocorneal angle

(goniodysgenesis), and in the iris and retina (retinal edema) were diagnosed by this technique. Each pathology will be described separately to highlight the elements on which the diagnosis is based.

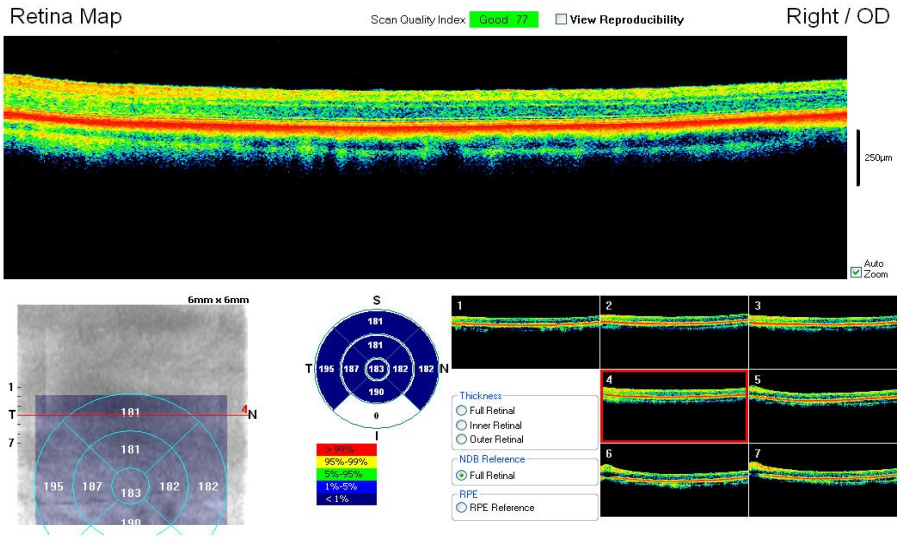

Figure 5. False-stained OCT image - normal retina

Corneal edema is a pathology of the eyeball that is caused by corneal endothelial dystrophy also known as endothelial degeneration. In situations where the cornea is normal, the endothelial cells function as a pump to remove the corneal fluid. This maintains the clear appearance of the cornea. Corneal endothelial dystrophy affects the inner layer of the cornea and the endothelial cells gradually disappear. This means that fluid is no longer removed from the cornea and results in corneal edema, clouding of the cornea, and decreased or "blurred" vision. In chronic corneal edema, the fluid accumulates, forming pockets, also known as bubbles. These bubbles can rupture and damage the outer layer of the cornea (the epithelium), giving rise to corneal ulcers (Figure 6. A, B, C, D).

A corneal ulcer is a condition of the cornea due to an injury or abrasion on the surface of the cornea. In superficial corneal ulcers, only the surface epithelium is affected (Figure 7. A, B). It is considered a less serious condition but still requires medical care. Deep corneal ulcers also affect the corneal stroma. The presence of a deep corneal ulcer usually indicates a bacterial infection, they release substances that degrade the corneal stroma, and the ulcer progresses in depth. In dogs the etiology of corneal ulcers is varied, trauma to the eyeball is the most common cause. Superficial corneal abrasions can occur as a result of physical or chemical trauma, such as rough play with other dogs, running through dry vegetation or woods, as well as some irritants such as shampoo, dust, or some bacterial infections.

The main symptoms of corneal ulcers include redness, excessive discharge, or epiphora. Superficial ulcers are usually not visible to the naked eye and can heal without further intervention within 3-10 days, depending on the size of the ulcer. In both cases studied it was possible to analyze both superficial and deep lesions with OCT aspect also confirmed in the study of Famose F. 2014.

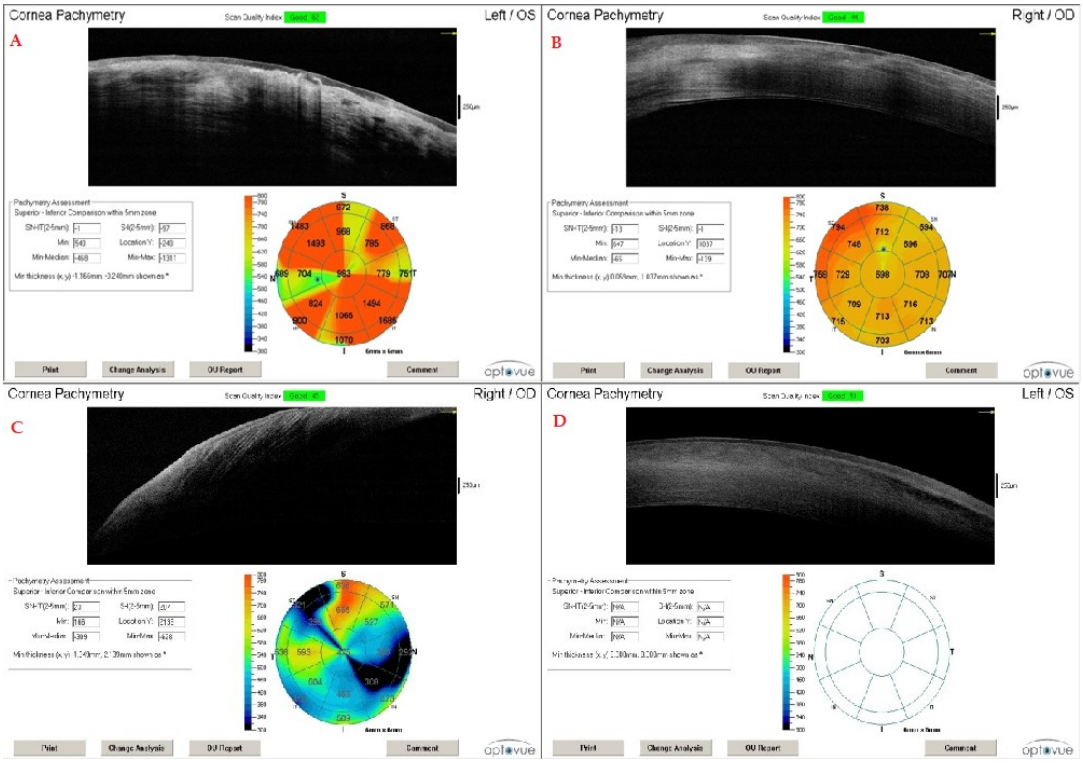

Figure 6. (A, B, C, D) Corneal edema; corneal pachymetry enlarged due to corneal edema, with visualization of edema fluid accumulated between the layers of the corneal stroma with damage to the architecture of the collagen lamellae (A). Change in the architecture of corneal layers due to peripheral ulcer edema, corneal surface uneven, in places thinned. Deeper structures of the eyeball are not visible by OCT (B). Corneal edema, with altered corneal layer architecture, oedematous areas between both superficial and deep corneal layers (C). Increased pachymetry, severe corneal edema, small ulcers, altered layer architecture, and injured epithelial layer (D).

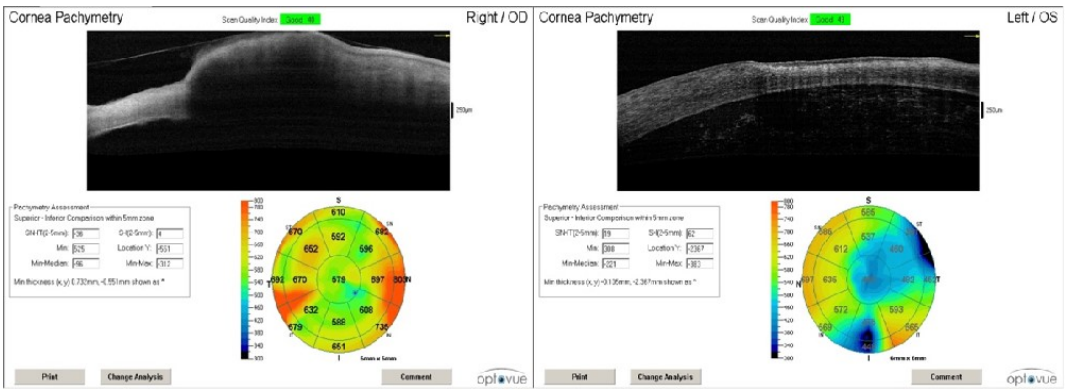

Figure 7. (A, B) Corneal ulcers. Undifferentiable corneal layers in the bulging area through desmetocele, corneal ulcer, desmetocele, and keratoglobus (A). Superficial corneal ulcer, cellular debris in the anterior chamber, and anterior displacement of the irido-crystalline complex (B).

Goniodysgenesis is an inherited abnormality of the aqueous humor outflow pathway from the anterior chamber of the eye due to narrowing of the iridocorneal angle or pectinate ligament dysplasia that prevents drainage (Figure 8. A, B, C). Goniometry studies have quantified a normal eye as one in which the open angle has an angle of ~329 mm (Ramos et al., 2009). Initially, these changes were thought to be congenital abnormalities, but it is now known that the iridocorneal angle can narrow with age and pectinate ligament dysplasia can be progressive (Oliver et al., 2016). These abnormalities are frequently associated with glaucoma risk and may be markers for other more serious abnormalities of the aqueous humor outflow pathways. Clinically, this type of pathology is manifested by: sudden onset blindness and pain associated with a marked increase in intraocular pressure.

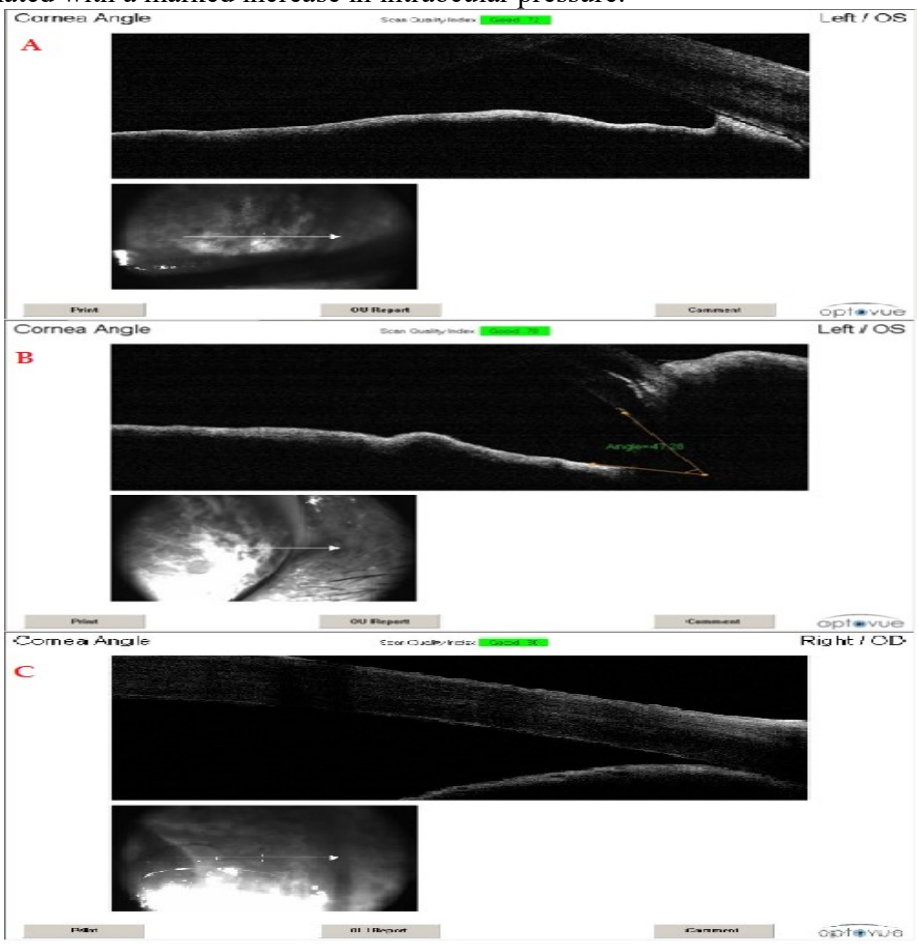

Figure 8. (A) Closed iridocorneal angle, covered by inflammatory debris, increased aqueous humor density, synechiae between iris and lens (posterior iridocorneal synechiae). (B) Open iridocorneal angle in both eyes. (C) closed iridocorneal angle in both eyeballs.

Retinal edema also called papillary edema is associated with edema of the optic disc located inside the retina (Figure 9. A, B). This swelling can lead to increased pressure on the brain and cause other symptoms such as inflammation of the optic nerves. When inflammation occurs, it interferes with the eye's ability to transmit retinal

information to the brain. In some cases, the optic nerve may be only partially inflamed, while in other cases the optic nerve is completely inflamed. Papilledema can affect both dogs and cats. Symptoms in this condition are manifested by an inability to orient themselves in the environment, may bump into things around them, can't find their place in their normal habitat, can sometimes trigger episodes of anxiety and fear, and an inability to catch toys or find hidden objects. Often patients may also display aggressive behavior.

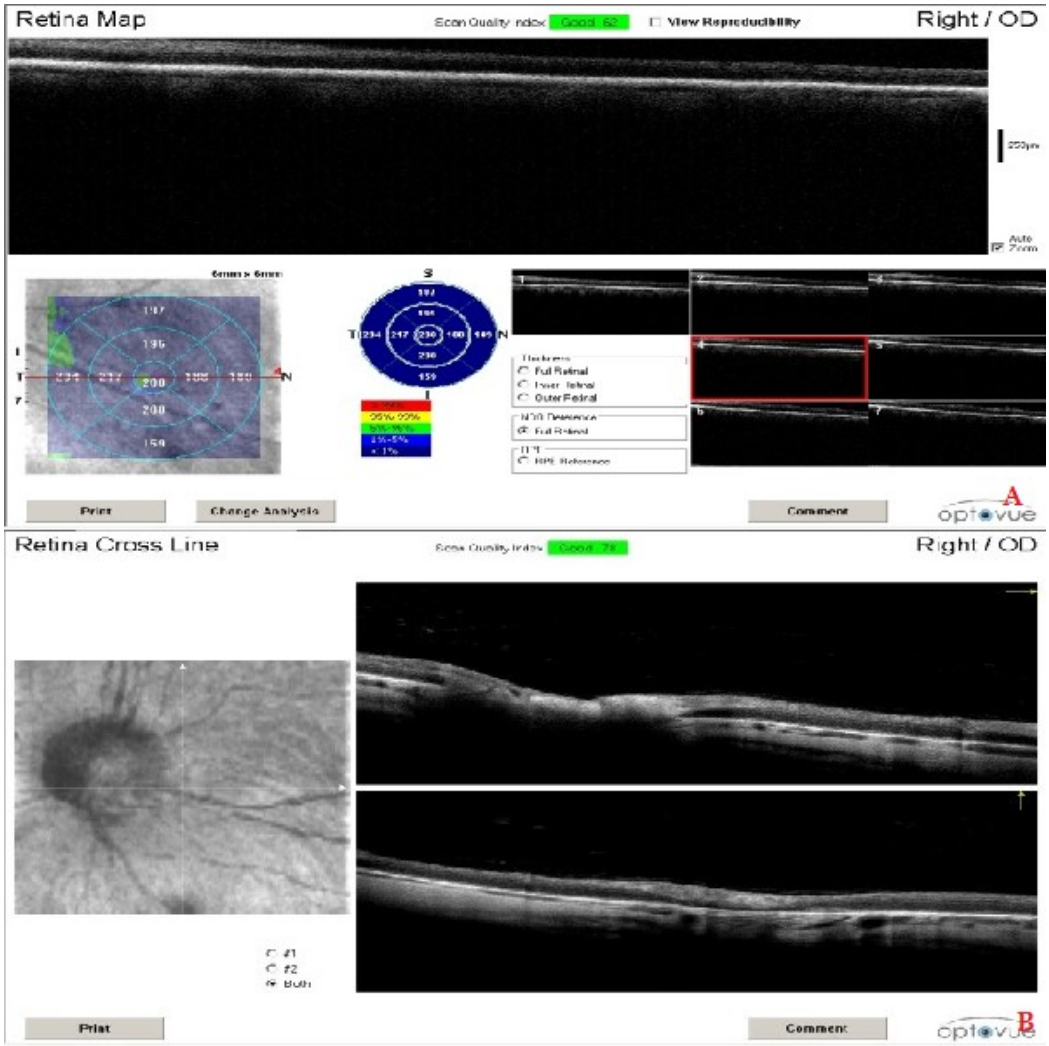

Figure 9. (A, B) Retinal edema; normal corneal pachymetry in both eyes, right eye with fluid between retinal layers, retinal edema (A). Distention of retinal layers, retinal edema, and multiple vacuoles present in retinal structure (B).

CONCLUSIONS

Optical coherence tomography is one of the medical imaging techniques used to examine various segments of the eyeball and is an in vivo, non-invasive, non-contact examination technique that provides highly accurate images.

Optical coherence tomography examination complements the information provided by the clinical examination and other paraclinical examinations of the eyeball, guiding the clinician in making the ophthalmic diagnosis.

Due to the structural complexity of the eyeball, optical coherence tomography examination plays an important role in diagnosing various ocular pathologies and in monitoring these pathologies after interventional actions.

Optical coherence tomography provides new insight into changes in corneal structures, the iridocorneal angle, the iris, and the retina.

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