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Anatomical and histological structures of eye and lacrimal gland in Norduz and Morkaraman sheep

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Abstract: The current study was conducted to determine the morphological, morphometric, and histological characteristics of bulbus oculi and lacrimal gland in sheep. For this purpose, 28 pairs (n = 7 males and n = 7 females) of bulbus oculi from Morkaraman and (n = 7 males and n = 7 females) Norduz sheep were analyzed. The bulbus oculi in the skulls were dissected from the orbit and removed. The morphometric data such as distance between endpoints of the dissected bulbus oculi in temporal, nasal, and dorsal directions, the length between endpoints of the pupil in dorsal and ventral directions, and as well as in temporal and nasal directions were measured with a digital caliper. For histological analyses, the eye tissues of Norduz and Morkaraman sheep were fixed in 10% formaldehyde solution. Then, the tissues were blocked by paraffin via passing them through the routine histological tissue follow-up solutions. Dissections in 6-µm thickness were made from the blocks. To evaluate the tissues histologically, tissue sections were stained with Crossmann's modified triple staining technique (triple staining). The mean values and standard deviations of the acquired data and the correlation coefficients among these characters were evaluated by the SPSS 22 program. The dorso-ventral diameter of bulbus oculi (BDV) was measured as an average of 25 ± 0.95 and 26.67 ± 3.19 mm in female and male Norduz sheep, respectively. Similarly, the BDV diameter in Morkaraman sheep was measured as 26.19 ± 1.04 mm in females and 26.41 ± 0.92 mm in males. As a result of analysis between genders in Norduz sheep, the BDV diameter, medio-lateral diameter of cornea (CML), dorso-ventral diameter of pupil (PDV), and dorso-ventral diameter of lens (LDVÇ) were identified statistically significant ($p < 0.05$). However, the results of the gender analysis in Morkaraman sheep demonstrated that none of the parameters were statistically significant ($p > 0.05$). The eye layers, the tunica fibrosa bulbi, tunica vasculosa bulbi, and tunica interna bulbi of both male and female Morkaraman and Norduz sheep were studied through the microscopic analysis. It was specified that both sheep species and both genders had a very wide tapetum fibrosum structure in the choroid of eye structures. It was also determined that the lacrimal gland had a seromucous characteristic and a tubuloacinar structure.

Key words: Eye anatomy, histology, lacrimal gland, sheep

1. Introduction

The eye, the organ of sight, and the primary component of the optical apparatus is the subject intensely studied in mammals. Besides primarily catching the light and fulfilling the visual sense, it is additionally the sensory organ containing biological rhythms and neurophysiological activities and transmitting nonvisual light information to the brain [1] The visual sense consists of bulbus oculi, nervus opticus, and organa oculi accessoria sections [2]. To evaluate disease pathophysiology, and as well as to perceive specific therapeutic approaches, a histological comprehension for the eye layers is necessary. Among the external structures of the eye, there are eyelashes, eyelids, muscles, accessory glands, and conjunctiva. The internal eye structures consist of three layers of tissues arranged concentrically. Of those, the sclera and cornea generate the outer layers, while the uvea, iris, ciliary body, and choroid are the divided and middle vascular layers. The retina consisted of nerve tissue forms the innermost layer; the rod and cone receptors layer, the membrane limitans externa, the outer nuclei layer, the outer plexiform, the inner nuclei layer, the inner plexiform, the ganglion cells layer, the nerve fibers layer and the membrane limitans interna layer [3,4]. Histologically, the lacrimal glands contain acini, composed of ranked myoepithelial cells with lightly stained secretory granules and large serous cells surrounded by rare and vascular stroma [5]. The front side of the bulbus oculi is called the pollus anterior, and the backside is called the pollus posterior. While the axis bonding these two sections is called axis bulbi externus (axis opticus), the axis connecting these two sections from the inside is called axis bulbi internus [6,7].

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The morphological and morphometric features of bulbus oculi vary among species and breeds. When the domestic mammals are compared to their body sizes, the largest bulbus oculi is present in cats followed by dogs, horses, and cattle, respectively [7]. Morkaraman sheep is one of the domestic breeds raised in the Eastern Anatolia region. It is especially raised in Erzurum, Kars, Ağrı and Van provinces. However, the Norduz sheep breed, which is one of the most significant genetic resources of Turkey, is solely raised in the Gürpınar district of Van province [8].

This study was conducted with the aim of contributing to the branches of science working on animal human experimental models in the field of clinical studies and ophthalmology by presenting anatomical, morphometric and histological data about the eye.

2. Materials and methods

2.1 Ethical approval

For the study, the research certificate was granted by Kafkas University Animal Experiments Local Ethics Committee (KAU-HADYEK) with the approval of the decision (Decision No: 2021/086).

2.2 Animals

A total of 28 pairs of bulbus oculi taken from adults (n = 7 males and n = 7 females), Morkaraman and (n = 7 males and n = 7 females), Norduz sheep were analyzed in this study.

2.3 Anatomical examination

The bulbus oculi in the skulls were dissected from the orbit and removed. The morphometric data such as distance between endpoints of the dissected bulbus oculi in temporal, nasal, and dorsal directions, the length between endpoints of the pupil in dorsal and ventral directions, and as well as in temporal and nasal directions, height and width of lacrimal gland (LGH, LGW) were measured with a digital caliper (Figures 1 and 2).

2.4 Histological examination

After macroanatomical and morphometric measurements, procedures for histological analyses were performed. The eye tissues of Norduz (4F/4M) and Morkaraman (4F/4M) sheep were fixed in 10% formaldehyde solution for histological analyses. Then, the tissues were blocked by paraffin via passing them through the routine histological tissue follow-up (70%–80%–90%–100% × 3 alcohol series and Xylol × 3) solutions. Dissections in 6-µm thickness were made from the blocks. To evaluate the tissues histologically, the tissue sections were stained with Crossmann's modified triple staining technique (triple staining). The sections were examined under a BX 51 light microscope (Olympus, Japan).

2.5 Statistical analysis

For statistical analysis, the mean values and standard deviations of the acquired data and the correlation coefficients among these characters were evaluated by the SPSS 22 program. The data were subjected to independent-samples t test, using the SPSS

22.0 software package. A p-value of <0.05 was considered statistically significant.

The bulbus oculi pictures provided in the study were photographed using a Canon digital camera. The Nomina Anatomica Veterinaria [9] was considered for the nomenclatures used.

3. Results

3.1 Morphometric results

Regarding the eyes of sheep, all measured parameters are given in Table. The dorso-ventral diameter of bulbus oculi (BDV) was measured as an average of 25 ± 0.95 and 26.67 ± 3.19 mm in female and male Norduz sheep, respectively.

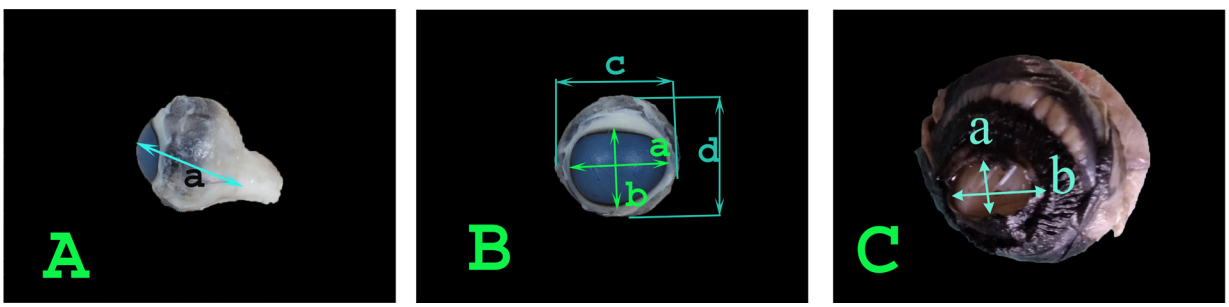

Figure 1. (A): Axial length/diameter (a): Length from pole anterior to pole posterior, (B): Measuring points of findings from Bulbus oculi: Medio-lateral (CML) diameter (a): The length between the temporal and nasal endpoints of the cornea, dorso-ventral (CDV) diameter, (b): The length between the dorsal end of the cornea and the ventral end of the cornea, medio-lateral (BML) diameter, (c): The length between the temporal and nasal endpoints of the bulbus oculi, dorso-ventral (BDV) diameter, (d): Length between the tip of the bulbus oculi in the dorsal direction and the end points in the ventral direction, (C): Measurement points taken from the pupil; dorso-ventral (PDV) diameter (a): Length between the tip of the pupil in the dorsal direction and the end points in the ventral direction, Medio-lateral (PML) diameter, (b): Length between the temporal and nasal endpoints of the pupil.

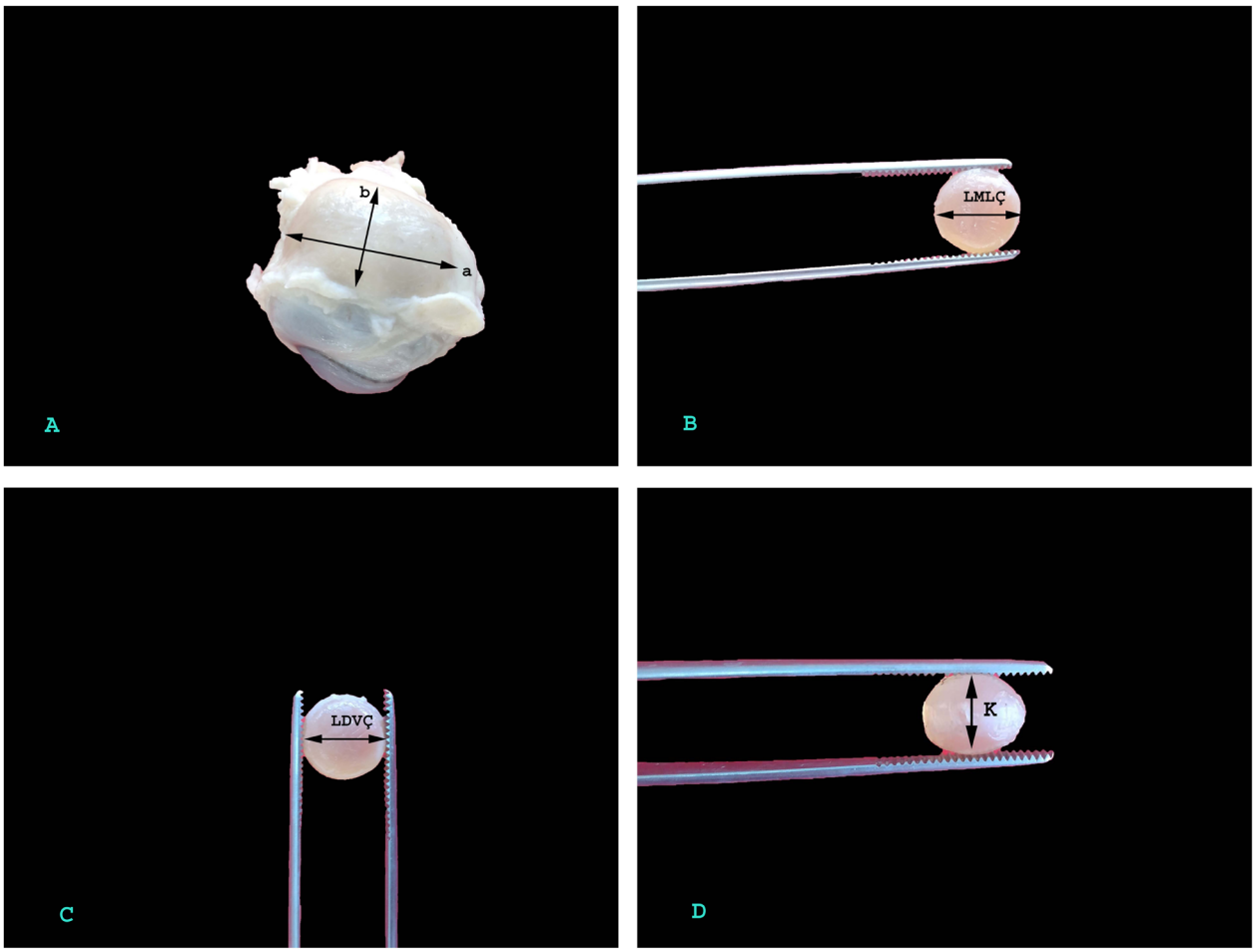

Figure 2. (A–D): Measuring points of the lacrimal gland and lens: a: The length of lacrimal gland (LGH), b: The weight of lacrimal gland (LGW), medio-lateral (LMLÇ) diameter, (B): The length between the temporal and nasal endpoints of the lens, dorso-ventral (LDVÇ) diameter, (C): Length between the dorsal end of the lens and the ventral end of the lens, Figure 2D (K) Thickness: The length between the anterior and posterior endpoints of the midpoint of the lens.

Similarly, the BDV diameter in Morkaraman sheep was measured as 26.19 ± 1.04 mm in females and 26.41 ± 0.92 mm in males (Figure 1). The length of lacrimal gland (LGH) (Figure 2A) was measured as an average of 24.15 ± 2.58 mm in female and 22.29 ± 0.96 mm in male Norduz sheep, respectively. This parameter in Morkaraman sheep was measured as 25.57 ± 1.44 mm in females and 23.88 ± 1.44 in males. As a result of analysis between genders in Norduz sheep, the BDV diameter, CML diameter, PDV diameter and LDVÇ diameter of lens were identified statistically significant ($p < 0.05$). However, the results of the gender analysis in Morkaraman sheep indicated that none of the parameters was statistically significant ($p > 0.05$).

3.2 Histological results

In the histological analyses of the eye structures of sheep at the light microscopic level, the tunica fibrosa bulbi (sclera, cornea), tunica vasculosa bulbi (choroid, corpus ciliare, iris), and tunica interna bulbi (retina) layers were identified.

In the tunica fibrosa bulbi layer, it was observed that the sclera section consisted of condensed and parallel collagen thread bundles. The shuttle-shaped fibroblasts, few melanocytes, and blood vessels were also identified among the collagen filaments (Figures 3A and 3B). In the cornea, which is the subsequent section of the sclera, the lamina epithelialis, Bowman's layer, stroma (substantia propria), Descemet's membrane, and lamina endothelium layers were distinguished from each other (Figures 3C and 3D). In addition, the lamina epithelialis was determined to consist of 8 to 9 cell lines. In the stroma part of the cornea, lamellar-structured collagen and keratoplasty within threads were observed. No blood vessels were found in the corneal layer. However, structures of the Schlemm's canal and trabecular meshwork (Fontana slits) were identified within the stroma of the sclera in the corneo-scleral section (Figures 4A and 4B).

Table. Average values of parameters acquired from bulbus oculi in sheep ([a, b, c, and d] $p < 0.05$ Norduz sheep).

Parameters	Morkaraman female sheep (mm)	Morkaraman male sheep (mm)	Norduz female sheep (mm)	Norduz male sheep (mm)
BDV[a] diameter	26.19 ± 1.04	26.41 ± 0.92	25 ± 0.95	26.67 ± 3.19
BML diameter	27.84 ± 0.61	28.18 ± 0.38	26.79 ± 0.83	26.86 ± 2.91
Axial diameter	27.18 ± 0.93	27.13 ± 0.87	27.57 ± 2.43	26.30 ± 2.29
Cornea DV diameter	14.73 ± 0.44	14.42 ± 0.48	14.89 ± 0.99	12.43 ± 1.64
Cornea ML[b] diameter	19.70 ± 0.8	19.82 ± 0.68	20.09 ± 0.25	16.50 ± 2.82
Pupilla DV[c] diameter	6.07 ± 0.66	5.50 ± 1.32	3.17 ± 0.30	4.45 ± 1.00
Pupilla ML	11.39 ± 0.7	11.50 ± 0.62	10.34 ± 0.45	10.97 ± 0.88
Lens DV[d] diameter	11.14 ± 0.75	11.59 ± 0.5	5.70 ± 0.37	6.79 ± 1.21
Lens ML diameter	11.40 ± 0.76	11.72 ± 0.79	8.01 ± 0.83	7.76 ± 1.13
Lens Thickness	7.93 ± 0.24	8.42 ± 0.63	5.08 ± 0.87	5.57 ± 0.81
Weight (g)	31 ± 2.34 g	32 ± 2.70 g	20.50 ± 1.71 g	20.50 ± 1.17 g
LGH (mm)	25.57 ± 1.44	23.88 ± 1.44	24.15 ± 2.58	22.29 ± 0.96
LGW (mm)	20.17 ± 1.71	20.69 ± 1.08	19.19 ± 2.13	15.77 ± 0.45

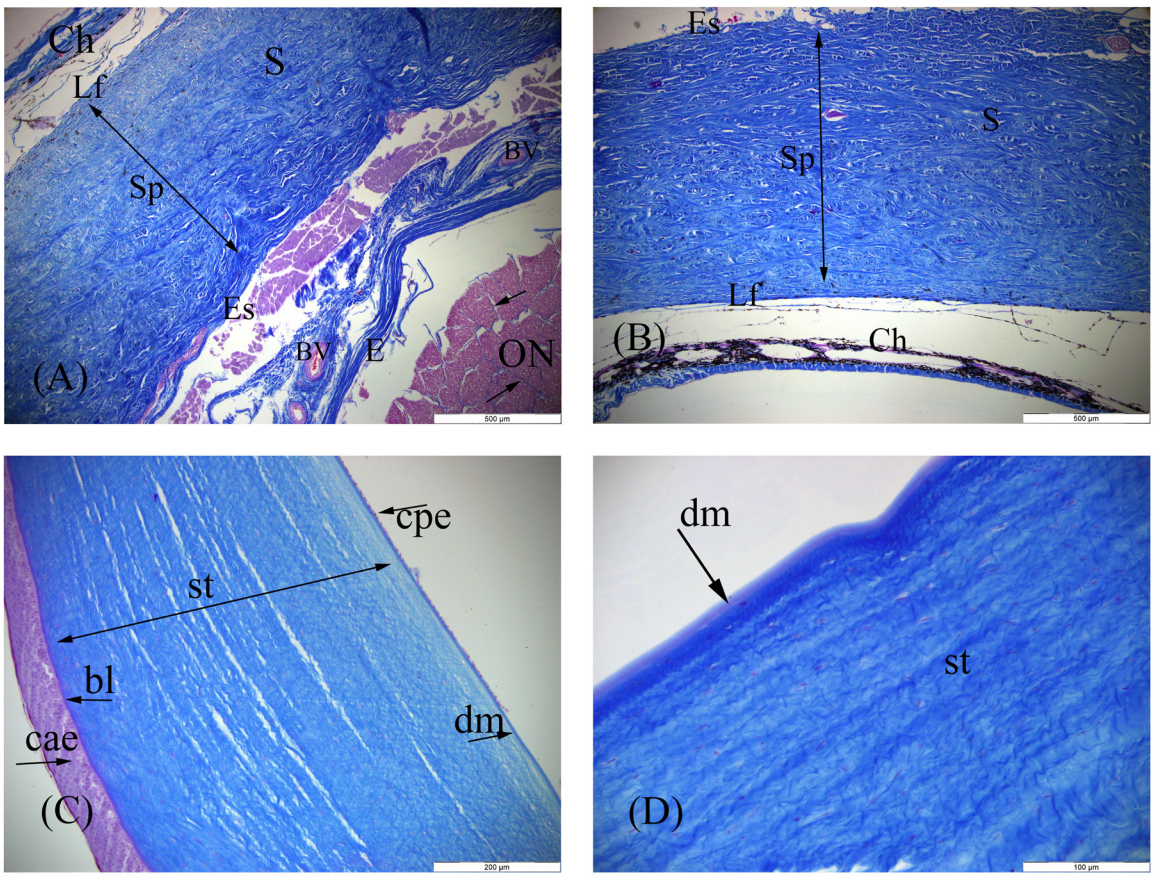

Figure 3. (A): Structure of the sclera in the male Morkaraman sheep eye, (B): Structure of sclera in female Norduz sheep eye, Ch: Choroid, BV: Blood vessel, E: Epinerium, Es: Episklera, Lf: Lamina fusca, ON: Optic nerve, S: Sclera, Sp: Substantia propria, Arrows: Perinerium of Optic nerve. (C): Structure of Cornea in male Morkaraman sheep eye, (D): Structure of Cornea in female Norduz sheep eye, bl: Bowman's layer, cae: corneal anterior epithelium, cpe: corneal porterior epithelium, dm: Descemet's membrane, st: stroma, Triple staining.

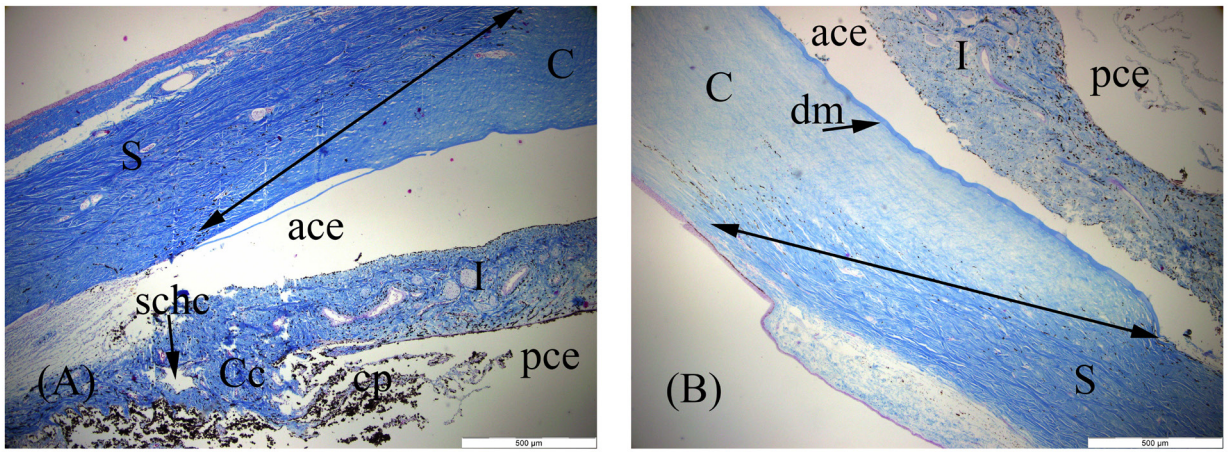

Figure 4. Corneoscleral section in the sheep eye, (A): Female Morkaraman, (B): Male Norduz. ace: anterior chamber of the eye, C: Cornea, Cc: Ciliary body, cp: Ciliary processes, dm: Descemet's membrane, I: Iris, pce: posterior chamber of the eye, S: Sclera, schc: Schlemm's canal, Triple staining.

In the choroid section of the tunica vasculosa bulbi layer, five distinct layers, namely lamina suprachoroidal, lamina vasculosa, tapetum fibrosum, lamina capillarum, and lamina basalis (Bruch's membrane), were identified in both species. The tapetum fibrosum was observed to consist of considerably wide collagen threads and contained fibroblasts within (Figures 5A–5D). In both species, it was also observed that the choroid structure in females was narrower and had more intense pigment cells when compared to males.

The corpus ciliare and processus ciliaris structures covered with bilayer cubic epithelium were identified as located between the iris and choroid (Figures 6A and 6B). The pigmented epithelial tissue of the iris, which is the subsequent section of the corpus ciliare, stroma with collagen fibers, nerve plexuses, blood vessels, numerous melanocytes, sphincter muscles, and its dilator muscles were observed. In Morkaraman sheep, pigment cells in the anterior margin layer of the iris were more intense than in Norduz sheep. However, pigment cells in Norduz sheep were denser in the stroma of the iris, and the muscle layer in the stroma was observed to consist of a more straight-sided muscle layer compared to Morkaraman sheep (Figures 6C and 6D).

The pigmented epithelial layer of the retina, which is unified by the choroid and formed the tunica interna bulbi layer, was identified to consist of 10 different layers, namely the rod and cone receptors layer, the membrane limitans externa, the outer nuclei layer, the outer plexiform, the inner nuclei layer, the inner plexiform, the ganglion cells layer, the nerve fibers layer and the membrane limitans interna layer (Figures 7A and 7B). The optic nerve surrounded by the epineurium and perineurium was also identified (Figure 3A). In addition to the eye structure, lacrimal gland structure was histologically studied in Norduz and Morkaraman sheep. In both species, the lacrimal gland was observed to be surrounded by a thin collagen tissue dividing it into several large lobes. Several adipocytes and blood vessels were identified within this collagen tissue. The lacrimal gland was also specified to be in a seromucous and tubuloacinar structure (Figures 8A and 8B).

4. Discussion

In this study, the bulbus oculi of sheep were evaluated anatomically and histologically. There were similar studies in the literature not for the breeds we analyzed, but for some other goat, sheep, and buffalo races.

The right medio-lateral diameter of bulbus oculi (BML/ML) in Sahel goats was stated as 8.12 ± 0.53 mm in males, and 8.34 ± 0.36 in females; and the left ML diameter was reported as 8.14 ± 0.34 mm and 8.20 ± 0.44 mm in males and females, respectively [10]. In addition, the ML diameter of bulbus oculi in two other goat breeds was also reported in the same research. Accordingly, the right and left ML diameters for the West African dwarf goats were 8.16 ± 0.74 mm and 7.70 ± 0.67 mm in males, and 8.50 mm and 8.47 ± 0.39 mm in females, respectively. In Red Sokoto goats; however, the right and left ML diameters were measured as 8.07 ± 0.15 mm and 7.87 ± 0.29 mm in males, and 8.83 ± 0.34 mm and 8.70 ± 0.31 mm in females, respectively. Among these three goat breeds, the DV diameters of bulbus oculi (BDV) were also measured and reported as follows; the right and left DV diameters for the Sahel goats were 7.17 ± 0.46 mm and 7.09 ± 0.37 mm in males, and 7.21 ± 0.49 and 7.13 ± 0.52 mm in females; for the West African dwarf goats, 6.82 ± 0.70 mm and 6.88 ± 0.87 mm in males, and 7.43 ± 0.35 mm and 7.39 ± 0.27 mm in females; and for the Red Sokoto goats, 6.97 ± 0.19 mm and 7.17 ± 0.03 mm in males, and 7.70 ± 0.34 mm and 7.53 ± 0.21 mm in females, respectively [10].

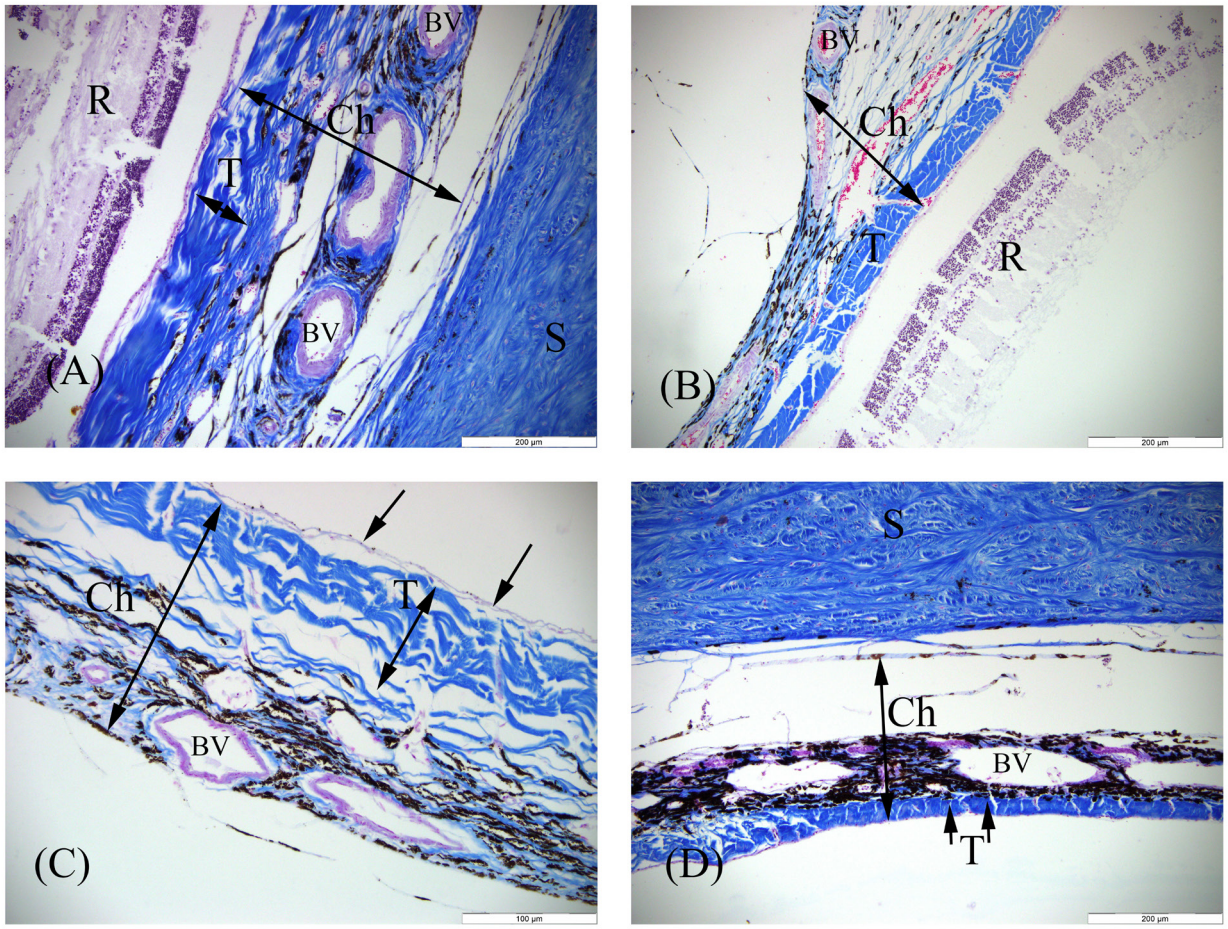

Figure 5. Structure of the Choroid in the sheep eye, (A): Male Morkaraman sheep, (B): Female Morkaraman sheep, (C): Male Norduz sheep, (D): Female Norduz sheep, Ch: Choroid, BV: Blood vessel, R: Retina, T: Tapetum fibrosum, arrows: Retinal pigment epithelium, Triple staining.

In a study conducted on Awassi sheep, the right and left DV diameters of the bulbus oculi was reported as 25.95 ± 0.49 mm and 26.56 ± 0.53 mm in males, and 29.33 ± 0.44 mm and 28.38 ± 0.46 mm in females, respectively. Consequently, the right and left ML diameters in male Awassi sheep were also measured as 28.11 ± 0.42 mm and 27.50 ± 0.39 mm, respectively [7]. In another research conducted on buffaloes (*Bubalus bubalus*), it was reported that the ML diameter of the bulbus oculi was measured as 35.10 ± 0.38 mm, and the DV diameter as 34.3 ± 042 mm [11]. Our study also reports that the DV diameters of the bulbus oculi in Morkaraman sheep were identified as 26.19 ± 1.04 mm in females and 26.41 ± 0.92 mm in males; and the right and left diameters were measured as 25 ± 0.95 mm and 26.67 ± 3.19 mm in Norduz sheep, respectively.

The ML diameter of the cornea (CML) in Barbary sheep (*Ammotragus lervia*) was reported as 25.05 ± 2.18 mm and the DV diameter (CDV) as 17.95 ± 1.68 mm [12]. In Awassi sheep; however, the right and left ML diameters of the cornea were stated as 21.99 ± 0.30 mm and 21.98 ± 0.32 mm in males, and 24.09 ± 0.38 mm and 24.09 ± 0.40 mm in females, respectively. In the same study, the right and left DV diameters of the cornea were determined as 17.08 ± 0.26 mm and 16.87 ± 0.38 mm in males, and 17.88 ± 0.43 mm and 18.66 ± 0.40 mm in females, respectively. In Morkaraman and Norduz sheep, the ML diameter of the cornea was also identified as 20.09 ± 0.25 and 16.50 ± 2.82 mm in males, and 19.70 ± 0.80 mm and 19.82 ± 0.68 mm in females, respectively.

Fornazari et al. [12] reported the thickness of the lens as 9.4 ± 0.33 mm in their study conducted on Barbary sheep (*Ammotragus lervia*). Verma et al. [11] reported the thickness of the lens in buffalo (*Bubalus bubalus*) as 8.67 ± 0.15 mm. Demircioğlu et al. [7] reported that the right and left average lens thickness of Awassi sheep was defined as 8.87 ± 0.21 mm and 19.28 ± 0.16 mm in males, and 10.08 ± 0.14 mm and 10.36 ± 0.16 mm in females, respectively. In our study, the average lens thickness

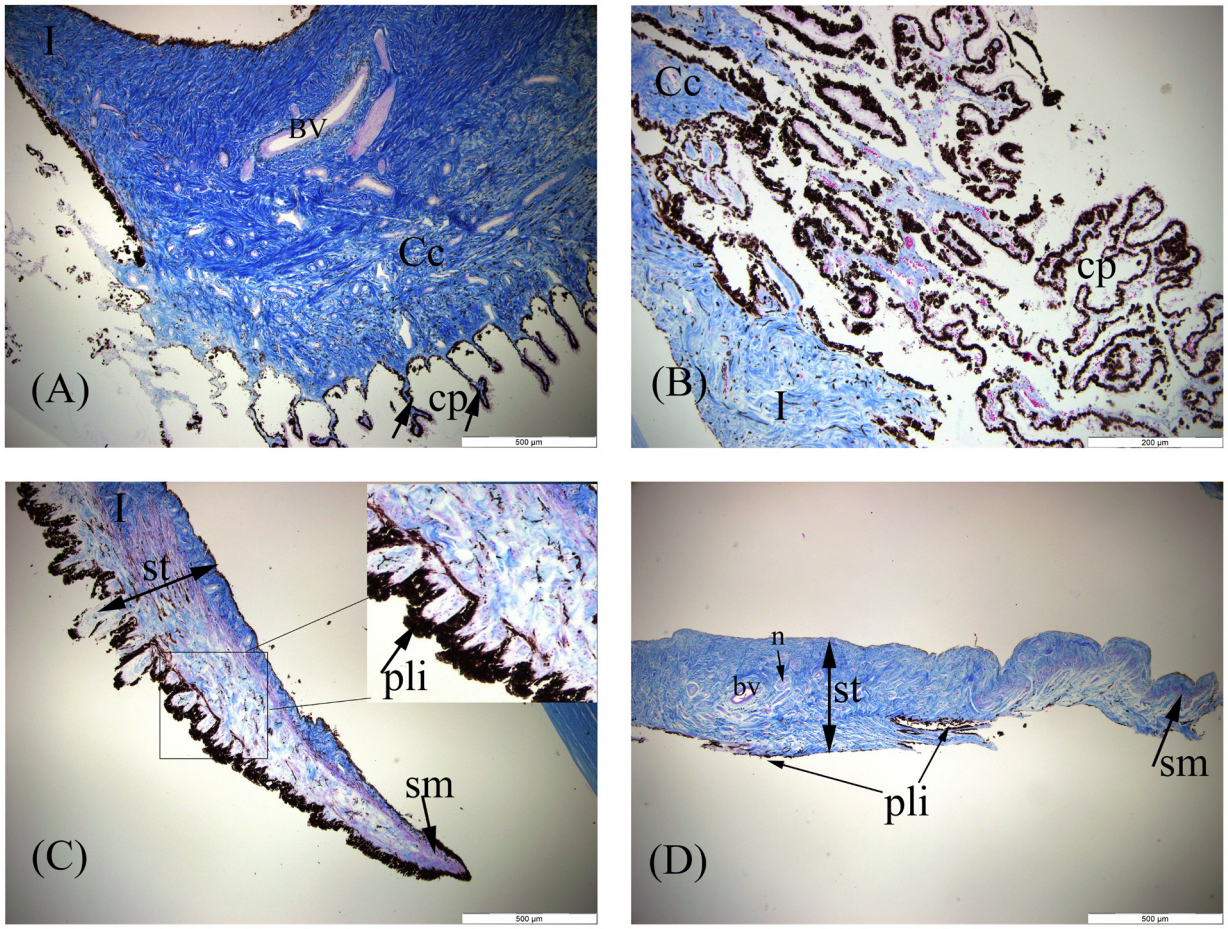

Figure 6. Structure of the Corpus ciliare, ciliary processes and iris in the male Morkaraman (A,C) and female Norduz (B,D) sheep eye, BV: Blood vessel, Cc: Corpus ciliare, cp: ciliary processes, I: Iris, n: nerve, pli: pigmented layer of the iris, sm: sphincter muscles, st: stroma of the iris, Triple staining.

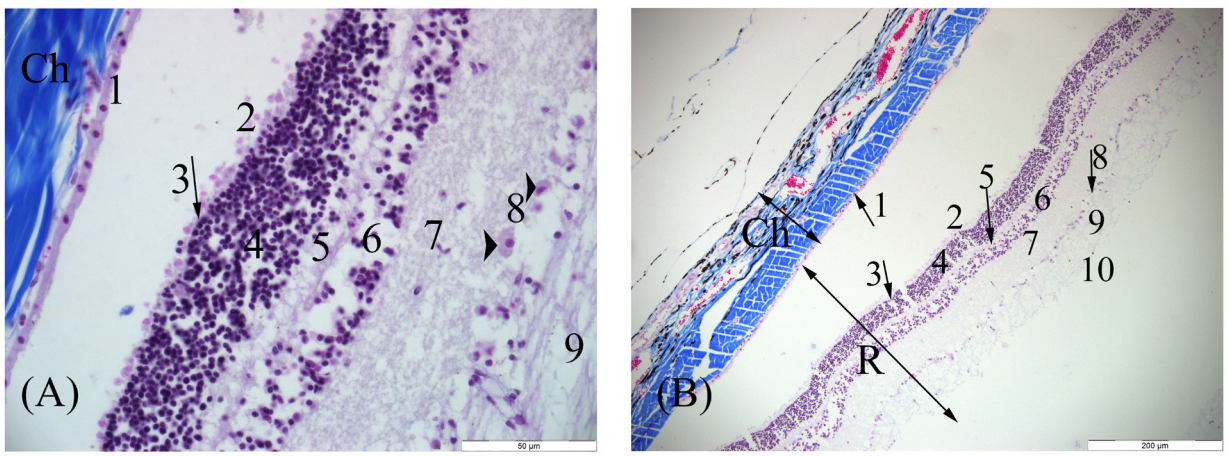

Figure 7. Characterization of the structure of the retina in the sheep eye, (A): Male Morkaraman sheep, (B): Female Morkaraman sheep, Ch: Choroid, 1: pigmented layer of the iris, 2: rod and cone receptors layer, 3: membrane limitans externa, 4: outer nuclei layer, 5: outer plexiform, 6: inner nuclei layer, 7: inner plexiform, 8: ganglion cells layer, 9: nerve fibers layer, 10: membrane limitans interna layer, Triple staining.

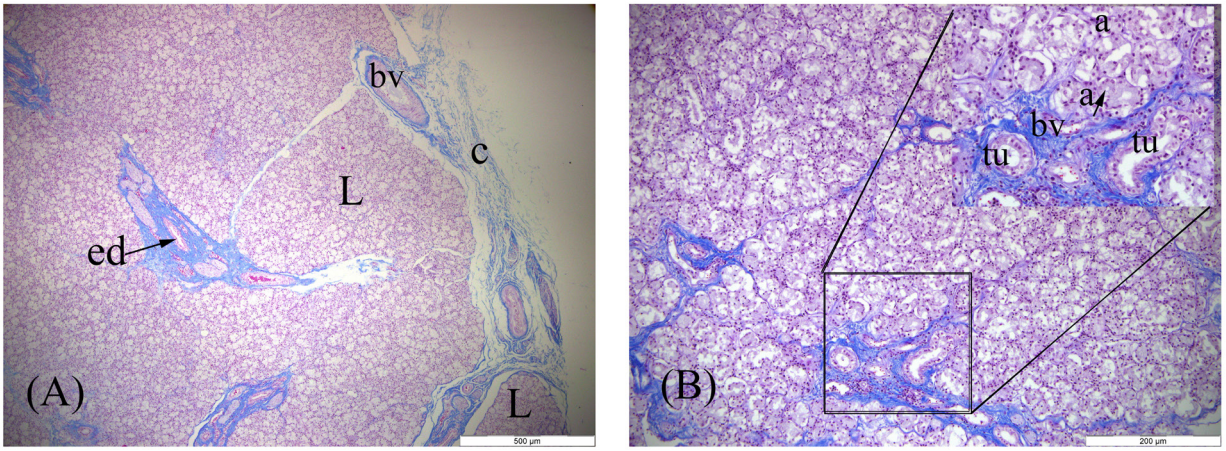

Figure 8. Lacrimal gland structure in the Morkaraman (A) and Norduz sheep (B), a: acini, bv: blood vessel, c: capsule, ed: excretory duct, L: lobes, tu: tubules, Triple staining.

in Norduz sheep was measured as 5.57 ± 0.81 mm in males and 5.08 ± 0.87 mm in females. However, the lens thickness in Morkaraman sheep was measured as 8.42 ± 0.63 mm in males and 7.93 ± 0.27 mm in females. Abuagla et al. [13] reported the diameter of the camel pupils as 2.04 ± 0.21 cm on the right and 2.08 ± 0.23 cm on the left. The right and left DV diameters of the pupil in Awassi sheep were identified as 6.75 ± 0.28 mm and 7.38 ± 0.33 mm in males, and 7.49 ± 0.28 mm and 7.69 ± 0.24 mm in females, respectively. In addition, the right and left ML diameters of the pupil in Awassi sheep were determined as 11.88 ± 0.29 mm and 11.83 ± 0.35 mm in males, and 13.58 ± 0.24 mm and 13.71 ± 0.24 mm in females, respectively. In our study, the DV and ML diameters of pupil in Norduz sheep were measured as 4.45 ± 1.00 mm and 10.97 ± 0.88 mm in males, and 3.17 ± 0.3 mm and 10.34 ± 0.45 in females, respectively. The same parameters in Morkaraman sheep; however, were measured as 5.50 ± 1.32 mm and 11.50 ± 0.62 mm in males, and 6.07 ± 0.66 mm and 11.39 ± 0.70 mm in females, respectively.

It was stated that the variation in lens thickness among males and females in Awassi sheep was statistically significant at the level of $p < 0.001$. In Norduz sheep, the parameters of the dorso-ventral diameter of pupil (PDV), ML diameter of cornea (CML), and lens DV diameter (LDV) were also identified statistically significant at the level of $p < 0.005$**.

The tunica fibrosa bulbi is the outer section and is the fibrous layer of the eye consisted of the sclera and cornea [14]. The sclera is a thick white membrane shaping the eyeball and the ocular structures located in the eye socket. The sclera consists of tight collagen tissue in mammals, and cartilage or bone tissue may also involve in the sclera structure in other vertebrates [15,16]. In our histological analyses, the eye sclera of Morkaraman and Norduz sheep was observed to consist of three layers, and this layer was composed of massive collagen threads and contained melanocytes as occurred in other mammals [17,18]. Alternatively, smooth muscle cell bundles in the sclera layer in the eyes of cattle, buffalos, donkeys, and goats were reported [19]. In our study, muscle cell bundles were also identified in the episclera layer of the sheep eye sclera.

In their study, Greene et al. [20] stated that the sheep cornea contained lamina epithelialis consisting of various cell layers, a thin Bowman's layer, a wide stroma layer, and a Descemet's membrane. Researchers carrying out the cornea of domestic animals and laboratory pets in previous studies speculated that the Bowman's layer is not present in all species, though they may be present only in primates [21]. The latter studies; however, reported that the Bowman's layer was present in various mammalian species such as pigs [22], cattle [23], deer [24], bears [25], sheep [20,26], and dogs [27]. In parallel with Greene et al. [20], this study also stated that the eye cornea of Norduz and Morkaraman sheep consisted of a well-placed epithelial layer, a thin Bowman's layer, a stroma with wide collagen threads, and a Descemet's membrane. Studies in domestic animals demonstrated that the epithelial layer of the cornea contained varying numbers of cell rows in species [28,29]. It was reported that the sheep eye cornea has an epithelial layer with 8 to 9 rows of cells. Moreover, our study further determined the Schlemm's canal and trabecular meshwork (Fontana tomies) structures in the cornea-scleral area.

In most mammals and domestic animals, the choroid is divided into five layers: suprachoroidal, vascular layer, tapetal region, capillary layer, and basal layer (Bruch's membrane) [30–32]. In their study, Ollivier et al. [33] stated that there was no tapetum lucidum in primates, red kangaroos, pigs, birds, and squirrels. In the same research; however, they reported that there was a tapetum lucidum in fishes, reptiles, crocodiles, bats, cats, dogs, ferrets, cows, sheep, goats, and lemurs. Since the retinal pigment

epithelium has a complete pigmentation in *Thyronomys swinderianus* rats [34], and *Cricetomys gambianus* mice [35], authors speculated that there was no tapetum lucidum in these species. In sheep, the tapetum is comprised of a collagen fiber layer and contains fibroblasts locally. While melanocytes are located densely in nontapetal areas in the choroid structure, they are absent on the tapetum fibrosum [36]. We determined in this study that the tapetum fibrosum area of the choroid, which has a considerable amount of blood vessels and melanocytes in sheep, consisted of larger collagen thread bundles. Moreover, it contained fibroblasts locally; however, it had no melanocytes.

We stated in our study that the corpus ciliare and processus ciliaris epithelial layer consisted of two layers; nonpigmented in the upper part and pigmented in the inner part, similar to the camel [37] and Sulawesi bears [18]. Blood vessels, nerve plexuses, and pigmented cells were observed abundantly within the dense collagen tissues of the stroma of the corpus ciliare. However, there were numerous capillaries and wide cells in the loose collagen tissue of the processus ciliaris. We also specified that the pigmented posterior epithelial surface of the iris, anterior epithelial surface with a simple epithelial row, and a stroma containing a considerable amount of melanocytes, fibroblasts, small blood vessels, nerve fibers, sphincter, and dilator muscles in collagen filaments were similar with several studies reported for other species [18,31,37,38].

Retina has been the research subject studied intensively in various species in terms of its primary significance in the sense of sight and enabling creatures to react with their environment [39,40,41]. Histologically, the retina consisted of 10 layers, as it was reported in camels [42], horses [43], and bears [25] species.

We determined in our study that the lacrimal gland is composed of serous, mucous, and seromucous glands in tubulo-acinar structure, and it contains pouring channels and blood vessels. We also observed that a thin collagen tissue surrounded the gland, and that tissue divided the gland into several lobes. It was further specified that the anatomical and histological structure of the lacrimal gland studied in humans and some other mammals were almost similar and composed of tubulo-acinar units [44,45]. Abbasi et al. (2014) reported that the glands in Lori's sheep were serous, mucous, and serous-mucous. In addition, Paszta et al. (2021) reported that the lacrimal gland was serous-mucous in dogs.

In the literature reviews, there are some studies conducted on bulbus oculi of domestic and wild animals. However, we have not encountered any research performed comparatively on anatomical and histological parameters, as we carried out in our study. Having detailed information on the type-specific characteristics of this anatomical, morphometric and histological researches on sheep eyes is vital for clinical studies. It is envisaged that the data obtained as a result of the study will contribute to those science branches which work on animal and human experimental models in the field of ophthalmology.

Ethical approval

This study was approved by the Kafkas University Animal Experiments Local Ethics Committee (Approval no: 2021/086).

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Conflict of interest

The authors have declared no conflicts of interest.

Contribution of authors

SD and SİA designed the study. SD and KA performed the macroanatomical and morphometric analysis. SİA, TD, and RU carried out histological examination. SD and SİA carried out the statistical analysis. SD, SİA, and KA performed the imaging all section. The manuscript was written by SD, SİA, and RU. All authors approved the final version.

References

1. Ohuchi H, Sato K, Habuta M, Fujita H, Bando T. Congenital eye anomalies: More mosaic than thought? Congenital Anomalies. 2019; 59 (3) : 56-73. doi: 10.1111/cga.12304.
2. Serbest A. Sensory Organs Anatomy of Domestic Mammals and Poultry (in Turkish). Bursa, Turkey; Uludağ Üniversitesi Veteriner Fakültesi publication; Publication No: 2010-3.
3. Sinnatamby and Chummy S. Last's Anatomy: Regional and Applied (MRCS Study Guides) 2011. 12th Edition. ISBN 9780702033957 Elsevier Ltd.
4. Sommers IG. Normal Histology Of The Eye. Histology and Histopathology of the Eye and Its Adnexa. 2013; 3-35.
5. Junquira LC, Carneiro J. Basic histology. 2003. 10th ed. McGraw- Hill Companies. USA 481-482.
6. König HE, Liebich HG. Veterinerinary Anatomy (Domestic Animals). 6th ed. Viyana-Münih: Medipres; 2015.
7. Demircioğlu İ, Yılmaz B. Morphometric investigation of bulbus oculi of Awassi Sheep (Ovis aries) (in Turkish with an abstract in English). Dicle Üniversitesi Veteriner Fakültesi Dergisi 2019; 12 (2): 108-111.

8. Koyuncu M. Sheep Breeding (in Turkish). Bursa, Turkey. Dora Publishing Distribution Ltd. Şti. 1st edn. 42;2019.

9. Nomina Anatomica Veterinaria International Committee on Veterinary Gross Anatomical Nomenclature (ICVGAN), Published by the Editorial Committee, Hannover. 2017

10. Olopade JO, Kwari HD, Agbashe IO, Onwuka SK. Morphometric Study of the Eyeball of Three Breeds of Goats. International Journal of Morphology 2005; 23 (4): 377-380. doi:10.4067/S0717-95022005000400015

11. Verma A, Pathak A, Farooqui MM, Prakash A. Prabhakar K. Gross and Morphometrical Observations of Eyeball in Buffalo Calf (Bubalus bubalus). Ruminant Science. 2016; 5 (2): 169-172.

12. Fornazari GA, Montiani-Ferreira F, de Barros Filho IR, Somma AT, Somna B. The Eye of the Barbary Sheep or Aoudad (Ammotragus lervia): Reference Values for Selected Ophthalmic Diagnostic Tests, Morphologic and Biometric Observations. Open Veterinary Journal. 2016; 6 (2): 102-113. doi: 10.4314/ovj.v6i2.6

13. Abuagla IA, Ali HA, Ibrahim ZH, An Anatomical Study On the Eye of the One-Humped Camel (Camelus Dromedarius). International Journal of Veterinary Science. 2016; 5 (3) : 137-141.

14. Di Fiore MSH. Atlas of Human Histology. 4th ed. Philadelphia, PA, USA: Lea & Febiger; 2001.

15. Öktay M. Comparative Anatomy of Vertebrate Animals (in Turkish). İstanbul, Turkey; İstanbul Üniversitesi Fen Fakültesi publication; 1998; 340-353.

16. Dursun N. Anatomy of domestic birds (in Turkish). Ankara, Turkey; Medisan Publication; 2002; 183: 206-216.

17. Nickel R, Schummer A, Seiferle E. The Anatomy of the Domestic Animals. Berlin, Germany: Springer Verlag GmbH; 2004.

18. Klećkowska-Nawrot JE, Goździewska-Harłajczuk K, Darska M, Barszcz K, Janeczek M. Microstructure of the eye tunics, eyelids and ocular glands of the Sulawesi bear cuscus (Ailurops ursinus Temminck, 1824) (Phalangeridae: Marsupialia) based on anatomical, histological and histochemical studies. Acta Zoologica 2019; 100 (2): 183-208. doi: 10.1111/azo.12251

19. Prince JH, Diesem CD, Eglitis I, Ruskall GL. Anatomy and Histology of the Eye and Orbit in Domestic Animals. Springfield, IL, USA: Charles C. Thomas Blackwell Scientific Publications; 1960.

20. Greene CA, Misra SL, Lee H, Mc Kelvie J, Kapadia K. at al. The Sheep Cornea: Structural and Clinical Characteristics. Current Eye Research. 2018; 43 (12) : 1432-1438. doi:10.1080/02713683.2018.1510970

21. Calmettes L, Deodati F, Planel H, Bee P. Etude Histologique et Histochimique de L'epithelium Anterieur. Arch Ophthalmol (Paris). 1956; 16: 481-506.

22. Camber O, Rehbinder C, Nikkila T, Edman P. Morphology of the pig cornea in normal conditions and after incubation in a perfusion apparatus. Acta Veterinaria Scandinavica 1987;28 (2): 127-34. doi: 10.1186/BF03548232

23. Merindano MD, Costa J, Canals M, Potau J, Ruano D. A comparative study of Bowman's layer in some mammals: relationships with other constituent corneal structures. Europen Journal Anatomy. 2002; 6: 133-140.

24. Rehbinder C, Winqvist G, Roos C. Structure of the cornea in some cervidae. Acta Veterinaria Scandinavica. 1977; 18: 152-158.

25. Kirbaş Doğan G, Koral Taşçi S, Dalga S, İlhan Aksu S. Anatomical and histological studies on the eyes of brown bear (Ursus arctos horribilis). Turkish Journal of Veterinary and Animal Sciences. 2020; 44: 871-878. doi:10.3906/vet-2002-22

26. Reichard M, Hovakimyan M, Wree A, Meyer-Lindenberg A, Nolte I et al. Comparative in vivo confocal microscopical study of the cornea anatomy of different laboratory animals. Current Eye Research 2010; 35 (12): 1072-1080. doi: 10.3109/02713683.2010.513796

27. Paszta W, Klećkowska-Nawrot JE, Goździewska-Harłajczuk K, Anatomical and morphometric evaluation of the orbit, eye tunics, eyelids and orbital glands of the captive females of the South African painted dog (Lycaon pictus pictus Temminck, 1820) (Caniformia: Canidae). PLoS ONE 2021; 16 (4): e0249368. doi:10.1371/journal. pone.0249368

28. Nautscher N, Bauer A, Steffl M, Amselgruber WM. Comparative morphological evaluation of domestic animal cornea. Veterinary Ophthalmology. 2016; 19 (4): 297-304. doi: 10.1111/vop.12298

29. Saadatlou MAE. Histoanatomical studies of the fibrous tunic of eye in Dromedary camel. Kafkas Universitesi Veteriner Fakültesi Dergisi. 2017; 23 (6): 911-915. doi: 10.9775/kvfd.2017.17976

30. Bacha JW, Bacha ML. The Eye. In Color Atlas of Veterinary Histology. 2nd ed. Philadelphia, PA, USA: Lippincott Williams & Wilkins, A Wolters Kluwer Company; 2000.

31. Slatter DH. Fundamento de Oftalmologia Veterinaria. 3rd ed. Sao Paulo, Brazil: Roca, 2005.

32. Malsawmkima BRK, Vyas YL, Bhayani DM. Histomorphological study on vascular tunics of the adult Surti buf-falo (Bubalus bubalis). International Journal of Interdisciplinary and Multidisciplinary Study 2014; 2: 24-28.

33. Ollivier FJ, Samuelson DA, Brooks DE, Lewis PA, Kallberg ME et al. Comparative morphology of the tapetum lucidum (among selected species). Veterinary Ophthalmology 2004; 7 (1): 11-22. doi: 10.1111/j.1463-5224.2004.00318.x

34. Peter-Ajuzıe I, Nwaogu I, Igwebuike U. Anatomical Assessment of the Eye of the African Grasscutter (Thryonomys swinderianus). Journal of Applied Life Sciences International. 2019; 20 (2): 1-8. doi: 10.9734/jalsi/2019/v20i230077

35. Peter-Ajuzie IK, Nwaogu IC, Ajaebili AC, 2020. Preliminary Anatomical Assessment of the Eye of the African Giant Rat (Cricetomys gambianus). Agricultural Science Digest. 2020; 40 (2): 218-220. doi:10.18805/ag.D-183

36. Braekevelt CR. Fine structure of choriocapillaries, bruch's membrane and retinal epithelium in the sheep. Anatomy and Embryology. 1983; 166 (3) : 415-25. doi: 10.1007/BF00305927

37. Kotb AM. Comparative morphological studies on the vascular tunic of the eyeball in some domestic mammals. Thesis submitted for the degree M.V. Sc of anatomy. Department of Anatomy and Histology. Assiut University Egypt. 2006.

38. König HE and Liebich HG. Anatomia zwierzat domowych. Galaktyka: Kolorowy atlas i podręcznik. 2006.

39. Altunay H. Fine structure of the retinal epithelium, Bruch's membrane and choriocapillaries in the Ostrich. Anatomia Histologia Embryologia. 2004; 33 (1): 38-41. doi: 10.1111/j.1439-0264.2004.00507

40. Samuelson DA. A textbook of Veterinary Histology. Copyright © 2007 by Saunders, an imprint of Elsevier Inc. 2007

41. Soliman SM, Adam SM, Abd allah UKM,. Light and electron microscopic structure of goat's retina. Beni-Suef Veterinary Medical Journal 6th Science Conference. 2010; 20 – 1: 52-62. doi: 10.21608/JVMR.2020.77580

42. Derbalah AEM. Light & Electron microscopical studies on the eye of one – humped camel (Camelus dromedaries). M. V. Sc. Thesis. Alex. Univ., Fac. Vet. Med., Cytol. & Histology Department Acta Ophthalmologyca 2002; 84: 1376-1384

43. Ehrenhofer MCA, Deeg CA, Resse S, Liebich HG, Stangassinger M. at al. Normal structure and age related changes of the equine retina. Veterinary Ophthalmology. 2002; 5 (1): 39-47. doi: 10.1046/j.1463-5224.2002.00210.x

44. Gorgiulo AM, Coliolo P, Ceccarelli P, Pedini V. Ultrastructural study of sheep lacrimal glands. Veterinary Research. 1999; 30: 345-351.

45. Abbasi M, Karimi H, Gharzi A. Preliminary Anatomical and Histological Study of Lacrimal Gland in Lori Sheep. Journal of Veterinary Science & Technology. 2014; 5: 1. doi:10.4172/2157-7579.100015