“GROSS AND HISTOMORPHOLOGICAL STUDY ON EYE BALL OF THE ADULT MARWARI GOAT
(Capra hircus)”

By
RAKESH KUMAR BARHAIYA
B. V. Sc. & A.H.

DEPARTMENT OF VETERINARY ANATOMY AND HISTOLOGY
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ANAND AGRICULTURAL UNIVERSITY
ANAND – 388 001 [GUJARAT]

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IN
VETERINARY ANATOMY AND HISTOLOGY

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2014
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DEDICATED TO
MY BELOVED PARENTS
&
TEACHERS
ABSTRACT
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“GROSS AND HISTOMORPHOLOGICAL STUDY ON EYE BALL OF THE ADULT MARWARI GOAT (Capra hircus)”

The present study entitled “Gross And Histomorphological Study On Eye Ball Of The Adult Marwari Goat (Capra hircus)” was carried out on eye balls of the ten adult Marwari goats. Immediately after collection of eye balls, they were subjected for ocular ultrasonography, echobiometrical and biometrical observations. Then 8-10 mm long incision was given in the limbus and whole eye ball fixed in Davidson’s fixative for 24-30 hours. The section of the sclera, cornea, lens, choroid, ciliary body, iris, irido-corneal angle and retina were stained with H. & E., Masson’s trichome and Periodic Acid Schiff (PAS).

Ultrasonography of eye ball (sonoanatomy) revealed cornea as a thin hyperechoic layer which formed the anterior wall of the anterior chamber. The anterior chamber was distended with the anechoic aqueous humor. The ciliary body and iris were seen as echogenic linear structure which extended from the peripheral globe towards the lens. The corpora nigra or iridica granules were seen as an echogenic round
structure on the anterior surface of the dorsal iris. The anterior lens capsule was appeared as a convex echogenic line which was separated from the concave echogenic line of the posterior lens capsule by the anechoic lens. The vitreal chamber was filled with anechoic fluid.

Echobiometrical observations of the eye ball were measured. The mean value of the anterior chamber depth, antero-posterior depth of the lens, vitreous chamber depth and antero-posterior axis of the globe were $0.27 \pm 0.02$ cm, $0.80 \pm 0.01$ cm, $1.14 \pm 0.01$ cm and $2.13 \pm 0.01$ cm, respectively.

The overall mean value of the weight of the right and left eye balls of adult Marwari goat was $10.062 \pm 0.06$ gm. The overall mean values of the antero-posterior axis, horizontal axis and vertical axis of the eyeballs of both sides were $25.21 \pm 0.05$ mm, $27.62 \pm 0.18$ mm and $26.89 \pm 0.03$ mm, respectively.

The cornea was elliptical in shape with a horizontal diameter greater than the vertical diameter. The overall mean values of the horizontal and vertical diameter of the cornea were $19.26 \pm 0.03$ mm and $14.81 \pm 0.04$ mm, respectively. The overall mean value of the thickness of the cornea was $0.852 \pm 0.03$ mm. It was $0.911 \pm 0.04$ mm at the center and $0.794 \pm 0.02$ at the periphery.

The transparent and avascular lens was biconvex with the degree of convexity more at posterior side than anterior side. The lens was completely enclosed within a very thin PAS positive capsule. Behind the anterior surface of the capsule there was a single layer of epithelial cell. The lens fibers constituted the main body of the lens. It was suspended by the zonular fibers which arise from the ciliary body and attached to the lens capsule at the lens equator. The mean values of the weight, A-P axis and diameter of the lens were $0.921 \pm 0.02$ gm, $10.056 \pm 0.03$ mm and $12.493 \pm 0.16$ mm, respectively.
The sclera begin at the periphery of the cornea and extended posteriorly up to the optic nerve. The sclera had three parts from outside to inside: the episclera, sclera and lamina fusca. The thickness of sclera was found to be varied from region to region, it was thickest at optic disc and thinnest at equator.

The cornea was composed of five layers a) Anterior Epithelium, b) Subepithelial basement membrane, c) Corneal stroma/Substantia propia, d) Descemet’s Membrane and e) Endothelium. Anterior epithelium (stratified squamous non-keratinized) was the outermost layer of the cornea and was composed of 5 to 9 rows of epithelial cells. The mean value of the total thickness of the cornea was 716.39 ± 13.84 μm. At the periphery and center it was 702.54 ± 42.11 μm and 730.24 ± 43.54 μm, respectively. The mean values of the thickness of the epithelial layers, thickness of stroma, thickness of the Descemet’s membrane and thickness of endothelium of the cornea were 77.20 ± 1.45 μm, 626.74 ± 12.02 μm, 10.70 ± 0.33 μm and 2.08 ± 0.10 μm, respectively.

The richly vascularized choroid extended from the ciliary body to the optic nerve and present between sclera and retina. The choroid consisted of the four layer: 1) Suprachoroidea, 2) Blood vessels layer, 3) Tapetum fibrosum and 4) Choriocapillaris. The total thickness of the choroid varied from region to region and tend to thicken along the posterior pole, becoming thinner towards the equator. The mean value of the thickness of the choroid was 45.53 ± 2.05 μm at the anterior/ora ciliaris retinae whereas, at the equator, it was 37.30 ± 3.48 μm and at the posterior pole/optic disc it was 50.64 ± 2.99 μm. The thickness of tapetum fibrosum was varied from 13.20 to 33.77 μm with the average of 26.40 μm.

The ciliary body was the anterior continuation of the choroid and it joined anteriorly with the iris. It was made up of the two ring shaped components: the pars
The pars plicata was the anterior most part of the ciliary body, comprised of ciliary process and the flat pars plana started from posterior termination of the ciliary process, and merged with anterior termination of the retina (ora ciliaris retinae). Both portion of the ciliary body consisted of the epithelium, stroma and smooth muscles.

Iris was extended from the ciliary body and cover the anterior surface of the lens, except for central opening i.e. pupil. It was mainly consisted of the stroma and the posterior epithelial lining. The stroma was comprised of the loose connective tissue with smooth muscles, blood vessels, melanocytes and fibroblasts.

The irido-corneal angle was the area, located at the periphery of the anterior chamber and formed by the junction of the corneoscleral tunic (Limbic zone), base of the iris and anterior ciliary body. The irido-corneal angle of the eye of the goat was large and triangular and it was comprised of the pectinate ligament, the ciliary cleft, the trabecular meshwork (uveal and corneoscleral) and the angular aqueous plexus.

The retina was the innermost layer of the tunic of the eye ball. Retina had two portion, one was sensory (pars optic retinae) and another one was nonsensory. Non-sensory part of the retina was started from the ora ciliaris retinae and covers the ciliary body (pars ciliaris retinae) and iris (pars iridis retinae). The sensory part of the retina was composed of ten layer: (1) the retinal pigmented epithelium (2) layer of rods and cones (3) external limiting membrane (4) outer nuclear layer (5) outer plexiform layer (6) inner nuclear layer (7) inner plexiform layer (8) ganglion cell layer (9) nerve fibers layer (10) internal limiting membrane.

The retinal pigmented epithelium (RPE) was the outermost single layer of flat cells of the retina. The cells of the RPE were pigmented except the area where the tapetum fibrosum was present. The next layer was layer of rods and cone cells which
comprised of only outer part of the rods and cones i.e. outer and inner segment. Outer limiting membrane separated the layer of rods and cones from the outer nuclear layer. The outer nuclear layer was composed mainly of nuclei of rods and cones. The outer plexiform layer was a thin layer that separated the outer nuclear layer from the inner nuclear layer. The inner nuclear layer was comprised of the nuclei of the horizontal cells, bipolar cells, amacrine cells and Muller’s cells. The inner plexiform layer was comprised of the bipolar and amacrine cell axon and dendrites of the ganglion cells. The ganglion cell layer was the innermost cell layer of the retina. The nerve fiber layer formed by the axon of ganglion cell. The internal limiting membrane was the innermost layer of the retina.

Thickness of the retina was found to be varied from region to region, it was thickest at optic disc and tapering towards the ora ciliaris retinae. The mean values of the total retinal thickness at Anterior/Ora ciliaris retinae, at equator and at posterior/Optic disc were 113.24 ± 5.68 µm, 139.82 ± 7.49 µm and 213.03 ± 14.45 µm, respectively.

Retinal detachment and folding of retina were the artifacts which found in present study. Retina detached from the retinal pigment epithelium or from choroid. It may be due to processing of tissue during preparation of block and sectioning. In more than 70 % of the sample, we found that retina took convex appearance vitreally which were almost round and oval in shape.
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I stand with the kernel of my endeavor while pursuing it, many a known and unknown hands pushed me forward, and learned soul put me on the right path and enlightened me with the knowledge and experience. I shall even remain indebted to them. I just cannot repay their kind debt they have done on me, but the kind words thanks say a lot.

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This thesis is a part of my individual success, but is more a part of the success of the mentioned individuals and others. Their ability to persuade my courage and encourage my determination have developed me to the person I am today, and I thank them for this. They have been the ones to mold me into the person I strive to be.

My eternal thanks to all of you!

Place: Anand

(Rakesh Kumar Barhaiya)

Date: / /2014
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Professor
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Anand Agricultural University, Anand, 388 001, Gujarat.

CERTIFICATE

This is to certify that the thesis entitled “Gross And Histomorphological Study On Eye Ball Of The Adult Marwari Goat (Capra hircus)” submitted by Mr. Rakesh Kumar Barhaiya (Reg. No. 04–1989–2012) in partial fulfillment of the requirements for the award of the degree of Master Of Veterinary Science in the subject of Veterinary Anatomy And Histology of the Anand Agricultural University is record of bona fide research work carried out by him under my guidance and supervision and the thesis has not previously formed the basis for the award of any degree, diploma or other similar title.

Rakesh Kumar Barhaiya has completed his course work and has passed the preliminary examination.

Place: Anand
Date: / / 2014

(D. M. Bhayani)
Major Advisor
This is to certify that, I have no objection for supplying to any scientist only one copy of any part of this thesis at a time through reprographic process, if necessary, for reference services in a library or documentation center.

Place: Anand

Date: / /2014

Rakesh Kumar Barhaiya

(D. M. Bhayani)

Major Advisor
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41. Photomicrograph of the optic disc (OD) and optic nerve (ON) showing optic nerve fibers converged into optic nerve and left the eye ball through the choroid and sclera. At the point of the leaving of the optic nerve, long posterior ciliary artery (LPC) entered into the globe. **LC:** Lamina cribrosa, **R:** Retina, **RV:** Retinal vein. (H. & E. 150X)

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INTRODUCTION
CHAPTER I
INTRODUCTION

Goat plays vital role in livelihood security, poverty alleviation and employment generation of a large population of small and marginal farmers and landless laborers of the country. Goat is one of the main species for meat production in India. Goat has all the characteristics required for efficient meat production viz. high prolificacy, more than one breeding season in a year, higher milk production and capacity to bear twins and triplets. Total population of goat in India was 154.00 million in 2010 which contributes 16.93 % of the total world’s goat population (FAOSTAT, 2010). India has 1st rank in goat population. Goat shared 3.77 % and 17.37 % in total milk production and meat production in India respectively (GOI, 2012).

Marwari breed derives its name after the region “Marwar” which is the natural habitat of the breed. It is found in an extensive area in Western Rajasthan comprising of Barmer, Bikaner, Jaisalmer, Jalore, Jodhpur, Nagaur and Pali districts. The breed also found in adjoining areas of northern Gujarat (Banerjee, 2012).

“An animal’s eyes have the power to speak a great language”

Martin Buber

Ophthalmology is an important and recognized discipline of veterinary medicine and ocular examination is important in most clinical examinations. Understanding of ocular disorders is based on knowledge of normal ocular structure and physiology.

The vertebrate eye is an optical instrument simulating an electronic camera which relays information received in the form of light to analyzing center in the cerebral
cortex. The eye itself is most simply described as layer of neural light sensitive tissue (the retina) held in shape by surrounding coat which protect it (the sclera) and nourish it (the choroid), and served by an optical system of a lens behind a transparent anterior extension of the sclera (the cornea), all of which combine to focus light on to the retina (Prince et al., 1960).

Vision is one of the most important sensory abilities of human as well as animals. Perception of the image of the objects enables animal to thrive and survive in its environment. The defective or poor visual power or the blindness affects the normal working efficiency and animals are prone to danger violent events and accident. So in order to find out various etiological factors of the blindness, the understanding of all the normal structure of the eye is essential.

The sclera is the major part of the fibrous tunic of the eye. It is tough and elastic since its main function is to protect the intraocular contents. The limbus is the transition zone between the cornea and sclera. At limbus, the homogeneous and transparent corneal collagen fibers become opaque and fibrous.

The cornea is the transparent front layer of the fibrous tunic and the most powerful refractory layer of the eye. Transparency and regular curvature are essential to focus light on the retina. Because it is avascular; it receives nutrients through the vessels of the limbus and the fluid from the anterior chamber. The cornea is one of the most densely innervated tissue in the body and supplied by sensory and autonomous nerve fibers (Muller et al., 2003). Cornea, being central and outermost part of the eye ball, is frequently subjected to get injury. Hence any defect and change in their structure may cause opacity, keratitis, ulcer etc.
The lens is transparent, biconvex, fine tuning refractive structure that focuses sharp image on the retina for acute vision. It is situated between the iris and the vitreous body. It is suspended by the zonular fibers arising from the ciliary body and attaching to the lens capsule at the lens equator. The lens is completely enclosed within a thick elastic capsule which plays major role in the vision by their accommodation capacity. The lens is deprived of blood supply postnatally. Subsequently, it depend upon the aqueous humor and, to a lesser extent, the vitreous for nourishment. Transparency of the lens result from its relatively dehydrated state, lamellar arrangement of fibers, smooth and uniform thickness of the lens capsule and the epithelium in the pupillary region. So any factors which cause change in normal structure of lens leads to disease condition such as cataract.

The choroid is an intermediate layer located between the sclera and retina, which is at the rear of the vascular tunic. It is highly vascularized and has multiple layers. The deepest layer is the tapetum, which is a reflective surface designed to pop up the light entering in the retina, thus increasing the dim light vision (Leite et al., 2013)

The ciliary body is a circumferential thickening of the vascular tunic that give rise to many fine suspensory ligaments that support the lens. It is involved with the accommodation of the lens and is responsible for the production of aqueous humor in the anterior segment of the eye ball.

The iris is the most anterior portion of the vascular tunic, it consists of a pigmented ring that sits between the cornea and the lens, whose primary function is to control the light entering the eye through the pupil.

The retina is a multilayered extension of the brain that play key role in vision (Komaromy, 2010). The retina consists of various cell types arranged in eight layers
and two membranes (Shara et al., 2013). Visual perception is a sensory process initiated at the retina, and completed in the cerebral cortex. Two main functions are performed by the retina: 1) the initial conversion of light energy into electric signals, phototransduction, which is carried out by photoreceptors; 2) a series of physiological processes performed by retinal interneurons (bipolar, horizontal and amacrine cells), in order to encode the different attributes of the visual stimuli (shape, movement and color) in electrical signals (Germain et al., 2010). Any changes in its structure may lead to temporary or permanent blindness.

Ocular ultrasonography (USG) is safe noninvasive technique to evaluate the intraocular and retrobulbar tissue of opaque eyes (Nyland and Mattoon, 1995). Two dimensional USG allows evaluation of structure such as cornea, the anterior chamber, the iris, the ciliary body, the lens, the vitreous chamber and the posterior section of the bulbar wall (Nautrup and Tobias, 2007). Ocular biometry is one of the method to measure the axial dimensions of the eye and determine the position of intraocular components by USG. Ocular biometry of eye has been useful for the assessment of certain pathological abnormalities such as phthisis bulbi, microphthalmia, scleral ectasia and congenital glaucoma (Brando, 2007 and Potter, 2009). Knowledge of the dimensions of the optical component is required for better understanding of clinical problems in vision.

A sound knowledge of normal gross anatomical and histological features, including possible individual variations, will greatly assist in recognizing pathology thus providing more accurate diagnosis and will aid in accurate tissue sampling. A number of studies have been carried out on the other system of goat but study on the eye ball is very little. This region is of considerable importance considering that it is an area for vision which is important for the well being and performance of the animal. It
has been observed that there was no research work on gross and histomorphology of the eye ball of goat in India in the available literature reviewed. Hence, with these views in mind, the present study in gross and histomorphological study on eye ball of the adult Marwari goat was undertaken which can help the veterinarian while treating the clinical cases of ocular diseases in goat in a systemic manner with following objectives:

1. To evaluate sonoanatomy and ocular echobiometrical dimensions of the eye ball by using two-dimensional ultrasonography.
2. To study gross morphology and biometry of the globe.
3. To study gross morphology and biometry of the cornea.
4. To study gross morphology, biometry and histomorphology of the lens.
5. To study histomorphology and micrometry of the sclera and cornea.
6. To study histomorphology of the ciliary body, iris and irido-corneal angle.
7. To study histomorphology and micrometry of the choroid and retina.
2.1 SONOANATOMY AND ECHOBIOMETRICAL DIMENSIONS OF THE EYE BALL

2.1.1 Sonoanatomy

Whitcomb (2002) reported the normal sonoanatomy of the horse eye. The anterior chamber was filled with anechoic fluid and was absorbed by the cornea, iris and anterior reflection of the lens capsule. The iris and ciliary body were seen as hyperechoic linear structure which extend from the peripheral globe towards the lens. The corpora nigra or iridica granules were seen as an echogenic sound of tissue on the anterior surface of the dorsal iris. The normal lens was anechoic. Only the anterior and posterior reflection of the capsule can be seen in normal eye. The normal vitreal chamber was filled with anechoic fluid. The retina was layer of cells lining the vitreal chamber. The normal retina cannot be differentiated from the choroidal layer.

Spaulding (2008) reported ultrasound imaging of dog eyes. In normal dog eye, the three cavities (anterior chamber, posterior chamber and vitreous body) have anechoic appearance. The first highly reflective line was the corneal surface. The anterior chamber was delineated by the cornea, the iris and the central lens capsule. The internal appearance of the normal eye was anechoic. Curvilinear hyperechoic interface appears at the anterior and posterior margin of the lens as the result of specular reflection, when scanned perpendicularly. This reflection was caused by the acoustic impedance difference between the fluid in anterior chamber and the sound interfacing with the surface of the lens. Posterior to the lens and extending to the posterior aspect
of the globe was the vitreal body, which filled up vitreous cavity. Retinal wall was hyperechoic which was not differentiated from the other two layers.

Assadnassab and Fartashvand (2013) studied the ultrasonographic appearance and measurements of normal eyes of live buffalo. They observed that on B-scan images, the buffalo eyes appeared as well-defined, ovoid structures with mostly anechoic contents. The anterior and posterior lens capsule and scleroretinal rim appeared hyperechoic, whereas the anterior aqueous chamber, lens, and vitreous chamber were anechoic. The cornea appeared as a double-peaked echo (2 convex interfaces) with a central, narrow anechoic space. The anterior lens capsule appeared as a convex echogenic line separated from the concave echogenic line of the posterior lens capsule by the anechoic lens. The iris and ciliary body were observed as linearly shaped moderately echoic structures. The iris was identified immediately adjacent to the anterior lens capsule with the thicker, irregular ciliary body lying peripheral to it. The anterior and posterior chambers of the aqueous appeared as a single, anechoic space. The vitreous chamber was imaged as a homogeneous, anechoic region between the posterior lens capsule and ciliary body anteriorly and the posterior ocular wall. The posterior ocular wall had a good echogenicity encountered.

2.1.2 Echobiometrical dimensions of the eye ball

Ribeiro et al. (2010) determined echobiometrical findings in the eyes of 30 adult goats. Mean and standard deviation from the ocular structure of the male and female goats respectively, were, 3.46 ± 0.55 mm, 3.33 ± 0.46 mm (anterior chamber depth); 8.60 ± 0.34 mm, 8.65 ± 0.39 mm (lens thickness); 11.34 ± 0.61 mm, 11.39 ± 0.66 (vitreal chamber depth); and 23.43 ± 0.92 mm, 23.39 ± 0.86 mm (axial globe length).

Patil et al. (2011) reported that the different parameters such as mean anterior chamber depth (ACD), crystalline lens thickness (CLT), diameter (CLD), vitreous
chamber depth (ACD), axial globe length (AGL) of right and left eye in male horse were 3.96±0.13, 4.22±0.17, 11.05±0.13, 11.45±0.16, 23.3±0.68, 23.3±0.68, 20.15±0.30, 19.8±0.29, 35.28±0.34, 35.50±0.32 (mm), respectively.

Assadnassab and Fartashvand (2013) described measurements of normal eyes of live buffalo. When comparing measurements, the antero-posterior depth of the lens, vitreous chamber and axial length of the globe on the left side were greater than on right. The antero-posterior depth of the lens of left and right were 1.135 ± 0.052 cm and 1.132 ± 0.053 cm, respectively, vitreous chamber depth of the left and right were 1.677 ± 0.042 cm and 1.670 ± 0.040 cm, respectively and axial length of the globe on left and right were 3.297 ± 0.037 cm and 3.292 ± 0.037 cm, respectively. The anterior chamber depth and scleroretinal rim wall thickness on the left side were also less than on the right side in each of the buffaloes. The anterior chamber depth of the left and right were 0.287 ± 0.015 cm and 0.291 ± 0.014 cm, respectively and scleroretinal rim thickness of the left and right were 0.155 ± 0.011 cm and 0.158 ± 0.010 cm, respectively. However these differences were reported not to be statistically significant.

2.2 GROSS MORPHOLOGY OF THE EYE BALL

Prince et al. (1960) described that shape of the eyeball of goat was spherical with larger horizontal axis than the A-P axis. Sclera was punctured at several points for the passage of nerves and blood vessels. The head of the optic nerve which was largest, situated in the posterior wall, somewhat lateral or medial to the posterior pole.

Konig and Liebich (2004) noted the shape and size of the domesticated animals and described that there was considerable variation in regard to the form and size of the eye ball between species and individuals. It was roughly spherical in carnivores. The outline of the eye ball was not evenly rounded, but displayed a larger curvature in its posterior part, than in its posterior part, where the cornea bulges forward. The cornea
formed the anterior, transparent segment of the fibrous layer of the eye ball. The highest point of the cornea called the vertex and its periphery, the limbus.

Gelatt (2007) mentioned that the eyes in domestic animals were quite variable in size, but their shapes were comparatively uniform, being spherical in most instances, in which the three axis of the globe (antero-posterior, horizontal or transverse and vertical) were nearly identical in dimensions. In sheep A-P axis was lesser than the other axis but horizontal and vertical axis were almost identical. The long posterior ciliary arteries were visualized at the three-o'clock and nine-o'clock positions when viewed posteriorly, passing from the optic nerve to the equator in the superficial sclera.

**2.2.1 Biometry of the eye ball**

Prince *et al.* (1960) noted the ranges of various dimensions of the eye ball of the goat. They reported that the antero-posterior axis of the eye ball was approximately 29 mm, both the horizontal and vertical diameter was about 32 mm each.

Panchbhai *et al.* (1988) reported the means of the following measurements of the different parameters in buffalo calves as follows: Antero-posterior axis - 3.19 cm, Vertical axis - 3.45 cm, Horizontal axis - 3.37 cm, Weight of eye ball - 21.41 gm.

Olopade *et al.* (2005) recorded that the mean horizontal and vertical axis of right and left eye of Sahel goat were 8.17 mm and 8.23 mm respectively whereas antero-posterior axis of the left and right eyeballs were 7.11 mm and 7.19 mm respectively. The average weight of the right and left eye ball of Sahel goat were 7.17 gm and 7.19 gm, respectively.

Gelatt (2007) described the dimensions of globe of domestic animals. He noted that A-P axis, horizontal axis and vertical axis of sheep were 26.85 mm, 30.86 mm and 30.02 mm, respectively.
Khaled and Abdalla (2013) reported that the average weight of eyeball in buffalo was $35.30 \pm 2.69$ gm.

2.3 CORNEA

2.3.1 Biometry

Prince et al. (1960) in goat noted that corneal curvature was steeper than the sclera there-fore cornea was slightly prominent. It was roughly horizontally in oval shape with slightly broader medial end. The transition between sclera and cornea was marked by a dark pigmented limbal ring. The vertical diameter and horizontal diameter of the cornea in sheep were 19 mm and 27 mm, respectively. In pig horizontal diameter and vertical diameter were 17-19 mm and 14-16.5 mm, respectively.

Panchbhai et al. (1988) measured the height and the width of the cornea in buffalo calves and recorded that the mean height (vertical diameter) and the mean width (horizontal diameter) were 2.05 cm and 2.53 cm, respectively.

Samuelson (1999) noted that the cornea was elliptical in shape, with a horizontal diameter greater than the vertical. In most ungulates, the differences between these diameters was much more pronounced, allowing a remarkable horizontal field of view that was further complemented by the lateral positioning of their orbits within their skulls. Corneal thickness varied also from species to species, from breed to breed and from individual to individual. In most domestic animals, it was less than 1 mm. In the bovine, it was 1.5-2.0 mm thick centrally and 1.5-1.8 mm in the peripherally.

Gelatt (2007) described that in ungulates cornea was elliptical in shape, with a horizontal diameter greater than the vertical which allowing for a remarkable horizontal field of view. In the dog and the cat, the difference between these diameters was small, thus making their corneas appear to be almost circular. The corneal thickness varied from species to species, from breed to breed and from individual to individual. In most
domesticated animal, it was less than 1 mm. The central and peripheral thickness of cornea for sheep were 0.8-2.0 mm and 0.3-0.5 mm, respectively as reported by them.

Maggs et al. (2008) mentioned that in domestic animals the horizontal diameter of the cornea was greater than the vertical diameter. This difference was especially notable in the large herbivores. The corneal thickness varied among species and across regions of the cornea but it was usually between 0.5 and 0.8 mm.

Faber et al. (2008) reported that corneal thickness of pig was 0.666 mm centrally, 0.657 mm nasally (medial), 0.713 mm inferiorly, 0.669 mm temporally, and 0.714 mm superiorly (mean values). The corneal diameter was also measured using caliper, and was 14.9 mm horizontally and 12.4 mm vertically (mean values).

### 2.3.2 Histology

Prince et al. (1960) described the histological structure of the cornea of goat and stated that it was composed of five layer from outward to inward as: a) anterior epithelium, b) Bowman’s membrane, c) substantia propria (stroma), d) Descemet’s membrane and e) posterior epithelium. They found that anterior epithelium (60-70 µm thick) was stratified squamous non keratinized epithelium in which the basal rows of cells were of columnar type.

Martin and Anderson (1981) observed four layers in the corneal structure of domestic animals which were; anterior epithelium, stroma, posterior limiting membrane (Descemet’s membrane) and posterior epithelium (endothelium). They noted that the additional layer, the anterior limiting membrane (Bowman’s membrane) was present in cattle but was indistinct histologically in other domestic animals. They reported that the anterior epithelium consisted of basal cells and superficial squamous cells. They found that the stroma or substantia propria was the main constituent of the cornea and composed of bundles of collagen fibers. According to them, the posterior
limiting membrane (Descemet’s membrane) was the exaggerated basal lamina of posterior epithelium and was formed by the fine collagen fibrils. Further they observed that the posterior epithelium was made up of single layer of cuboidal cells.

Banubakode (1992) studied the histology of cornea in cattle and observed five layers as above. He reported that the epithelium was stratified squamous non-keratinized type and composed of 7 to 12 rows of epithelial cells. Bowman’s membrane was homogeneous in appearance and seen to be continuous with the substantia propria, which constituted the major part of the cornea. The substantia propria was noted to be composed of regularly arranged sheets or lamellae of the collagen fibers. The Descemet’s membrane was homogeneous in appearance and the most posterior layer, the endothelium was composed of single row of flattened polygonal cells.

Ramkrishna et al. (1997) studied the histomorphology of cornea in Indian water buffalo. They reported that the cornea was thickest at the cornea-scleral junction and the cornea consisted of four layers (1) Anterior corneal epithelium (2) Substantia propria (3) Descemet’s membrane and (4) Corneal endothelium. According to them, the anterior corneal epithelium was composed of stratified squamous non-keratinized epithelium having 5-10 layers. The subepithelial basal lamina was not evident. Substantia propria was more compact towards the epithelium and consisted predominantly of collagen and elastic fibers with fibroblast cells running parallel to the surface of cornea. Corneal endothelium consisted of a single layer of low cuboidal cells with round or elongated vesicular nuclei.

Khaled (2003) reported that in bovine, the corneal epithelium, was a stratified squamous consisting of 14-17 layers of epithelial cells. The next membrane, membrane of Bowman, was prominent in bovine cornea. The substantia propria was composed of collagenous fibers arranged in regular layers parallel to each other. The predominating
cell type of the corneal substantia propria was the fibroblast, located mainly between the collagen layers. The Descemet’s membrane was a fairly thick, glossy, homogeneous membrane and consisted mainly of collagen fibers. The corneal endothelium consisted of single layer of low cuboidal cells or single layer of flattened cells.

Konig and Liebich (2004) mentioned that cornea in domestic animals composed of five layers: a) anterior epithelium, b) anterior limiting membrane or Bowman’s membrane, c) substantia propria (stroma), d) posterior limiting membrane or Descemet’s membrane and e) posterior epithelium. The anterior epithelium consist of several layers of the squamous cell and was continuous with bulbar conjunctiva. The substantia propria consisted of the collagen fibers that were arranged in distinct lamellae and keratocytes which were arranged between these lamellae. The cornea was avascular. The posterior epithelium was composed of the simple squamous epithelium.

Dellmann (1993) noted that the cornea was composed of five layers: (a) anterior epithelium, (b) subepithelial basement membrane, (c) substantia propria, or stroma, (d) posterior limiting lamina (Descemet's membrane) and (e) posterior epithelium (corneal endothelium).

Gelatt (2007) noted that cornea of domestic animals was consist of four, and sometime five layers viz. the epithelium, Bowman's layer (rarely present), stroma, Descemet's membrane and endothelium. In larger animal the anterior epithelium was consist of the single cell layer of basal cells, which were columnar in shape and lied on a thin basement membrane. Corneal epithelium was thicker at the periphery of the cornea than the center. Beneath the anterior epithelium there was a basement membrane, which was enhanced histologically when stained with periodic acid – Schiff (PAS). The substantia propria comprised 90% of the thickness of the cornea. The bulk of corneal stroma was composed of thin collagen fibrils. Bowman’s layer was not seen
in most animals as described in primates. Bowman’s membrane had been described in herbivores animals and most recently in giraffe. Descemet’s membrane was a homogenous, acellular membrane which was actually an exaggerated basement membrane of the posterior endothelium. The corneal endothelium was a single layer of flattened cells lining the inner cornea.

2.3.3 Micrometry of cornea

Prince et al. (1960) in goat noted that the substantia propria was about 0.66 mm thick, Descemet’s membrane was from 30 to 45 micron and the endothelium was about 4 micron (µm) thick. The peripheral and central total thickness of the sheep were 0.6 mm and 0.5 mm, respectively.

Camber et al. (1987) studied the histology of pig cornea. They noted that the number of cell layers in the epithelium was 17 to 23 and the mean thickness of the cornea was 722 µm.

Banubakode (1992) reported the mean value of the thickness of the cornea in cattle as 933.72 ± 15.35 µm. He reported that the mean value of the thickness of the different layers of the cornea as Epithelial layer: 72.08 ± 2.90 µm, Number of epithelial cell layers: 9.28 ± 0.17 and Endothelium: 2.22 ± 0.067 µm.

Khaled (2003) reported that the mean value of the thickness of the different layers of bovine cornea as Corneal epithelium: 98 ± 1.5 µm, Substantia propria: 580 ± 4.0 µm, Descemet’s membrane: 30 ± 1.0 µm and Corneal endothelium: 8 ± 0.3 µm.

2.4 LENS

Maggs et al. (2008) in domestic animals mentioned that the lens was a transparent, avascular, biconvex body with an anterior surface that was flatter or less curved than the posterior surface. The centers of the anterior and posterior surfaces were called as anterior and posterior poles. The rounded circumference was the equator,
which has numerous irregularities where zonular fibers attached. Its anterior aspect was in contact with the posterior surface of the iris and filled the pupil. Its posterior aspect was in contact with the vitreous body.

2.4.1 Biometry

Prince et al. (1960) recorded the diameter of the lens in goat which was 13.8 mm and A-P axis of the lens was 10 mm. The anterior curvature of the crystalline lens was considerably steeper than the posterior curvature and as a result the iris pushed forward slightly to make a relatively shallow anterior chamber.

Panchbhai et al. (1988) recorded the biometry of the lens in buffalo calves. They recorded that the weight, antero-posterior axis and diameter of the lens were 1.56 gm, 1.004 cm and 1.47 to 1.84 cm, respectively.

Banubakode (1992) reported the mean value of the different measurements of the lens in cattle as: weight of the lens 2.21 ± 0.035 gm, thickness of the lens 1.22 ± 0.008 cm and diameter 1.84 ± 0.009 cm.

Gelatt (2007) mentioned that weight of the lens of sheep was about 2.3 gm and average diameter and central thickness were 14.5 mm and 10.0 mm, respectively.

2.4.2 Histology

Prince et al. (1960) described histological structure of lens in goat. They observed that the lens was covered by connective tissue capsule which varied in thickness, increasing particularly in the regions of attachment of the zonular ligaments. Behind the anterior surface of capsule there was a single layer of cuboidal epithelium. He noted that the posterior surface of lens was devoid of epithelial cells.

Dellmann (1993) described microscopic structure of the lens in the dog and found that lens was composed of lens capsule, lens epithelium and lens fibers. The lens was entirely surrounded by the lens capsule, which were made up of collagen fibrils.
arranged in several layers of lamellae. The rostral surface of the lens was lined by a simple cuboidal to columnar epithelium and at the equator, the epithelium differentiated into lens fibers. In the course of this process, the nuclei and most of the cells organelles were disappeared.

Gelatt (2007) in domestic animals noted that lens was completely enclosed within a thick, PAS positive elastic capsule. The thickness of the capsule varied by region, with the thinnest being the posterior pole. Inside the anterior capsule there was a single layer of lens epithelium. The cells were cuboidal to squamous, become columnar near the equator and elongated into slender hexagonal lens fibers. The lens epithelium lined only the anterior lens capsule.

2.4.3 Micrometry

Prince et al. (1960) in goat mentioned that anteriorly the capsule was 50 µm thick, and at the equator and posterior surface it was 20 µm thick each.

Gelatt (2007) in canine noted that lens capsule was 8 to 12 µm thick at the equator, 50 to 70 µm thick anteriorly, and only 2 to 4 µm thick posteriorly.

2.5 SCLERA

2.5.1 Histology

Prince et al. (1960) in goat noted that sclera was mainly composed of collagenous and elastic, varied considerably in shape and thickness. Surrounding the sclera there was a thin elastic and vascular membrane called the episclera.

Leeson and Leeson (1970) in domestic animals noted that the sclera is a white, tough layer of dense connective tissue which formed the posterior 5/6 of the fibrous tunic that protects the eye and maintains its form.

Ramkrishna et al. (1997) studied the histomorphology of fibrous tunic of eye ball in Indian water buffalo. They reported that the sclera was fibro-vascular and was
divisible into episclera, sclera proper and lamina fusca. The episclera was loose and vascular having fibrous connective tissue. The sclera proper was made of dense regular connective tissue with few elastic fibers and fibroblast cells. Adjacent to the choroid, the pigment cells formed lamina fusca.

Khaled (2003) reported that in the bovine eyeball, the sclera consisted of flat ribbons of collagenous bundles running in various directions with fine elastic nets, fibroblasts and occasional melanocytes between them. He noted that the sclera can be subdivided into three layers: the outermost layer, the episcleral tissue which consisted of loose fibroelastic tissue. In the middle layer, the sclera proper (substantia propria), which was composed of bundles of collagenous fibers were oriented mainly parallel to the surface but with some interweaving. The innermost layer, termed the lamina fusca or dark layer, was composed of much smaller bundles of collagenous fibers.

Konig and Liebich (2004) in domestic animals mentioned that the substantia propria of the sclera consist of a dense network of collagen fibers in parallel orientation. Some elastic fibers were dispersed within this collagenous network.

Dellmann (1993) in domestic animals mentioned that sclera was a white, tough layer of dense irregular connective tissue. Bundles of collagen fibers contained a few elastic fibers and elongated fibroblast as well as melanocytes in some areas, and arranged parallel to the surface of the globe. In the layer of the sclera adjacent to choroid, elastic fibers were predominated and fibroblasts and melanocytes were more numerous, this layer was referred to as the lamina fusca sclerae. The optic nerve leaved the eye through numerous perforation in a disk like area referred to as the area cribrosa sclerae.

Gelatt (2007) noted that sclera merged with the peripheral cornea and the bulbar conjunctiva to formed transition zone i.e. limbus. At this point it was pigmented to
varying degree. The sclera contained elastic fibers that were interlaced among the collagen fibers, melanocytes (anteriorly) and fibrocytes. Scleral thickness varied considerably among and in different areas of the globe. It was thinnest at equator, especially at the insertion of the extraocular muscles whereas, it was thickest at the region of the optic nerve entrance or posterior pole. The external boundary of the sclera was in the form of thin collagenous and vascular membrane i.e. episclera.

Maggs et al. (2008) in domestic animals described that the sclera was composed of three layers. From outside to inside they were the episclera, the sclera proper or scleral stroma, and the lamina fusca. The episclera was composed of a dense, highly vascular, fibrous layer that binds Tenon’s capsule to the sclera. Collagenous fibers within the episclera blend into the superficial scleral stroma. The scleral stroma, like the corneal stroma, was composed of collagen fibers and fibroblasts. However, scleral collagen fibers differ in diameter and shape, run in different directions in different parts of the globe, and were not regularly spaced, thus making the sclera nontransparent. The lamina fusca was the zone of transition between the sclera and the outer layers of the choroid and ciliary body.

### 2.5.2 Micrometry

Prince et al. (1960) reported that in goat near the limbus it had the same thickness as the cornea but it then decreased rapidly to its minimum thickness at the equator (0.2 mm), and then thickened again to attain its maximum thickness at the posterior pole (1.5 mm).

Konig and Liebich (2004) mentioned that the sclera varied in thickness, being thinnest near to the equator (up to 0.5 mm) and gaining in thickness towards the posterior pole of the eye ball in domestic animals.
Gelatt (2007) in sheep reported that the thickness of the sclera at center of the posterior wall and entry point of the optic nerve was about 1.0 - 1.2 mm, there was no increase in thickness of the sclera at entry point of the optic nerve. At equator of the globe and limbus it was 0.25-0.30 mm and 0.4-0.5 mm, thick respectively.

2.6 CHOROID

2.6.1 Histology and Micrometry

Prince et al. (1960) reported the histological structure of the choroid in goat. They found that the choroid was made of four layers which were suprachoroidea, a layer of large blood vessels, choriocapillaris (layer of small vessels) and Bruch’s membrane. They noted that the suprachoroidea layer was an avascular membrane of elastic fibers, pigmented connective tissue and fine transparent lamellae, with fibroblast on their surface. A layer of large blood vessels was very prominent. Bruch’s membrane was also rather difficult to identify except in the region where tapetum was thickest. Bruch’s membrane divided the choriocapillaris from the outermost layer of the retina. The tapetum was a reflecting layer of tissue which was fibrous in ungulates. It was situated behind the retina between the choriocapillaris and large blood vessels layer of the choroid. At its thickest point, the tapetum appeared to be 30 µm thick, tapering gradually to its border. Thickness of the choroid in the goat was about 50 µm excluding a tapetum. Whereas in sheep it was 60 µm thick in the center of the fundus.

Ramkrishna et al. (1997) reported that the choroid of Indian water buffalo was highly vascular and comprised of five layers which were (1) Suprachoroid layer (2) Vessel layer (3) Tapetum fibrosum layer (4) Choriocapillary layer and (5) Basal complex or Bruch’s membrane. They noted that the suprachoroid layer consisted of the collagen and elastic fibers along with pigment cells. The vessel layer was composed of very large blood vessels separated by the suprachoroidal stroma. The tapetum fibrosum
layer was fibro-vascular and the thickness was inconstant due to overlying vessel layer and the arterioles surrounded by pigment cells were seen in this layer. The fourth layer, choriocapillaris layer, consisted of a single layer of capillaries next to the tapetum and also the capillaries were arranged in a continuous chain form. The basal lamina of these capillaries appeared to be fused with Bruch’s membrane. The basal complex or Bruch’s membrane was found to be sandwiched between the chorio-capillary layer and pigment epithelium of retina.

Khaled (2003) reported that in the bovine eyeball, the choroid can be subdivided into four layers such as (1) the suprachoroid layer (46 ± 1.5 μm) consisted of bundles of collagen. They were separated by numerous spaces, the perichoroidal spaces, and were continuous with the connective tissue of the sclera. (2) The vessel layer consisted of intercrossing large (72 ± 2.5 μm) and medium sized (40 ± 1.4 μm) arteries and veins, separated by loose connective tissue stroma rich in chromatophores. It contained strands of smooth muscle cells. The tapetum was fibrous, consisting of dense regular connective tissue fibers. The choriocapillary layer (50 ± 1.5 μm) contained a dense network of capillaries. It was immediately adjacent to the pigmented epithelial layer of the retina. The basal complex, also referred to as Bruch’s membrane (0.6 ± .005 μm) separated the choroid from retina.

Konig and Liebich (2004) in domestic animals mentioned that choroid was a pigmented, highly vascular layer. It was composed of four layers: 1) Suprachoroidea, 2) Vascular layer, 3) Tapetum lucidum and 4) Choriocapillaris layer.

Dellmann (1993) in domestic animals mentioned that the choroid can be subdivided into five layers which were suprachoroidea layer, vessel layer, tapetum lucidum, choriocapillaris layer and basal complex. The suprachoroidea layer was loosely structured consisting of bundles of collagen fibers and some elastic fibers. The
cell population of this layer was consisted of fibroblast, numerous flat melanocytes, and occasional macrophages. The tapetum was a light reflecting layer which was not present throughout the choroid, located mainly in the dorsal half of the fundus of the eye. In herbivores the tapetum was fibrous, consisting of intermingling collagen fibers and few fibroblast. The choriocapillaris layer was a dense network of capillaries immediately adjacent to the pigmented epithelial layer of the retina. It separated the choroid from the retina.

Gelatt (2007) in domestic animals described that histologically choroid had externally to internally five layers which were suprachoroidea, stroma with large vessels, stroma with medium sized vessels and tapetum and choriocapillaris. The suprachoroidea consisted of elastic, heavily pigmented connective tissue that formed a transition between the sclera and the choroid. Immediately internal to the suprachoroidea there was a vascular large vessels layers which were embedded in loose connective tissue containing melanocytes and fibrocytes. A small layer of medium sized vessels and pigmented reticular connective tissue lied internally to the large vessels layer. In most domesticated animal, the dorsal portion of the choroid at the medium sized vessel layer contain a layer of reflective tissue called tapetum lucidum. The tapetal layer was composed of regularly arranged collagenous fibers in goat and other herbivores. The choriocapillaris was the innermost layer of choroidal vessels, forming a thin layer of capillaries which was separated from the retinal pigment epithelium (RPE) by a basement membrane complex known as Bruch’s membrane.

2.7 CILIARY BODY

Ramkrishna et al. (1997) reported that in Indian water buffalo, the ciliary body formed the ring and presented ciliary muscle and processes. The smooth muscle fibers were parallel to sclera, meridional in arrangement with few circular fibers. The basal
plate presented connective tissue core with large blood vessels. The ciliary processes consisted of numerous thin folds covered by two layer stratified cuboidal epithelium, whose superficial cells were non pigmented while the deeper tall columnar were deeply pigmented. The peculiarity of these cells was reported that the apices of the layer had its own basal lamina.

Khaled (2003) reported that in the bovine eyeball, the ciliary body consisted of the following layers: the supraciliaris (10 ± 1 μm) layer consisting of bundles of collagen and some elastic fibers. The cell population of this layer consists of fibroblasts, numerous flat melanocytes, some smooth muscle cells and occasional macrophages. The stroma of the ciliary body (656 ± 7.1 μm) contained a large number of blood vessels, arteries and veins and this layer extended as dense network of capillaries into the ciliary processes. The Bruch’s membrane of the ciliary body (5 ± 0.1 μm) was continuous with the Bruch’s membrane of the choroidea and extended anteriorly to the root of the iris. The pigmented epithelium layer (22 ± 0.8 μm) was the continuation of the pigmented epithelium of the retina. It consisted of simple cuboidal or low columnar cells with rounded nuclei. The nonpigmented epithelial layer (15± 0.5 μm) was the internal cellular lining of the ciliary body with cuboidal or low columnar cells containing oval nuclei. Each ciliary process consisted of a central core of connective tissue stroma and blood vessels covered by a double layer of epithelium: an inner, pigmented, cuboidal epithelium and an outer nonpigmented cuboidal epithelium.

Dellmann (1993) mentioned that the ciliary body was the direct anterior continuation of the choroid. It begin posteriorly at the ora serrata, a sharply outlined dentate border that marks the transition between the optic part (pars optica retinae) and the blind part (pars caeca retinae) of the retina. Anteriorly, the ciliary body was continued with the iris and participates in the formation of the trabecular meshwork of
the irido-corneal angle. All layers of the choroid extend into the ciliary body, except the tapetum lucidum and the choriocapillary layer. Anteriorly, the ciliary body projected ciliary processes into the posterior chamber. Collectively, the ciliary processes formed a region of the ciliary body referred to as the pars plicata (corona ciliaris). The processes greatly increased the surface area for production of aqueous humor and also serve as the origin for zonular fibers, which attached to the lens. The posterior portion of the ciliary body was flat and smooth and was referred to as the pars plana. Histologically, the ciliary body consisted of ciliary epithelium, a vascular layer, and the ciliary muscle.

Gelatt (2007) described that the ciliary body was an anterior continuation of the choroid, and it joined with the iris. The largest component of the anterior uvea was triangular in sagittal section, with its apex continuing into the choroid, the inner side facing the lens and vitreous body, and the outer side facing the sclera. Topographically, the ciliary body was divided into an anterior pars plicata (i.e., corona ciliaris) and a posterior pars plana. The pars plana was the first flat, posterior portion extending from the posterior termination of the processes to the peripheral termination of the retina (i.e., ora ciliaris retinae). Each ciliary process consisted of a central core of stroma and blood vessels covered by a double layer of epithelium; an inner, nonpigmented, cuboidal epithelium, which formed a complete, internal monocellular lining of the ciliary body; and an outer, pigmented, cuboidal epithelium, which also was only one cell layer thick.

2.8 IRIS

Ramkrishna et al. (1997) reported that in Indian water buffalo, the thickness of the iris was decreased towards the free margin. The stroma was composed of loose connective tissue with blood vessels, melanocytes and fibroblasts. The anterior surface consisted of pigmented cells and the posterior surface showed two layered pigmented
epithelium. The superficial non pigmented epithelium of the ciliary processes formed superficial layer of cells, however which were heavily pigmented while the deeper cells were less pigmented. No iridial granules (granula iridica) were reported to be seen along the pupillary margin of the iris. The sphincter muscles were seen along the pupillary margin, while the dilator muscles were seen at the base of the ciliary processes.

Khaled (2003) reported that histologically the bovine iris consisted of three layers: 1) An anterior epithelial layer which consisted of fibroblasts and melanocytes and was continued across the iridocorneal angle into the posterior epithelium of the cornea. 2) A middle layer of connective tissue stroma, which contained two smooth muscles (dilatator and sphincter pupillae muscles) and 3) The posterior layer of the pigmented epithelium. He also reported the presence of granula iridis (iris granules) at the pupillary edge of the stroma of the iris. They were large cysts filled with fluid, lined by pigmented epithelium and show a dense capillary network.

Gellat (2007) described that the iris was divided into the anterior border layer, the stroma and sphincter muscle and histologically the posterior epithelial layers. The iris stroma was composed of fine collagenous fibers, many chromatophores, and fibroblasts. Along the upper edge of the pupil in herbivores, several round black masses are present. They vary in size and were called granula iridica (i.e. corpora nigra). Similar smaller masses also exist on the lower edge of the pupil. These pigmented masses, which were extensions of the posterior pigmented epithelium. This granula iridica was not seen in carnivores.

Zayed et al. (2012) reported that in buffalo histologically, the iris was covered anteriorly by a thin epithelial layer consisting of flat or fusiform cells underlined by a thin layer of spindle-shaped melanocytes (anterior stromal sheath) and posteriorly by a thick pigmented epithelium formed by highly folded layer of cuboidal to low columnar
pigmented epithelial cells. The stroma of the iris was composed of a network of fine collagen fibers, which host blood vessels, iridial muscles and numerous melanocytes. Towards the pupillary border of the iris, the posterior pigmented epithelium demonstrated cystic-like collections forming the Corpora nigra.

2.9 IRIDO-CORNEAL ANGLE

Gelatt (2007) described that the irido-corneal angle (ICA) was formed by the junction of the corneoscleral tunic, base of the iris and an anterior recession of the ciliary body, which was known as the cilioscleral sinus or cleft. Pectinate ligaments span the opening of the cilioscleral sinus from the pigmented corneoscleral junction to the root of the iris. Behind the pectinate ligaments and within the cilioscleral sinus was a matrix of loose tissue strands, the trabecular meshwork. The trabecular meshwork consists of crisscrossing collagen cords that are covered by cells.

Kassab et al. (2001) reported that buffalo irido-corneal 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 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 was 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.

Kassab and Zoghby et al. (2010) in goat reported that irido-corneal angle was comprised of the pectinate ligament, the ciliary cleft, the trabecular meshwork (uveal and corneoscleral) and the angular aqueous plexus.

2.10 RETINA

2.10.1 Histology and Micrometry

Retina lied only in the posterior portion and covered the choroid. The retina was composed of a sensory portion, also referred to as the pars optica retinae, and a non-sensory portion, which begin at the ora serrata and covered the ciliary body, as the pars ciliaris retinae, and the iris, as the pars iridis retinae. (Prince et al., 1960; Bloom and Fawcett, 1970; Leeson and Leeson, 1970; Tortora and Anagnostakos, 1981; Samuelson, 1999).

Prince et al. (1960) described the histology of the retina in goat. They noted that retina was composed of ten layer and these were: (1) pigment epithelium, (2) visual cell layer, (3) external limiting membrane, (4) outer nuclear layer, (5) outer plexiform layer, (6) inner nuclear layer, (7) inner plexiform layer, (8) ganglion cell layer, (9) optic nerve fiber layer, and (10) internal limiting membrane.

Adjacent to the choroid there was a layer of flat polygonal cells which were more adhered to the choroid than the visual cell layer. Pigment epithelium was free of pigment where it was backed by tapetum and its thickness was about 20 µm in goat. The visual cell layer was consisted of visual cell which were: the rods and cones which react to the light. External limiting membrane was composed of the outer ends of Muller’s fibers which was passed through the rest of the retina, and the inner ends of which form the inner limiting membrane. The outer nuclear layer was consisted of the
nuclei of the rods and cones. The outer nuclear layer was consisted of about 5 rows of cells measured 30 µm in goat although at the posterior pole this was slightly increased as there were 6 or 7 rows of cells. The outer plexiform layer was consisted of the terminal arborizations of the rod and cones axon, and the dendrites of the bipolar cells of the adjacent inner nuclear layer. They measured thickness of the outer plexiform layer which was about 15 µm. The inner nuclear layer was formed by centripetal bipolar cells and horizontal cells. The cells in this layer maintained connection between the visual cell layer and ganglion cell layer but horizontal cells was not involved in the actual transmission of stimuli. Inner nuclear layer was 26 to 30 µm thick in goat with 5-6 rows of cells. The inner plexiform layer was also consisted of the arborization of the bipolar cells of the inner nuclear layer and ganglion cell layer on its another side. It was about 30 µm thick in goat. The dendrite of the ganglion cell layer branched to a number of bipolar in the inner plexiform layer. The internal limiting membrane was innermost layer of retina.

Dellmann (1993) in domestic animals mentioned the microscopic structure of the retina. Except at the transition towards the ora ciliaris retinae and at the optic disc, the retina was composed of the ten layers.

Gelatt (2007) in domestic animals described that the inner sensory retina contain nine layers, and the supportive pigmented epithelium was the tenth layer. The optic retina extended from the optic disc to the ora ciliaris retinae, in which it was reduced to the two epithelial cell layers of the ciliary body. The retinal pigmented epithelium (RPE) was a layer of flat, polygonal cells that form the outermost part of the retina. The cell were usually densely pigmented but they were devoid of pigment overlying the dorsal choroid that contain the tapetum lucidum. The basement membrane of the RPE and adjacent choriocapillaris formed a complex called Bruch’s membrane. The
neurosensorial layer varied in thickness, being thickest near the optic disc and tapering to the ora ciliaris retinae. The width of each layer decreased but the nerve fiber layer contributed the most to the variation in thickness. Most animals had a central retina of approximately 200 to 240 µm and a peripheral retina of 100 to 190 µm. The thickness of the equine retina which was varied from 80 µm at the ora ciliaris retinae to 250 µm medial to the optic nerve and it was for the most part less than 130 µm. None of the domestic animal had a fovea, but an area of high cone density frequently occurred i.e. area centralis. This area lied 3 to 4 mm dorsolateral to the optic disc in the goat. The visual streak was the region of the retina with greatest concentration of the ganglion cells. The visual cell layer contained the only the outer and inner segment of the rods and cones with their nuclei in the outer nuclear layer. Outer nuclear layer contained the soma or cell bodies of the photoreceptors cell. The number of rows of nuclei varied greatly according to the species and location in the retina. In the central retina, the dog and cat possess the greatest depth of rows which were 12-15 and 19-20 respectively, whereas 5 in the horse and pig and 10 in the cattle. The outer nuclear layer gradually become thin in the peripheral retina as the density of rods and cones decreased. Cone nuclei were universally situated next to the external limiting membrane. In mammals, cones were usually larger, oval and more euchromatic than the rod nuclei. Rod nuclei were smaller, round to oval, darker and more heterochromatic. The outer plexiform layer consisted of synapse between the rods and cone axon and dendrites of the bipolar and horizontal cell. Inner nuclear layer was consisted of the soma of the horizontal, bipolar, amacrine and Muller cells. The horizontal cell nuclei were positioned along the outermost margin of the inner nuclear layer, whereas the amacrine cell were positioned along the innermost margin. The bipolar nuclei and Muller cell nuclei compose the intermediate zone of the inner nuclear layer. The inner plexiform layer was the synaptic
region between the first and second order neuron and it was notably thicker than the outer plexiform layer in all vertebrate animals especially those have fovea or well defined area centralis. Ganglion cell layer was the inner most layer of the retina and consist of the single layer of cell, except in the area centralis and visual streak at which it might be two or three cell layer thick. Axon of ganglion cell gathered in the nerve layer, then turn at right angle and course to the posterior pole, at which the optic nerve exit. Large retinal blood vessels occur in the nerve fiber layer as well as in the ganglion cell and inner plexiform layer. The nerve fiber layer increased in thickness as it approached the optic disc.

Germain et al. (2010) reported that vertebrate retina was organized in superimposed layers, formed by the different cells. The retina contain five major types of cells: photoreceptors (rods and cones), bipolar cells, horizontal cells, amacrine cells and ganglion cells. In general, cell somas were grouped in three distinct nuclear layers, separated by two connecting plexiform layers, where synapses between cells are formed. The innermost layer was the ganglion cell layer, which contained the cell bodies of the ganglion cells and displaced amacrine cells. The next cell layer was the inner nuclear layer, which contained the cell bodies of the amacrine cells, the bipolar cells, and the horizontal cells; it may also contain some displaced ganglion cells. The next cell layer was the outer nuclear layer, which contained the cell bodies of the photoreceptors. Outside of these layers, the layer of photoreceptor outer segments contained the light-sensitive elements of the retina. Interspersed between the ganglion cell layer and the inner nuclear layer was the inner plexiform layer, which contains the axons of bipolar cells, dendrites of ganglion cells, cell processes of amacrine cells (axons and/or dendrites) and displaced cell bodies of the amacrine cells. Between the outer and inner nuclear layers there was the outer plexiform layer, which contained the
axon terminals of photoreceptors, the dendrites of bipolar and cell processes of horizontal cells (axons and/or dendrites).

2.10.2 Artifacts of retina

Margo and Lee (1995) reported the role of fixative osmolarity in the production of tissue artifact in whole eye ball fixation. They reported that Whole eyes fixed in 4% buffered formaldehyde (10% neutral buffered formalin) demonstrate a variety of artifacts, including separation of the neurosensory retina from the retinal pigment epithelium. They postulated that the osmolarity of 4% buffered formaldehyde causes contraction of the internal compartments of the eye leading to several artifactual changes commonly observed in routine histologic sections.

Chen and Nathans (2007) reported that in diverse mammals, multiple microscopic retinal folds or pseudorosettes were associated with some inherited retinopathies, foetal or early postnatal exposure to cytotoxic chemicals or ionizing radiation, and a variety of foetal or early postnatal viral infections.

Milles (2012) mentioned that folding of retina (Lang’s fold) usually occurred in eye ball neonates and children which has been subjected to fixative such as formalin. This artifacts of fixation was not observed in the living eye or in unfixed eye. Lang’s fold was thought to be resulted from traction on peripheral retina by shortening of the vitreous humor base and posterior lens zonules caused by tissue fixation. Retinal detachment was another retinal artifacts in which retina was detached from the RPE.

2.10.3 Optic disc

Prince et al. (1960) in goat mentioned that optic nerve head was slightly oval with horizontal axis longer than the vertical. The lamina cribrosa was very powerful in this animal and it was 0.4 mm thick. The large retinal vessels can be clearly seen in section passing through the lamina cribrosa.
Gelatt (2007) in domestic animal mentioned that retinal ganglion cell axon leaved the nerve fiber layer and formed the optic nerve head or optic disc and from this area they passed through the choroid and sclera and enter into the orbit. The optic disc included the retinal and choroidal portion of the optic nerve.
CHAPTER III

MATERIALS AND METHODS

The present work was carried out on “Gross And Histomorphological Study On Eye Ball Of The Adult Marwari Goat (Capra hircus)” at the Department of Veterinary Anatomy and Histology in collaboration with Department of Veterinary Surgery & Radiology and Department of Veterinary Pathology. The eye balls of ten adult goats were collected immediately after slaughter from the abattoir.

Immediately after collection of eye balls, they were subjected for ocular ultrasonography and biometry. The dissection of the eye balls were carried out by freeing the fat, the extra ocular muscles and the periorbital tissue in order to facilitate the correct measurement of the eye balls. The dorsal and ventral sides of the eye balls were determined by observing the tendon of dorsal oblique muscles and ventral exit of optic nerve respectively. The medial and lateral sides of the eye balls were detected by finding more pointed lateral end of oval shaped cornea. The ocular ultrasonography and measurement of the different parameters of the ten eye balls were recorded as below:

3.1 SONOANATOMY AND ECHOBIOMETRICAL DIMENSIONS OF THE EYE BALLS

Ultrasonographic anatomy (sonoanatomy) and ocular echobiometrical dimensions of the ten eye balls were done by using ultrasound machine (e- saote MY Lab 40 VET) using 7.5-18 MHz linear transducer (Fig.1A & 1B). The focal range of 7.5-10 MHz was used for scanning of vitreous chamber and retinal wall and 12-18 MHz was used for the scanning of the anterior chamber and lens (Kumar, 2012). Time gain compensation was adjusted to meet the clear image.
Following ocular echobiometrical dimensions (Fig. 2) were measured -

I. **Anterior chamber depth**: Distance between echoes from the posterior corneal surface and the anterior lens surface.

II. **Antero-posterior depth of the lens**: Distance between echoes from the anterior and posterior surface of the lens.

III. **Vitreous chamber depth**: Distance between echoes from the posterior lens surface and the retina.

IV. **Antero-posterior axis of the eye ball**: Distance between echoes from the posterior corneal surface to the retina.

### 3.2 BIOMETRY OF THE EYE BALL

Following biometrical observations of the eye balls were measured as below-

I. **Weight**: Each eye ball was weighed on the scientific weighing machine.

II. **Antero-posterior axis**: The distance between the anterior and posterior pole of the eye ball was measured by using digital Vernier caliper.

III. **Horizontal axis**: It was recorded as the distance between the entrances of the long posterior ciliary arteries on either side of the eye ball.

IV. **Vertical axis**: It was measured as the distance between the point of insertion of the dorsal oblique muscles and a point just ventral to the optic nerve (Fig. 3).

### 3.3 CORNEA

Following biometrical observations of cornea were measured as below-

I. **Horizontal diameter of the cornea**: It was recorded as longest medio-lateral distance of the cornea with the help of digital Vernier caliper.

II. **Vertical diameter of the cornea**: It was measured as the maximum vertical diameter of the cornea with the help of digital Vernier caliper.
III. Central and peripheral thickness of the cornea: It was measured as thickness of the cornea at mid central and periphery of the cornea.

Histological Procedure:

After taking ocular ultrasonography and biometry of the eye balls and cornea, whole eye balls were processed for histological preparation, 8-10 mm long incision was given in the limbus at 12 O’clock position. Then whole eye ball fixed in Davidson’s fixative for 24-30 hours.

Davidson’s fluid is an excellent fixative for fixation of whole eye ball but conventional 10% formalin causes artificial cellular shrinkage and poor cellular and nuclear resolution of the retina. Formaldehyde penetrate tissue well but takes more time because sclera stand as a physical barrier that protect the retina and inhibit the penetration of fixative (Shara et al., 2013). Davidson’s fixative is an acetic acid-alcohol- formalin based fixative in which alcohol denatured the protein by breaking hydrogen bonds and disturbing their tertiary structure and acetic acid increase the penetration. It has been advocated and widely used for the preservation of eye ball, maintaining retinal attachment during fixation and processing and providing better preservation of the retinal nuclear layer and sensory specialization of the rods and cones (Latendresse et al., 2002).

Composition of Davidson’s Fluid (Latendresse et al., 2002)-

1) 39 % Formaldehyde: 2%
2) Ethanol: 35%
3) Glacial Acetic Acid: 10%
4) Distilled water: 53%

After fixation, incision in the limbus was extended, then lens was extracted out and subjected for gross morphological study and biometry.
3.4 LENS

The measurement of different parameters of the lens were recorded as follows:

I.  **Weight**: Each lens was weighed on the scientific weighing machine.

II. **A-P axis**: A-P axis of the lens was measured as the maximum distance between the highest points on both the curvature of the lens by using the digital Vernier caliper.

III. **Maximum Diameter**: Maximum diameter was recorded as the maximum distance between the points where two curvature meet each other with the help of digital Vernier caliper (fig.4).

3.5 HISTOLOGY OF SCLERA, CORNEA, LENS, CHOROID, CILIARY BODY, IRIS, IRIDO-CORNEAL ANGLE AND RETINA

The tissue pieces of the cornea and lens of 4-8 mm size and tunic (sclera, choroid and retina) of eye balls of 3-4 mm width were cut along with iris and ciliary body from the different regions because it was helpful to prevent detachment of retina from the choroid. Keep them in tap water for 60 to 90 minutes for sufficient removal of fixative and treated with ascending grade of alcohol and cleared in xylene (Humason, 1966). Then the tissue were embedded in paraffin as per the method suggested by Drury and Wallington (1980).

The paraffin sections of 5 µm thick were taken and subjected to routine and special staining techniques as under:

3. Periodic Acid Schiff (PAS), (Singh and Sulochana, 1996).


3.6 MICROMETRY

The micrometrical measurements were recorded by using 10X graduated eye piece (fig.5) for the component of different tunics of the eye ball as follows:

1. Total thickness of the sclera at anterior/limbus, equator and posterior side.

2. Total thickness and thickness of different layers of the cornea at mid central and periphery/limbus of the cornea.

3. Total thickness of the choroid at anterior/ora ciliaris retinae, equator and posterior side.

4. Total thickness of the retina at anterior/ora ciliaris retinae, equator and posterior/optic disc.

5. Thickness of the different layers of the retina at equator.

The section of the sclera, cornea, lens, choroid, ciliary body, iris and retina were micro graphed. The statistical analysis was carried out to derive the mean, standard error (S.E.), coefficient of variation (C.V. %) and ‘t’ test.
The present study entitled “Gross And Histomorphological Study On Eye Ball Of The Adult Marwari Goat” was carried out at the Department of Veterinary Anatomy & Histology in collaboration with Veterinary Surgery & Radiology and Veterinary Pathology, College of Veterinary Science & A. H., Anand Agricultural University, Anand, Gujarat. The observations and the results of measurements of different structures of the eye ball including sclera, cornea, lens, choroid, ciliary body, iris and retina in adult Marwari goat were recorded in the present study. The study was made irrespective of the sex of animals. The results of the present study have been discussed under different headings as follows:

4.1 Sonoanatomy and Echobiometrical dimensions of the eye ball

4.1.1 Sonoanatomy

Two- dimensional B-mode ultrasonography (USG) was performed using linear array transducer (7.5 MHz to 18 MHz) to evaluate the internal structure of normal eye ball (fig.6). Sonoanatomy of the adult Marwari goat revealed cornea as a thin hyperechoic layer which formed the anterior wall of the anterior chamber. The cornea appeared as a double-peaked echo (2 convex interfaces) with a central, narrow anechoic space. The anterior chamber and vitreous body were visualized having anechoic appearance, with few reflectors. It was bordered by the cornea, iris and anterior reflection of the lens capsule. The anterior chamber was distended with the anechoic aqueous humor. The ciliary body and iris were seen as echogenic linear structure which extend from the peripheral globe towards the lens. The corpora nigra or iridica granules
were seen as an echogenic round structure on the anterior surface of the dorsal iris. The anterior lens capsule was appeared as a convex echogenic line which was separated from the concave echogenic line of the posterior lens capsule by the anechoic lens. The vitreal chamber was filled with anechoic fluid. The retinal layer was appeared as linear echogenic line. In the present study, it was not possible to identify individual retinal, choroidal or scleral layer. The present study on ultrasonographic observations of the adult Marwari goat are similar as described by Whitcomb (2002) in eye ball of horse, Assadnassab and Fartashvand (2013) in eye ball of buffalo. However, in contrary to present study the corpora nigra was not seen on edge of the iris in dog as reported by the Spaulding (2008).

4.1.2 Ocular echobiometry

(1) Anterior chamber depth

The overall mean value of the anterior chamber depth of the eye balls of both sides was 0.27 ± 0.02 cm. The mean value of the anterior chamber depth was 0.25 ± 0.024 cm with the range between 0.12 to 0.38 cm in right eye balls and it was 0.29 ± 0.020 cm with the range between 0.19 to 0.39 cm in the left eye balls. There was no significant difference (P>0.05) in anterior chamber depth of left and right eye balls.

The present study showed that the anterior chamber depth of the left eye was non-significantly higher than that of the right eye which is in agreement with observations of Assadnassab and Fartashvand (2013) in buffalo and Patil et al. (2011) in male horse.

The present observations in adult Marwari goat are lower than the findings of Ribeiro et al. (2010) in male (3.46 ± 0.55) and female (3.33 ± 0.46 mm) adult goats. It may be due to breed variation. The present findings are lower than that of Patil et al. (2011) in right (3.96 ± 0.13) and left eye balls (4.22 ± 0.17 mm) of male horse. It may
be due to species variation or variation in size of the animal. Whereas the present observations are in agreement with the result of Assadnassab and Fartashvand (2013) in right (0.291 ± 0.014) and left eye ball (0.287 ± 0.015) of live buffalo.

This study showed that anterior chamber depth varied with the species, breed and size of the animal and individual.

(2) Antero-posterior axis of the lens

The overall mean value of the antero-posterior depth of the lens of both sides was 0.80 ± 0.01 cm. The mean value of AP-axis of the lens in the right eye balls was 0.81 ± 0.032 cm with the range between 0.67-0.94 cm and it was 0.79 ± 0.028 cm with the range between 0.68-0.95 cm in the left eye balls. There was no significant difference (P>0.05) in antero-posterior axis of the lens of left and right eye balls.

The present observations in adult Marwari goat are similar as reported by Ribeiro et al. (2010) in male (8.60 ± 0.34 mm) and female (8.65 ± 0.39 mm) adult goat. The present findings are lower than that of Patil et al. (2011) in right (11.05±0.13 mm) and left (11.45±0.16 mm) eye balls of male horse and that of Assadnassab and Fartashvand (2013) in right (1.132 ± 0.053 cm) and left eye ball (1.135 ± 0.052 cm) of live buffalo. It may be due to species variation or difference (P>0.05) in size of the animal.

(3) Vitreous chamber depth

The overall mean value of the vitreous chamber depth of the eye balls of both sides was 1.14 ± 0.01 cm. The mean value of vitreous chamber depth in the right eye balls was 1.13 ± 0.036 cm with the range between 0.93-1.26 cm and it was 1.15 ± 0.033 cm with the range between 0.99-1.34 cm in the left eye balls. There was no significant difference (P>0.05) in vitreous chamber depth of left and right eye balls.
According to Ribeiro et al. (2010) the mean value of the vitreous chamber depth of eye ball of adult goat was $11.34 \pm 0.61$ mm which is similar to presently studied Marwari goat. But in horse vitreous chamber depth of right eye ($20.15 \pm 0.30$ mm) and left eye ($19.8 \pm 0.29$ mm) as reported by Patil et al. (2011) and vitreous chamber depth of left ($1.677 \pm 0.042$ cm) and right eye ball ($1.670 \pm 0.040$ cm) in buffalo as described by Assadnassab and Fartashvand (2013) are higher than the present observations.

(4) Antero-posterior axis of the eye ball

The overall mean value of the antero-posterior axis of the eye ball of both sides was $2.13 \pm 0.01$ cm. The mean value of the antero-posterior axis in the right eye balls was $2.14 \pm 0.031$ cm with the range between 2.01-2.32 cm and it was $2.12 \pm 0.021$ cm with the range between 2.01-2.18 cm in the left eye balls. There was no significant difference in antero-posterior axis of left and right eye balls.

The antero-posterior axis of the globe ($23.39 \pm 0.86$ mm) of the adult goat as reported by Ribeiro et al. (2010) is higher than that of Marwari goat studied presently, it may be due to breed variation. The observations of the present study are lower than the findings of Patil et al. (2011) in right ($35.28 \pm 0.34$) and left eye ball ($35.50 \pm 0.32$) of male horse. The present observations of adult Marwari goat are also lower than that of Assadnassab and Fartashvand (2013), in right ($3.297 \pm 0.037$) and left eye balls ($3.292 \pm 0.037$) of the buffalo.

The present study of echobiometrical dimensions of the eye balls of the adult Marwari goat showed that there is no significant difference in all parameters of the echobiometrical dimensions of right and left eye balls. However there are considerable variations in regard to the species, breed, size of the animal and individuals.
4.2 Gross morphology of the eye ball

The shape of the eye ball was almost spherical. Anterior one fifth part of the eye ball was formed by transparent cornea whereas remaining posterior part of the eye ball was formed by the tough white fibrous structure i.e. sclera. The transition area between the cornea and sclera i.e. limbus characterized by pigmentation of conjunctiva which was loosely attached to the sclera in that area. The shape of the pupil was oval in horizontal plane. Along the dorsal and ventral margin of the iris, round to oval shape black masses were present i.e. granula iridica (fig.9). The A-P axis of the eye ball was lesser than the other axis but the horizontal axis of the eye ball was slightly larger than the vertical axis. The cornea was devoid of blood supply. At the posterior part of the sclera it was perforated for the entry of optic nerve. Optic nerve was located ventral and lateral to the posterior pole. Long posterior ciliary arteries were situated at 3 O’ and 9 O’ clock position (fig.7). Topographically four vortex veins were emerged from the sclera posterior to the equator (fig.8). The posterior cavity of the eye ball was filled with transparent, jelly like vitreous humor. The center of the cornea (anterior pole) and posterior center of the scleral curve formed the geometrical axis of the eye ball (Fig.10). The findings of gross morphology of the eye ball in the present study are similar as reported by Prince et al. (1960) in goat, Konig and Liebich (2004) in domestic animals and Gelatt (2007) in ungulates.

The present study showed that horizontal and A-P axis of the eye ball was larger than the vertical axis which is not in agreement with the Gelatt (2007) in sheep, in which they mentioned that horizontal and vertical axis were almost identical.
4.2.1 Biometry of the eye ball

1. Weight

The overall mean value of the weight of the eye balls of both sides of adult Marwari goat was 10.062 ± 0.06 gm. The mean value of the weight of the right eye balls was 10.068 ± 0.36 gm with the range of 8.64 to 11.98 gm and it was 10.056 ± 0.34 gm with the range between 8.44 to 12.00 gm in left eyes. These differences between right and left eye balls were not found to be statistically significant.

The present study showed that the mean value of the weight of the eye balls of adult Marwari goat is lower than the findings of Panchbhai et al. (1988) in eye ball (21.41 gm) of buffalo calves and that of the Khaled and Abdalla (2013) in eye ball (35.30 ± 2.69 gm) of adult buffalo. These observations showed that weight of the eye ball varied with species, age of the animal and size of the animal. Whereas the observations of the present study is higher than that of the Olopade et al. (2005) in right (7.17 gm) and left (7.19 gm) eye ball of Sahel goat, it may be due to variation in breed and size of the animal.

2. Antero-posterior axis

The overall mean value of antero-posterior axis of the eye balls of both sides of adult Marwari goat was 25.21 ± 0.05 mm. The mean value of antero-posterior axis of the right eye balls was 25.26 ± 0.49 mm with the range between 22.66 to 28.01 mm whereas it was 25.16 ± 0.42 mm with the range between 22.76 to 27.00 mm in the left eye balls. There was no significant difference (P>0.05) in antero-posterior axis of left and right eye balls.

The present observations of mean value of antero-posterior axis of the eye balls of the adult Marwari goat is lower than the findings of Prince et al. (1960) in eye balls (29 mm) of adult goat, Panchbhai et al. (1988) in eye balls (3.19 cm) of buffalo calves.
Olopade et al. (2005) reported that antero-posterior axis of the left (7.11 mm) and right (7.19 mm) eyeballs of Sahel goat which were lesser than the Marwari goat studied presently. It may be due to breed difference. A-P axis of eye ball of sheep was 26.85 mm as mentioned by Gelatt (2007) was almost similar to the observation of present study.

3. Horizontal axis and Vertical axis

The overall mean value of the horizontal axis of the eye balls of both sides was 27.62 ± 0.18 mm. The mean value of the horizontal axis of the right eye balls was 27.62 ± 0.45 mm with the range between 25.10 to 29.65 mm. It was 27.63 ± 0.45 mm with the range between 25.00 to 29.53 mm in the left eye balls.

The overall mean value of the vertical axis of the eye balls of both sides 26.89 ± 0.03 mm. The mean value of the vertical axis of the right eye balls was 26.86 ± 0.53 mm with the range of 23.76 to 29.90 mm and it was 26.92 ± 0.49 mm with the range of 23.86 to 28.21 mm in the left eye balls. There was no significant difference (P > 0.05) in antero-posterior axis of left and right eye balls.

The present study showed that length of the horizontal axis was slightly higher than the vertical axis which is contrary to the findings of Prince et al. (1960) in eye balls of the goat in which they mentioned that horizontal (32 mm) and vertical diameter (32 mm) was almost identical and the mean value of the horizontal axis and vertical axis in present study is lower than that of Prince et al. (1960).

Olopade et al. (2005) reported that the mean values of horizontal and vertical axis of right and left eye of Sahel goat were 8.17 mm and 8.23 mm respectively which are much lesser than the present study. The observations of the present study are found to be lower than that of the Gelatt (2007) in sheep in which he mentioned as horizontal axis was 30.86 mm and vertical axis was 30.02 mm.
4.3 Gross morphology of the cornea

The present study showed that the cornea was found to be elliptical in shape with a horizontal diameter greater than the vertical diameter (fig.9). The present observations showed that cornea had greater curvature than the sclera, which gives the bulging appearance of the cornea. Cornea was the anterior, avascular transparent layer of the outermost fibrous tunic of the eye ball having a broader end at the medial side and a more pointed end at the lateral side (fig.9). These finding are similar to those reported by Prince et al. (1960) in goat, Panchbhai et al. (1988) in buffalo calves, Samuelson (1999) in ungulates, Konig and Liebich (2004) in domestic animals, Gelatt (2007) in ruminants, Faber et al. (2008) in pig. However in dog, cornea was almost circular as described by Gelatt (2007) and Maggs et al. (2008) which is contrary to the present study.

The present study showed that greater horizontal diameter of the cornea in small and large ruminants, gives the remarkable horizontal field of view and the positioning of the eye ball in head is more lateral, which also increase the wider panoramic field. From the above observation, we can say that these anatomical features are associated with the habit and activity of the animal. Greater curvature of the cornea is responsible for marked refraction of light Gelatt (2007).

4.3.1 Biometry of the cornea

1. Horizontal diameter

The overall mean value of the horizontal diameter of the cornea of eye balls of both sides in adult Marwari goat was 19.26 ± 0.03 mm. The mean value of the horizontal diameter of the cornea in right eye ball was 19.248 ± 0.49 mm with the range of 15.84 to 20.95 mm. It was 19.308 ± 0.52 mm with the range of 15.79 to 21.05 mm
in left eye ball. There was no significant difference (P>0.05) in horizontal diameter of the cornea of left and right eye balls.

The present study of horizontal diameter of the cornea is found to be lower than that of Prince et al. (1960) in cornea (27 mm) of sheep, Panchbhai et al. (1988) in cornea (2.53 cm) of buffalo calves. Whereas the observation of present study is found to be similar as described by Prince et al. (1960) in cornea (17-19 mm) of pig. However it is higher than the findings of Faber et al. (2008) in cornea (14.9 mm) of pig.

2. Vertical diameter

The overall mean value of the vertical diameter of the cornea of both sides was 14.81 ± 0.04 mm. The mean value of the vertical diameter of the cornea in right eye ball was 14.77 ± 0.54 mm with the range of 12.60 to 17.61 mm. It was 14.86 ± 0.49 mm with the range of 12.80 to 17.00 mm in left eye ball.

The findings of the present study are lower than that of Prince et al. (1960) in sheep (19 mm), Panchbhai et al. (1988) in buffalo calves (2.05 cm). However it is higher than the pig (12.4 mm) as described earlier by Faber et al. (2008). Whereas present study is found to be similar as described by Prince et al. (1960) in cornea (14-16.5 mm) of pig.

The present study showed that there are variations in horizontal diameter and vertical diameter of the cornea. This may be due to variation in species, breed, age and size of the animal. The measurements of horizontal and vertical diameter of the cornea in pig are different in the findings of Faber et al. (2008) and Prince et al. (1960), so we can conclude that variations may be depend on individuality or size of the animal.

3. Thickness

The overall mean value of the thickness of cornea of both sides was 0.852 ± 0.03 mm. The mean value of the thickness of cornea was 0.911 ± 0.04 mm at the center
and 0.794 ± 0.02 at the periphery with the range between 0.74 to 1.14 mm at the center and 0.67 to 1.00 mm at the periphery.

In present study we found that thickness of the cornea at center was higher than thickness of the cornea at periphery which is similar to findings of Samuelson (1999) in bovine and Gelatt (2007) in domestic animals.

The present observations on thickness of the cornea in adult Marwari goat is lower than that of Samuelson (1999) in corneal thickness (1.5-2.0 mm thick centrally and 1.5-1.8 mm peripherally) of bovine. The present observations is in agreement with the Samuelson (1999) in bovine in which he stated that mean thickness of the cornea of domestic animal was less than 1 mm, and it is also in agreement with Gelatt (2007) in which they observed that corneal thickness at central and periphery was 0.8-2.0 mm and 0.3-0.5 mm respectively in sheep. Maggs et al. (2008) mentioned that corneal thickness varied among species and across regions of the cornea but is usually between 0.5 and 0.8 mm which is almost similar to findings of present study.

The present study showed that there was no significant difference (P>0.05) in any parameter of biometry of the cornea of left and right eye balls in adult Marwari goat. It was found that thickness of the cornea at center is higher than the periphery in small ruminants whereas in large ruminant it was opposite to the present study. The present study showed that the variations in thickness of the cornea vary among the species, age and size of the animal.

4.4 Gross morphology of the lens

The present work showed that the lens was almost circular and biconvex with the degree of convexity more at posterior side than anterior side. It was totally transparent and avascular (fig. 12). The lens was completely enclosed within a very thin capsule. It was suspended by the zonular fibers which arise from the ciliary body and
attached to the lens capsule at the lens equator (fig.10, 12). Its anterior surface was in contact with the posterior surface of the iris and fills the pupil. Its posterior surface was in contact with the vitreous body (fig.10). These observations is in agreement with the finding of Prince et al. (1960) in goat, Gelatt (2007) in domestic animals and Maggs et al. (2008) in domestic animals.

4.4.1 Biometry of lens

1. Weight

The overall mean value of the weight of the lens of both sides in adult Marwari goat was 0.921 ± 0.02 gm. The mean value of the weight of the lens in right eye balls was 0.895 ± 0.04 gm with the range between 0.70 to 1.14 gm and it was 0.948 ± 0.06 gm with the range between 0.75 to 1.46 gm in left eye balls. There was no significant difference (P>0.05) in weight of the lens of left and right eye balls.

The present mean value of weight of lens in adult Marwari goat is found to be lower than those reported by Gelatt (2007) in sheep (2.3 gm), Panchbhai et al. (1988) in buffalo calves (1.56 gm) and Banubakode (1992) in cattle (2.21 ± 0.035 gm). It may be due to species difference.

2. Antero-posterior axis

The overall mean value of the A-P axis of the lens of both sides was 10.056 ± 0.03 mm. The mean value of the A-P axis of the lens in right eye balls was 10.12 ± 0.23 mm with the range between 9.00 to 11.08 mm. It was 10.05 ± 0.23 mm with the range of 9.08 to 11.19 mm in left eye balls.

The mean value of the A-P axis of the lens of Marwari goat in present study is in agreement to the findings of Prince et al. (1960) in goat (10.0 mm), Gelatt (2007) in sheep (10.0 mm) and Panchbhai et al. (1988) in buffalo calves (1.004 cm). While the
observations of the present study are lower than that of Banubakode (1992) in cattle (1.22 ± 0.008 cm).

3. Maximum diameter

The overall mean value of the maximum diameter of the lens of both sides was 12.493 ± 0.16 mm. The mean value of the diameter of the lens in right eye balls was 12.468 ± 0.31 mm with the range between 11.25 to 14.01 mm and it was 12.493 ± 0.30 mm with the range between 11.29 to 14.00 mm in left eye balls. There was no significant difference in the maximum diameter of the lens of left and right eye balls.

The observations of the present study are found to be lower than that of Prince et al. (1960) in goat (13.8) mm, Panchbhai et al. (1988) in buffalo calves (1.47 to 1.84 cm), Banubakode (1992) in cattle (1.84 ± 0.009 cm) and Gelatt (2007) in sheep (14.5 mm). These variations may be due to variation in species and age of the animal.

4.5 Histology and micrometry of sclera, cornea, lens and choroid

4.5.1 Sclera

I. Histology

The sclera was begin at the periphery of the cornea and extended posteriorly to the optic nerve. The sclera was relatively rigid in nature which protect the eye from trauma and help to maintain the intraocular pressure. The sclera had three part from outside to the inside (fig.13), which were as follows:

A. The episclera
B. The scleral stroma and
C. Lamina fusca

These observations are found to be similar with the observations of Ramkrisha et al. (1997) in Indian water buffalo, Khaled (2003) in bovines and Maggs et al. (2008) in domestic animals.
A. The episclera

Episclera formed the external boundary of the sclera. It was consisted of loosely arranged collagen fibers. The episclera had rich blood supply (fig.13). Similar findings were obtained by Prince et al. (1960) in goat, Ramkrishna et al. (1997) in Indian water buffalo, Khaled (2003) in bovines, Gelatt (2007) and Maggs et al. (2008) in domestic animals.

B. The scleral stroma

It was the largest component of the sclera which was comprised of the bundles of collagen fibers in which some fibroblast was scattered (fig.13, 17). It was continued with the peripheral cornea and bulbar conjunctiva and form the transition zone (limbus) (fig.18). Similar results were observed by Prince et al. (1960) in goat, Leeson and Leeson (1970) in domestic animals, Ramkrishna et al. (1997) in Indian water buffalo, Khaled (2003) in bovine, Konig and Liebich (2004), Dellmann (1993), Gelatt (2007) and Maggs et al. (2008) in domestic animals. At the limbus, epithelium of the cornea was thicker and contained closely packed pigmented cells and pigmented palpebral conjunctiva which give the black coloration of the sclera at this area (fig.18).

C. Lamina fusca

The innermost layer of the sclera was the lamina fusca which consisted of the loose collagen fibers, fibroblast and scattered melanocyte. Lamina fusca formed transition between the sclera and underlying choroid (fig.13). Similar findings were reported by Ramkrishna et al. (1997) in Indian water buffalo, Khaled (2003) in bovine, Dellmann (1993), Gelatt (2007) and Maggs et al. (2008) in domestic animals.

The present study showed that histologically sclera has similar structure as it is observed in other domestic animals.
II. Micrometry

The thickness of sclera was found to be varied from region to region, it was thickest at around the optic nerve and thinnest at equator. This observation of the present study is similar as reported by Prince et al. (1960) in goat, König and Liebich (2004) and Gelatt (2007) in domestic animals.

Histologically, the mean values of the thickness of the sclera at the anterior/limbus was $400.42 \pm 18.40 \mu m$ with the range between 270.20 to 450.50 \mu m and at the equator it was $196.53 \pm 10.92 \mu m$ and at the posterior pole it was $663.99 \pm 35.55 \mu m$ with the range between 456.32 to 909.21 \mu m.

According to Gelatt (2007) in sheep, thickness of sclera at entry point of the optic nerve and posterior pole was 1.0 -1.2 mm, at equator of the globe was 0.25-0.30 mm and at limbus was 0.4-0.5 mm which are similar to the observations of present study except the thickness of the sclera at posterior pole which is higher than the present study. Prince et al. (1960) in goat reported that thickness of the sclera at the equator (0.2 mm) which is similar to present study and at the posterior pole (1.5 mm) which is higher than the present study.

The observations of present study showed that variation in thickness of the sclera may be due to differences among species and age of the animal and it also depend on individuality of the animal.

4.5.2 Cornea

I. Histology

The present study on cornea of adult Marwari goat was found to be composed of five layers (fig.14). These layers from the outward to the inward were as follows:

a) Anterior Epithelium

b) Subepithelial basement membrane
c) Corneal stroma/ Substantia propria

d) Descemet’s Membrane and

e) Endothelium

The observations of the cornea in present study on adult Marwari goat are similar to the Prince et al. (1960) in goat, Khaled (2003) in buffalo, Konig and Liebich (2004) and Gelatt (2007) in domestic animals except that Bowman’s membrane was not found in present study. Martin and Anderson (1981) in domestic animal described that cornea was composed of only four layers and they did not find Bowman’s layer, these observations are similar to the present study. Dellmann (1993) in domestic animals reported that cornea was composed of five layers: (a) anterior epithelium (b) subepithelial basement membrane (c) substantia propria or stroma (d) posterior limiting lamina (Descemet’s membrane) and (e) posterior epithelium (corneal endothelium) which are found to be similar to the observations of the present study.

1. Anterior Epithelium

Anterior epithelium (stratified squamous non-keratinized) was the outermost layer of the cornea and composed of 5 to 9 rows of epithelial cells (fig.14, 15, and 16). The basal cells of the epithelial layers were columnar whereas anterior most cells were squamous. The cells of the center zone of the epithelium were found to be progressively round to flattened (polyhedral cell) which was known as wing cell (Fig.15). The cells of anterior epithelium at the limbus part found to be pigmented which give the black coloration of this area (fig.18).

2. **Subepithelial basement membrane**

   It was the next subsequent layer over which the basal cells were lying. It was quite thin and homogenous in appearance (fig.14, 15 and 16). It was very difficult to find out the line of demarcation between the basement membrane and the next adjacent layer, the substantia propria.

   These findings are similar to the findings of Dellmann (1993) in domestic animals.

3. **Corneal stroma or Substantia propria**

   This layer constituted the major part of the cornea and was found to be composed of regularly arranged sheets or lamellae of the collagen fibers along with the fibroblast cells (Fig.14, 15 and 16).


4. **Descemet’s Membrane**

   Descemet’s membrane was interposed in between the stroma and the endothelium. It was thin and homogenous in appearance (Fig.17).

5. The Endothelium

The endothelium was found to be the last and the most posterior layer of the cornea which was composed of single row of flattened cells with prominent nuclei lying beneath the Descemet’s membrane (fig.17).

These observations of present study are found to be similar as described by Prince et al. (1960) in different domestic animals, Martin and Anderson (1981) in cattle, Banubakode (1992) in cattle, Ramkrishna et al. (1997) in Indian water buffalo, Khaled (2003) in bovine, Dellmann (1993) and Gelatt (2007) in domestic animals.

II. Micrometry

The thickness of the different layers of cornea was found to be varied from region to region. Micrometrical measurements of different layers of the cornea were recorded as follows:

1. Total thickness of the cornea

The overall mean value of total thickness of the cornea was 716.39 ± 13.84 μm. The mean value of the thickness of the cornea was 702.54 ± 42.11 μm with the range between 482.34 μm to 886.13 μm at the periphery and it was 730.24 ± 43.54 μm with the range between 493.49 to 901.21 μm at the center. The mean value of the total thickness of the cornea was thickest at the center and thinnest at the periphery.

The observations of the present study are found to be similar as described by Prince et al. (1960) in sheep (0.7 mm) and Camber et al. (1987) in pig (722 μm). Banubakode (1992) reported the mean value of total thickness of the cornea in cattle was 933.72 ± 15.35 μm which is higher than that of the present study.

2. Thickness of the anterior epithelium

The overall mean value of the thickness of the anterior epithelium was 77.20 ± 1.45 μm. The mean value of the thickness of the anterior epithelial layer was 75.75 ±
5.78 μm with the range between 62.17 to 123.12 μm at the periphery and it was 78.66 ± 5.31 μm with the range between 66.21 to 121.50 μm at the center.

The thickness of epithelial layer was reported by Prince et al. (1960) in goat (60-70 μm) and Banubakode (1992) in cattle (72.08 ± 2.90 μm) which are almost similar to the present study whereas Khaled (2003) in bovine (98.00 ± 1.50 μm) which is higher than the present study. This variation in the thickness of epithelial layer of the cornea may be due to the difference in the species, breed or size of the animal.

3. Number of epithelial cell layers

The overall mean value of the number of the epithelial cell layers of the cornea was 6.33 ± 0.5. The average number of the epithelial cell layers of the cornea was 5.83 ± 0.26 with the range between 5 to 7 cells at the periphery and it was 6.83 ± 0.35 with the range between 5 to 9 at the center.

The observations of the present study are found to be lower than that of Camber et al. (1987) in pig (17 to 23 rows) and Banubakode (1992) in cattle (9.28 ± 0.17). It may be due to species difference.

4. Thickness of the stroma

The overall mean value of the thickness of stroma was 626.74 ± 12.02 μm. The mean value of the thickness of the corneal stroma was 614.71 ± 41.63 μm with the range of 406.24 to 802.31 μm at the periphery and it was 638.77 ± 42.67 μm with the range of 415.41 to 812.32 μm at the center.

Prince et al. (1960) in goat reported that the thickness of the stroma was 0.66 mm which is similar to the finding of present study.

5. Thickness of the Descemet’s membrane

The overall mean value of the thickness of the Descemet’s membrane was 10.70 ± 0.33 μm. The mean value of the thickness of the Descemet’s membrane was 10.37 ±
0.39 µm with the range of 8.12 to 12.30 µm at the periphery and it was 11.03 ± 0.51 µm with the range between 8.01 to 14.12 µm at the center.

The observations of the present study are found to be lower than that of Prince et al. (1960) in goat (40 µm) and Khaled (2003) in bovine (30 ± 1 µm). These variation in the thickness of Descemet’s membrane of the cornea may be due to the differences in the species, breed or size of the animals.

6. **Thickness of the endothelium**

The overall mean value of the thickness of endothelium was 2.08 ± 0.10 µm. The mean value of the thickness of endothelium was 2.03 ± 0.10 µm with the range between 1.28 to 2.46 µm at the periphery and it was 2.13 ± 0.11 µm with the range between 1.26 to 2.68 µm at the center.

The mean value of thickness of endothelium in present study is lower than that of Prince et al. (1960) in goat (4 µm) and Khaled (2003) in bovine (8 ± 0.3 µm). Banubakode (1992) in cattle reported the thickness of endothelium as 2.22 ± 0.067 µm which is almost similar to the present study.

4.5.3 Lens

I. Histology

The lens was observed to be composed of the following three components (fig.19)-

1. The capsule
2. The anterior epithelium
3. The lens fibers

The same observation had been reported earlier by Prince et al. (1960) in domestic animals, Martin and Anderson (1981) in domestic animals, Banubakode

1. Capsule

The lens was completely enclosed within a thick PAS positive capsule. Anterior capsule was found to be thicker than the anterior capsule (fig.22). It was homogenous in appearance (fig.21). This observation is in concurrence with those reported by Prince et al. (1960) in domestic animals, Martin and Anderson (1981) in domestic animals, Banubakode (1992) in cattle, Dellmann (1993) in domestic animals, Gelatt (2007) and Maggs et al. (2008) in domestic animals.

2. Anterior epithelium

The anterior epithelium was a single layer of cells which was situated just behind the anterior capsule (fig.20, 21). These cells were cuboidal at the center but they were found to be columnar towards the equator (fig.20). The posterior surface of the capsule was devoid of the posterior epithelium.

The observation of the present study are similar as reported by Prince et al. (1960) in domestic animals, Martin and Anderson (1981) in domestic animals, Banubakode (1992) in cattle, Dellmann (1993) in cattle, Gelatt (2007) and Maggs et al. (2008) in domestic animals.

3. Lens fibers

The lens fibers constituted the main body of the lens (fig.22). This observation is in accordance with that reported by Banubakode (1992) in cattle, Dellmann (1993) in cattle and Gelatt (2007) in domestic animals. Immediately anterior to the lens equator there was a proliferative zone (zone of mitosis) within the anterior epithelium. The cells within this zone begin to mitosis and transformed into newly formed lens fibers (fig.20), these observations are similar as described by Gelatt (2007) in domestic animals.
Regarding the histological structure of lens, there is no much variation between the adult Marwari goats in present study with the observations in other domestic animals.

II. Micrometry

The mean thickness of the anterior capsule and that of posterior capsule were 32.40 µm and 10.60 µm respectively.

Prince et al. (1960) in goat mentioned that anteriorly the capsule was 50 µm thick, and at posterior surface it was 20 µm thick which are higher than the present study.

Gelatt (2007) in canine noted that lens capsule was 50 to 70 µm thick anteriorly which is higher than the present study and only 2 to 4 µm thick posteriorly which is lower than the present study.

4.5.4 Choroid

I. Histology

The richly vascularized layer i.e. choroid was observed as a dark pigmented layer which was present between sclera and retina. It was extended from the ciliary body to the optic nerve. The anterior margin of the choroid joined with the ciliary body which was not serrated (ora ciliaris retinae). The choroid was consisted of the four layers, which were as follows:

1) Suprachoroidea
2) Blood vessels layer
3) Tapetum fibrosum
4) Choriocapillaris

The observations of the present studies in adult Marwari goat are almost in accordance with those reported by Prince et al. (1960) in goat, Dellmann (1993) in

1. Suprachoroidea

Suprachoroidea was loosely attached to the overlying sclera. It was consisted of the collagen fibers, some fibroblast and heavily pigmented connective tissue that formed the transition between the sclera and choroid. Suprachoroidea was devoid of blood vessels (fig.35).

2. Blood vessels layer

Immediately internal to the suprachoroidea, blood vessels were present which were embedded in loose connective tissue containing melanocytes and fibroblast (fig.34, 35).

3. Tapetum fibrosum

The tapetum was present between the blood vessels layer and the single layer of choriocapillaris beneath the retina. It was composed of closely and regularly arranged collagen fibers which were parallel to the retinal surface and somewhere fibrocyte were also present (fig.35).

4. Choriocapillaris

The choriocapillaris was the innermost layer of the choroid. The choriocapillaris forming the very thin layer of endothelium of capillaries which was separated from the retinal pigmented epithelium of the retina (fig.34, 35).

The basal complex which was consisted of the basement membrane of the endothelium and basement membrane of the retinal pigmented epithelium formed the Bruch’s membrane (fig.35). These findings are similar as described by the Prince et al. (1960) in goat, Dellmann (1993) in domestic animals, Ramkrishna et al. (1997) in Indian water buffalo, Khaled (2003) in bovine and Gelatt (2007) in domestic animals.
II. Micrometry

The total thickness of the choroid was found to be varied from region to region. The choroid tend to thicken along the posterior pole, becoming thinner towards the equator. The mean thickness of the choroid was $45.53 \pm 2.05 \, \mu m$ with the range from $36.53 \, \mu m$ to $56.21 \, \mu m$ at the anterior/ora ciliaris retinae whereas, at the equator, it was $37.30 \pm 3.48 \, \mu m$ with the range from $27.02$ to $67.55 \, \mu m$. At the posterior pole/optic disc the mean value of the thickness of the choroid was $50.64 \pm 2.99 \, \mu m$ with the range between $38.14$ to $54.04 \, \mu m$.

The thickness of tapetum fibrosum was found to be varied from $18.20$ to $33.77 \, \mu m$ with the average of $26.40 \pm 0.19 \, \mu m$.

Prince *et al.* (1960) in goat mentioned that the thickness of the choroid was about $50 \, \mu m$ excluding a tapetum and $60 \, \mu m$ in sheep. The thickness of tapetum was $30 \, \mu m$ thick which is almost similar to findings of the present study.

Khaled (2003) in bovine reported that the thickness of choroid was $208.6 \pm 6.905 \, \mu m$ which is much higher than the present study. This variation in the thickness of choroid may be due to the differences in the species, breed or size of the animal.

4.6 Histology of ciliary body, iris and irido-corneal angle

4.6.1 Ciliary body

The ciliary body was the anterior continuation of the choroid and it joined anteriorly with the iris (fig.23, 27). It was attached to the internal surface of the sclera. It was made up of the two ring shaped components: the pars plicata and pars plana. The pars plicata was the anterior most part of the ciliary body which consisted of the number of ciliary process (fig.23, 24). The flat pars plana started from these posterior termination of the process (fig.26), and merged with anterior termination of the retina (ora ciliaris retinae). Both portion of the ciliary body consisted of the epithelium, stroma
and smooth muscles (fig.24). The ciliary epithelium had two cell layer. The inner epithelium layer was nonpigmented and was contiguous with the aqueous humor of the posterior chamber (fig.25). At the ora ciliaris retinae, the sensory retina was converged into the single layer of nonpigmented ciliary epithelium which extended anteriorly until it become the posterior epithelial layer of the iris (fig.26, 28). The outer ciliary epithelium was pigmented (fig.25) and united with retinal pigmented epithelium at the ora ciliaris retinae. It was continued as the posterior pigmented epithelial layer of the iris (fig.28). Each ciliary process was consisted of the central core of stroma and blood vessels covered by bilayer of epithelium. The stroma of the ciliary body was composed of the fibroblast, blood vessels and melanocytes and it was most abundant in the pars plicata. The smooth muscles of the ciliary body was mostly oriented along the meridional plane and they were also associated with melanocytes (fig.24).

Similar observations were reported earlier by Prince et al. (1960) in goat, Dellmann (1993) in domestic animals, Ramkrishna et al. (1997) in Indian water buffalo, Khaled (2003) in bovine and Gelatt (2007) in domestic animals.

4.6.2 Iris

Iris was extended from the ciliary body and covered the anterior surface of the lens, except for central opening i.e. pupil. It was mainly consisted of the stroma and the posterior epithelial lining (fig.27). The stroma was comprised of the loose connective tissue with smooth muscles, blood vessels, melanocytes and fibroblasts. The iridial sphincter muscles which was located as circularly arranged bundle of smooth muscles within the posterior stroma of the pupillary zone. The anterior surface of the iris was formed by sheet of fibroblast and melanocyte and in direct contact with aqueous humor of the anterior chamber. The posterior epithelium was formed by the two layer of the pigmented epithelium. The anterior layer was direct continue with the pigment
epithelium of the ciliary body whereas the posterior layer which was densely pigmented continue with the nonpigmented epithelium of the ciliary body (fig.28). At the pupillary margin, different size of round black masses were present i.e. corpora nigra/granula iridica (fig.32). These were the extension of the posterior pigment epithelium.

The present histological observations of the iris are in accordance with those reported by Khaled (2003) in bovine, Ramkrishna et al. (1997) in Indian water buffalo, Gelatt (2007) in domestic animals and Zayed et al. (2012) in buffaloes. However, granula iridica in the pupillary margin of the iris was not present as earlier reported by Ramkrishna et al. (1997) in Indian water buffalo and Gelatt (2007) in carnivore which is contrary to the present study.

4.6.3 Irido-corneal angle

The irido-corneal angle was the area, located at the periphery of the anterior chamber. The irido-corneal angle was formed by the junction of the corneoscleral tunic (Limbic zone), base of the iris and anterior ciliary body. The irido-corneal angle of the eye of the goat was large and triangular. It was comprised of the pectinate ligament, the ciliary cleft, the trabecular meshwork (uveal and corneoscleral) and the angular aqueous plexus (AAP). The pectinate ligament was located on the anterior part of the iridocorneal angle (fig. 29). It was a strong, band-like structure extending from the iridal base to the limbic zone (fig.31). The ciliary cleft was the space, which was bordered by the pectinate ligament anteriorly, the limbal zone from the outer aspect, and the base of the iris and the ciliary body from the inner aspect. The ciliary cleft contained large amount of trabecular tissue. Trabecular tissue had two parts: the uveal part and the corneoscleral part (fig.29). The uveal meshwork was the inner part of the trabecular meshwork. It was composed of numerous strands of trabeculae. There were large intertrabecular spaces between the trabeculae which was known as space of Fontana
The corneoscleral meshwork was the external part of the trabecular meshwork and characterized by small trabeculae that in turn small intertrabecular spaces.

The observations of present study are similar as described by Kassab et al. (2001) in buffalo, Gelatt (2007) in domestic animal and Kassab and Zoghby et al. (2010) in goat.

4.7 HISTOLOGY AND MICROMETRY OF THE RETINA

4.7.1 Retina

I. Histology

The retina was the innermost layer of the tunic of the eye ball. Retina had two portion one was sensory (pars optic retinae) and another one was nonsensory. Non sensory part of the retina started from the ora ciliaris retinae (fig.11, 36) and covered the ciliary body (pars ciliaris retinae) and iris (pars iridis retinae). These observations of the present study are similar as described by Prince et al. (1960) in goat, Bloom and Fawcett (1970), Leeson and Leeson (1970), Dellmann (1993), Tortora and Anagnostakos (1981) and Samuelson (1999) in domestic animals.

The sensory part of the retina was composed of ten layer which were from outside to inside as follows (fig.33):

1. Retinal pigmented epithelium (RPE)
2. Layer of rods and cones
3. External limiting membrane
4. Outer nuclear layer
5. Outer plexiform layer
6. Inner nuclear layer
7. Inner plexiform layer
8. Ganglion cell layer
(9) Nerve fiber layer and

(10) Internal limiting membrane

These observations of the present study in adult Marwari goat are found to be similar as described by Prince et al. (1960) in domestic animals, Dellmann (1993) in cattle, Khaled (2003) in bovine and Gellat (2007) in domestic animals.

(1) Retinal pigmented epithelium (RPE)

The RPE was the outermost layer of the retina (fig.33). It was a monolayer of flat cells (fig.35). It was the continuation of the outer pigmented epithelium of the ciliary body. The cells of the RPE were pigmented except the area where the tapetum fibrosum was present (fig.34, 35). The basement membrane of the RPE and the endothelium of the choriocapillaris layer formed a basal complex which was known as Bruch’s membrane (fig.35). These observations are found to be similar as described by Prince et al. (1960) in goat, Dellmann (1993) in domestic animals, Khaled (2003) in bovine and Gelatt (2007) in domestic animals.

(2) Layer of rods and cones

The next layer of rod and cone cells was situated just below the RPE. This layer comprised of only outer part of the rods and cones i.e. outer and inner segment. These segments were closely packed together, side by side and they were arranged radially, being parallel to the incoming light through pupil (fig.33). Outer segments of the photoreceptive rod and cone could be readily distinguished with the light microscope in our study, as a layer adjacent to the pigmented epithelium (fig.37). These findings are similar as described by Prince et al. (1960) in goat, Dellmann (1993) in domestic animals, Gelatt (2007) in domestic animals and Germain et al. (2010) in vertebrates.
(3) **External limiting membrane**

External limiting membrane separated the layer of rods and cones from the outer nuclear layer (fig.33, 37 and 38).

(4) **Outer nuclear layer**

The outer nuclear layer was comprised of nuclei of rods and cones which were arranged in 5 to 7 rows (fig.33, 34 and 37) which is in agreement with the findings of Prince *et al.* (1960) in goat, Dellmann (1993) in domestic animals and Germain *et al.* (2010) in vertebrates. The nuclei of the cones were located in the proximity of this layer and form only a single row and took lighter stain and larger than the rod nuclei, whereas the nuclei of the rods formed several layers in the inner portion of this layer and took dark stain (fig.38) which is similar as described by Gelatt (2007) in domestic animals.

(5) **Outer plexiform layer**

The outer plexiform layer was a thin layer, separated the outer nuclear layer from the inner nuclear layer. It was composed mainly of axons of rods and cones that synapse with dendrite of the horizontal cell and bipolar cells (fig.33, 37 and 38). These finding are similar as described by Prince *et al.* (1960) in goat, Dellmann (1993) in domestic animals, Gelatt (2007) in domestic animals and Germain *et al.* (2010) in vertebrates.

(6) **Inner nuclear layer**

The inner nuclear layer was comprised of the nuclei of the horizontal cells, bipolar cells, amacrine cells and Muller’s cells (fig.33, 37). In this layer four different types of nuclei were identified (fig.38). The nuclei of horizontal cells were larger and took lighter stain with prominent single nucleolus. It was positioned along the outer margin of the inner nuclear layer. The amacrine cell nuclei were located vitreally in the inner nuclear layer and they were recognized by euchromatic nuclei. The nuclei of the
bipolar cells and Muller’s cells were situated in the center zone of the inner nuclear layer. Nuclei of the Muller’s cell were identified as they were angulated and had dense chromatin than other nuclei in the inner nuclear layer. Bipolar cells formed the largest population in this layer and characterized by euchromatic to somewhat heterochromatic nuclei (fig.38). These observations in present study are similar as described by Gelatt (2007) in domestic animals and Germain et al. (2010) in vertebrates.

(7) Inner plexiform layer

The inner plexiform layer was comprised of the bipolar and amacrine cell axons and dendrites of the ganglion cells. It was thicker than the inner plexiform layer. Some displaced nuclei of amacrine cell were also identified in this layer (fig.33, 37 and 38) which is similar as described by Germain et al. (2010) in vertebrates.

(8) Ganglion cell layer

The ganglion cell layer was the innermost cell layer of the retina. It was consisted of the single layer of ganglion cells but in some area it was 3 to 4 rows of cells (fig.33, 37 and 38).

(9) Nerve fiber layer

The nerve fiber layer was formed by the axons of ganglion cells (fig.33, 34 and 37). The thickness of nerve fiber layer was increased as it goes to the optic disc. Large retinal blood vessels were seen in the nerve fiber layer but it was also present in the ganglion cell layer as well as in the inner plexiform layer (fig.36). These observations in present study are similar as described by Gelatt (2007) in domestic animals and Germain et al. (2010) in vertebrates.

(10) Internal limiting membrane

The internal limiting membrane was the innermost layer of the retina which was formed by the basal lamina of the Muller’s cell (fig.33, 37). These findings in present
study are similar as described by the Prince et al. (1960) in goat, Dellmann (1993) in domestic animals, Gelatt (2007) in domestic animals and Germain et al. (2010) in vertebrates.

II. Micrometry

Thickness of the retina was found to be varied from region to region. It was thickest at optic disc and tapering towards the ora ciliaris retinae.

The mean values of the total thickness of the retina at different regions were as below-

<table>
<thead>
<tr>
<th></th>
<th>Anterior/Ora ciliaris retinae (µm)</th>
<th>Equator (µm)</th>
<th>Posterior/Optic disc (µm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>113.24 ± 5.68</td>
<td>139.82 ± 7.49</td>
<td>213.03 ± 14.45</td>
</tr>
<tr>
<td>Range</td>
<td>80.79-144.24</td>
<td>105.8-198.15</td>
<td>124.21-270.22</td>
</tr>
</tbody>
</table>

Gelatt (2007) described that most animals had a central retina of approximately 200 to 240 µm and a peripheral retina of 100 to 190 µm which are almost similar to findings of present study on adult Marwari goat. Gelatt (2007) in equine also reported that total thickness of the retina was 80 µm at the ora ciliaris retinae, 250 µm medial to the optic nerve and it was for the most part less than 130 µm. These observations are found to be almost similar as studied presently.

The mean values of the thickness of the different layers of the retina at equator were recorded as below-

<table>
<thead>
<tr>
<th></th>
<th>Pigmented epithelium (µm)</th>
<th>Layer of rods and cones (µm)</th>
<th>Outer nuclear layer (µm)</th>
<th>Outer plexiform layer (µm)</th>
<th>Inner nuclear layer (µm)</th>
<th>Inner plexiform layer(µm)</th>
<th>Nerve fiber layer (µm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>1.94±0.10</td>
<td>18.50±1.34</td>
<td>26.16±2.52</td>
<td>7.49±0.85</td>
<td>17.31±1.50</td>
<td>21.43±1.74</td>
<td>13.65±2.02</td>
</tr>
</tbody>
</table>
Prince et al. (1960) in goat noted that thickness of the pigmented epithelium was 20 µm which is higher than the present study. The outer nuclear layer was consisted of about 5 rows of cells measured 30 µm in goat although at the posterior pole this was slightly increased as there were 6 or 7 rows of cells which was almost similar as present study but the thickness of the outer nuclear in present study was slightly lower. It may be due to breed difference and also size of the animal and individual of animal. They mentioned that thickness of the outer plexiform layer was 14 µm, inner nuclear layer was 26 to 30 µm with 5-6 rows of cells, and inner plexiform layer was 30 µm thick in goat which was found to be higher than the findings of present study. The variation in thickness of the different layer of retina may be due to variation in area of interest where the measurement has taken.

4.7.2 Artifacts of the retina

The present study showed that retina was detached from the retinal pigment epithelium and sometime retina was also detached from the choroid. At the site of retinal detachment, outer segment of the intact photoreceptors and fragment of retinal pigment epithelium were present (fig.39). Similar findings are reported by Margo and Lee (1995) and Milles (2012). It may be due to processing of tissue for preparation of block and sectioning. In more than 70 % of the sample, we found that retina took convex appearance vitreally which was look like fold. It was almost round and oval in shape (fig.39, 40). The present study showed that thickness of the different layers of retina were abruptly thicker in retinal fold than the adjoining retina. Number of rows of nuclei in outer and inner nuclear layer were also higher than the surrounding retina (fig.40). The length of retinal fold was found to be 130 µm to 210 µm and 74 µm to 198 µm in height. This retinal fold may be due to either artifacts of fixation as earlier described by Milles (2012) or hereditary as reported by Chen and Nathans (2007). The retinal fold
was not observed in unfixed enucleated eye. After fixation in Davidson’s fluid, grossly we found folding of the retina (fig.11). It may be due to fixation, because fixative (formalin) cause the shrinkage of fibrous tunic, shortening of the vitreous body and posterior lens zonules that leads to traction of retina and resulting into folding of very delicate and soft layer of nervous tissue i.e. retina. Similar findings are in accordance with the observation of the Margo and Lee (1995) and Milles (2012).

4.8 Histology of the optic disc

At the posterior side, axons of the ganglion cell leaved the eye ball through the choroid and sclera and form the optic disc. From the optic disc optic nerve entered into the orbit. Optic head was oval in shape (fig.41). At the point of leaving of optic nerve through sclera, scleral collagen fibers become reduce and separated and formed the sieve like partition of connective tissue in sclera i.e. lamina cribrosa (fig.41, 42). Optic nerve fiber of the retina clustered into fascicles or bundles as they crossed the lamina cribrosa and the bundles of optic nerve were are surrounded by collagenous septa and glial cells (fig.42). Lamina cribrosa also provided the passage for retinal blood vessels (fig.41). Similar observations are reported earlier by Prince et al. (1960) and Gelatt (2007) in domestic animals.

4.9 Statistical analysis

After application of student’s paired ‘t’ test, the following observations were obtained.

The echobiometrical mean values of anterior chamber depth, antero-posterior depth of the lens, depth of vitreous chamber and antero-posterior axis of the globe in the right eye balls did not show significant difference from the left eye balls at 5% level of significance (Table no. 1).
The biometrical mean values of the weight, antero-posterior axis, horizontal axis and vertical axis of the right eye balls did not show significant difference with the left eye balls at 5% level of significance (Table no. 2).

The biometrical mean values of the vertical diameter and horizontal diameter of the cornea were not significantly different in right and left eye balls at 5% level of difference (Table no. 2).

The weight, maximum diameter and thickness of the lens showed non-significant difference between the right and left eye balls at 5% level (Table no. 2).

The micrometrical mean values of the total thickness of cornea, thickness of epithelial layer, thickness of stroma, thickness of Descemet’s membrane and thickness of endothelium did not show significant difference between the periphery and center of the cornea in each eyeball at 5% level (Table no. 3).
The present study entitled “Gross And Histomorphological Study On Eye Ball Of The Adult Marwari Goat (Capra Hircus)” was carried out on eye balls of the ten adult Marwari goats. Immediately after collection of eye balls, they were subjected for ocular ultrasonography, echobiometrical and biometrical observation. Then 8-10 mm long incision was given in the limbus and whole eye ball fixed in Davidson’s fixative for 24-30 hours. The sections of the sclera, cornea, lens, choroid, ciliary body, irido-corneal angle, iris and retina were stained with H. & E., Masson’s trichome and Periodic Acid Schiff (PAS). The micrometrical measurements were recorded by using 10X graduated eye piece.

Based on the results of present study following conclusions were drawn:

1. Ultrasonography of eye ball (sonoanatomy) revealed cornea as a thin double-peaked hyperechoic (2 convex interfaces) layer with a central, narrow anechoic space which formed the anterior wall of the anterior chamber.

2. The anterior chamber and vitreal chamber was filled with anechoic fluid. The mean values of the anterior chamber depth and vitreous chamber depth were $0.27 \pm 0.02$ cm and $1.14 \pm 0.01$ cm, respectively.

3. The lens was anechoic, whereas the anterior and posterior reflections of the lens were observed. The mean value of the antero-posterior depth of the lens was $0.80 \pm 0.01$ cm.

4. The ciliary body and iris were seen as echogenic linear structure which extend from the peripheral globe towards the lens. The corpora nigra or iridica granules were seen as an echogenic round structure on the anterior surface of the dorsal iris.
5. The mean value of the weight of the eye balls of adult Marwari goat was $10.062 \pm 0.006$ gm. The mean values of the antero-posterior axis, horizontal axis and vertical axis of the eyeballs were $25.21 \pm 0.05$ mm, $27.62 \pm 0.18$ mm and $26.89 \pm 0.03$ mm, respectively.

6. The cornea was elliptical in shape with a horizontal diameter greater than the vertical diameter. The overall mean values of the horizontal and vertical diameter of the cornea were $19.26 \pm 0.03$ mm and $14.81 \pm 0.04$ mm, respectively.

7. The transparent and avascular lens was biconvex with the degree of convexity more at posterior side than anterior side. The mean values of the weight, A-P axis and diameter of the lens were $0.921 \pm 0.02$ gm, $10.056 \pm 0.03$ mm and $12.493 \pm 0.16$ mm, respectively.

8. The tough fibrous outermost layer of the tunic of eye ball was sclera which had three part from outside to inside: the episclera, the scleral stroma and lamina fusca. The thickness of sclera was thickest at around the optic nerve ($663.99 \pm 35.55$ μm) and thinnest at equator ($196.53 \pm 10.92$ μm).

9. Histologically cornea was composed of five layers a) Anterior Epithelium, b) Subepithelial basement membrane, c) Corneal stroma/Substantia propria, d) Descemet’s Membrane and e) Endothelium.

10. The mean value of the thickness of the cornea was $716.39 \pm 13.84$ μm. The thickness of the cornea at center ($730.24 \pm 43.54$ μm) was higher than thickness of the cornea at periphery ($702.54 \pm 42.11$ μm).

11. The mean value of the thickness of the epithelial layers, thickness of stroma, thickness of the Descemet’s membrane and thickness of endothelium of the cornea were $77.20 \pm 1.45$ μm, $626.74 \pm 12.02$ μm, $10.70 \pm 0.33$ μm and $2.08 \pm 0.10$ μm, respectively.
12. The choroid was consisted of the four layer: 1) Suprachoroidea, 2) Blood vessels layer, 3) Tapetum fibrosum and 4) Choriocapillaris. The mean value of the thickness of the choroid was $45.53 \pm 2.05 \mu m$ at the anterior/ora ciliaris retinae and at the equator, it was $37.30 \pm 3.48 \mu m$ whereas at the posterior pole/optic disc it was $50.64 \pm 2.99 \mu m$.

13. The thickness of tapetum fibrosum was varied from 13.20 to 33.77 μm with the average of 26.40 μm.

14. The irido-corneal angle was the area, located at the periphery of the anterior chamber and formed by the junction of the corneoscleral tunic (Limbic zone), base of the iris, and anterior ciliary body. It was comprised of the pectinate ligament, the ciliary cleft, the trabecular meshwork (uveal and corneoscleral) and the angular aqueous plexus.

15. The sensory part of the retina was composed of ten layer: (1) the retinal pigmented epithelium (2) layer of rods and cones (3) external limiting membrane (4) outer nuclear layer (5) outer plexiform layer (6) inner nuclear layer (7) inner plexiform layer (8) ganglion cell layer (9) nerve fibers layer (10) internal limiting membrane.

16. Retina detached from the retinal pigment epithelium or from choroid. It may be due to processing of tissue during preparation of block making and sectioning. In more than 70 % of the sample, the retina took convex appearance vitreally which was look like fold. It was almost round and oval in shape. The length of retinal fold found to be 130 μm to 210 μm and height 74 μm to 198 μm.

17. Thickness of the retina varied with the position, it was thickest at optic disc and tapered towards the ora ciliaris retinae.
18. The mean value of the total retinal thickness at Anterior/Ora ciliaris retinae, at equator and at posterior/Optic disc were 113.24 ± 5.68 µm, 139.82 ± 7.49 µm and 213.03 ± 14.45 µm, respectively.


APPENDIX – I
<table>
<thead>
<tr>
<th>Sr. No.</th>
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<th>RIGHT</th>
<th>LEFT</th>
<th>‘t’ value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>EYE BALL</td>
<td>RANGE</td>
<td>MEAN±SE</td>
<td>C.V. %</td>
</tr>
<tr>
<td>1</td>
<td>Anterior chamber depth (cm)</td>
<td>0.12 - 0.38</td>
<td>0.25 ± 0.024</td>
<td>31.49</td>
</tr>
<tr>
<td>2</td>
<td>Antero-posterior depth of lens (cm)</td>
<td>0.67 - 0.94</td>
<td>0.81 ± 0.032</td>
<td>12.82</td>
</tr>
<tr>
<td>3</td>
<td>Depth of vitreous chamber (cm)</td>
<td>0.93 - 1.26</td>
<td>1.13 ± 0.036</td>
<td>10.19</td>
</tr>
<tr>
<td>4</td>
<td>Antero-posterior depth of globe (cm)</td>
<td>2.01 - 2.32</td>
<td>2.14 ± 0.031</td>
<td>4.69</td>
</tr>
</tbody>
</table>

**Table no. 1: Statistical analysis of echobiometrical dimensions of 20 eye balls in adult Marwari goat**

**SE:** Standard error, **C.V. %:** Percentage of coefficient of variation, **Superscript (ab):** statistically non-significant at 5 % level.
Table no. 2: Statistical analysis of biometrical observations of 20 eye balls in adult Marwari goat.

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>PARAMETERS</th>
<th>RIGHT</th>
<th>LEFT</th>
<th>‘t’ value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>EYE BALL</td>
<td>RANGE</td>
<td>MEAN±SE</td>
<td>C.V. %</td>
</tr>
<tr>
<td>1</td>
<td>Weight (gm)</td>
<td>8.64-11.98</td>
<td>10.068 ± 0.36</td>
<td>11.41</td>
</tr>
<tr>
<td>2</td>
<td>Antero-posterior axis (mm)</td>
<td>22.66-28.01</td>
<td>25.26 ± 0.49</td>
<td>6.16</td>
</tr>
<tr>
<td>3</td>
<td>Horizontal axis (mm)</td>
<td>25.10-29.65</td>
<td>27.62 ± 0.45</td>
<td>5.20</td>
</tr>
<tr>
<td>4</td>
<td>Vertical axis (mm)</td>
<td>23.76-29.90</td>
<td>26.86 ± 0.53</td>
<td>6.35</td>
</tr>
<tr>
<td></td>
<td>CORNEA</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Vertical diameter (mm)</td>
<td>12.60-17.61</td>
<td>14.77 ± 0.54</td>
<td>11.57</td>
</tr>
<tr>
<td>6</td>
<td>Horizontal diameter (mm)</td>
<td>15.84-20.95</td>
<td>19.248 ± 0.49</td>
<td>8.14</td>
</tr>
<tr>
<td>7</td>
<td>Thickness (mm)</td>
<td>0.74-1.14(c)</td>
<td>0.911 ± 0.04(c)</td>
<td>15.44(c)</td>
</tr>
<tr>
<td></td>
<td>LENS</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Weight (gm)</td>
<td>0.70-1.14</td>
<td>0.895 ± 0.04</td>
<td>0.04</td>
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<tr>
<td>9</td>
<td>Thickness (mm)</td>
<td>9.00-11.08</td>
<td>10.12 ± 0.23</td>
<td>7.39</td>
</tr>
<tr>
<td>10</td>
<td>Maximum diameter (mm)</td>
<td>11.25-14.01</td>
<td>12.468 ± 0.31</td>
<td>7.89</td>
</tr>
</tbody>
</table>

SE: Standard error. C.V, %: Percentage of coefficient of variation (c): center of cornea, (p): periphery of cornea. Superscript (ab): statistically non-significant at 5 % level.
Table no. 3: Statistical analysis of micrometry of different layers of cornea of 20 eye balls in adult Marwari goat.

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>PARAMETERS</th>
<th>CENTER</th>
<th>PERIPHERY</th>
<th>'t' value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>RANGE</td>
<td>MEAN±SE</td>
<td>C.V. %</td>
</tr>
<tr>
<td>1</td>
<td>Number of epithelial cell Layers</td>
<td>5-9</td>
<td>6.83 ± 0.35</td>
<td>16.31</td>
</tr>
<tr>
<td>2</td>
<td>Thickness of anterior epithelium (µm)</td>
<td>66.21-121.50</td>
<td>78.66 ± 5.31</td>
<td>21.37</td>
</tr>
<tr>
<td>3</td>
<td>Thickness of stroma (µm)</td>
<td>415.41-812.32</td>
<td>638.77 ± 42.67</td>
<td>21.12</td>
</tr>
<tr>
<td>4</td>
<td>Thickness of Descemet’s membrane (µm)</td>
<td>8.01-14.12</td>
<td>11.03 ± 0.51</td>
<td>14.83</td>
</tr>
<tr>
<td>5</td>
<td>Thickness of endothelium (µm)</td>
<td>1.26-2.68</td>
<td>2.13 ± 0.11</td>
<td>16.51</td>
</tr>
<tr>
<td>6</td>
<td>Total thickness (µm)</td>
<td>493.49-901.21</td>
<td>730.24 ± 43.54</td>
<td>18.85</td>
</tr>
</tbody>
</table>

SE: Standard error, C.V. %: Percentage of coefficient of variation, Superscript (ab): statistically non-significant at 5%.
Table no. 4: Statistical analysis of micrometrical observations of sclera, choroid and retina of 20 eye balls in adult Marwari goat.

<table>
<thead>
<tr>
<th>Sr. no.</th>
<th>PARAMETER</th>
<th>ANTERIOR/ ORA CILIARIS RETINAE</th>
<th>EQUATOR</th>
<th>OPTIC DISC/ POSTERIOR POLE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>RANGE</td>
<td>MEAN ± SE</td>
<td>C.V. %</td>
</tr>
<tr>
<td>1</td>
<td>SCLERA</td>
<td>Total thickness (µm)</td>
<td>270.20 - 450.50</td>
<td>400.42 ± 18.40</td>
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<tr>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>CHOROID</td>
<td>Total thickness (µm)</td>
<td>36.53 - 56.21</td>
<td>45.53 ± 2.05</td>
</tr>
<tr>
<td>3</td>
<td>RETINA</td>
<td>Total thickness (µm)</td>
<td>80.79 - 144.24</td>
<td>113.24 ± 5.68</td>
</tr>
</tbody>
</table>

SE: Standard error, C.V. %: Percentage of coefficient of variation
APPENDIX – II
Fig. 1A Ultrasonography of the eye ball of adult Marwari goat performed by ultrasound machine (e- saote MY Lab 40 VET) using linear array transducer (fig.1B).

Fig. 2 Ultrasonography of the eye ball of adult Marwari goat showing echo- biometrical dimensions of the eye ball.

**D1**: Anterior chamber depth, **D2**: Antero-posterior depth of the lens, **D3**: Vitreous chamber depth, **D4**: Antero-posterior axis of the eye ball.
Fig. 3 Measurement of the biometrical dimensions (vertical axis) of the eye ball and diameter of the lens by using digital Vernier caliper (fig. 4).

Fig. 5 Micrometrical measurements of the sections (cornea) of the eye ball by using graduated eye piece.
Fig. 6 Ultrasonography of the eye ball of adult Marwari goat showing the normal sonoanatomy of the eye ball with following internal structures:

Fig. 7 Gross morphology of the eye ball viewed posteriorly showing optic nerve (OP) and long posterior ciliary artery (LPC).

Fig. 8 Gross morphology of the eye ball viewed dorsally showing vortex vein (V).
Fig. 9 Gross morphology of the eye ball viewed anteriorly showing transparent cornea (C), which is continued with the sclera at limbus (LM). Arrow (GI) showing the granula iridica (black mass) on the dorsal and ventral margin of the iris. Horizontally oval in shaped pupil (P). M: Medial side, L: Lateral.

Fig. 10 Gross morphology of the eye ball after bisecting at meridional plane showing, transparent, jelly like vitreous body that fills the posterior cavity of the eye ball. Center of the cornea (anterior pole: AP) and posterior center of the scleral curve (posterior pole: PP) form the geometrical axis of the eye ball. C: Cornea, P: Pupil, I: Iris, E: Equator, T: Tunic of the eye ball.
Fig. 11 Gross morphology of the eye ball after fixation in Davidson’s fluid showing the intact retina and retinal fold. **Black arrow** showing the anterior margin of the retina join with the ciliary body at the ora ciliaris retinae. **OD**: Optic disc, **CB**: Ciliary body, **I**: Iris, **C**: Cornea, **T**: Tunic of the eye ball.

Fig. 12 Gross morphology of transparent, almost circular biconvex lens showing the posterior surface (PS) which is more convex than the anterior surface (AS). **Blue arrow** showing the attachment of the zonular fibers at the equator (E).
Fig. 13 Photomicrograph of the sclera of adult Marwari goat showing episclera having blood vessels (BV), transition between sclera and choroid (lamina fusca). (Masson’s trichome, 30X)

Fig. 14 Photomicrograph of the cornea of adult Marwari goat, showing the anterior epithelium (AP), resting upon a thin basement membrane (BM). Stroma formed the main body of the cornea. Red arrow shows nuclei of basal cell and Black arrow shows nuclei of squamous cell. E: Endothelium, SSE: Stratified squamous non-keratinized epithelium. (Masson’s trichome, 150X)
Fig. 15 Photomicrograph of the cornea of adult Marwari goat showing the anterior epithelium (AP): the basal cells (BC) which are columnar, wing cells (WC) which are polyhedral in shape and anterior most squamous cells (SC). (Masson’s trichome, 300X)

Fig. 16 Photomicrograph of the cornea of adult Marwari goat showing anteriorly cornea lined by stratified squamous epithelium (SSE) lied on basement membrane (BM), and fibrocyte (F) scattered in the stroma. AP: Anterior epithelium. (H. & E. 300X)
Fig. 17 Photomicrograph of the cornea of adult Marwari goat showing, posteriorly cornea lined by flat nuclei of the endothelium (E) and Descemet’s membrane (DM) above the endothelium. F: Fibrocyte. (H. & E. 300X)

Fig. 18 Photomicrograph of the junction between cornea and sclera (Limbus) showing, both the corneal anterior epithelium (CAP) and bulbar conjunctiva (BC) are covered by a non-keratinized stratified squamous epithelium at their junction and the cells of the bulbar conjunctiva are pigmented. CS: Corneal stroma. (Masson’s trichome, 700X)
**Fig. 19** Photomicrograph of the lens of the adult Marwari goat showing the anterior capsule (C), newly formed lens fibers (LF,N) and old lens fibers (LF,O). (H. & E. 30X)

**Fig. 20** Photomicrograph of the lens showing columnar shape nuclei of the anterior epithelium (AP) at equator. The anterior epithelium has a proliferative zone at which cell mitosis (N), formed the lens fibers (LF). (H. & E. 700X)
**Fig. 21** Photomicrograph of the lens showing the anterior capsule (AC), anterior epithelium (AP) and lens fibers (LF). (H. & E. 700X)

**Fig. 22** Photomicrograph of the lens of adult Marwari goat showing the PAS positive lens capsule. Anterior capsule (AC) is thicker than the posterior capsule (PC). LF: lens fibers. (PAS, 30X)
Fig. 23 Photomicrograph of the ciliary body of the adult Marwari goat. Ciliary body has two parts, the flat pars plana and the pars plicata having ciliary process. PC: Palpebral conjunctiva, BC: Bulbar conjunctiva. (H. & E. 30X)

Fig. 24 Photomicrograph of the pars plicata of ciliary body showing, ciliary process and stroma having smooth muscle fibers (SM), blood vessels (BV) and melanocytes. (H. & E. 75X)
Fig. 25 Photomicrograph of the ciliary process. Ciliary process comprised of stroma having blood vessels (BV) and two layered epithelium. Inner layer was non pigmented epithelium (NPE) and outer layer was pigmented epithelium (PE). (Masson’s trichome, 300X)

Fig. 26 Photomicrograph of the pars plana of the ciliary body, lined by pars ciliaris retinae (non pigmented epithelium) and pigmented epithelium (PE). (H. & E. 300X)
**Fig. 27** Photomicrograph showing, iris extended from the anterior margin of the ciliary body cover the posterior surface of the cornea. Anterior surface (AS) and posterior surface (PS) of the iris facing towards the anterior chamber (AC) and posterior chamber (PC) respectively. **ICA:** Irido-cornea angle. (H. & E. 30X)

**Fig. 28** Photomicrograph of the iris showing the anterior surface formed by the sheet of the fibrocyte and melanocytes (M) and posterior surface lined by highly pigmented posterior epithelium. Stroma of the iris comprised of loose connective tissue, melanocytes, fibrocyte and smooth muscles fibers (SM) within the posterior stroma (iridial sphincter muscles). (H. & E. 150X)
**Fig. 29** Photomicrograph of the irido-corneal (triangular) angel, formed by base of the iris, anterior ciliary body and limbus. It contain uveal (UTM) and corneoscleral (CSTM) trabecular meshwork which is bordered by pectinate ligament (PL) anteriorly. **AAP:** Angular aqueous plexus, **BV:** Blood vessel. (H. & E. 75X)

**Fig. 30** Photomicrograph of the corneoscleral trabecular meshwork showing inter-trabecular spaces or space of Fontana (red stars) between trabeculae and adjacent angular aqueous plexus (AAP). **Blue arrows** showed, squamous cell and melanin pigment present on the surface of trabeculae. (Masson’s trichome, 300X)
**Fig. 31** Photomicrograph of the pectinate ligament (PL) which make the anterior border of the irido-corneal angel. **AC:** Anterior chamber, **TM:** Trabecular meshwork, **C:** Cornea. (H. & E. 150X)

**Fig. 32** Photomicrograph of the edge of the iris showing round masses i.e. granula iridica (GI) which is extension of the posterior epithelium (PE; highly pigmented) of the iris. (Masson’s trichome, 300X)
RPE: Retinal pigment epithelium, LRD: Layer of rods and cones,
ELM: External limiting membrane, ONL: Outer nuclear layer,
OPL: Outer plexiform layer, INL: Inner nuclear layer,
IPL: Inner Plexiform layer, GCL: Ganglion cell layer,
NFL: Nerve fiber layer, ILM: Internal limiting membrane.
Fig. 34 Photomicrograph of the retina (R) and choroid (C) of adult Marwari goat showing, the single layer of retinal pigment epithelium (RPE) is pigmented where tapetum fibrosum is not present in the choroid. CC: Choriocapillary. (H. & E. 300X)

Fig. 35 Photomicrograph of the retina (R) and choroid (C) showing, the single layer of retinal pigment epithelium (RPE) devoid of pigmentation where tapetum fibrosum (T) is present in the choroid. Black arrow indicate flat nuclei of the choriocapillary, blue arrow indicate fibroblast scattered in the tapetum fibrosum, green arrow indicating highly pigmented suprachoroidea. Blood vessels (BV) are present between tapetum and suprachoroidea surrounded by melanocytes (M) and fibrocyte. LF: Lamina fusca. (H. & E. 300X)
Fig. 36 Photomicrograph of the retina showing the ora ciliaris retinae (OCR) from where the sensory part of the retina started. **RBV:** Retinal blood vessel. (Masson’s trichome, 150X).  

Fig. 37 Photomicrograph of the tunic of the eye ball showing sclera, choroid without tapetum fibrosum and retina. Retina showing ten layers; **RPE:** Retinal pigment epithelium, **LRD:** Layer of rods and cones, **ELM:** External limiting membrane, **ONL:** Outer nuclear layer, **OPL:** Outer plexiform layer, **INL:** Inner nuclear layer, **IPL:** Inner Plexiform layer, **GCL:** Ganglion cell layer, **GC:** Nuclei of ganglion cells, **NFL:** Nerve fiber layer, **ILM:** Internal limiting membrane. (H. & E. 150X)
Fig. 38 Photomicrograph of the retina of adult Marwari goat showing the different layers of the retina. Inner nuclear layer comprised of the nuclei of horizontal cell (H), bipolar cells (B), amacrine cell (A), Muller’s cell (M). Some displaced nuclei of amacrine cell founded in inner plexiform layer (IPL). LRD: layer of rods and cones, ELM: External limiting membrane, ONL: Outer nuclear layer, OPL: Outer plexiform layer, INL: Inner nuclear layer, GC: Nuclei of ganglion cells. (Masson’s trichome, 750X)
Fig. 39 Photomicrograph of the retinal fold of the adult Marwari goat. Retina takes a convex appearance vitreally and retinal detachment from the choroid. **Arrow** showing the nerve fiber layer (thread like) which hold the retinal fold in position. (H. & E. 75X)

Fig. 40 Photomicrograph of the retinal fold showing that thickness of the different layer of the retina abruptly increased from the intact retina, number of rows of cells in outer nuclear layer (**ONL**), inner nuclear layer (**INL**) and ganglion cell layer (**GCL**) increased and nuclei of rods and cones are densely packed. **LRC:** Layer of rods and cones, **IPL:** Inner plexiform layer. (Masson’s trichome, 300X)
Fig. 41 Photomicrograph of the optic disc (OD) and optic nerve (ON) showing optic nerve fibers converged into optic nerve and left the eye ball through the choroid and sclera. At the point of the leaving of the optic nerve, long posterior ciliary artery (LPC) entered into the globe. LC: Lamina cribrosa, R: Retina, RV: Retinal vein. (H. & E. 150X)

Fig. 42 Photomicrograph of the optic disc (OD) showing, the optic nerve fibers (ONF) entered into the orbit through the lamina cribrosa (LC). The connective tissue of the sclera forms a sieve like framework, which subdivided the optic nerve into bundles of fibers. (H. & E. 300X)