The Morphology of the Iridocorneal Angle in the Eye of Buffaloes (Bos bubalis): A Light and Scanning Electron Microscopic Study

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Summary: The morphology of the iridocorneal angle in the eye of the buffalo (Bos bubalis) was studied in eighteen eyes using light and scanning electron microscope (SEM). The buffalo iridocorneal angle included the pectinate ligament, the ciliary cleft, the trabecular meshwork (uveal and corneoscleral) and the angular aqueous plexus. The pectinate ligament was prominent anteriorly and appeared as strong, thick compact structure. The strands of the pectinate ligament were short and had narrow spaces between them as observed by SEM. The ciliary cleft appeared quadrilateral and contained large amount of trabecular tissue that could be divided into two parts, the uveal part and the corneoscleral part. The uveal meshwork was the internal part of the trabecular meshwork. It occupied wide area in the anterior region and narrow area in the posterior one. It composed of thick-pigmented trabeculae in the anterior part, which became thin and loose in the posterior part. Their intertrabecular spaces were large and wide anteriorly. The corneoscleral meshwork was the external part of the trabecular meshwork. It was narrow anteriorly and widened posteriorly. Their trabeculae were non-pigmented and closely arranged and the intertrabecular spaces were small. The angular aqueous plexus consisted of four to five veins. They were located between the outer border of the corneoscleral meshwork and the inner border of the sclera. These results of the iridocorneal angle suggest important implications for understanding the glaucoma disease in buffaloes.

The iridocorneal angle describes the structures associated with the base of the iris, the anterior ciliary body, the inner of the cornea and sclera. The morphology of the iridocorneal angle is clinically important as through it the aqueous humor leaves the anterior chamber of the eye (Gelatt, 1981).

The iridocorneal angle has been investigated extensively in rabbits (Bergmanson, 1985), horses (Samuelson et al., 1989; De Geest et al., 1990), human (Segawa, 1972; Gierok et al., 1974), pigs (De Geest et al., 1987; McMenamin and Steptoe, 1991), camels (Rahi et al., 1980) and dogs (Samuelson and Gelatt, 1984; Bedford and Grierson, 1986). However, only few papers reported some structures of the iridocorneal angle in ruminants (Huggert and Esklund, 1958; Anderson et al., 1980). In buffaloes, there are no reports have been published for studying the iridocorneal angle using scanning electron microscope (SEM).

The pectinate ligament is one of the important structures associated with the iridocorneal angle. It extends from the Descemet’s membrane of the cornea near the limbus to the base of the iris. It is more rudimentary in human and primates while it is highly developed in other animals, especially herbivorous (Costa-Vila et al., 1987; Simones et al., 1996). It had been studied in horses, donkeys, ox, sheep, goats, dogs, cats, pigs and rabbits by light microscope and SEM (De Geest et al., 1987 and 1990; Simones et al., 1996) but there are no studies on the buffalo.

Therefore, the aims of this study were; first, to investigate the buffalo iridocorneal angle and the aqueous humor outflow system using light and scanning electron microscope, second, to compare the results of the buffalo iridocorneal angle and the...
pectinate ligament with that of the other domestic animals and then using these results for understanding the disease of glaucoma in buffaloes.

Materials and Methods

Eighteen normal eyes from adult buffaloes (Bos bubalis) in various ages and sexes were used in this work. The eyes were obtained from Benha slaughterhouse in Egypt. The eyeballs were enucleated immediately after slaughtering and immersed in 10% formalin solution with phosphate buffer (pH 7.4) for fixation. Small cut was made in the cornea to allow formalin solution to penetrate inside the eyeball and make good fixation for the inner structures of the eyeball.

Thirteen eyes were used for light microscopic study. The eyeballs were divided midway between the equator and the limbus and the lens was removed. The anterior half of the eye was subdivided into different pie-shaped segments of 2 or 3 mm in thickness. These segments were put in 10% formalin solution, then dehydrated and embedded in resin and paraffin. The steps of embedding the specimens in resin (hydroxy methyl methacrylate) were dehydration in a series of ethanol dilutes (70–90%), infiltration and polymerization at room temperature. Frontal sections of 3, 5, or 10 μm in thickness were made using the ordinary microtome and stained with Periodic Acid Schiff (PAS) and haematoxylin and eosin.

Five eyes were used for scanning electron microscopic study. They were prepared as the same as mentioned for the light microscopic study. They were dehydrated in ascending grades of alcohols, isopentyl acetate for 2–3 days, critical point dried with carbon dioxide, mounted on aluminum holders and coated with platinum in a sputtering device. Finally, the structures were examined with the scanning electron microscope (SEM) (Hitachi S – 225 O N).

The nomenclature used in this study was according to international committee on veterinary gross (1994a) and histological (1994b) nomenclature.

Results

The iridocorneal angle of the eye of the buffalo included the following structures: the pectinate ligament, the ciliary cleft, the trabecular meshwork (uveal and corneoscleral) and the angular aqueous plexus (Figs. 1, 2).

The Pectinate Ligament (Ligamentum Pectinatum)

The pectinate ligament (Figs. 1–3) was a sturdy, thick compact structure lying on the anterior part of the iridocorneal angle. Its shape was conical or prismatic, extending from the base of the iris to the posterior margin of the Descemet's membrane of the cornea. It was short and prominent measuring about 350–420 μm in length. Its thickness was 120–150 μm in near the base of the iris and 40–75 μm near the limbus. The base of the pectinate ligament was wide at the iris and decreased at the cornea (Figs. 1, 3). It had melanin pigments, especially near the iris (Fig. 1).

Under the SEM, the strands of the pectinate ligament appeared short and slender, some of these strands were thick and the others were thin (Fig. 3). There were spaces of various shapes and widths between the strands of the pectinate ligament. These spaces might be triangular, oval and ovoid in shape. The width of these spaces ranged from 75 to 100 μm.

The Ciliary Cleft (Sinus Ciliaris)

The ciliary cleft was the space, which was bordered by the pectinate ligament anteriorly, the limbal zone from the outer aspect, and the core of the iris and the ciliary body from the inner aspect (Figs. 1, 2). Its shape was somewhat rectangular or quadrilateral. The distance from the pectinate ligament to the posterior part of the iridocorneal angle was 0.9–1.4 mm. The height of the ciliary cleft was 0.7–0.9 mm. It enclosed the trabecular meshwork.

The Trabecular Meshwork (Reticulum Trabeculae)

The buffalo eye contained large amount of trabecular tissues that regulated the aqueous humor outflow. It could be divided into two parts: the uveal part and the corneoscleral part (Figs. 1, 2).

a) The Uveal Meshwork (UM)

The uveal meshwork was the internal part of the trabecular meshwork (Figs. 1, 2, 4). It placed between the corneoscleral meshwork externally and the base of the iris internally. It composed of strands or trabeculae of various thicknesses (Figs. 1, 4). These trabeculae were thicker anteriorly and became thin and loose posteriorly, and they intermingled with each other forming network in the posterior part. There were intertrabecular spaces (spaces of Fontana) between the trabeculae. These spaces were wide anteriorly (100–150 μm) and decreased gradually till became narrow posteriorly (20–40 μm) (Figs. 1, 4). The trabeculae were made of collagen, and there were melanin pigments and endothelial cells on their surface (Fig. 1). The melanin pigments were abundant in the anterior part of
the uveal meshwork and near the stroma of the iris. There were also few round trabeculae in the anterior part of the ciliary cleft. Their intertrabecular spaces might be oval, ovoid and rounded as viewed by SEM (Fig. 5).

b) The Corneoscleral Meshwork (CSM)

The corneoscleral meshwork was the external part of the trabecular meshwork (Figs. 1, 2, 4). It located between the inner part of the sclera externally and the uveal trabeculae internally. It extended from just behind the pectinate ligament and continued posteriorly. The corneoscleral meshwork could be demarcated from the uveal meshwork by their smaller intertrabecular spaces. It filled a narrow area in the anterior region and a wide area posteriorly. Its trabeculae came in contact with the caudal aspect of the pectinate ligament near the cornea (Fig. 1). The corneoscleral meshwork consisted of large internal cylindrical trabeculae in the anterior part and small thin trabeculae in the posterior part. Trabeculae were closely arranged and their intertrabecular spaces were small and elongated. These trabeculae contained many endothelial cells but no pigments. Few pigments could be seen in the border between the corneoscleral and uveal meshwork. Trabeculae were very thin and compact and there were spaces of various widths among them as seen by SEM.

The Angular Aqueous Plexus (AAP)

The AAP consisted of four to five separate veins (Fig. 2). These veins positioned between the outer border of the corneoscleral meshwork and the inner border of the sclera (Figs. 1, 2). They were lined by endothelial cells, which were continuous with that of the trabecular meshwork. There were also some pigments of the sclera that might be on the margin of the veins. The AAP drained into the episcleral venous plexus through the small collector channels. The intrascleral venous plexus could be observed.

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Fig. 1. High magnification of frontal histological section shows clearly the different parts of the buffalo iridocorneal angle. Abbreviations are the same in Fig. 1. Scale bar: 100 μm.
The Limbus

The limbus could be defined as the border between the transparent cornea and the opaque sclera (Figs. 1, 2). Its outer view appeared macroscopically as a gray zone with circumferential length about 76–82 mm. This gray transition zone was the site of any surgical operation for glaucoma and cataract.

On the other hand, the limbus could be determined microscopically as the junction of the irregular, eosinophilic scleral collagen fibers and the regular, less eosinophilic collagen fibers of the cornea.

Fig. 2. The iridocorneal angle of the eye in the buffalo. a) Photomicrograph of frontal section of the buffalo iridocorneal angle as seen with light microscope stained with PAS and Haematoxylen stain. b) Scanning electron micrograph of the entire iridocorneal angle in the buffalo. AC: anterior chamber, AAP: angular aqueous plexus, CC: ciliary cleft, CP: ciliary processes, CSM: corneoscleral meshwork, P: pectinate ligament, UM: uveal trabeculae, C: cornea, I: iris and S: sclera. Scale bar: 200 μm.
Discussion

The present debate explains the features of the buffalo iridocorneal angle, which helps consequently in understanding the glaucoma disease in buffaloes.

The general morphology of the iridocorneal angle of the buffalo was similar to that of the other domestic animals (Troncosco and Castroviejo, 1936; Bergmanson, 1985; De Geest et al., 1987 and 1990; Samuelson and Lewis, 1995).

The pectinate ligament of the buffalo was the stoutest pectinate ligament of the domestic animals, which is in good agreement with the earlier reports in other ruminants (Troncosco and Castroviejo, 1936; Samuelson and Lewis, 1995). On the other hand, the pectinate ligament was delicate and less developed in dogs (Martin, 1975), pigs (De Geest et al., 1987) and rabbits (Ruskell, 1961; Simones et al., 1996).

The structure of the buffalo pectinate ligament was compact and strong with small intertrabecular spaces; this differs from that of horses, which appeared as fenestrated sheet (De Geest et al., 1990). In contrast, the pectinate ligament of dogs (Samuelson and Gelatt, 1984) and rabbits (Bergmanson, 1985) was constructed by separate and radially oriented trabeculae. The strands of the pectinate

Fig. 3. Scanning electron micrographs of the pectinate ligament in the buffalo. a) Lateral view of the pectinate ligament near its attachment to the cornea. b) Anterior view of the pectinate ligament showing the short strands (t) and intertrabecular spaces (r). Abbreviations are the same in Fig. 1. Scale bar for a: 50 μm and for b: 100 μm.
ligament in the buffalo inserted perpendicularly on the corneal limbus, corresponding to that recorded in horses (De Geest et al., 1990).

So, the structure and shape of the buffalo pectinate ligament partially compensate for the weakness of ciliary muscle, support the iridal base and prevent the collapse of the ciliary cleft. Also, the anterior components of the eye are consequently held in place during accommodation of the lens and iridal meiosis (Duke-Elder and Wyber, 1961; Tri-

Fig. 4. Scanning electron micrograph of the trabecular meshwork showing the distinction between the uveal trabeculae and the corneoscleral meshwork of the buffalo iridocorneal angle. t: trabeculae, r: intertrabecular spaces and other abbreviations are the same in Fig. 1. Scale bar: 100 μm.

Fig. 5. Scanning electron micrograph of the caudal part of the uveal meshwork showing the irregular spaces of Fontana (t) between the trabeculae (r). Scale bar: 50 μm.
The corneoscleral trabecular meshwork extended along the whole length of the outer wall of the ciliary cleft, like that in pigs (McMenamin and Steptoe, 1991) and dogs (Samuelson and Gelatt, 1984). While, De Geest et al. (1990) in horses observed that it occupied only the posterior angle of the ciliary cleft. The present results also revealed that the CSM came in contact with the insertion of the pectinate ligament in the cornea and this came in agreement with that reported in bison and pigs by Samuelson and Lewis (1995). On the other hand, the aforementioned authors (Samuelson and Lewis, 1995) observed that the CSM inserted at about 5 mm posterior to the pectinate ligament in the sheep and horses. So, the arrangement of these CSM may help in keeping the iridocorneal angle from collapse and consequently decrease the incidence of open angle glaucoma in buffalo.

Tripathi (1974) mentioned that the aqueous humor exits through the iridocorneal angle via AAP and intrascleral plexus (conventional route) and the uveoscleral route (unconventional route). Since the trabecular tissues are abundant in the iridocorneal angle of the buffalo, so there may be little resistance to the aqueous outflow along the conventional route at the corneoscleral meshwork, similar to that in cattle and horses (Huggert and Esklund, 1958; Samuelson et al., 1989). Therefore the uveoscleral pathway (unconventional route) may play a small role in the removal of the aqueous humor in buffaloes. This latter opinion concurred with that of Smith et al. (1986) and Samuelson et al. (1989) in horses.

The results of the buffalo angular drainage vessels simulate the reports that were recorded in pigs (De Geest et al., 1987), horses (De Geest et al., 1990), cats (Richardson, 1982), dogs, ox, and rabbits (Samuelson and Gelatt, 1984; Tripathi, 1974) and with the canal of Schlemm in primates (Tripathi, 1971 and 1973).

Since the angular aqueous plexus in the buffalo composed of four to five apparent veins, thus these trabecular veins are sufficient for the regular removal of the aqueous humor from the anterior chamber of the eye (conventional route).

Overall, the aqueous humor drains through the endothelium that lines the angular aqueous plexus or Schlemm's canal. Previous studies (Tripathi, 1974; Samuelson et al., 1982) reported that the fluid drains through many routes as the intercellular spaces or pinocytotic vesicles or intracellular channels or vacuoles but there is no general agreement for the actual pathway.

The scleral spur that was observed in pigs (McMenamin and Steptoe, 1991; Samuelson and Lewis, 1995) and human (Hogan et al., 1971) couldn't be detected in this study.

In conclusion, the results of the morphology of the iridocorneal angle in the buffalo revealed that the incidence of glaucoma in buffalo might be very rare.

References

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