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Microscopic Study of *Bulbus oculi* in Aleppo (Damascus) goat

Estudio microscópico del *Bulbus oculi* en cabras de Alepo (Damasco)

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ABSTRACT

The eye is one of the most complex and essential sensory organs, responsible for perceiving environmental stimuli. This study aimed to histologically examine the eye structure of the Aleppo (Damascus) goat (*Capra hiscus*), a breed widely raised in the Eastern Mediterranean and Southeastern Anatolia regions for milk and meat production. Twenty eyeballs (*bulbus oculi*) were collected from 10 adult goats (5 males and 5 females) and processed using standard histological methods. The examination revealed the presence of the three main ocular tunics: the fibrous tunic (sclera and cornea), the vascular tunic (choroid, ciliary body, and iris), and the nervous tunic (retina). The sclera consisted of three layers episcera, substantia propria, and lamina fusca, with abundant collagen fibers and melanocytes. The cornea was characterized by a non-keratinized stratified squamous epithelium, Bowman's layer, collagenous stroma, Descemet's membrane, and an endothelium. Schlemm's canal and trabecular meshwork were identified at the sclerocorneal junction. The choroid contained five distinct layers, including a tapetum fibrosum composed of organized collagen bundles but lacking melanocytes. The ciliary body and iris exhibited a bilayered epithelium and well-developed smooth muscle structures. The retina consisted of ten layers, consistent with other mammalian species, and no significant histological differences were observed between male and female goats. This study provides a foundational histological reference for the Aleppo goat eye and may contribute to future clinical and experimental studies involving ocular health and comparative anatomy.

Keywords: Aleppo (Damascus) goat; eye; histology; histochemistry

RESUMEN

El ojo es uno de los órganos sensoriales más complejos y esenciales, responsable de percibir estímulos del entorno. Este estudio tuvo como objetivo examinar histológicamente la estructura ocular de la cabra (*Capra hiscus*) de Alepo (Damasco), una raza ampliamente criada en las regiones del Mediterráneo Oriental y el Sureste de Anatolia para la producción de leche y carne. Se recolectaron veinte bulbos oculares (*bulbus oculi*) de 10 cabras adultas (5 machos y 5 hembras) y se procesaron utilizando métodos histológicos estándar. El examen reveló la presencia de las tres túnicas principales del ojo, la túnica fibrosa (esclerótica y córnea), la túnica vascular (coroides, cuerpo ciliar e iris) y la túnica nerviosa (retina). La esclerótica estaba compuesta por tres capas, epiesclerótica, substantia propria y lámina fusca, con abundantes fibras de colágeno y melanocitos. La córnea se caracterizaba por un epitelio escamoso estratificado no queratinizado, la capa de Bowman, un estroma colagenoso, la membrana de Descemet y un endotelio. Notablemente, en la unión esclerocornea se identificaron el canal de Schlemm y la malla trabecular. La coroides contenía cinco capas distintas, incluyendo un tapetum fibrosum compuesto por haces de colágeno organizados pero sin melanocitos. El cuerpo ciliar y el iris mostraron un epitelio bicapa y estructuras musculares lisas bien desarrolladas. La retina estaba compuesta por diez capas, consistentes con las de otras especies de mamíferos, y no se observaron diferencias histológicas significativas entre cabras machos y hembras. Este estudio proporciona una referencia histológica fundamental sobre el ojo de la cabra de Alepo y puede contribuir a futuros estudios clínicos y experimentales relacionados con la salud ocular y la anatomía comparada.

Palabras clave: Cabra de Alepo (Damasco); ojo; histología; histoquímica

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INTRODUCTION

The eye is one of the most essential sensory organs, which is critical in enabling communication between living organisms and their environments [1]. Structurally, the visual system comprises the optic nerve, the eyeball (*bulbus oculi*), and the accessory ocular structures (*organa oculi accessoria*), making it one of the most complex sensory systems in the body. These components are highly sensitive to light, environmental stimuli, and various diseases [2 , 3].

A histological understanding of the neuroectoderm derived structures and ectodermal layers of the eye is essential for elucidating disease pathophysiology and for the development of targeted therapeutic approaches. Anatomically, the eye is composed of multiple overlapping tissue layers. The external structures include the eyelids, ocular muscles, accessory glands, conjunctiva, and eyelashes. Internally, the eye consists of three concentrically arranged layers: the outer fibrous layer (sclera and cornea), the middle vascular layer or uvea (comprising the iris, ciliary body, and choroid), and the innermost neural layer the retina. Each of these layers has distinct histological characteristics and can be further subdivided [4 , 5].

The Aleppo goat (*Capra hiscus)* originally bred in Damascus, Syria, is among the most prolific goat breeds and is valued in several Middle Eastern countries for both milk and meat production [6 , 7]. Aleppo goats typically have long hair and range in color from reddish and dark chestnut to brown, often with white markings. Characterized by a ram-like head and long, pointed ears, adult males weigh between 70–90 kg, while females typically weigh between 55–60 kg [8]. In Turkey, they are predominantly raised in the Eastern Mediterranean and Southeastern Anatolia regions [9 , 10].

Previous literature has primarily focused on the gross anatomy, histology, and pathology of ocular tissues across various animal models [3 , 11 , 12 , 13 , 14 , 15 , 16 , 17].

The present study aims to contribute to scientific fields utilizing animal-human experimental models by providing histological data on the Aleppo goat eye, which may serve as a foundation for future clinical and experimental research.

MATERİALS AND METHODS

Ethical approval

This study was approved by the Kafkas University Local Ethics Committee for Animal Experiments (KAU-HADYEK) under Decision No: 2024/168.

Animals

A total of 20 eyeballs (*bulbus oculi*) obtained from adult Aleppo goats (n = 10 males and n = 10 females) were utilized in this study. 10 eye tissues from male and female goats were used, so that each animal had 2 eyeballs.

Histological technique

Following dissection, the eye tissues were fixed in 10% neutral buffered formalin for histological evaluation. The samples were processed using a standard histological protocol: dehydration through a graded ethanol series (70%, 80%, 90%, and absolute alcohol, three changes each), clearing in xylene (three changes), and embedding in paraffin. Serial sections of 6 µm thickness were cut using a microtome (Leica RM2125 RTS, Germany). The tissue sections were stained with Crossman's modified triple staining method. Microscopic examination was performed using a BX51 light microscope (Olympus, Japan) and was photographed (DP72 Olympos, Japan).

RESULTS AND DISCUSSIONS

The tissues study of the eyes of Aleppo goats revealed the presence of three distinct tunics. These were: the outer fibrous layer (comprising the sclera and cornea, or *tunica fibrosa bulbi*), the vascular layer (consisting of the choroid, ciliary body, and iris, or *tunica vasculosa bulbi*), and the inner neural layer (*tunica interna bulbi*), which includes the retina.

Within the sclerocorneal coat, forming the outer or fibrous layer, both scleral and corneal structures were observed. In both male and female goats, the sclera was composed of three layers: the episclera, the substantia propria, and the lamina fusca. The scleral stroma consisted predominantly of thick collagen fibers, among which vascular structures and nerve fibers were noted. In the lamina fusca, adjacent to the choroid, thinner collagen bundles were present, along with melanocytes (FIGS. 1 A, B). The tenon space, also known as the episcleral space, was visible between the scleral substantia propria and the episclera.

The cornea, the transparent frontal window of the eye, exhibited a stratified, non-keratinized squamous epithelium anteriorly, a stroma composed of parallel collagen lamellae centrally, and a posterior single-layered non-keratinized squamous epithelium. At the sclerocorneal junction, the Schlemm's canal and Fontana spaces (trabecular meshwork) were identified. The *tunica fibrosa bulbi* (sclera and cornea) constitutes the outermost layer of the eye. In mammals, the sclera is primarily composed of dense connective tissue, though in some vertebrates (e.g., geese, ducks), it may also include cartilage or bone [18 , 19]. In Aleppo goats, the sclera was histologically composed of three layers episclera, stroma (*substantia propria*), and lamina fusca similar to other mammalian species [20 , 21]. These layers contained collagen fibers, and melanocytes and nerve endings were also observed in some areas. Previous studies have indicated the presence of smooth muscle bundles within the scleral layers of cattle (*Bos taurus)*, buffalo (*Bubalus bubalis*), donkeys (*Equus asinus*), and goats (*Capra hircus*) [22], which is consistent with our findings, as smooth muscle bundles were detected in the episcleral layer of Aleppo goats.

The choroid, which contains a dense concentration of pigment cells, was found to be composed of five distinct layers: the lamina supracoroidea, lamina vasculosa, tapetum fibrosum, lamina choriocapillaris, and lamina basalis (Bruch's membrane). The tapetum fibrosum contained numerous fibroblasts and large collagen bundles (FIGS. 1 C, D).

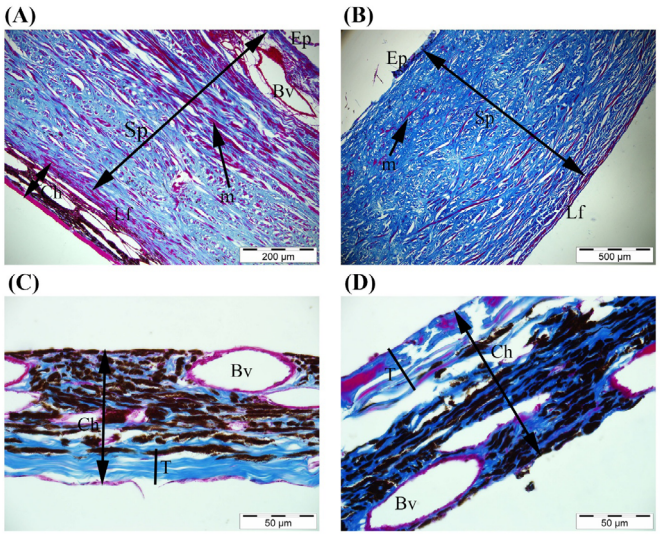

FIGURE 1. Histological features of sclera and choroid in male and female Aleppo goats. A: Female Aleppo goat's sclera, B: Male Aleppo goat's sclera, C: Female Aleppo goat's choroid, D: Male Aleppo goat's choroid, Bv: Blood vessel, Ch: Choroid, Ep: Episclera, Lf: Lamina fusca, m: muscle bundle, Sp: Substantia propria, T: Tapetum fibrosum, Triple staining.

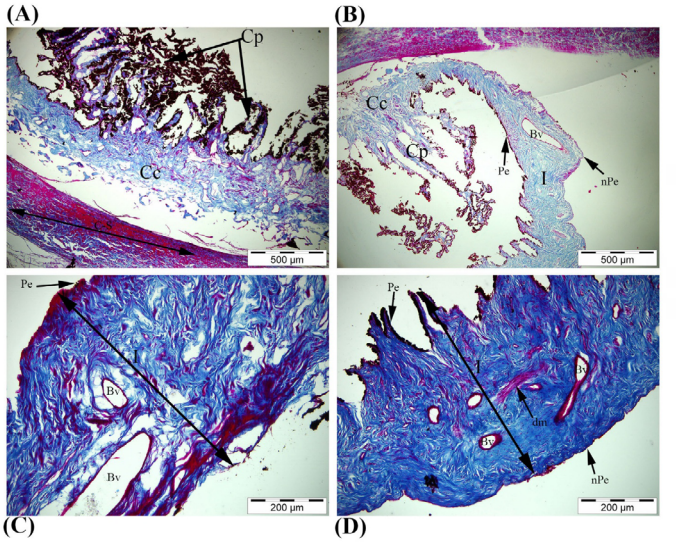

FIGURE 2. Histological features of corpus ciliare and iris in male and female Aleppo goats. A: Female Aleppo goat's corpus ciliare, B: Male Aleppo goat's corpus ciliare, C: Female Aleppo goat's iris, D: Male Aleppo goat's iris, Bv: Blood vessel, C-S: Cornea-scleral area, I: Iris, Cc: Corpus ciliare, Cp: Ciliary processus, dm: dilator muscle, nPe: Non-pigmented epithelium, Pe: Pigmented-epithelium. Triple staining.

In the *tunica vasculosa bulbi*, between the iris and the choroid, the corpus ciliare and *processus ciliaris* were lined by a bilayered cuboidal epithelium. Numerous melanocytes, nerve plexuses, blood vessels, as well as well-developed dilator and sphincter muscle fibers, were observed within the iris, which represents the anterior continuation of the *corpus ciliare* (FIG. 2). The cornea is a transparent, avascular structure with a dense neural network that protects the eye against external trauma and foreign bodies. It has been described in numerous mammalian species, including donkeys (*Equus asinus*), horses (*Equus caballus*), ruminants (domestic and wild) (Ruminantia), rodents (Rodentia), marine mammals (Cetacea and *Pinnipedia*), herbivores (*Herbivora*), pigs (*Sus scrofa domesticus*), bears (Ursidae), and primates (Primates). In mammals, the cornea is composed of multiple layers: stratified non-keratinized *squamous epithelium* at the surface, followed by the Bowman's membrane, stromal layer, Descemet's membrane, and the innermost endothelium [23 , 24 , 25 , 20 , 21 , 12]. Although earlier studies suggested that the Bowman's membrane is found only in primates (*Primates*) [26], later research has demonstrated its presence in various other mammals, such as pigs (*Sus scrofa domesticus*), cattle (*Bos taurus*), deer (Cervidae), bears (Ursidae), sheep (*Ovis aries*), and dogs (*Canis lupus familiaris*) [27 , 28 , 29 , 30 , 31].

In this study, the cornea of Aleppo goats exhibited a structure consistent with other mammals: a regular epithelial layer, a thin Bowman's membrane, a dense collagenous stroma, Descemet's membrane, and an endothelium. Additionally, the presence of Schlemm's canal and the trabecular meshwork (Fontana's spaces) at the corneoscleral junction was confirmed.

The retina, or *tunica interna bulbi*, consisted of ten layers arranged from the outer to the inner surface: the pigment epithelium (adjacent to the choroid), rods and cones layer, outer limiting membrane, outer nuclear layer, outer plexiform layer, inner nuclear layer, inner plexiform layer, ganglion cell layer, nerve fiber layer, and the inner limiting membrane (FIG. 3). In most domestic mammals, the choroid is divided into five layers: lamina supracoroidea, vascular layer, tapetal layer, choriocapillary layer, and Bruch's membrane [32 , 33 , 34]. The tapetum is present in both vertebrates and invertebrates and is located within the choroid or deep layers of the retina in vertebrates. Structurally, the tapetum is categorized into two types: *tapetum cellulosum* (cellular) and *tapetum fibrosum* (acellular). *Tapetum fibrosum*, which was observed in this study, consists of tightly packed collagen fibers and lacks cellular components [35]. It has been reported that the *tapetum lucidum* is absent in primates (*Primates*), pigs (*Sus scrofa domesticus*), birds (Aves), and squirrels (Sciuridae), but is present in reptiles (*Reptilia*), fish (*Pisces*), dogs (*Canis lupus familiaris*), bats (Chiroptera), cattle (*Bos taurus*), cats (*Felis catus*), sheep (*Ovis aries*), crocodiles (Crocodylidae), goats (*Capra hircus*), lemurs (Lemuroidea), and ferrets (*Mustela putorius furo)* [3 , 12 , 15 , 36 , 37 , 38]. In the examined samples, the choroid of Aleppo goats was observed to be rich in melanocytes and blood vessels, whereas the tapetum fibrosum was composed of regularly arranged collagen bundles and contained no melanocytes.

The bilayered epithelial structure of the *corpus ciliare* and *processus ciliaris* in Aleppo goats pigmented internally and non-pigmented externally was similar to that observed in camels (*Camelus dromedarius*) [37], bears (Ursidae) [12 , 21], sheep (*Ovis aries*) [15], and goats (*Capra hircus)* [16]. Similarly, in the iris stroma, a rich vascular network, dilator and sphincter muscles, dense connective tissue, and nerve fibers were identified. The dilator and sphincter muscles were well-developed in Aleppo goats.

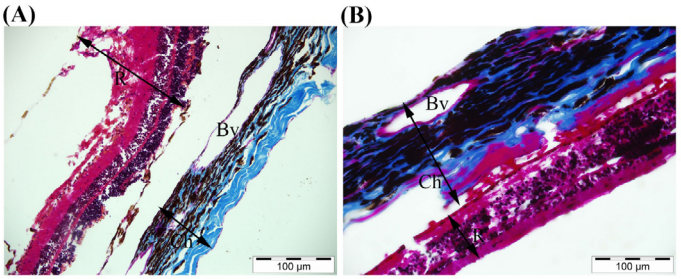

FIGURE 3. Histological features of corpus retina in male and female Aleppo goats. A: Female Aleppo goat's retina, B: Female Aleppo goat's retina, Bv: Blood vessel, Ch: Choroid, R: Retina, Triple staining.

Histologically, the retina of Aleppo goats was composed of ten distinct layers, similar to other mammalian species [3 , 12 , 15 , 16 , 38 , 39]. No histological differences were observed between male and female specimens.

CONCLUSION

This histological investigation of the Aleppo goat eye is significant not only because it represents the first such study on this specific breed but also due to its contribution to identifying species-specific characteristics. These findings provide valuable foundational knowledge for future clinical and comparative research, particularly in the fields of veterinary ophthalmology, histology, and experimental animal models.

Conflict of interest

The authors declare that they have no conflict of interest.

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