Int. J. Morphol.,
43(4):1146-1155, 2025.

Topographical Map and Histochemical Evaluation of Camel Cornea

Mapa Topográfico y Evaluación Histoquímica de la Córnea del Camello

Ahmed Magdy[1]; Reda Rashed[2]; Khaled Shoghy[2]; Samy F. Mahmoud[3]; Dalia I Saleh[3]; Liana Fericean[4]; Banatean-Dunea Ioan[4]; Mihaela Ostan[4] & Mohamed Abdo[1,2]

MAGDY, A.; RASHED, R.; SHOGHY, K.; MAHMOUD, S.F.; SALEH, D.I.; FERICEAN, L.; IOAN, B-D.; OSTAN, M. & ABDO, M. Topographical map and histochemical evaluation of camel cornea. *Int. J. Morphol., 43(4)*:1146-1155, 2025.

SUMMARY: The dromedary camel is one of the most significant domestic animals in arid and semi-arid countries because of its ability to provide high-quality food in very difficult conditions. The dromedary camel's cornea most certainly plays a major survival role in dry and semiarid environments. The anatomical and histological evaluation of the cornea relieved the unique structures of camel cornea, and it is related to surviving in harsh environment. In this work we aim to provide a fundamental histochemical and topographical evaluation of camel cornea by using H&E, P.A.S, and Masson trichrome stains. The corneas of twelve adults, healthy camels were removed as soon as they were slaughtered. Nine components make up each cornea: peripheral dorsal (PD), peripheral ventral (PV), peripheral nasal (PN), peripheral temporal (MT), central (C), middle dorsal (MD), middle ventral (MV), middle nasal (MN), and peripheral temporal (PT). The results investigated that the corneal epithelium and stroma appeared thick. The corneal stroma had parallel collagens fibers enclosed keratocytes. Also, the presence of the glomerular layer (Bowman's layer, BL) and a strong P.A.S positive reaction in all corneal regions. We concluded that the structure of the camel cornea is very different from human and other domestic animals. The unique structure of the cornea might be an adaptation to help the camel survive in a hot and dry climate.

KEY WORDS: Histochemical; Topographical map; Dromedary Camel; Cornea.

INTRODUCTION

There are currently 25 to 27 million camels worldwide, including one and two humped (dromedary and bactrian) camels. This number has lately grown. Nearly 90 % of the species Camelus is made up of dromedary camels, which are more common than bactrian camels (Kadim *et al*., 2008). The dromedary camel, which is mostly found in the Middle East and Africa, is one of the most significant domestic animals in arid and semi-arid countries because of its ability to provide high-quality food in very difficult conditions (Babiker & Yousif, 1990). The dromedary camel's eye is crucial to its survival in these dry regions. Dromedary camels have unique features in their eyes that allow them to survive in these desert regions (Rahi *et al*., 1980). It has been demonstrated that the corneal epithelium of fish, birds, and domestic animals contains stratified squamous cells (Meek & Boote, 2004; Mazher, 2012; Farouk *et al*., 2022). in which the outermost cell layer had several microplicae and flattened cells with bulging nuclei (Derbalah, 2001; Hayashi *et al*., 2002). This is a study survey on the cornea of dromedary camel including the following: provide a fundamental morphometrical and topographical study of the camel cornea's structure by using H&E stain; investigate and differentiate the connective tissue components of the camel corneal stroma using Masson trichrome; visualize and ensure the presence of glomerular layer (Bowman's layer) (BL) in camel cornea by P.A.S stain; diameter of camel corneal epithelium, stroma and Descemet mem. and its adaptation in the surrounding harsh environment of the desert. The middle temporal region and middle nasal region revealed the highest thickness of epithelium, middle ventral region showed the highest thickness of stroma and middle temporal region showed highest thickness of Descemet mem. Presence of the glomerular layer (BL) by P.A.S stain in all corneal regions. Blue collagen fibers and their organization done.

[1]Department of Animal Histology and Anatomy, School of Veterinary Medicine, Badr University in Cairo (BUC).
[2]Department of Anatomy and Embryology, Faculty of Veterinary Medicine, University of Sadat City 32897, Sadat City, Egypt.
[3]Department of Biotechnology, College of Science, Taif University, Taif, Saudi Arabia.
[4]Department of Biology and Plant Protection, Faculty of Agriculture, University of Life Sciences "King Michael I" from Timisoara, Timisoara, Romania.
FUNDING. Taif University, Saudi Arabia, supporting this work through project number (TU-DSPP-2024-53).

Received: 2025-02-02 Accepted: 2025-05-13

MATERIAL AND METHOD

Experimental animals. The corneas of twelve healthy one humped camel (*Camelus dromedarius*) were obtained from the El-Basateen slaughterhouse, Cairo, Egypt. Following the hygienic killing of seemingly healthy animals. The institutional ethics committee of Sadat University has evaluated and approved all experimental and husbandry protocols in accordance with ethical standards.

Tissue preparation. Using a fresh razor blade resting on a clear plastic dish, each cornea was cut into nine tiny specimens, each of which represented a specific area of the cornea. Central (C), middle dorsal (MD), middle ventral (MV), middle nasal (MN), middle temporal (MT), peripheral dorsal (PD), peripheral ventral (PV), peripheral nasal (PN), and peripheral temporal (PT) are the names given to the acquired samples. A portion of the gathered specimens were immediately submerged in 10 % neutral buffered formalin to be examined histologically and immunohistochemically (Fig. 1).

Histological staining.

H & E stain. To get ready for paraffin sectioning, the fixed samples were first dehydrated in ethyl alcohol, then cleaned with xylene, and then embedded in paraffin wax. Hematoxylin and eosin stain were used to stain sections for a general histological analysis (Dibal *et al*., 2022).

PAS stain. Periodic acid produces aldehyde (RCHO+RCHO), which may be colored using Schiff's reagent, when it reacts with the 1,2-glycol linkage (-CHOH -CHOH-) of carbohydrates in tissue sections, using Paraffin sections for carbohydrates histochemistry (Rahmoun *et al*., 2020).

Masson trichrome stain. Stain is employed to differentiate connective tissue elements, allowing for detailed examination of the collagen fibers that form the stromal matrix. This is crucial for understanding the structural integrity and biomechanical properties of the camel cornea (Elfky *et al*., 2023).

Photomicroscopy and qualitative measurements. The stained sections as well as IHC sections were viewed. Images were obtained using an Olympus research optical microscope equipped with an Olympus digital camera. The magnification scale bar has been reported on the given photomicrographs.

Statistical analysis. The numerical data were recorded, tabulated, and analyzed using SPSS version 28 Statistical Analysis System package (SPSS, 2021) (Purwanto *et al*., 2021). Carried out according to Argyrous (2011) to evaluate mean diameter of the different corneal parts; epithelium, stroma and descemet's Membrane in different corneal area.

RESULTS

Histological staining. The cornea appeared as a thin, translucent, totally non-vascularized membrane (Fig. 1) with various layers; Epithelium, glomerular membrane, Stroma, Descemet's membrane, and Endothelium were visible (Fig. 2: C1, MD1, MV1; Fig. 3: MN1, MT1, PD1; Fig. 4: PV1, PN1, PT1). The epithelium layer was multilayered. The non-keratinized stratified squamous epithelium made up anterior corneal epithelium that was mostly composed of ten–twelve layers of epithelial cells (Fig. 2: C1, MD1, MV1; Fig. 3: MN1, MT1, PD1; Fig. 4: PV1, PN1, PT1). Six to eight layers of polyhedral cells with deeply stained acidophilic cytoplasm and central, spherical, darkly stained nuclei made up the intermediate layers (Fig. 2: C1, MD1, MV1; Fig. 3: MN1, MT1, PD1; Fig. 4: PV1, PN1, PT1). Two to three layers of flattened cells with deeply stained acidophilic cytoplasm and elongated, darkly stained nuclei characterized the basal cells (Fig. 2: C1, MD1, MV1; Fig. 3: MN1, MT1, PD1; Fig. 4: PV1, PN1, PT1). The measurements of the epithelium among the different corneal parts were tabulated in Table I and

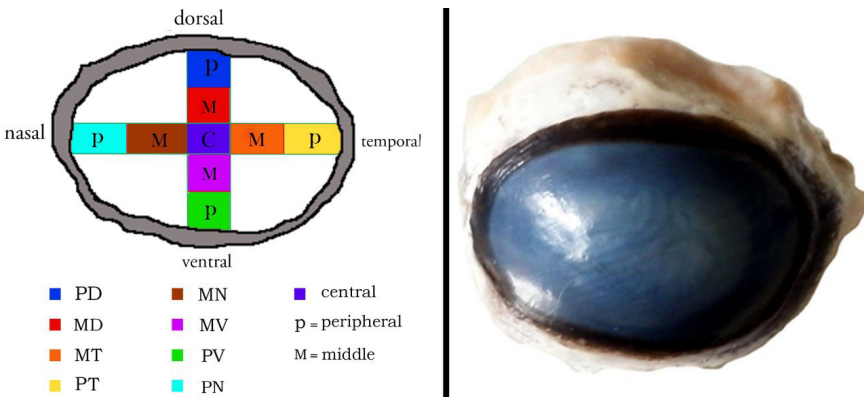

Fig. 1. Dissections of camel cornea into several anatomical parts: C, MD, MV, MN, MT, PD, PV, PN, and PT. for histochemical and topographical evaluation. C, central; MD, middle dorsal; MN, middle nasal; MT, middle temporal; MV, middle ventral; PD, peripheral dorsal; PN, peripheral nasal; PT, peripheral temporal; PV, peripheral ventral.

described in Figure 5. Our study revealed that corneal epithelium was the thickest in the middle corneal parts respectively, (MT, MN, MV, and MD) (Fig. 2: MD1, MV1; Fig. 3: MT1 and MN1). Basement membrane appeared clearly in Figure 3 (MT1, MT2, MN2). Also, our results showed that the presence of the BL in all cornea parts (C, MD, MV, MN, MT, PD, PV, PN, PT) (Fig.2: C3, MD3, MV3; Fig. 3: MN3, MT3, PD3; Fig.4: PV3, PN3, PT3). The glomerular layer of the cornea had a pink to magenta hue, due to the presence of glycoproteins and other compounds rich in carbohydrates after the highly positive reaction of the P.A.S staining, The glomerular layer of the cornea was an acellular corneal structure, formed because of ongoing epithelial-stromal interactions, had a pink color. Hence, these results proved that the camel cornea in all different corneal parts consist of five layers; epithelium, glomerular layer, stroma, Descemet membrane, and endothelium (Fig. 2: C3, MD3, MV3; Fig.3: MN3, MT3, PD3; Fig.4: PV3, PN3, PT3).

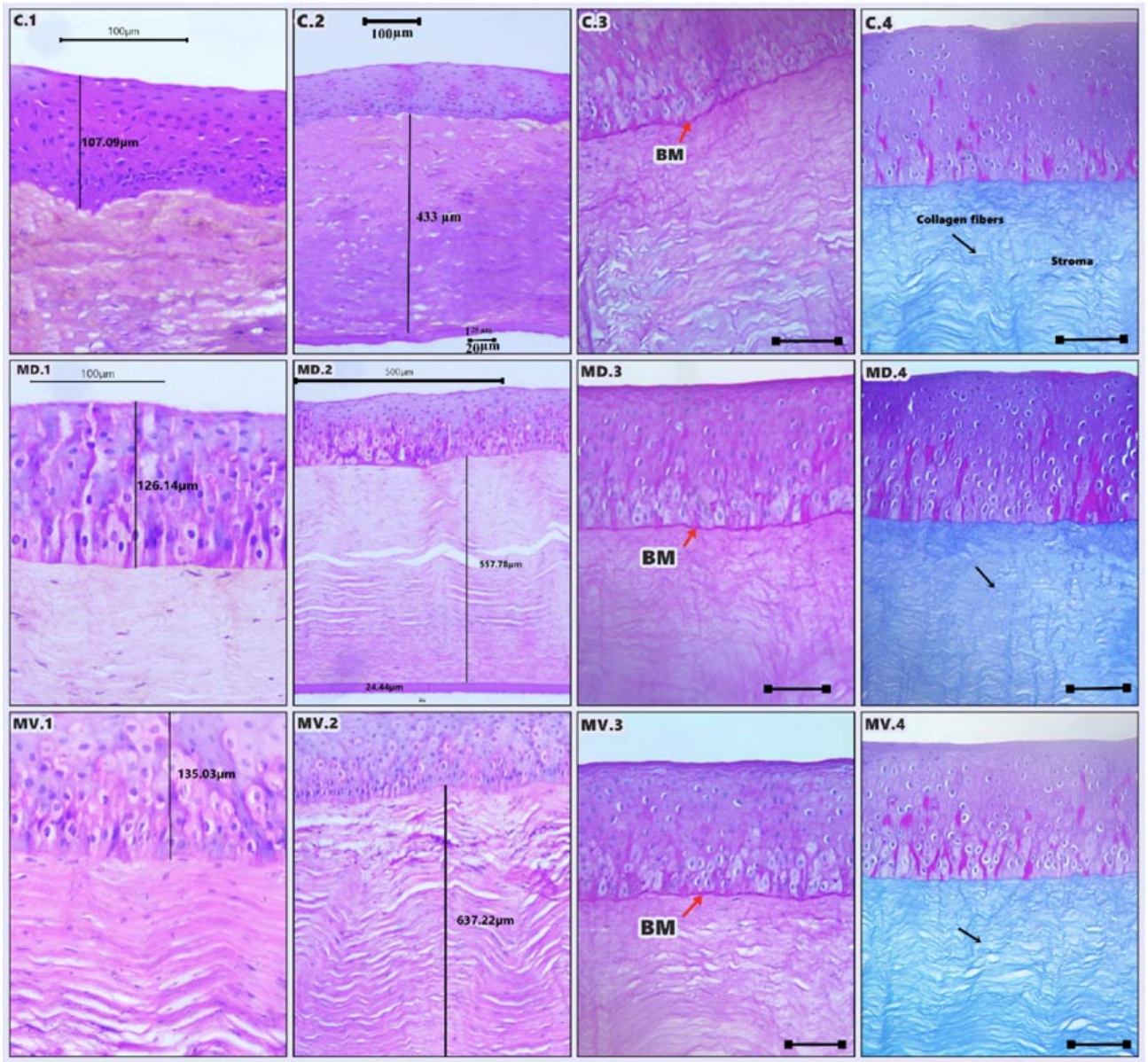

Fig. 2. Photomicrograph of camels' cornea; (C1, MD1, MV1) stained with H&E stain showing the diameter of corneal epithelium in central corneal region, middle dorsal region, and middle ventral region. Scale bar 100 µm. (C2, MD2, MV2) stained with H&E stain showing the diameter of corneal stroma and Descemet's membrane in central corneal region, middle dorsal region, and middle ventral region. (C3, MD3, MV3) stained with P.A.S stain showing the presence of the Bowman's Layer (BL) which gives a strong positive P.A.S reaction in central corneal region, middle dorsal region, and middle ventral region (red arrows). Scale bar; 20 µm. (C4, MD4, MV4) stained with Masson Trichrome stain illustrated that the stroma's collagen fibers were deeply blue in color, dense, wavy and irregular bundles in central corneal region, middle dorsal region, and middle ventral region (black arrows). Scale bar; 50 µm.

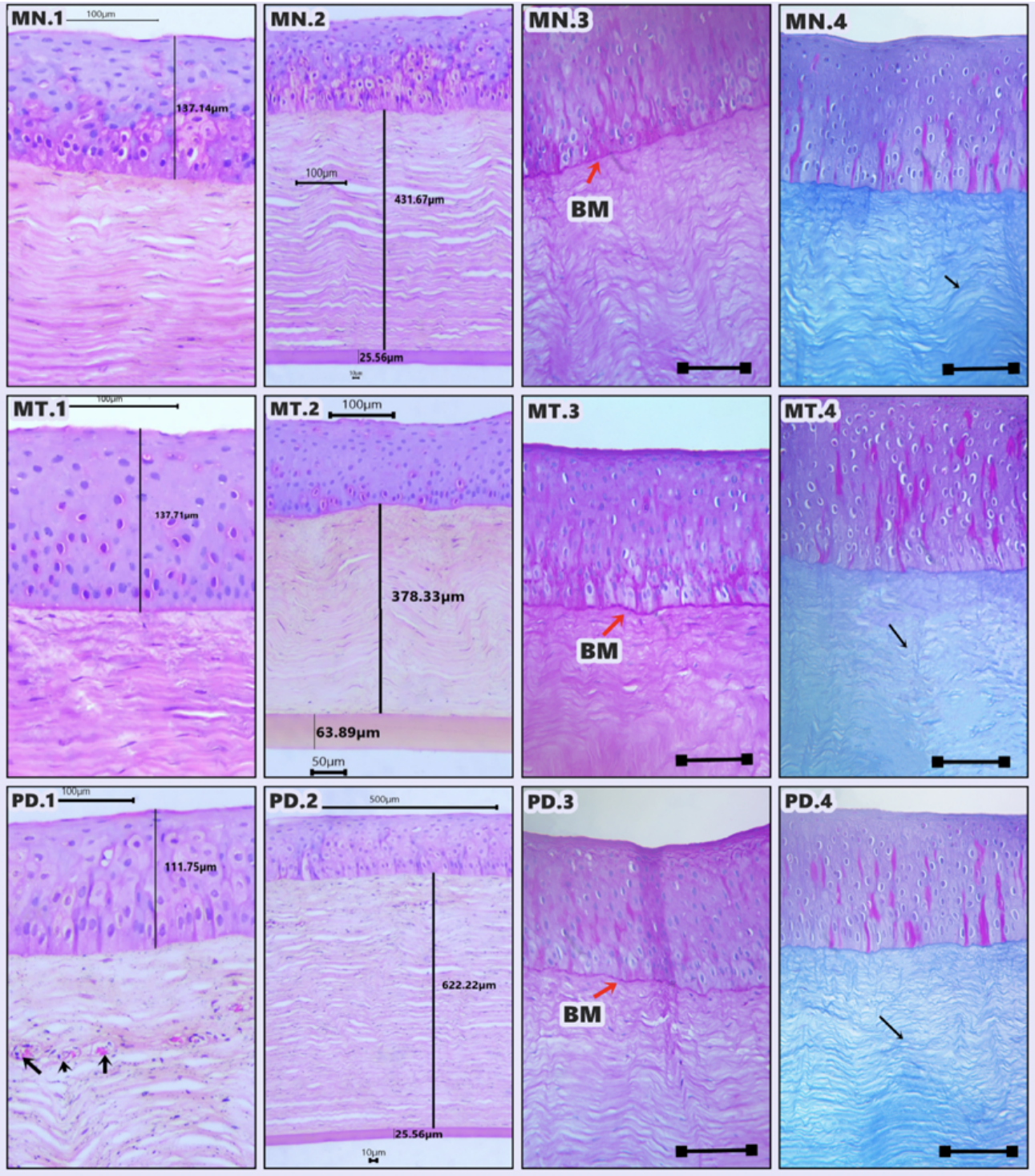

Fig. 3. Photomicrograph of camels' cornea; (MN1, MT1, PD1) stained with H&E stain showing the diameter of corneal epithelium in middle nasal region, middle temporal region, and peripheral dorsal region. Also, (PD1; peripheral dorsal region) expressed the presence of blood vessels (black arrows). Scale bar 100 µm. (MN2, MT2, PD2) stained with H&E stain showing the diameter of corneal stroma and Descemet's membrane in middle nasal region, middle temporal region, and peripheral dorsal region. (MN3, MT3, PD3) stained with P.A.S stain showing the presence of the Bowman's Layer (BL) which gives a strong positive P.A.S reaction in middle nasal region, middle temporal region, and peripheral dorsal region (red arrows). Scale bar; 20 µm. (MN4, MT4, PD4) stained with Masson Trichrome stain illustrated that the stroma's collagen fibers were deeply blue in color, dense, wavy and irregular bundles in middle nasal region, middle temporal region, and peripheral dorsal region (black arrows). Scale bar; 50 µm.

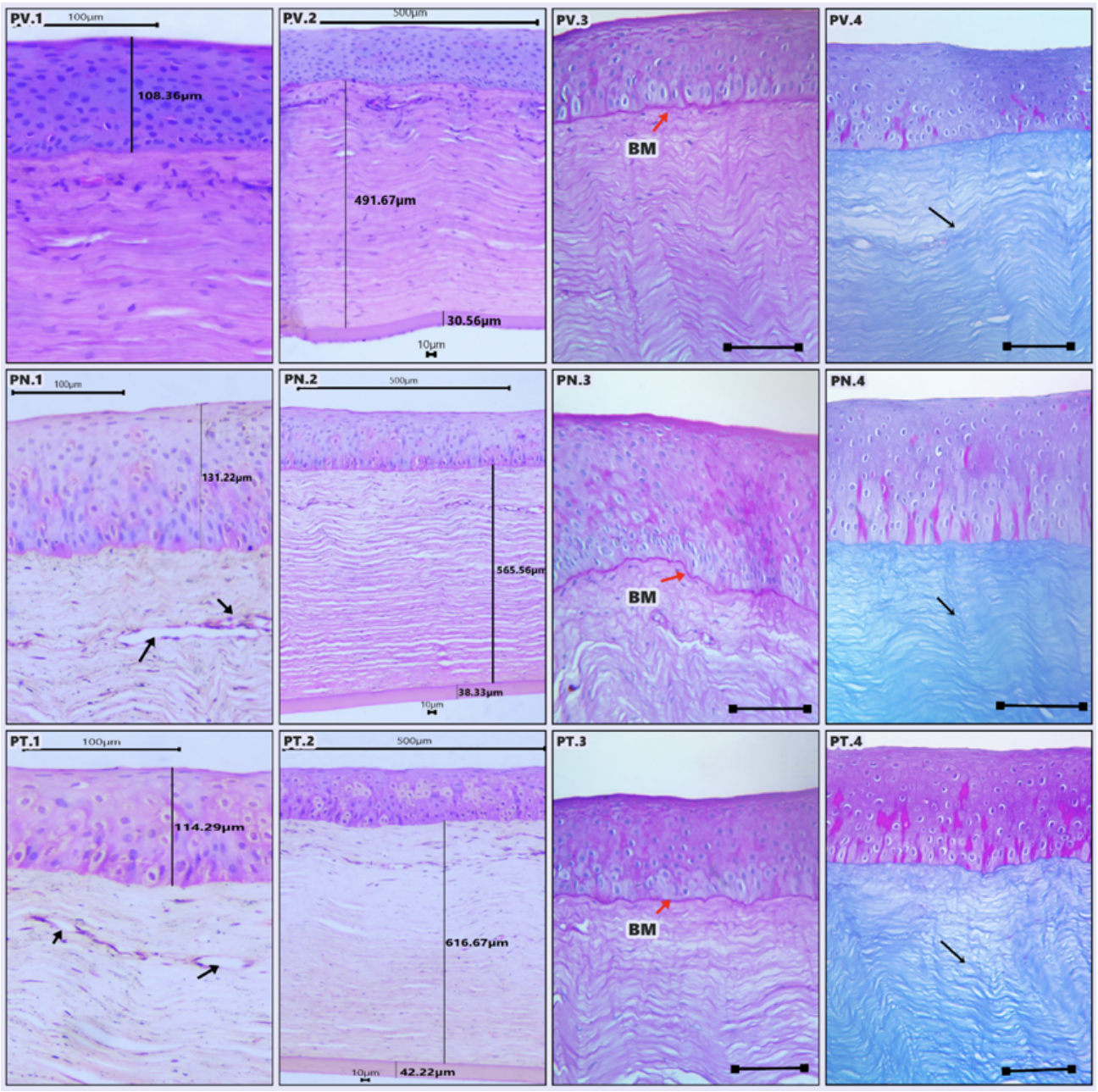

Fig. 4. Photomicrograph of camels' cornea; (PV1, PN1, PT1) stained with H&E stain showing the diameter of corneal epithelium in peripheral ventral region, peripheral nasal region, and peripheral temporal region. Also, (PN1; peripheral nasal region and PT1; peripheral temporal region) expressed the presence of blood vessels (black arrows). Scale bar 100 µm. (PV2, PN2, PT2) stained with H&E stain showing the diameter of corneal stroma and Descemet's membrane in peripheral ventral region, peripheral nasal region, and peripheral temporal region. (PV3, PN3, PT3) stained with P.A.S stain showing the presence of the Bowman's Layer (BL) which gives a strong positive P.A.S reaction in peripheral ventral region, peripheral nasal region, and peripheral temporal region (red arrows). Scale bar; 20 µm. (PV4, PN4, PT1) stained with Masson Trichrome stain illustrated that the stroma's collagen fibers were deeply blue in color, dense, wavy and irregular bundles in peripheral ventral region, peripheral nasal region, and peripheral temporal region (black arrows). Scale bar; 50 µm.

The corneal stroma was dense and thick, rich in collagen and fibroblasts, roughly 90 % of the corneal wall's thickness. Keratocytes were found in the collagen fibril lamellae that make up the stroma (Fig. 2: C2, MD2, MV2; Fig.3: MN2, MT2, PD2; Fig.4: PV2, PN2, PT2). Furthermore, the amounts of blood vessels were very clear in peripheral corneal parts (Fig. 3: PD2; Fig. 4: PV2, PN2, PT2). A special arrangement of uniformly sized, closely

spaced, parallel collagen fibrils made up the extracellular matrix. The cornea's stroma showed a pink to magenta coloring. (Fig. 2: C2, MD2, MV2; Fig. 3: MN2, MT2, PD2; Fig. 4: PV2, PN2, PT2). The measurements of the stroma among the different corneal parts were also tabulated and mentioned in Table I and Figure 5. Also, the thick and dense corneal stroma, together with collagen fibril lamellae and keratocytes, were visible in the camel's cornea when stained with Masson's trichrome. The collagen fibers had an uneven pattern, a uniform size, a blue stain, and an overlapping appearance (Fig. 2: C4, MD4, MV4; Fig. 3: MN4, MT4, PD4; Fig. 4: PV4, PN4, PT4). The stroma's collagen fibers were deeply blue in color, collagen fibers were visible as dense, wavy bundles that supported and preserved the stroma's structural integrity that appeared in all corneal parts (Fig. 2: C4, MD4, MV4; Fig. 3: MN4, MT4, PD4; Fig. 4: PV4, PN4, PT4).

The Descemet's membrane (Fig. 2: C2, MD2, MV2; Fig. 3: MN2, MT2, PD2; Fig. 4: PV2, PN2, PT2) was pink, thick, and amorphous membrane, composed of a nearly

It was simple squamous posterior epithelium (Fig. 2: C2, MD2, MV2; Fig. 3: MN2, MT2, PD2; Fig. 4: PV2, PN2, PT2). However, the boundaries between cells in this layer of epithelium are unclear.

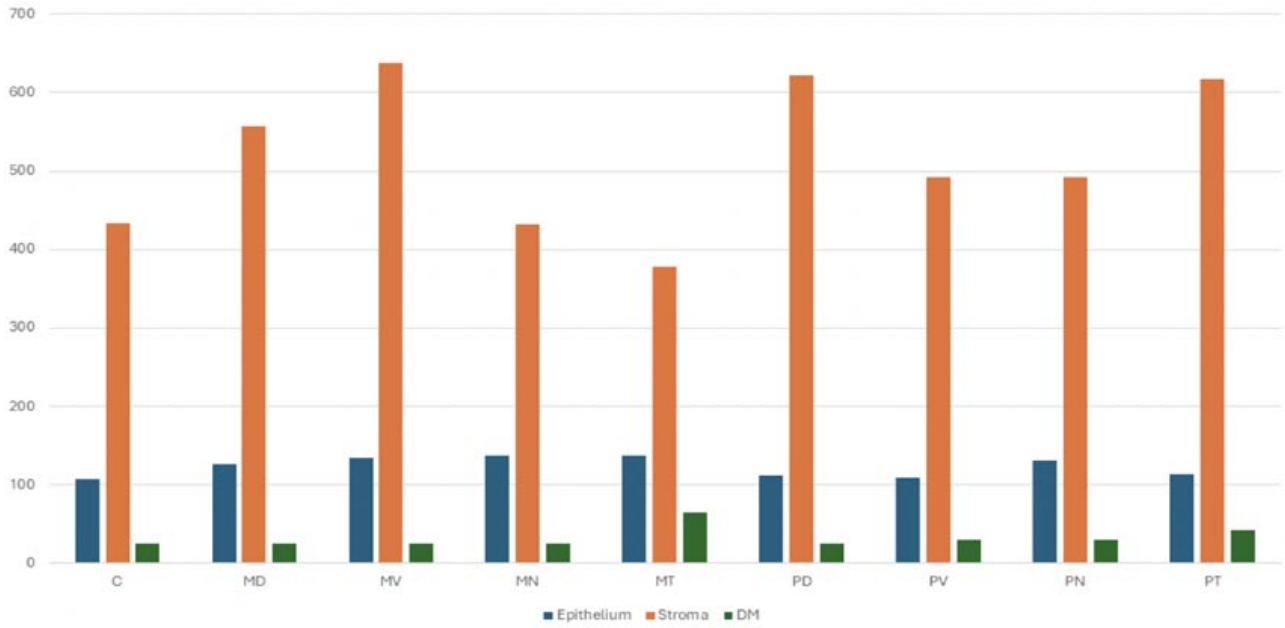

Fig. 5. Measurements of the Camels' Cornea Layers thickness; epithelium, stroma, and Descemet's membrane respectively, in all parts (C), central corneal region; (MD), middle dorsal region; (MN), middle nasal region; (MT), middle temporal region showed the highest thickness of Descemet's membrane; (MV), middle ventral region showed the highest thickness of the stroma; (PD), peripheral dorsal region; (PN), peripheral nasal region; (PT), peripheral temporal region; (PV), peripheral ventral region.

Table I. The diameters and Mean (mm) of Epithelium, Stroma, and Descemet membrane (DM) are among different parts of corneal.

Cornea parts	Epithelium	Stroma	DM
C	107.09 ± 106	433.21 ± 433	25.00 ± 25
MD	126.14 ± 126	557.78 ± 558	24.44 ± 25
MV	135.03 ± 135	637.22 ± 637	25.00 ± 25
MN	137.14 ± 136	431.67 ± 433	25.56 ± 25
MT	137.71 ± 136	378.33 ± 376	63.89 ± 64
PD	111.75 ± 112	622.22 ± 623	25.56 ± 25
PV	108.36 ± 109	491.67 ± 492	30.56 ± 30
PN	131.22 ± 130	491.67 ± 493	30.56 ± 30
PT	114.29 ± 115	616.67 ± 617	42.22 ± 43

DISCUSSION

In the study of Leuenberger (1978) the corneal epithelium acts as a crucial barrier between the tear film and the stroma, ensuring a smooth corneal surface. This barrier was essential for maintaining the optical properties of the cornea, such as refraction and transparency. Harmful particles, such as bacteria and viruses, can enter the stroma of the cornea if the surface layers are damaged. This was important because a virus may multiply in altered epithelial cells of the epithelium, which is where viral corneal illnesses frequently start. Also, the study emphasized how epithelial cells migrated from the defect's margins to treat corneal lesions rapidly. However, until regenerated epithelial cells created a basement membrane, the adhesion between the stroma and the epithelium was weak. Recurrent erosions may result from the lack of this membrane. According to Kleckowska-Nawrot *et al*. (2022) in their study applied on wild ruminant animals showed a multilayered cornea made up of the posterior corneal epithelium, the proper substance of the cornea with an associated posterior limiting membrane (Descemet's membrane), and the stratified squamous non-keratinized epithelium in all of the animals under examination. However, in the present study it is intriguing to consider that there was an anterior limiting membrane, sometimes referred to as glomerular layer, behind the anterior corneal epithelium in dromedary camel. However, camel cornea was discovered to be primarily composed of four layers, including the corneal epithelium, corneal stroma, corneal endothelium, and Descemet's membrane. These findings are in line with camel observations reported in earlier research (Konsowa & Abd-Aalaziz, 1999; Derbalah, 2001; Almubrad & Akhtar, 2012; Saadatlou, 2017; Rahmoun *et al*., 2020). On the other hand, cornea was found to consist of five layers in other domesticated animal species, with the glomerular membrane sitting on top of them (Konsowa & Abd-Aalaziz, 1999; Hayashi *et al*., 2002; Joyce, 2003; Mazher, 2012). Additionally, our findings ensured that the glomerular membrane is clearly observed in dromedary camel. Also, Akhtar (2013) reported that most of the anterior stroma of camel cornea did not swell according to our results, we suggested this due to the presence of glomerular layer in the camel cornea, which plays an important part in the hydration of the cornea. Comparative studies suggested that the camel's corneal dimensions and histological features may differ from those of other species, which is important for veterinary ophthalmology (Kassab, 2012). In the present study, epithelium makes up 36 % of the camel corneal thickness. The epithelium diameter was very thick in middle parts of cornea than the peripheral parts. It is suggested that middle corneal parts need more protection than peripheral parts which are already melanin pigment protected. Additionally, thick epithelium may prevent the corneal stroma from drying up by enabling the hot weather to evaporate water from the surface of epithelial cells, but not basal cells, keeping the stroma moist. In addition, the basal epithelial cells were much larger than those of humans and cows. We believe that environmental factors have an impact on epithelial thickness as reported in Almubrad & Akhtar (2012). Additionally, Hifny *et al*. (2005) said that cows had the thickest corneas, followed by pigs and donkeys, while sheep had the thinnest corneas, followed by camels, goats, and buffalo. The corneas of goats and buffalo, on the other hand, have almost the same thickness. In contrast, in the present finding, the cornea of a camel was the thickest corneas among animals. As supported with the findings of Kassab (2012), where the stroma and epithelium of camel corneas are comparatively thick, which is essential for their adaptation to dry settings. The cornea's primary function is protection from exterior threats and plays a significant role in the eye's optical system, which is mostly determined by its transparency and capacity to concentrate and refract light rays. In order to develop more effective treatments for corneal disorders, the majority of research on the structure and function of the cornea is often carried out on laboratory animals, such as mice, rats, rabbits, and hens, which serve as animal models for human resources (Kleckowska-Nawrot *et al*., 2022). The corneal stroma, which made up 90 % of the cornea's thickness in most mammals, is a ligament-type structure made up of clear strips of dense connective tissue (Cholkar *et al*., 2013). The thickness of the stroma and epithelium distinguished the camel cornea from that of other vertebrates) Akhtar, 2013(. In the current study, the corneal stroma was formed from collagen fibers arranged in a lamellar fashion. The cornea gained transparency and tensile strength from this configuration. Also, the stroma made up a large amount of the cornea's thickness and was located between the epithelium and the endothelium. This agreed with the results reported by Tharwat & El-Tookhy (2021), Kleckowska-Nawrot *et al.* (2022) and Rahi *et al*. (1980). In this study, it was investigated that the stroma's collagen fibers were thickest in middle ventral corneal part and visible as a dense, wavy bundles, widely distributed, and abundant in the tissue, that supported and preserved the stroma's structural integrity. This agrees with Almubrad & Akhtar (2012) and Almubrad *et al*. (2010).

The Descemet's Membrane (DM) appeared between the corneal stroma and endothelium and served as base membrane for endothelium of the cornea; it played a crucial role in maintaining corneal transparency and integrity. This is also described by Almubrad & Akhtar (2012) and Kleckowska-Nawrot *et al*. (2022) in different wild ruminants. And, our results showed that Descemet's Membrane in all corneal parts appeared thick (25 -30 μm) in thickness and reached maximum thickness in middle temporal corneal

part, that agreed with the results demonstrated by Rahi *et al*. (1980) which noted that when compared to other species, the camel's eye's Descemet membrane was much thicker. The cornea's structural integrity may be improved by this adaptation, making it more resilient to external pressures like wind and dust. This distinguishes the cornea from those of other animals and ads to its strength in harsh environments.

The corneal endothelium was represented by two to three layers of flattened cells with elongated, darkly pigmented nuclei and strongly stained, acidophilic cytoplasm. These findings matched the cornea of several animal species (Kassab, 2012; Abdo *et al*., 2014; Rahmoun *et al*., 2020). Glomerular layer (BL) is situated in front of the stroma and behind the epithelium's epithelial basement membrane (EBM), It is generally acknowledged that collagen type I, which makes up 84 % of the cornea, is the primary collagen type and the primary cause of Bowman's layer, There was a variation in the composition of the collagen fibrils in BL because their diameter is less than that of the stroma (Sirolova *et al*., 2024). Hayashi *et al*. (2002) observed that higher animals often have thicker, more developed Bowman's layer than lesser mammals. In Bowman's layer, the collagen fibril diameter was nearly constant across all species under investigation. Sirolova *et al*. (2024) in his review about the function of Bowman's layer, hypothesized that Bowman's layer could be involved in maintaining the cornea's shape, Bowman's layer was given a specific barrier function by several authors. On the other hand, the situation with the presence or absence of an anterior limiting membrane, also known as glomerular layer, located under the anterior corneal epithelium is interesting. This work showed a clear presence of glomerular layer in the camel cornea after histological examination by P.A.S staining. Glomerular layer was first described in humans by William Bowman in 1947. This investigation showed that the cornea of a camel was mostly made up of five layers: the corneal epithelium, Bowman's layer, corneal stroma, Descemet's membrane and endothelium. But previous research (Konsowa & Abd-Aalaziz, 1999; Derbalah, 2001; Almubrad & Akhtar, 2012; Saadatlou, 2017; Rahmoun *et al*., 2020; Farouk *et al*., 2022) showed in their results that the cornea mainly consists of four layers and the Bowman's membrane did not exist. However, studies on other domesticated animal species have demonstrated that the cornea is made up of five layers, which are topped by the Bowman's membrane (Konsowa & Abd-Aalaziz, 1999; Hayashi *et al*., 2002; Joyce, 2003; Mazher, 2012). Our results showed the presence of Bowman's layer due to the positive reaction of the P.A.S stain in all corneal regions; C, central corneal region, MD, middle dorsal region, MV middle ventral region, MN, middle nasal region, MT, middle temporal region, PD, peripheral dorsal region, PV, peripheral ventral region, PN, peripheral nasal region, PT peripheral temporal region that have been examined in this work, while Nautscher *et al*. (2016) results showed all examined domestic animal corneas; cows, horse, pig, goats were composed of four layers: corneal epithelium, stroma, Descemet's membrane (DM), and corneal endothelium. Notably, Bowman's layer was not detected in any of the samples using the periodic acid–Schiff (PAS) reaction. Also, it is said that Bowman's layer (BL), which lay underneath the human corneal epithelium, confronts the foundation membrane on its anterior aspect, and in domestic animals, the presence of a Bowman's layer is particularly doubtful. Furthermore, because animal corneal tissue is commonly employed in human research and for therapeutic purposes, attention is increasingly paid to species-specific variations in the morphological and physiological characteristics of the cornea. The basement membrane given P.A.S positive reaction in all examined animals (cows, horse, pig, goats), but in cat possessed cells of columnar shape in the stratum basale. But in this investigation the camel cornea showed P.A.S positive reaction to the presence of Bowman's layer. Also, in Merindano *et al*. (2003) his results showed that the carnivorous appeared to lack BL, the primates except the lemur developed the Bowman's layer, while the group of herbivores Bowman's layer was well defined. Wilson (2020) suggested that A "palisade of filaments" that stretch from the basal lamina into the anterior stroma started to form Bowman's layer about the thirteenth week of pregnancy and the epithelium was the source of collagen type V in Bowman's layer. Also, Wilson & Hong (2000) hypothesized that Because of cytokine-mediated interactions between corneal epithelial cells and underlying keratocytes, as well as the detrimental chemotactic and apoptotic effects of low levels of cytokines like interleukin-1 that are gradually released as epithelial cells die, and slow during normal development, Bowman's layer forms in the corneas of those species that have one. Kleckowska-Nawrot *et al*. (2022) mentioned in his work that Bowman's membrane is not a characteristic feature of all mammals and is absent in dogs, cats and lemurs. Quoted by Merindano *et al*. (2003) whereas a 9.7 ± 1.7 µm thick, acellular structure that consists of three to four collagen layers cited by Nautscher *et al*. (2016) and Merindano *et al*. (2003), in a study on 40 different species of mammals (Carnivores, Primates & Herbivores), showed that glomerular layer does not occur in carnivores, *Lepilemur mustelinus* (Primates) similarly to Wislocki (1952) as well as in *Tapirus terrestris, Equus caballus, Equus caballus przewalskii, Cervus elaphus, Rangifer tarandus, Antilope cervicapra, Ovis musimon, Ovis aries, Sus Domestica, Sus scrofa* and *Loxodonta africana*. However, regarding only ruminants, according to Merindano *et al*. (2003), This layer occurred

in *Dama dama, Cervus unicolor, Giraffa camelopardalis, Bos primigenius, Bos indicus* and *Taurotragus oryx*. Comparing our research and that of Merindano *et al*. (2003), it can be seen that the presence or absence of glomerular layer is a species feature. However, according to the above mentioned researchers, domestic animals do not acquire this layer to the same extent as humans and other primates. We suggested the presence of a glomerular layer in camel cornea, due to the different living conditions of camels in desert areas and harsh climatic conditions that require greater protection for the cornea of the eye. In this study, it was investigated that the stroma's collagen fibers were deeply blue in color, which suggested that they were widely distributed and abundant in the tissue. Collagen fibers were visible as dense, wavy bundles that supported and preserved the stroma's structural integrity. That is agree with Almubrad *et al*. (2010), Almubrad & Akhtar (2012) and Zhang *et al*. (2024). It is made up of translucent lamellae of thick, regular connective tissue and resembles ligamentous tissue (Eurell & Frappier, 2013). Furthermore, the results revealed that the collagen fibrils inside a particular lamella have a consistent diameter, all parallel to each other, and run the entire breadth of the cornea, which agrees with the findings of Cobo *et al*. (2024). Tsukahara *et al*. (2010), in their research discovered that birds have far fewer keratocytes than mammals, even though keratocytes are crucial for maintaining proper corneal clarity. This can explain the camel cornea transparency and moisture in harsh environments. Also, Cobo *et al*. (2024) revealed in his research the importance of keratocytes in corneal stroma by releasing structural elements required for tissue integrity and functionality, keratocytes contribute significantly to the preservation of extracellular matrix.

CONCLUSION

The cornea of the dromedary camel is uniquely adapted to its harsh desert environment, showcasing significant structural and functional differences compared to other species. These adaptations, such as the presence of Bowman's layer, thick epithelium, and unique aquaporin-1 expression patterns, contribute to maintaining corneal hydration, transparency, and resilience. The findings emphasize the importance of these features in protecting environmental stressors like UV radiation, heat, and dehydration. This study highlights the camel cornea's potential as a model for exploring ocular adaptations and advancing treatments for corneal conditions under extreme conditions.

ACKNOWLEDGMENTS. The authors extend their appreciation to Taif University, Saudi Arabia, for supporting this work through project number (TU-DSPP-2024-53)

MAGDY, A.; RASHED, R.; SHOGHY, K.; MAHMOUD, S. F.; SALEH, D. I.; FERICEAN, L.; IOAN, B-D.; OSTAN, M. & ABDO, M. Mapa topográfico y evaluación histoquímica de la córnea del camello. *Int. J. Morphol., 43(4)*:1146-1155, 2025.

RESUMEN: El camello dromedario es uno de los animales domésticos más importantes en los países áridos y semiáridos debido a su capacidad para proporcionar alimento de alta calidad en condiciones muy difíciles. La córnea del dromedario sin duda desempeña un papel fundamental en la supervivencia en ambientes secos y semiáridos. La evaluación anatómica e histológica de la córnea permitió apreciar las estructuras únicas de la córnea del camello, lo cual está relacionado con la supervivencia en entornos hostiles. En este trabajo, nuestro objetivo fue proporcionar una evaluación histoquímica y topográfica fundamental de la córnea de camellos mediante tinciones de hematoxilina y eosina (H&E), PAS y tricrómico de Masson. Se extrajeron las córneas de doce camellos adultos sanos inmediatamente después del sacrificio. Cada córnea está compuesta por nueve componentes: dorsal periférica (PD), ventral periférica (PV), nasal periférica (PN), temporal periférica (MT), central (C), dorsal media (MD), ventral media (MV), nasal media (MN) y temporal periférica (PT). Los resultados revelaron que el epitelio y el estroma corneales presentaban un engrosamiento. El estroma corneal presentaba fibras de colágeno paralelas que rodeaban queratocitos. Además, se observó la presencia de la capa de Bowman (BL) y una fuerte reacción positiva de PAS en todas las regiones corneales. Concluimos que la estructura de la córnea de camellos es muy diferente a la de los humanos y otros animales domésticos. Esta estructura única de la córnea podría ser una adaptación que ayuda al camello a sobrevivir en climas cálidos y secos.

PALABRAS CLAVE: Histoquímica; Mapa topográfico; Camello dromedario; Córnea.

REFERENCES

Abdo, M.; Hosaka, Y.; Erasha, A.; Nada, M.; Ali, S. & Uehara, M. Prenatal development of the eye tunics in the dromedary camel (*Camelus dromedarius*). *Anat. Histol. Embryol., 43(4)*:257-64, 2014.

Akhtar, S. Ultrastructure alteration in the corneal stroma of hydrated camel corneoscleral button and corneal button. *Microsc. Res. Tech., 76(1)*:86-93, 2013.

Almubrad, T. & Akhtar, S. Ultrastructure features of camel cornea--collagen fibril and proteoglycans. *Vet. Ophthalmol., 15(1)*:36-41, 2012.

Almubrad, T.; Khan, M. F. J. & Akhtar, S. Swelling studies of camel and bovine corneal stroma. *Clin. Ophthalmol., 4*:1053-60, 2010.

Argyrous, G. *Statistics for Research: With a Guide to SPSS*. Thousand Oaks, SAGE, 2011.

Babiker, S. A. & Yousif, O. K. Chemical composition and quality of camel meat. *Meat Sci., 27(4)*:283-7, 1990.

Cholkar, K.; Dasari, S. R.; Pal, D. & Mitra, A. K. *Eye: Anatomy, Physiology and Barriers to Drug Delivery*. In: Mitra, A. K. (Ed.). Ocular Transporters and Receptors. Amsterdam, Elsevier, 2013. pp.105-58.

Cobo, R.; Navarro-Sempere, A.; Mielgo, P.; Segovia, Y. & García, M. The corneal structure of the yellow-legged gull, *Larus michahellis* (Naumann, 1840). *J. Morphol., 285(12)*:e70015, 2024.

Derbalah, A. *Light and Electron Microscopical Studies on the Eye Of One-Humped Camel* (*Camelus dromedarius*). MVSc Thesis. Alexandria, Alexandria University, Faculty of Veterinary Medicine, Department of Cytology and Histology, 2001.

Dibal, N. I.; Garba, S. H. & Jacks, T. W. Histological stains and their application in teaching and research. *Asian J. Health Sci., 8(2)*:ID43, 2022.

Elfky, S. A.; Elzoghby, E. M.; Attia, H. F. & Abdelghaffar Emam, M. Histological and immunohistochemical studies of the adrenal cortex in she-camel with special reference to age variation. *Benha Vet. Med. J., 45(1)*:32-9, 2023.

Eurell, J. A. & Frappier, B. L. *Dellmann's Textbook of Veterinary Histology.* Hoboken, John Wiley & Sons, 2013.

Farouk, S. M.; Mahmoud, S. F.; Eldoumani, H.; Shoghy, K.; Abdel-Megeid, N. S. & Abdo, M. Scanning electron microscopy and morphometric analysis of superficial corneal epithelial cells in dromedary camel (*Camelus dromedarius*). *Microsc. Res. Tech., 85(5)*:1685-93, 2022.

Hayashi, S.; Osawa, T. & Tohyama, K. Comparative observations on corneas, with special reference to Bowman's layer and Descemet's membrane in mammals and amphibians. *J. Morphol., 254(3)*:247-58, 2002.

Hifny, A.; Abdalla, K.; Aly, K. & Kamel, G. Biometrical studies on the cornea in some domestic animals. *Anat. Histol. Embryol., 34(Suppl. 1)*:18, 2005.

Joyce, N. C. Proliferative capacity of the corneal endothelium. *Prog. Retin. Eye Res., 22(3)*:359-89, 2003.

Kadim, I.; Mahgoub, O. & Purchas, R. A. A review of the growth, and of the carcass and meat quality characteristics of the one-humped camel (*Camelus dromedaries*). *Meat Sci., 80(3)*:555-69, 2008.

Kassab, A. Ultrasonographic and macroscopic anatomy of the enucleated eyes of the buffalo (Bos bubalis) and the one-humped camel (*Camelus dromedarius*) of different ages. *Anat. Histol. Embryol., 41(1)*:7-11, 2012.

Kleckowska-Nawrot, J.; Gozdziewska-Harlajczuk, K. & Barszcz, K. Comparative histology of the cornea and palisades of Vogt in the different wild ruminants (Bovidae, Camelidae, Cervidae, Giraffidae, Tragulidae). *Animals (Basel), 12(22)*:3188, 2022.

Konsowa, M. & Abd-Aalaziz, S. Comparative anatomy and histology of the cornea in some domestic animals. *Zagazig Univ. Med. J., 7*:478-95, 1999.

Leuenberger, P. M. Functional morphology of the cornea. *Adv. Ophthalmol., 35*:94-166, 1978.

Mazher, K. Light and scanning electron microscopical studies of goat's cornea. *Assiut Vet. Med. J., 58(135)*:121-5, 2012.

Meek, K. M. & Boote, C. The organization of collagen in the corneal stroma. *Exp. Eye Res., 78(3)*:503-12, 2004.

Merindano, M. D.; Costa, J.; Canals, M.; Potau, J. & Ruano, D. A comparative study of Bowman's layer in some mammals: relationships with other constituent corneal structures. *Eur. J. Anat., 6(3)*:133-40, 2003.

Nautscher, N.; Bauer, A.; Steffl, M. & Amselgruber, W. M. Comparative morphological evaluation of domestic animal cornea. *Vet. Ophthalmol., 19(4)*:297-304, 2016.

Purwanto, A.; Asbari, M. & Santoso, T. I. Analisis data penelitian marketing: perbandingan hasil antara amos, smartpls, warppls, dan spss untuk jumlah sampel besar. *J. Ind. Eng. Manag. Res., 2*:216-27, 2021.

Rahi, A.; Sheikh, H. & Morgan, G. Histology of the camel eye. *Acta Anat. (Basel), 106(3)*:345-50, 1980.

Rahmoun, D. E.; Lieshchova, M.; Gherissi, D. E. & Hadjeris, T. Anatomical and histological characteristics of the dromedary eye (*Camelus dromedarius*). *Theor. Appl. Vet. Med., 8(2)*:132-8, 2020.

Saadatlou, M. A. E. Histoanatomical studies on the fibrous tunic of eye in dromedary camel. *Kafkas Univ. Vet. Fak. Derg., 23(6)*:911-5, 2017.

Sirolova, Z.; Polachova, M.; Baxant, A.-D.; Studeny, P.; Krivosheev, K. & Netukova, M. A review of Bowman's layer structure, function, and transplantation. *Cell Tissue Bank, 25(4)*:897-908, 2024.

Tharwat, M. & El-Tookhy, O. Ocular ultrasonography in camels (*Camelus dromedarius*): a review. *J. Camel Pract. Res., 28(2)*:185-90, 2021.

Tsukahara, N.; Tani, Y.; Lee, E.; Kikuchi, H.; Endoh, K.; Ichikawa, M. & Sugita, S. Microstructure characteristics of the cornea in birds and mammals. *J. Vet. Med. Sci., 72(9)*:1137-43, 2010.

Wilson, S. E. Bowman's layer in the cornea- structure and function and regeneration. *Exp. Eye Res., 195*:108033, 2020.

Wilson, S. E. & Hong, J. W. Bowman's layer structure and function: critical or dispensable to corneal function? A hypothesis. *Cornea, 19(4)*:417-20, 2000.

Wislocki, G. B. The anterior segment of the eye of the rhesus monkey investigated by histochemical means. *Am. J. Anat., 91(2)*:233-61, 1952.

Zhang, X.; Qiu, J.; Feng, Y.; Zheng, J.; Xiang, J.; Gu, J.; Shan, K. & Shi, Q. Rapid detection of guttae area using aniline blue staining in Fuchs endothelial corneal dystrophy mouse model. *Clin. Exp. Pharmacol. Physiol., 51(10)*:e13921, 2024.

Corresponding author:
Mohamed Abdo
Department of Animal Histology and Anatomy
School of Veterinary Medicine
Badr University Cairo
Department of Anatomy and Embryology
Faculty of Veterinary Medicine
University of Sadat City
Sadat City 32897
EGYPT

E-mail: mohamed.abdo@vet.usc.edu.eg

Corresponding author:
Liana Fericean
Department of Biology and Plant Protection
Faculty of Agriculture
University of Life Sciences “King Michael I” from Timisoara
Timisoara
ROMANIA

E-mail: Mihaelafericean@usab-tm.ro