B-Mode Ultrasound Biometry of Intraocular Structures in Dogs
M.V.Sc. Thesis
Department of Veterinary Surgery and Radiology
College of Veterinary and Animal Science
Rajasthan University of Veterinary and Animal Sciences,
Bikaner-334001 (Rajasthan)

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Major Advisor: Dr. S. K. Jhirwal

ABSTRACT
Transcorneal ultrasonographic scanning of 74 eyes of 37 healthy
dogs of 11 different breeds of either sex was performed without any
sedation, anaesthesia or analgesia. Qualitative echo-biometric findings of
the eyes were described and measurements of the ocular structures were
obtained.

In present study transcorneal intraocular echo-biometric study of four
parameters were performed i.e. aqueous chamber depth (ACD), lens
thickness (LT), vitreous chamber depth (VCD) and axial globe length
(AGL) by 5-14 MHz linear transducer at 4 cm scanning depth with suitable
gain (55%).

Statistically non-significant (P ≥ 0.05 and P ≥ 0.01) differences were
observed in all parameters when compared left and right eyes of male as
well as female dogs within and among skull conformation groups
(dolichocephalic, mesocephalic and brachycephalic).

There were no significant differences in all four parameters of
dolichocephalic skull group. For mesocephalic and brachycephalic skull
groups statistically significant differences were present in all four
parameters among age groups. When all four parameters were compared
among skull conformation groups statistically significant (P ≤ 0.05)
differences were observed in lens thickness, vitreous chamber depth and
axial globe length was statistically non-significant (P ≥ 0.05 and P ≥ 0.01).
The present study provides an inside echo-morphometric view of the inner
ocular structures in healthy eyes of dogs of different skull conformations.
बी - मोड अल्ट्रासूंड द्वारा श्वानों की अन्तः नेत्र संरचनाओं का मापन

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अनुसूचण

नर एवं मादा कुल 37 स्वस्थ श्वानों की 74 आँखों का नेत्र पटल से पराध्वचनक अवलोकन या क्रमवीक्षण बिना किसी भी बेहोश करने की क्रिया / निष्ठरीतन, संज्ञाहरण या दर्द निवारक दवा के बिना किया गया। आँखों के गुणात्मक गुंज वायोमेट्रिक निष्कर्षों को वर्णित किया गया और नेत्र संरचनाओं के माप प्राप्त किये।

वर्तमान अध्ययन के आर - पार इको - वायोमेट्रिक अध्ययन में 5 - 14 मंगाहर्ट रेखिक ट्रांसड्यूसर द्वारा 4 मी.भ. की अवलोकन गहराई एवं उपयुक्त लक्ष्य (55%) पर चार मापन किए गए जिसमें जलीय कक्ष की गहराई (एसीडी), लेंस की मोटाई (एलटी), कांचाभ कक्ष की गहराई (वीसीडी), और अक्षीय गोलक लंबाई (एजीएल) शामिल हैं।

सभी खोपडी रचना समूह (दीर्घशिरस्क, मध्यशिरस्क और लघुशिरस्क) के भीतर नर एवं मादा श्वानों तथा उनकी दायीं एवं बायीं आँख के सभी मापदंडों में प्राप्त अंतर सांचख्यिकीय रूप से (पी ≥ 0.05 और पी ≥ 0.01) असार्थक पाया गया।

दीर्घशिरस्क खोपडी समूह के सभी चार मापदंडों में कोई सांचख्यिकीय महत्वपूर्ण / सार्थक अंतर नहीं था। मध्यशिरस्क और लघुशिरस्क खोपडी समूहों के लिए सांचख्यिकीय महत्वपूर्ण अंतर आयु समूहों के बीच तथा सभी चार मापदंडों में उपस्थित थे। जब सभी चार मापदंडों की तुलना खोपडी रचना समूहों के बीच की गयी तो लेंस की मोटाई, कांचाभ कक्ष की गहराई और अक्षीय गोलक लंबाई में सांचख्यिकीय महत्वपूर्ण अंतर (पी ≤ 0.05) पाया गया, जबकि दायीं और बायीं आँखों में अंतर सांचख्यिकीय रूप से गैर महत्वपूर्ण (पी ≥ 0.05 और पी ≥ 0.01) था। वर्तमान अध्ययन अलग खोपडी रचना के श्वानों के स्वस्थ आँखों में अंतरिक नेत्र संरचनाओं की एक इको-मोडेलमेट्रिक तृप्ति प्रदान करता है।
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(Narendra Kumar Kumawat)
Annexure 1

SONOGRAMS OF DOLICHOCEPHALIC SKULL GROUP
Age Group 1 (Male 15 days to 1.5 Years)

1D: Corneal thickness, 2D: aqueous chamber depth (ACD), 3D: vitreous chamber depth (VCD) and 4D: lens thickness (LT).

Fig. 1: Normal B-Mode ultrasonogram of left eye of 6 months old male Doberman

Fig. 2: Normal B-Mode ultrasonogram of right eye of 6 months old male Doberman
Age Group 2 (Female 15 days to 1.5 Years)

1D: Axial globe length (AGL)

Fig. 3: Normal B-Mode ultrasonogram of left eye of 15 months old female German Shepherd

1D: Aqueous chamber depth (ACD), 2D: lens thickness (LT) and 3D: vitreous chamber depth (VCD)

Fig. 4: Normal B-Mode ultrasonogram of right eye of 15 months old female German Shepherd
Age Group 3 (Male 1.5 Years onwards)

1D: Aqueous chamber depth (ACD), 2D: lens thickness (LT) and 3D: vitreous chamber depth (VCD)

Fig. 5: Normal B-Mode ultrasonogram of left eye of 9 years male old Daschund

1D: Aqueous chamber depth (ACD), 2D: lens thickness (LT) and 3D: vitreous chamber depth (VCD)

Fig. 6: Normal B-Mode ultrasonogram of right eye of 9 years old male Daschund
Age Group 4 (Female 1.5 Years onwards)

4D: Lens thickness (LT), 5D: aqueous chamber depth (ACD) and 6D: vitreous chamber depth (VCD)

Fig. 7: Normal B-Mode ultrasonogram of left eye of 9.5 years old female German Shepherd

8D: Corneal thickness and 9D: axial globe length (AGL)

Fig. 8: Normal B-Mode ultrasonogram of right eye of 9.5 years old female German Shepherd
SONOGRAMS OF MESOCEPHALIC SKULL GROUP
Age Group 1 (Male 15 days to 1.5 Years)

1D: Axial globe length (AGL)

Fig. 9: Normal B-Mode ultrasonogram of left eye of 4 months old male Pakistani Bully

1D: Aqueous chamber depth (ACD), 2D: lens thickness (LT) and 3D: vitreous chamber depth (VCD)

Fig. 10: Normal B-Mode ultrasonogram of right eye of 4 months old male Pakistani Bully
Age Group 2 (Female 15 days to 1.5 Years)

1D: Aqueous chamber depth (ACD), 2D: lens thickness (LT) and 3D: vitreous chamber depth (VCD)

Fig. 11: Normal B-Mode ultrasonogram of left eye of 1.5 years old female Rottweiler

1D: Axial globe length (AGL)

Fig. 12: Normal B-Mode ultrasonogram of right eye of 1.5 years old female Rottweiler
Age Group 3 (Male 1.5 Years onwards)

4D: Aqueous chamber depth (ACD), 5D: lens thickness (LT) and 6D: vitreous chamber depth (VCD)

Fig. 13: Normal B-Mode ultrasonogram of left eye of 4.5 years old male Labrador Retriever

4D: Aqueous chamber depth (ACD), 5D: lens thickness (LT) and 6D: vitreous chamber depth (VCD)

Fig. 14: Normal B-Mode ultrasonogram of right eye of 4.5 years old male Labrador Retriever
Age Group 4 (Female 1.5 Years onwards)

1D: Aqueous chamber depth (ACD), 2D: lens thickness (LT) and 3D: vitreous chamber depth (VCD)

Fig. 15: Normal B-Mode ultrasonogram of left eye of 7 years old female Labrador Retriever

1D: Axial globe length (AGL)

Fig. 16: Normal B-Mode ultrasonogram of right eye of 7 years old female Labrador Retriever
SONOGRAMS OF BRACHYCEPHALIC SKULL GROUP
Age Group 1 (Male 15 days to 1.5 Years)

1D: Aqueous chamber depth (ACD), 2D: lens thickness (LT) and 3D: vitreous chamber depth (VCD)

Fig. 17: Normal B-Mode ultrasonogram of left eye of 10 months male old Pug

1D: Aqueous chamber depth (ACD), 2D: lens thickness (LT) and 3D: vitreous chamber depth (VCD)

Fig. 18: Normal B-Mode ultrasonogram of right eye of 10 months male old Pug
Age Group 2 (Female 15 days to 1.5 Years)

1D: Aqueous chamber depth (ACD), 2D: lens thickness (LT) and 3D: vitreous chamber depth (VCD)

Fig. 19: Normal B-Mode ultrasonogram of left eye of 1 year old female Pit bull

1D: Aqueous chamber depth (ACD), 2D: lens thickness (LT) and 3D: vitreous chamber depth (VCD)

Fig. 20: Normal B-Mode ultrasonogram of right eye of 1 year old female Pit bull
Age Group 3 (Male 1.5 Years onwards)

1D: Aqueous chamber depth (ACD), 2D: lens thickness (LT) and 3D: vitreous chamber depth (VCD)

Fig. 21: Normal B-Mode ultrasonogram of left eye of 4 years old male Pug

1D: Aqueous chamber depth (ACD), 2D: lens thickness (LT) and 3D: vitreous chamber depth (VCD)

Fig. 22: Normal B-Mode ultrasonogram of right eye of 4 years male old Pug
Age Group 4 (Female 1.5 Years onwards)

1D: Aqueous chamber depth (ACD), 2D: lens thickness (LT) and 3D: vitreous chamber depth (VCD)

Fig. 23: Normal B-Mode ultrasonogram of left eye of 5 years old female Napoleon Mastiff

1D: Aqueous chamber depth (ACD), 2D: lens thickness (LT) and 3D: vitreous chamber depth (VCD)

Fig. 24: Normal B-Mode ultrasonogram of right eye of 5 years old female Napoleon Mastiff
CERTIFICATE - I

Date............... 

This is to certify that Dr. Narendra Kumar Kumawat had successfully completed the comprehensive examination held on...............as required under the regulations for Master of Veterinary Science degree.

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Head
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CERTIFICATE - II

Date......................

This is to certify that this thesis entitled “B-Mode Ultrasound Biometry of Intraocular Structures in Dogs” submitted for the degree of Master of Veterinary Science in the subject of Veterinary Surgery and Radiology embodies bonafide research work carried out by Dr. Narendra Kumar Kumawat under my guidance and supervision and that no part of this thesis has been submitted for any other degree. The assistance and help received during the course of investigation have been successfully acknowledged. The draft of the thesis was also approved by the advisory committee on..................

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(Dr. G. S. Manohar)
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This is to certify that the thesis entitled “B-Mode Ultrasound Biometry of Intraocular Structures in Dogs” submitted by Dr. Narendra Kumar Kumawat to the Rajasthan University of Veterinary and Animal Sciences, Bikaner, in partial fulfilment of requirements for the degree of Master of Veterinary Science in the subject of Veterinary Surgery and Radiology, after recommendation by the external examiner, was defended by the candidate before the following members of the examination committee. The performance of the candidate in the oral examination on his thesis has been found satisfactory. We, therefore, recommend that the thesis be approved.

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Date……………………

This is to certify that Dr. Narendra Kumar Kumawat of the Department of Veterinary Surgery and Radiology, College of Veterinary and Animal Sciences, Bikaner has made all corrections/modifications in the thesis entitled “B-Mode Ultrasound Biometry of Intraocular Structures in Dogs” which were suggested by the external examiner and the advisory committee in the oral examination held on……………The final copies of the thesis duly bound and corrected were submitted on........................, are enclosed herewith for approval.

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Enclosed: One original and two hard bound copies of the thesis, forwarded to the Dean, Post Graduate Studies, RAJUVAS, Bikaner through the Dean, College of Veterinary and Animal Science, Bikaner.
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List of Abbreviations

ACD – Aqueous chamber depth

AGL – Axial globe length

AINP-DIMSCA – All India Network Program on Diagnostic Imaging and Management of Surgical Conditions in Animals

A-mode – Amplitude mode

ANOVA – Analysis of Variance

B-Mode – Brightness mode

BO – Bony orbit

B-scan – Brightness scan

BZD – Bi-zygomatic diameter

CT – Computerised tomography

FOD – Fronto-occipetals diameter

IBM – International Business Machines

ICAR – Indian Council of Agricultural Research

IOP – Intraocular pressure

LT – Lens thickness

MHz – Mega Hertz

MR – Magnetic resonance

SPSS – Statistical Package for the Social Sciences

VCD – Vitreous chamber depth
B-Mode Ultrasound Biometry of Intraocular Structures in Dogs
बी- मोड अल्ट्रासाउंड द्वारा श्वानों की अन्तः नेत्र संरचनाओं का मापन

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5. Discussion

Ultrasound is considered a safe procedure for the patient, the operator and nearby personnel, allowing it to be performed in any location without the need for specific safety precautions (Preston and Shaw, 2001). It is non-invasive and so therefore well tolerated in unsedated animals, making serial examinations to monitor progression of the condition, response to treatment or to practice scanning techniques possible (Nyland and Mattoon, 2002).

Ocular ultrasound is an addition to, not a replacement for routine ophthalmic examination including assessment of menace, blink and pupillary light response, fluorescein staining, nasolacrimal evaluation, determination of intraocular pressure, and examination of anterior and posterior segments using a bright focal light source and direct and indirect ophthalmoscopy or bio-microscopy, respectively (Reef, 1998; Gonzalez et al., 2001; Gorig et al., 2006).

Even for animals for which direct observation of intraocular structures is possible, ultrasonography may be helpful for tumour identification, performance of measurements, and comparison of findings to those for the contralateral eye (Gonzalez et al., 2001). Structures that cannot be observed by use of routine ophthalmologic examination techniques, such as ciliary bodies or retro-bulbar spaces, can be evaluated via ultrasonography (Wilkie and Gilger, 1998 and Hoffmann and Kostlin, 2004).

The refractive status of the eye is influenced by the diameter of the globe (axial length), corneal power (keratometry) (Sorsby et al., 1957; Wilkie and Whittaker, 1997), anterior chamber depth and lens power (Goss and Erickson, 1990; Garner et al., 1992) so the data of present study may help in the calculation of the dioptric power of intraocular lens implant regardless of the breed on the basis of skull conformation. And also may be helpful in estimating prosthetic globe size after enucleation in dogs as reported by Gaiddon et al., (1991).
The characterisation of dolichocephalic, mesocephalic and brachycephalic skull conformations (Table – 1) for the present study was as proposed before by Diesem (1986), Zink (2000), Tutt (2008), Jeffrey et al., (2013), Stone et al., (2016) and Coren (2016). The format and size of the canine skull vary according to the breed and individual conformation (Beserra et al., 2009). The eyes of different breeds of dogs have different shapes, dimensions, and retina configurations (Jonica et al., 2003).

Each skull confirmation group was further divided into four on the basis of age and sex. Age groups were divided according to the age of skeletal maturity on the basis of closure of epiphyseal growth plates in dogs reported to be in range of 8.5 months to 13.75 months (Chapman, 1965; Sumner-Smith, 1966; Yonamine et al., 1980 and Geiger et al., 2016).

Opening of eyes in pups was reported to be between ten to fifteen days by Paunksnis et al., (2001) and Ferriera et al., (2003). Boroffka (2005) concluded that in young pups, clinical examination of the eyes was not possible until the eyelids have opened during the first 14 days and thereafter, it was difficult because of restless behaviour, small globe size, and the incompletely developed tapetum lucidum, but these factors did not limit ultrasonographic examination of the eye, hence the lower limit of the age in present study was justified.

Boroffka et al., (2006) concluded that intra and inter-observer repeatability errors did not contribute to the occurrence of discrepant results when B-mode ultrasound was used as tool for ocular biometry. However, the percentage difference between observations can be high for smaller measurements. Although discrepancies relative to intra and inter-observer repeatability were acceptable for measuring intraocular structures by means of B-mode ultrasonography in dogs. In the present study all the observation and measurements were performed by single observer.
The B-mode probe used in the present study operated at a frequency of 5-14 MHz, allowed complete evaluation of the globe which was in accordance with Ribeiro et al., (2010) and Martins et al., (2010b). The scanning depth was kept 4 cm which allowed excellent evaluation of the intraocular structures and was in agreement with Whitcomb (2002).

Hillyer (1993) stated that transpalpebral and trans-corneal ultrasonographic techniques were useful to evaluate the normo-echoic ocular pattern of the eye. However, trans-corneal technique has some risk of corneal damage but outweighed by the enhanced image quality therefore transcorneal method was adopted in present study.

Trans-corneal ocular ultrasonography was performed only in healthy dogs to obtain good quality normo-echoic sonogram of eyes on which biometric study was conducted. The criteria for selection of ocular ultrasonographic techniques in present study were in corroboration with previous researchers as Hager et al., (1987), Hillyer, (1993); Read and Barnett, (1995) and Williams and Wilkie (1996).

The present study was conducted in lateral recumbency by manual restrain and blepherostasis on unsedated dogs similar to Lee et al., (2003) and Bentley (2015). This allowed adequate evaluation of the eye globe, avoided rotation of eye ball and upward movement of third eyelid which were reported as the common problems faced in sedated or general anesthetised and closed eyelids by Penninck et al., (2001), Mustafa (2005) and Dar et al., (2014). Thus, sedation and general anaesthesia proposed previously by Schiffer et al., (1982), Hager et al., (1987) and Gonçalves et al., (2009) did not appear necessary and with these techniques, risks inherent in anaesthesia, as well as additional costs, were eliminated in present study.

Many parameters in the anterior segment may be lost in the near-field reverberation artefact as observed by Goddard (1995), Poulsen et al., (2000), Nautrap et al., (2000) and a standoff can be used to avoid this problem as advocated by Goddard (1995). Conductive gel used as a
standoff pad in present study as advocated by Dziezyc et al. (1987), Silva et al., (2010) and Singh et al., (2015) was effective and allowed adequate evaluation of the anterior segment of the eye, as well as identification of its structures in all eyes evaluated for the obtainment of reliable images and measurements.

The water bath method alleviates the problem of the near field artefact by offsetting the transducer 1 - 2 cm from the eye (Hager et al., 1987) but the problem with the water bath technique is that reverberation of sound waves occurs within the water bath creating linear artefacts that become superimposed over the image of the eye as reported by Park et al., (1981). The gel standoff used in present study helped in overcoming these artefacts as well allowed better visualisation of the intraocular structures and provided adequate contact of the transducer with the surface of the cornea, with minimal pressure on the eye, which resulted in less discomfort for the patients which was in accordance with McMullen and Gilger (2006), Wilkie et al., (2006) and Toni et al., (2010).

After ultrasound examination, excess coupling gel was carefully wiped from the eyes as reported by El-Tookey and Tharwat (2013) and rinsed with sterile 0.9% sodium chloride solution as stated by Martins et al., (2010a) to prevent the corneal irritation (Hager et al., 1987; Kealy and McAllister, 2000; Maggs et al., 2008; Martins et al., 2010a; Assadnassab and Fartashvand, 2011 and Singh et al., 2015); and eyes were re-examined for the identification and treatment, if necessary, of iatrogenic corneal lesions resulting from the examination as advised by Martins et al., (2010a). In present study no iatrogenic corneal lesions were noticed from the examination, this was in accordance with Soares et al., (1998), Gonçalves et al., (2000) and Gonçalves et al., (2009) in dogs and cats and by Toni et al., (2010) in rabbits.

No standardised labelling or exam system exists in veterinary ophthalmology that compares to the system in physician-based ophthalmology. The conventions used in human patients, however, can be easily adapted to veterinary patients. Typically, scans are labelled
vertical axial when the probe marker is at 12:00. Horizontal axial scans are always done with the marker facing towards the patient's nose. Oblique scans are labelled according to the clock hour the probe marker is facing (Bentley, 2015). In present study, saggital plane (vertical plane) was used for two-dimensional imaging of the globe and probe angle was adjusted slightly in order to obtain good quality ultrasonograms.

The ultrasonographic appearances of present study corroborated with ophthalmologically normal eyes of dogs (Paunksnis et al., 2001), feline (Gilger et al., 1998), equine (Svaldeniene et al., 2004), bovine (Potter et al., 2008), cattle (Assadnassab and Fartashvand, 2011), buffalo (Assadnassab and Fartashvand, 2013) and camel (Yadegari, et al., 2013) except dimensions or measurements.

B-scan ultrasonography images of normal contra-lateral eyes depicted three cavities with corneal surfaces as the first highly reflective lines which were in agreement with Boroffka et al., (2006). The globe was observed as a round and well-delimited structure with distinct borders in bony orbit and all three primary structures in the globe; the anterior chamber, vitreous chambers and the lens appeared anechogenic (Singh et al., 2015). The cornea generated two echoes: the first one corresponded to its epithelium and the second to its Descemet’s membrane which was in accordance with El-Tookhy et al., (2012). Corneal thickness may be assessed with a high resolution probe and both corneal tumours and sequestrums appears hyperechoic as reported by Bentley (2015). The measurements of the complete length of the eye and ACD were performed from inner peak of the cornea to the posterior pole of the eye in present study.

The anterior and posterior chambers of the aqueous appeared as a single, anechoic space which was in agreement with Assadnassab and Fartashvand (2013). Inflammatory debris associated with anterior uveitis can appear as an ill-defined area of increased echogenicity within the anterior chamber as reported by Penninck et al., (2001). El-Tookhyl and
Tharwat (2013) observed that hypopyon appears ultrasonographically as a hyperechoic mass in the anterior chamber of sheep and goat.

In normal dogs, the iris and posterior chamber are usually difficult to distinguish from the adjacent ciliary bodies but using high-resolution transducers, the posterior chamber can be seen as an anechoic, triangular space between the lens, ciliary body, and iris as reported by Penninck et al., (2001) however, in present study at 14 MHz frequency it was possible to observe distinguished anterior chamber, ciliary bodies and posterior chamber as well.

The iris and the ciliary body were relatively hyperechogenic structures. However, on ultrasonic examination they appeared at the lateral margins of the lens. The iris leaflets were identifiable as echoic linear bands continuous with the ciliary body, which was found immediately posterior to the iris leaflets circumferentially; these findings were in corroboration with Scotty et al., (2004). Differentiation between iris cysts and iris masses as well as evaluation of tumour extent is facilitated by a high resolution probe. Cysts can appear as thin walled, fluid filled structures, or anterior displacement of the iris due to the cysts can be noted as stated by Bentley, (2015).

The anterior and posterior margins of the lens were hyperechogenic creating a distinct delineation between the chambers and the lens. It was possible to identify the lens by identifying both anterior and posterior capsules. Anterior lens capsule appeared as convex hyperechoic line while posterior lens capsule appeared as concave hyperechoic line and the nucleus of the lens was identified as an anechoic area between two hyperechoic lines of the anterior and posterior lens capsules these findings corroborates with Williams (2004).

Echogenicity, size and shape of the lens may change with the type of cataract and its duration. Changes within a cataractous lens produce acoustic inhomogeneities as reported by Spaulding (2008). The hyperechogenicity of the anterior and posterior capsules was detected.
independent of the developmental stage of the cataract by Martins et al., (2010a).

In present study, the vitreous chamber filled with vitreous humour was identified as anechoic area between the posterior lens capsule and hyperechoic posterior pole of the eye. These findings corroborated with Williams (2004) and Haraldsen (2014). Detection of the vitreous changes depends on the time gain compensation settings as stated by van der Woerdt et al., (1993) and Chaudhari et al., (2013).

The posterior pole of the eye, which includes the retina, the choroid and the sclera, was identified as a hyperechogenic and concave structure in present study. It was hard to differentiate retina, choroid and sclera and was collectively termed as sclero-retinal rim. The optic disc appeared as a slightly brighter region that may be either raised or depressed, relative to the posterior globe, in normal eyes. The optic nerve and extra-ocular muscles were hyperechoic, relative to the echogenic retro-bulbar fat separating them just posterior to the globe surrounded by hypoechoogenic ocular muscles. These structures converged toward the posterior orbital apex near the optic canal, forming a cone shape, with the base at the posterior wall of the globe. These findings of present study corroborated with Haraldsen (2014).

In present study, the hyper-echogenicity of the optic nerve was presumably due to orientation of the beam parallel to the nerve fibers and the highly organised, homogeneous structure of the optic nerve compared to adjacent fat as reported by El-Maghraby et al., (1995), Goddard (1995) and Potter et al., (2008).

Penninck et al., (2001) reported that retrobulbar cellulitis can appear as a diffuse, non-deforming lesion of the retrobulbar space and the echogenicity of this lesion can vary from diffusely hyperechoic to the point of not identifying the optic nerve, to subtle hypoechoic areas. Retrobulbar abscess often appears as a hypoechoic mass with or without deformity of the posterior wall of the globe.
Although there are satisfactory data about ophthalmic ultrasound in dogs, data regarding the correlation of the size of intraocular structures and skull conformation are scarce (Toni et al., 2013). Considering the wide variety of breeds and their significance as experimental models for the study of human myopia as described by Black et al., (2008) as well as the increasing number of cataract surgeries being performed daily in veterinary facilities, it becomes important to know the intraocular measurements for different skull conformations.

Most of the biometric studies using either A-mode or B-mode have been performed in adult dogs (Ekesten, 1994; Beserra et al., 2009; Martins et al., 2010a,b; Silva et al., 2010; Toni et al., 2013; Boillot et al., 2014; Tavana et al., 2014; Kobashigawa et al., 2015), a very few studies are reported which include young dogs (Paunksnis et al., 2001; Boroffka, 2005; Tuntivanich et al., 2007) and a very fewer studies have been reported describing skull conformation in dogs and their comparisons (Cottrill et al., 1989; Mieres et al., 2007; Tuntivanich et al., 2007; Toni et al., 2013).

There was no statistically significant difference observed in biometric values of intraocular structures between right and left eyes of the dogs of either sexes in same skull conformation groups which corroborated with data reported in dogs by other authors (Williams, 2004; Zhou et al., 2006; Tuntivanich et al., 2007; Silva et al., 2010; Squarzoni et al., 2010; Toni et al., 2013; Mirshahi et al., 2014). With this, it was possible to say that measurements of the normal eye can provide reliable parameters for determination of the size of eye prosthesis in cases of malformation or enucleation of the opposite eye (Toni et al., 2013).

1) COMPARISON OF ECHOBIOMETRIC PARAMETERS WITHIN SKULL GROUPS:

In present study, no significant differences were found between measurements of right and left eyes within all respective age groups as well either sex for ACD, LT, VCD and AGL (both at P > 0.01 and P > 0.05) for all three skull groups which was in agreement with previous studies in
dogs by Svaldenienė et al., (2000), Whitcomb (2002), Boroffka et al., (2005), Toni et al., (2013) and in other species by Singh et al., (2015). Scarce data were found for comparison of dolichocephalic skull conformation group regarding echo-biometrics of eye in young dogs i.e. for group 1 and group 2.

**A** Dolichocephalic skull group

**(I)** Aqueous chamber depth (ACD):

Mieres et al., (2007) reported a correlation between the size of eye structures and dolichocephalic canine head. Toni et al., (2013) reported ACD in dolichocephalic adults 3.07 ± 0.65 mm and Mieres et al., (2007) 3.00 ± 0.08 mm which were contrary to findings of present study in adult dolichocephalic dogs (3.79 ± 0.37 mm and 4.59 ± 0.05 mm, respectively for groups 3 and 4), may be due to breed differences.

**(II)** Lens thickness (LT):

Toni et al., (2013) reported LT in dolichocephalic adults 7.00 ± 0.81 mm and Mieres et al., (2007) 7.60 ± 0.06 mm which were contrary to findings of present study in adult dolichocephalic dogs (for groups 3 and 4 LT was 6.31 ± 0.12 mm and 6.50 ± 0.14 mm, respectively) may be due to breed differences.

**(III)** Vitreous chamber depth (VCD):

Toni et al., (2013) reported VCD in dolichocephalic adults 9.75 ± 0.98 mm and Mieres et al., (2007) 8.90 ± 0.12 mm; present study measurements of VCD for adult dolichocephalic dogs were in agreement with (for group 3 and 4 VCD 9.57 ± 0.50 mm and 9.49 ± 0.23 mm, respectively) above reports.

**(IV)** Axial globe length (AGL):

AGL values of adult dolichocephalic dogs in present study for group 3 and 4 were 19.79 ± 0.82 mm and 20.10 ± 0.22 mm, respectively were found in agreement with 19.82 ± 0.95 mm of reports of Toni et al., (2013) and 19.40 ± 0.18 mm of reports of Mieres et al., (2007).

**B** Mesocephalic Skull Group

There were many documented reports on mesocephalic skull breed regarding ocular dimensions but scarce data were found for ACD, LT, VCD and AGL in young mesocephalic dogs. Though reports may be there
but skull conformation or breeds which come in mesocephalic skull conformation were scarcely reported in studies. Data of young dogs of present study might be helpful for further echo-biometric studies.

(I) **Aqueous chamber depth (ACD):**

Silva *et al.*, (2010) evaluated ocular parameters in English Cocker Spaniel dogs older than eight years and ACD was reported to be 3.66 ± 1.46 mm for right eye and 3.32 ± 0.74 mm for left eye. Average ACD for adult males was 3.07 ± 0.37 mm and 3.52 ± 1.25 mm for adult females. These were similar to findings with present study except group 2 which may be due to variation of age within individuals of group.

Mutti *et al.*, (1999) studied myopia in Labrador Retriever dogs and ACD was observed 4.29 ± 0.36 mm in non myopes which was in accordance with present study. ACD was reported 3.08 ± 0.67 mm in adult mesocephalic dogs by Toni *et al.*, (2013) which was similar to group 2 (female from 15 days to 1.5 years) findings of present study but contrary to adults may be due to breed differences.

Difference in average parameters of ACD for group 1 (male from 15 days to 1.5 years) from other age groups was statistically significant (at P > 0.01 highly significant and at P > 0.05 significant) which may be due to age and weight difference from other groups as reported by Sampaio *et al.*, 2002).

(II) **Lens thickness (LT):**

Silva *et al.*, (2010) evaluated ocular parameters in English Cocker Spaniel dogs older than eight years and LT was reported to be 7.14 ± 0.35 mm for right eye and 7.19 ± 0.57 mm for left eye. Average LT for adult males was 7.04 ± 0.61 mm and 7.07 ± 0.44 mm for adult females; present study findings were contrary to above which may be possibly due to breed differences and variation of age within individuals of group.

Mutti *et al.*, (1999) studied myopia in Labrador Retriever dogs and LT was observed 7.85 ± 0.51 mm in non myopes and Toni *et al.*, (2013) reported LT in adult mesocephalic dogs to be 7.02 ± 0.87 mm both were higher than the observations of present study may be due to breed and age differences.
Difference in average parameters of left and right eye for LT of group 1 was statistically significant from group 3 and group 4 (both at P > 0.01 and P > 0.05, highly significant and significant, respectively) which may be due to age difference in young and adult as globe size and intraocular structures increase with age as stated by Tuntivanich et al., (2007).

Difference of group 2 average parameters from group 1, group 3 and group 4 was not statistically significant which may be due to age.

(III) Vitreous chamber depth (VCD):

Silva et al., (2010) evaluated ocular parameters in English Cocker Spaniel dogs older than eight years and VCD was reported to be 9.13 ± 0.82 mm for right eye and 9.83 ± 0.59 mm for left eye. Average LT for adult males was 10.01 ± 0.38 mm and 9.27 ± 0.71 mm for adult females; present study findings corroborated with above.

Mutti et al., (1999) observed VCD 10.02 ± 0.40 mm in mesocephalic Labrador Retriever adults which was contrary to present study. Toni et al., (2013) reported VCD in adult mesocephalic dogs to be 8.76 ± 1.23 mm which were similar to findings of adult dogs of present study.

Difference in average parameters of left and right eye for VCD of group 1 from group 3 and group 4 was statistically significant (at P > 0.05) may be due to age and weight differences as concluded by Sampaio et al., (2002). Difference of group 2 average parameters from group 1, group 3 and group 4 was not statistically significant (both at P > 0.01 and P > 0.05) may be due to higher age of animals in group 2.

(IV) Axial globe length (AGL):

Tuntivanich et al., (2007) found that AGL increases from the age of 2 weeks to 52 weeks and ranges from 13.65 ± 0.18 mm to 19.52 ± 0.18 mm. Present study results were contrary to findings of 2 weeks because of age differences but were in the stated range.

Silva et al., (2010) evaluated ocular parameters in English Cocker Spaniel dogs older than eight years and AGL was reported to be 19.93 ± 1.22 mm for right eye and 20.34 ± 0.96 mm for left eye. Average AGL for adult males was 20.12 ± 1.26 mm and 19.87 ± 1.01 mm for adult females. The observations of present study for AGL of both right and left eyes for groups 3 and 4 corroborated with above. Toni et al., (2013) found AGL in
mesocephalic dogs to be 18.86 ± 1.45 mm which was less than adults of present study; may be due to age and breed differences.

Average parameters of left and right eyes for VCD of group 1 differed from group 2 and group 3 and was statistically significant (at P > 0.05) which corroborated with Tuntivanich et al., (2007). Differences in average parameters of group 4 from group 1, group 2 and group 3 were statistically insignificant possibly due to wide variation in age of dogs in group 1 and 2. Average parameters of group 2 were also statistically insignificant from group 3 and group 4 (both at P > 0.01 and P > 0.05) possibly due to wide variation of age of the dogs in group 2.

(C) Brachycephalic Skull Group

Scarce reports were found regarding the comparison of data of ACD, LT, VCD and AGL in young brachycephalic dogs.

(I) Aqueous chamber depth (ACD):

Toni et al., (2013) found ACD in brachycephalic dogs 2.92 ± 0.37 mm and Kobashigawa et al., (2015) reported ACD 4.06 ± 0.10 mm for Shih Tzu dogs; first was contrary but later was in accordance with present study findings.

Differences in average parameters of left and right eyes for ACD of group 1 from group 3 were statistically significant (at P > 0.01 highly significant and at P > 0.05 significant), possibly due to age difference as reported by Tuntivanich et al., (2007) in mesocephalic dogs. Differences of average parameters of group 2 and group 4 were statistically insignificant from each other and from group 1 and group 3 (both at P > 0.01 and P > 0.05) possibly due to age variation in groups.

(II) Lens thickness (LT):

Toni et al., (2013) reported LT in brachycephalic dogs 7.03 ± 0.61 mm and Kobashigawa et al., (2015) reported LT 6.62 ± 0.03 mm for Shih Tzu dogs; first was contrary but later was in agreement with present study observations.

Differences in average parameters of left and right eyes for LT of group 1 from group 4 were statistically significant (at P > 0.01 highly significant and at P > 0.05 significant) may be due to age difference as reported in other breeds by Tuntivanich et al., (2007). Differences in
average parameters of group 2 and group 3 were statistically insignificant in between and from group 1 and group 4 (both at $P > 0.01$ and $P > 0.05$) age of the dogs in respective age group may affect the parameters investigated.

(III) **Vitreous chamber depth (VCD):**

Kobashigawa *et al.*, (2015) reported VCD of $9.56 \pm 0.05$ mm in adult Shih Tzu dogs and Toni *et al.*, (2013) reported VCD of $9.48 \pm 0.74$ mm in brachycephalic breeds; both were in agreement with present study.

Observations of VCD for group 1 and 3 differed significantly (at $P > 0.05$) possibly due to age variations as reported by Vosough *et al.*, (2008). Difference in average parameters of group 2 and group 4 was statistically insignificant in between and from group 1 and group 3 (both at $P > 0.01$ and $P > 0.05$), possibly due to wide variation in age of the dogs in group 1 and 2.

Deprivation and defocus resulted in an elongated vitreous chamber as studied in the macaque by Raviola and Wiesel (1985); Hung *et al.*, (1995), Judge and Graham (1995) and in other mammals such as the tree shrew by Marsh-Tootle and Norton (1989); Siegwart and Norton (1993) and in the chick by Wallman and Adams (1987); Wildsoet and Wallman, (1995). Results of the vitreous chamber depth of present study may be helpful in the detection of changes during deprivation and defocus in dogs.

(IV) **Axial globe length (AGL):**

Kobashigawa *et al.*, (2015) reported AGL in adult Shih Tzu dogs to be $20.25 \pm 0.13$ mm and Toni *et al.*, (2013) observed AGL in brachycephalic breeds $19.43 \pm 0.60$ mm; present study findings corroborated with both of the above.

Differences of average parameters of group 1 (male from 15 days to 1.5 years) from other age groups were statistically significant (at $P > 0.01$ highly significant and at $P > 0.05$ significant) possibly due to age differences while among group 2, group 3 and group 4 it was statistically
insignificant (both at $P > 0.01$ and $P > 0.05$); which was in agreement with Kobashigawa et al., (2015).

(2) COMPARISON OF ECHOBIOMETRIC PARAMETERS AMONG DIFFERENT SKULL GROUPS:

Echobiometric findings of aqueous chamber depth, lens thickness, vitreous chamber depth and axial globe length for dolichocephalic, mesocephalic and brachycephalic skull group were compared between right and left eye as well sex and were found statistically insignificant as reported by Cottrill et al., (1989), Toni et al., (2013) and Kobashigawa et al., (2015).

(I) Aqueous chamber depth (ACD) among skull groups

Toni et al., (2013) reported insignificant difference for ACD among all three skull groups with average findings of $3.07 \pm 0.65$ mm, $3.08 \pm 0.67$ mm and $2.92 \pm 0.37$ mm for dolichocephalic, mesocephalic and brachycephalic skull groups, respectively. The observations of present study were in agreement with the above findings.

(II) Lens thickness (LT) among skull groups

Toni et al., (2013) reported non-significant difference of LT among different skull conformation groups with average LT of $7.00 \pm 0.81$ mm, $7.02 \pm 0.87$ mm and $7.03 \pm 0.61$ mm for dolichocephalic, mesocephalic and brachycephalic skull group, respectively which were in agreement with present study except brachycephalic skull group. The exception for brachycephalic skull group was possibly because differences for smaller measurements may be significant as reported by Boroffka (2006) and may also be due the average age of the study population because only adult dogs were included by Toni et al., (2013).

The normal lens thickness of dogs has been determined, varying from $7.30$ mm to $9.80$ mm by Williams (2004) which was higher than the observations of present study possibly due to age and breed differences.

Svaldeniene et al., (2004) concluded that the dolichocephalic dogs had the biggest eyeball and its elements were the biggest in all dogs' group which was in agreement with present study except the LT was
observed higher in mesocephalic skull group and it significantly differed from brachycephalic skull group.

(III) Vitreous chamber depth (VCD) among skull groups

Toni et al., (2013) reported non-significant difference among different skull conformation groups with average findings of VCD 9.75 ± 0.98 mm, 8.76 ± 1.23 mm and 9.48 ± 0.74 mm for dolichocephalic, mesocephalic and brachycephalic skull group, respectively which was in agreement with present study (both at the level of P > 0.01 and P > 0.05).

(IV) Axial globe length (AGL) among skull groups

Toni et al., (2013) reported a significant difference between dolichocephalic and mesocephalic skull groups with average findings of AGL 19.82 ± 0.95 mm, 18.86 ± 1.45 mm and 19.43 ± 0.60 mm for dolichocephalic, mesocephalic and brachycephalic skull group, respectively. In present study statistically significant difference was found between dolichocephalic and brachycephalic skull groups (both at the level of P > 0.01 and P > 0.05) which was contrary to the above findings but was in agreement with Gaiddon et al., (1991) which stated that axial ocular length did not depend on age or sex, but was significantly greater in dogs of large breed.

Skull conformation of brachycephalic dogs did not influence intraocular measurement values when compared to dolichocephalic and mesocephalic dogs. Skull conformation of dolichocephalic dogs had an influence in values of vitreous chamber and the complete length of the eye when compared to mesocephalic dogs (Toni et al., 2013). In present study differences were found when comparing mean values of VCD and AGL between dolichocephalic and mesocephalic group. These findings sustained the conclusion which reported that dolichocephalic dogs have a larger axial length of the eye when compared to mesocephalic dogs (Cottrill et al., 1989 and Toni et al., 2013).

Ocular dimensions varied considerably and depended on species, age, and sex (Schiffer et al., 1982; Cottrill et al., 1989; Ekesten, 1994; Paunksnienè et al., 1997 and Osuobeni and Hamidzada, 1999); in present
study ocular dimensions varied according to age in all three skull conformation groups which were in agreement with above studies.

Findings of present study also corroborated with Cottrill et al., (1989) which stated that dolichocephalic breeds had a longer eye globe (AGL) than mesocephalic breeds but the difference was not statistically significant.

Data of present study when compared with age, axial and sagittal measurements increased significantly with age as stated by El- Tookhy et al., (2012), which indicated ocular tissue growth as stated in other reports by Lim et al., (1992) but this was not significant between adults as reported by Tuntivanich et al., (2007).

Studies of Aguirre (1972), Gum et al., (1984) and Tuntivanich et al., (2003) stated that the eyes of dogs were not fully developed at birth: over the first 2 to 3 months of age the canine eye continues to develop and became adult-like in function and during this maturation period there was an increase in axial globe length. But due to wide range of age in groups (15 days to 1.5 years and 1.5 years onwards) in present study such relationship between age and AGL could not be established.

Significant differences in the axial globe length described by Ekesten and Torrång (1995) and by Tuntivanich et al. (2007) were not observed by Silva et al., 2010. However, in the study of Tuntivanich et al. (2007), the axial globe length increased up to 52 weeks, and thereafter such increases were not significant. In present study AGL increased in dolichocephalic skull group but it was not significant, may be due to wide variation of age in group 1 and 2. AGL in mesocephalic and brachycephalic males (between group 1 and 3) increased significantly in present study but in females of both skull conformation groups such changes were not statistically significant may be due to less age and breed differences of the females in group 2 and 4.

Cottrill et al., (1989) reported that axial ocular length was significantly longer in men than women. The same result was found in the
dog by Tomlinson and Phillips (1990); however, an independent study by Schiffer et al., (1982) reported no significant differences which corroborated with present study. Cottrill et al., (1989) reported that the lengths of the right and the left eyes were equal in all species studied and dolichocephalic breeds had a longer globe than mesocephalic breeds; this was in accordance with present study.

The axial globe length in adult dogs has been reported by a number of authors and in those reports by Schiffer et al., (1982), Cottrill et al., (1989) and Gaiddon et al., (1991); the mean AGL ranged from 20.00 to 21.91 mm which was higher than the present study this was possibly due to age and breed differences.

Many workers had reported that the ocular dimensions increase with the advance of age in the dogs (Tauntivanich et al., 2007) in the buffaloes and camels (Ahmed et al., 2009), in the Asian elephant (Bapodra et al., 2010) and goat (Ribeiro et al., 2009) which was in agreement with the present study except a few parameters possibly due to less age and breed differences in the groups.

Age was found to be the most significant predictor of the lens dimensions which is true for all mammalian species, as the lens cortex enlarges throughout life as the result of new lens fibre production as concluded by Williams (2004) and Bapodra et al., (2010); findings of present study were in agreement with above statements.

On the basis of above discussion it was concluded that

1. B-mode ultrasound can be used to study the normal echogenicity of the main ocular structures.
2. It is possible to determine the reference values for depth of the anterior chamber, lens, vitreous chamber and antero-posterior depth of the globe in healthy dolichocephalic, mesocephalic and brachycephalic dogs.
3. Lens thickness and vitreous chamber depth had a significant correlation with canine head (i.e. skull conformation).
4. As the AGL increases between 2 to 52 weeks, more elaborated studies in young age groups might be needed for better conclusions and to check reference values.
1. Introduction

The dog had accompanied man all over the world since its domestication 15,000 years ago (Savolainen et al., 2002) and it is the most abundant canid on earth (Green and Gipson, 1994) with a great impact on the environment. The dog was the first domesticated animal (Larson et al., 2012) and has been the most widely kept for working, hunting and pet animal in human history.

Eye is one of the most important sense organs associated with vision. The eye is made up of three coats, enclosing three transparent structures. The outermost layer, known as the fibrous tunic, is composed of the cornea and sclera. The middle layer, known as the vascular tunic or uvea, consists of the choroid, ciliary body, and iris. The innermost is the retina, which gets its circulation from the vessels of the choroid as well as the retinal vessels.

Ocular ultrasonography is a good diagnostic tool for routine ophthalmic examinations (Gorig et al., 2006). Ultrasonography enables the evaluation of intraocular structures and gives immediate result with excellent definition. Ultrasonography is valuable in the investigation of both ocular and orbital diseases. Ultrasonography is safe, non-invasive, well tolerated, non-toxic, rapidly performed and relatively inexpensive. Ultrasonography is a two-dimensional imaging technique that allows a veterinarian to evaluate internal body structure to be seen by recording echoes or reflections of ultrasonic waves which is helpful in determining anatomical standards and pathological alterations, imaging of the size and texture of organs.

Ultrasonography is used for various purposes viz., evaluation of intraocular details obscured from visualisation by the ocular media opacities, evaluation of retino-choroidal lesions especially tumours even with clear media, differentiation of solid from cystic and homogenous from heterogeneous masses, examination of retrobulbar soft tissue masses and normally present orbital structures (to differentiate proptosis from
exophthalmos), identification, localisation and measurement of non radio-opaque/radio-opaque foreign bodies, detection of retinal detachment, detection of lens dislocation or rupture, detection of vitreous degeneration, guidance of fine-needle aspirates of orbital and ocular lesions, ocular biometry and pachmetry (Goddard, 1995; Kealy and McAllister, 2000; Maggs et al., 2008 and Ribeiro et al., 2009).

Ultrasound scanning technique is used in diagnostic imaging. Ultrasonography has become a very useful diagnostic tool in ophthalmology. The diagnostic ophthalmic ultrasound is based upon ‘pulse-echo’ technique. Two-dimensional ultrasound is an excellent way to evaluate the eye and orbit (Lavach, 1989; Goddard, 1995; Maggs et al., 2008).

Both A-mode and B-mode of ultrasound has been used for the measurements of intraocular structures. Application of A-mode ultrasonography to the eyes was first described by Mundt and Hughes in 1956 (Chaudhari et al., 2013) and elaborated extensively by Oksala (1967), Bronson (1969), Ossoinig (1967 and 1983) and many others.

The use of B-scan ultrasonography was initiated in ophthalmology by Baum and Greenwood in 1960 (Chaudhari et al., 2013) and developed further by Purnell and Sokollu (1962) independently. B-mode system introduced in the late 1950’s, produces cross sectional representation of ocular and orbital anatomy which can be readily interpreted. These images have proven extremely useful in the diagnosis of a broad spectrum of disease state (Coleman et al., 1979).

The development of high resolution instruments has made it possible to examine the eye and orbit carefully with both the A-scan (time-amplitude) and the B-scan (scanned, intensity-modulated) techniques (Ossoinig, 1966; Coleman, 1972). Each of these techniques has certain advantages. Examination with the A-scan is somewhat more rapid and a careful examination of the globe can be made by using quantisation and kinetic studies. Through tissue calibration, an actual differentiation of
intraocular and orbital lesions often can be diagnosed. B-scan ultrasonography has the advantage of giving an anatomical display very similar to that of a section through the eye and orbit, and this facilitates the interpretation.

The first ocular echogram was published in 1956. Since then, ophthalmic ultrasound has developed into a multifaceted diagnostic discipline, the basic methods being A-scan and B-scan, Doppler techniques and recently also three-dimensional approaches. Unique for ophthalmology is the newly invented, highly resolving equipment utilising ultrasound frequencies of 50 MHz and higher, so-called ultrasound biomicroscopy. Regarding intraocular morphology, ultrasonic evaluation in experienced hands is superior to other imaging methods. As for orbital pathology, imaging by computerised tomography (CT) and magnetic resonance (MR) appears more complete. Ultrasound is valuable, however, in particular as part of the initial clinical work-up, and for the follow-up of orbital diseases. Furthermore, tissue differentiation by way of ultrasound is of great value with regard to certain entities (Fledelius, 1997).

Ocular ultrasound plays an important role in situations that prevent normal examination include lid problems (e.g., severe edema, partial or total tarsorrhaphy), keratoprosthesis, corneal opacities (e.g., scars, severe edema), hyphema, hypopyon, miosis, pupillary membranes, dense cataracts or vitreous opacities (e.g., haemorrhage, inflammatory debris) (Qureshi et al., 2010).

Diagnostic B-scan ultrasonography permits topographical examination of the eye and to characterise the location, size, shape, echotexture, consistency, insertion and relationship to neighbouring structures of any eye tumour mass. It also allows kinetic evaluation such as mobility and vascularity of intraocular masses (Hatem, 1996; Gonzalez et al., 2001; Matton and Nyland, 2002).

Ultrasonography plays an important role before cataract surgery. It contributes to satisfactory postoperative results making it useful for the
evaluation of the posterior segment and also with respect to the selection of patients who will be submitted to cataract removal. Veterinary ocular biometry has much potential that allows the establishment of the proper intraocular lens to be used in lens replacement (McMullen and Gilger, 2006; Gift et al., 2009; Ribeiro et al., 2009), estimating prosthetic globe size after enucleation in dogs (Gaiddon et al., 1991) and in feline (Gilger et al., 1998).

Other indications involve biometric measurements of intraocular and orbital structures, and determination of axial eye length for artificial lens power calculations. Ocular biometry is a useful tool for the assessment of abnormalities such as phthisis bulbi, microphthalmia, pseudoexophthalmia, sclera ectasia and congenital glaucoma (Brandao et al., 2007 and Potter et al., 2008) and also enophthalmos, Buphthalmos, or exophthalmos due to the presence of retro-bulbar masses (Whitcomb, 2002).

Transcorneal ultrasonography enables the evaluation of intraocular structures in eyes with opaque, diseased corneas in order to evaluate the prognosis for vision following resolution of the corneal disease (El-Tookhyl and Tharwat, 2013).

The normal canine eye is characterised by a well-lined round structure with anechoic contents. Rostrally, the cornea appears as two parallel hyperechoic lines, which are slightly curved and follow the shape of the globe. The stroma between the reflecting epithelial lines appear anechoic. The second hyperechoic structure which can be seen is the anterior lens capsule. There is also a visible convex curve, indicating where the anterior chamber ends and the lens begins. The next hyperechoic structure is the lens capsule, indicating the end of the lens and the beginning of the vitreous body. The ciliary bodies appear as echogenic structures in the periphery of the lens. It is hard to differentiate the iris, choroid and sclera, so together they are called the scleroretinal rim. Scleroretinal rim enclosing the shape of the globe, lines the anechoic
vitreous body. At the ventrocaudal area of the retina is the optic disc visible as a slightly hyperechoic area (Haraldsen, 2014).

Ultrasound is feasible to perform four measurements of the eye by ophthalmic ultrasound; anterior chamber depth, which includes the axial distance from the cornea to the anterior capsule of the lens; lens thickness, measured from the anterior capsule of the lens to the posterior capsule of the lens; vitreous chamber depth, measured from the posterior capsule of the lens to the posterior pole of the eye; and the axial length of the eye, which corresponds to the measurement from the cornea to the posterior pole of the eye (Cottrill et al., 1989; Gonzalez et al., 2001).

Data regarding the comparison of intraocular structures and different skull conformations in dogs are scarce. Considering the wide variety of breeds and their significance as experimental models for the study of human myopia (Black et al., 2008) as well as the increasing number of cataract surgeries being performed daily in veterinary facilities, it becomes important to know the intraocular measurements for different skull conformations.

Affections of the eye are commonly encountered in all the species of animals. If they are not treated in time, the vision may be hampered, which may impair the physiology, draught ability, utility and productivity of animals leading to economic loss to the animal owners (Slatter, 1990).

Knowledge of the ultrasonographic appearance and normal dimensions of the eye would serve as a basis for ultrasonographic examinations when ocular disease may have caused alterations in the dimensions and appearance intraocular structures (Potter et al., 2008). Knowledge of the dimensions of the optical components is required to better understand of many research and clinical problems in vision (Wong et al., 2001). This requirement is met in general by giving a quantitative description of the dioptrics of a typical eye (schematic or model eye) (Gorig et al., 2006).
Therefore, keeping above information in mind, the present work was undertaken to study the B-mode ultrasonographic appearance of the globe and intraocular structures of eye and to evaluate the ultrasonographic measurements of globe and intraocular structures of eye in dogs with the following objectives:

1. To study the B-mode ultrasonographic appearance of the globe and intraocular structures of eye in dogs.
2. To study the ultrasonographic measurements of globe and intraocular structures of eye in dogs.
7. Literature Cited


3. MATERIALS AND METHODS

The present clinical study entitled “B-Mode Ultrasound Biometry of Intraocular Structures in Dogs” was carried out at the clinics of Department of Veterinary Surgery and Radiology, Bikaner (Rajasthan) during the period from October 2016 to December 2016. Dogs of both the sexes were examined for the biometry.

In the present study, B-Mode Ultrasound Biometry of Intraocular Structures in Dogs was conducted on 74 eyes of 37 clinically healthy dogs which were brought for clinical check-up to Department of Veterinary Surgery and Radiology, Bikaner.

A) History of patient

History of vision changes, age, any injury, time elapsed since occurrence of problem, use of recent medications and presence of diabetes was obtained from the dog owner.

B) Gross examination

The eyes were checked for clarity of cornea, opacity of lens, cataract, conjunctival appearance, conjunctival vascularity and discharge, if any.

C) Biometry

Ultrasonographical examination:-

Ophthalmic ultrasonography was done by using high frequency sound waves to get measurement and produce detailed images of eye. The examination was generally performed with the dogs awake. Sterile, water soluble lubricating acoustic gel (SUJA Medical Corporation, Jaipur, Rajasthan, India) approved for the eye was used. The patient’s eyelids were manually held open by the restrainer while the head was secured. The dogs were kept in lateral recumbency during examination.
Considering the history about the vision obtained from the owner and the observations made during the ophthalmic examinations of the patient, 74 eyes from 37 healthy dogs were selected for the B-mode ultrasound biometry.

D) Instrumentation

Ultrasound biometry of the eyes of dogs presented was performed with an ultrasound machine (Ultrasonix Vet, Ultrasonix Medical Corporation, Canada) using a 5-14 MHz linear transducer (Fig. 1).

E) Examination procedure

a) Pre-examination medications

No pre-examination drug or medication was used during the B-mode ultrasound biometry of the eyes in dogs.

b) Anaesthesia

All dogs presented during the study period were examined and biometric measurements were performed using verbal and physical restraining without any sedation or anaesthesia / analgesia.

c) Positioning and preparation of the dogs

The dogs were placed in lateral recumbency facing the head towards the ultrasound machine. Eyes were thoroughly flushed with physiological saline before performing the ultrasound examination.

d) Examination technique

Dogs were kept in lateral recumbency during the examination. Eye lids were held open manually (Fig. 2). Sterile coupling gel was used and directly placed on the cornea for examination. Sterile coupling gel (SUJA Medical Corporation, Jaipur, Rajasthan, India) (Fig. 3B) was used
Fig. 1: Ultrasonix Vet Ultrasound machine (Ultrasonix Medical Corporation, Canada) with probes (5-14 MHz Linear array transducer – left side and 2-5 MHz convex transducer – right side).
as standoff to create acoustic window. Transducer (Linear probe L5-14) (Fig. 3A) was directly placed on the cornea after application of coupling gel. Scanning depth was kept 4 cm while frequency was set to 14 MHz. Care was taken not to put any undue pressure on cornea to avoid any possible changes in biometric measurements. The globes were examined in a sagittal (longitudinal) plane (Fig. 2) as standard described models (El-Maghraby et al., 1995; Nautrap et al., 2000; Potter et al., 2008). A schematic diagram to represent the globe and probe position has been shown in Fig. 4.

Good quality echo-morphometric sonograms were obtained in male and female of all groups. Optimal B-scan sonogram along the central optic axis enabled visualisation of the cornea, aqueous chamber, anterior lens capsule, posterior lens capsule, vitreous chamber, posterior ocular wall. The aqueous chamber depth (ACD) - distance between echoes of mid-cornea to the anterior lens capsule, lens thickness (LT) - distance between echoes of anterior and posterior lens capsule, vitreous chamber depth (VCD) - distance between the echoes of posterior lens capsule to the retina and axial globe length (AGL) - distance between echoes of mid cornea to outmost sclera were measured. All measurements were made on freeze-frame images to two decimal places using native ultrasound software and internal callipers for B-mode distances. All measurements were taken in triplicate.

e) Post-examination care

After examination of the eyes excess sterile coupling gel was wiped off with the help of cotton from surrounding of eye lids and margins while eyes were rinsed off with physiological saline to remove coupling gel. No other special care was taken post-examination.
Fig. 2: A Labrador Retriever adult male in lateral recumbency during ultrasonographic examination. Probe positioned in sagittal/longitudinal plane.
Fig. 3A: Linear Array Probe 5-14 MHz.

Fig. 3B. Sterile Coupling Gel For Ultrasound (SUJA Medical Corporation, Jaipur, Rajasthan, India).
Fig. 4: Schematic diagram of canine eye, its chambers, structures and probe position.
(F) Place of work:

In the present study the ocular echo-biometry was carried out on the healthy dogs of different breeds reported during study period and during the eye check up camp held from 15/11/2016 to 19/11/2016 organised by Rajasthan University of Veterinary and Animal Sciences, Bikaner and AINP-DIMSCA, ICAR, at Clinics of Department of Veterinary Surgery and Radiology, College of Veterinary and Animal Science, Rajasthan University of Veterinary and Animal Sciences, Bikaner. Various clinically healthy cases were evaluated on the basis of echogenicity and biometry.

(G) Statistical analysis:

The dogs were grouped according to their skull conformation and further sub-grouped on the basis of age and sex. Statistical analysis of collected data was done as per Snedecor and Cochran (1989).

The mean and standard error for each set of ocular measurements were calculated and presented as mean ± standard error. B-mode echobiometric measurements of left and right eye compared for male and female of dogs. The average of echo-biometric parameters of left and right eyes was calculated and compared between male and female dogs as well as in study groups and in age groups. Skull confirmation group data were compared using a two-tailed Student’s t-test, one way ANOVA; IBM-SPSS version 20 statistical analysis tool for windows to determine whether differences between the measurements were significant or non-significant. The level of statistical significance was set at both P ≤ 0.05 and P ≤ 0.01.
4. Results

The present study “B-Mode Ultrasound Biometry of Intraocular Structures in Dogs” was performed on 74 eyes of 37 dogs of various breeds reported during study period.

Eleven different breeds (37 dogs) were presented during the study period: Labrador Retriever (11), Pug (4), German Shepherd (4), Pit-bull (4), Rottweiler (3), Daschund (2), Doberman (2), Pomeranian (2), Pakistani Bully (2), Napoleon Mastiff (2) and Dalmation (1). These breeds were divided into three groups according to their skull conformation (Diesem, 1986) (Table 1) i.e.

1. Dolichocephalic
2. Mesocephalic
3. Brachycephalic

The dogs of each breed reported during study period were distributed into four different subgroups.

Group I. Male dogs between 15 days to 1.5 years of age
Group II. Female dogs between 15 days to 1.5 years of age
Group III. Male dogs from 1.5 years onward
Group IV. Female dogs from 1.5 years onward

The intraocular ultrasonographic biometry of both the right and left eye of each dog was carried out and following parameters were measured.

1. Aqueous chamber depth (ACD)
2. Lens thickness (LT)
3. Vitreous chamber depth (VCD) and
4. Axial globe length (AGL)

Conductive gel used as a standoff pad was effective and allowed adequate evaluation of the anterior segment of the eye, as well as identification of its structures in all eyes evaluated.
Table 1: Classification of dog breeds studied, according to skull conformation

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Skull Group</th>
<th>Breed</th>
<th>Number</th>
<th>Skull Group Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Dolichocephalic</td>
<td>German Shepherd</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Daschund</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Mesocephalic</td>
<td>Doberman</td>
<td>2</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Labrador Retriever</td>
<td>11</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Rottweiler</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Pakistani Bully</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Brachycephalic</td>
<td>Pomeranian</td>
<td>2</td>
<td>19</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Dalmation</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Pug</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Pit bull</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Napoleon Mastiff</td>
<td>2</td>
<td>10</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td>11</td>
<td>37</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>37</td>
<td>37</td>
</tr>
</tbody>
</table>
Normal ultrasonogram of a healthy eye of a dog has been shown in Fig. 5. The globe was observed as a round and well-delimited structure with distinct borders in bony orbit. All three primary structures in the globe, the anterior chamber, vitreous chambers and the lens were anechogenic. The anterior chamber filled with aqueous humour was identified as an anechoic area in B-mode ultrasound just behind the cornea while cornea was characterised by two parallel and convex hyperechoic lines near the contact area of transducer. Therefore, the measurement of complete length of the eye was performed from inner peak of the cornea to the posterior pole of the eye.

The anterior and posterior margins of the lens were hyperechogenic creating a distinct delineation between the chambers and the lens. It was possible to identify the lens by identifying both anterior and posterior capsules. Anterior lens capsule appeared as convex hyperechoic line while posterior lens capsule appeared as concave hyperechoic line and the nucleus of the lens was identified as an anechoic area between two hyperechoic lines of the anterior and posterior lens capsules. The iris and the ciliary body were relatively hyperechogenic structures that in reality circumferentially surround the lens. However, on ultrasonic examination they appeared at the lateral margins of the lens.

The vitreous chamber, filled with vitreous humour, was identified as anechoic area between the posterior lens capsule and posterior pole of the eye which appears hyperechoic.

The posterior pole of the eye, which includes the retina, the choroid and the sclera, was identified as a hyperechogenic and concave structure. It was hard to differentiate retina, choroid and sclera and collectively termed as sclero-retinal rim. The optic disc appeared as a slightly brighter region that may be either raised or depressed, relative to the posterior globe, in normal eyes. The optic nerve and extra ocular muscles were hypoechoic, relative to the echogenic retro-bulbar fat separating them just posterior to the globe surrounded by hypoechogenic ocular muscles. These structures converged toward the posterior orbital apex near the optic canal, forming a cone shape, with the base at the posterior wall of the globe.
1: Cornea
2: Aqueous chamber depth (ACD)
3: Iris
4: Anterior lens capsule
5: Ciliary body
6: Lens thickness (LT)

7: Posterior lens capsule
8: Vitreous chamber depth
9: Sclero-retinal rim
10: Optic disc and
11: Optic nerve

**Fig. 5: Normal B - Mode ultrasonogram of left eye of 10 months old male Pug dog.**
Echobiometric findings of various parameters within and among different skull groups were compared for right and left eye. Results of echobiometric measurements for different skull groups observed were as follows:

1. **COMPARISON OF ECHOBIOMETRIC PARAMETERS WITHIN SKULL GROUPS:**

(A) **Dolichocephalic Skull Group**

(I) **Aqueous chamber depth (ACD):** (Table – 2, Fig. – 6)

Aqueous chamber depth (ACD) in group 1 (male between 15 days to 1.5 years) was 4.15 ± 0.00 mm for right eye while 3.96 ± 0.04 mm for left eye. For group 2 (female between 15 days to 1.5 years) ACD was 4.06 ± 0.01 mm for right eye and 4.06 ± 0.04 mm for left eye. While for group 3 (male 1.5 years onwards) right and left eye ACD values were 3.82 ± 0.58 mm and 3.78 ± 0.70 mm, respectively. Group 4 (female 1.5 years onwards) ACD values were 4.66 ± 0.06 mm and 4.15 ± 0.18 mm for right and left eye, respectively.

Average echobiometric parameters for ACD of both right and left eyes for groups 1, 2, 3 and 4 were 3.92 ± 0.13 mm, 4.06 ± 0.02 mm, 3.79 ± 0.37 mm and 4.59 ± 0.05 mm, respectively. Overall average findings for right and left eye of all groups were 4.17 ± 0.16 mm and 4.00 ± 0.18 mm, respectively. There was no significant difference between measurements of right and left eyes within all respective age groups for ACD (both at P > 0.01 and P > 0.05). Difference in average parameters for ACD was statistically insignificant among age groups as well sex of the dog (both at P > 0.01 and P > 0.05).

(II) **Lens thickness (LT):** (Table – 3, Fig. – 7)

Echobiometric findings for lens thickness (LT) in dolichocephalic skull group were 6.18 ± 0.12 mm for right eye and 6.60 ± 0.21 mm for left eye for group 1 (male between 15 days to 1.5 years). For group 2 (female between 15 days to 1.5 years) LT was 6.49 ± 0.01 mm for right eye and 6.50 ± 0.05 mm for left eye. While for group 3 (male 1.5 years onwards) right and left eye LT values were 6.31 ± 0.25 mm and 6.31 ± 0.16 mm, respectively. Group 4 (female 1.5 years onwards) LT values were 6.64 ± 0.25 mm and 6.36 ± 0.14 mm for right and left eyes, respectively.
Table 2: ACD (mm) in dolichocephalic skull group

<table>
<thead>
<tr>
<th>Group</th>
<th>Right Eye (Mean ± SE)</th>
<th>Left Eye (Mean ± SE)</th>
<th>Overall (Mean ± SE)</th>
</tr>
</thead>
<tbody>
<tr>
<td>GROUP 1</td>
<td>4.15 ± 0.00</td>
<td>3.69 ± 0.04</td>
<td>3.92 ± 0.13</td>
</tr>
<tr>
<td>GROUP 2</td>
<td>4.06 ± 0.01</td>
<td>4.06 ± 0.04</td>
<td>4.06 ± 0.02</td>
</tr>
<tr>
<td>GROUP 3</td>
<td>3.82 ± 0.58</td>
<td>3.78 ± 0.70</td>
<td>3.79 ± 0.37</td>
</tr>
<tr>
<td>GROUP 4</td>
<td>4.66 ± 0.06</td>
<td>4.51 ± 0.06</td>
<td>4.59 ± 0.05</td>
</tr>
<tr>
<td>OVERALL</td>
<td>4.17 ± 0.16</td>
<td>4.00 ± 0.18</td>
<td></td>
</tr>
</tbody>
</table>

Not significant at both $P \geq 0.05$ and $P \geq 0.01$

Fig. 6: ACD in dolichocephalic skull group
Table 3: LT (mm) in dolichocephalic skull group

<table>
<thead>
<tr>
<th>Group</th>
<th>Right Eye (Mean ± SE)</th>
<th>Left Eye (Mean ± SE)</th>
<th>Overall (Mean ± SE)</th>
</tr>
</thead>
<tbody>
<tr>
<td>GROUP 1</td>
<td>6.18 ± 0.12</td>
<td>6.60 ± 0.21</td>
<td>6.39 ± 0.15</td>
</tr>
<tr>
<td>GROUP 2</td>
<td>6.49 ± 0.01</td>
<td>6.50 ± 0.05</td>
<td>6.49 ± 0.02</td>
</tr>
<tr>
<td>GROUP 3</td>
<td>6.31 ± 0.25</td>
<td>6.31 ± 0.16</td>
<td>6.31 ± 0.12</td>
</tr>
<tr>
<td>GROUP 4</td>
<td>6.64 ± 0.25</td>
<td>6.36 ± 0.14</td>
<td>6.50 ± 0.14</td>
</tr>
<tr>
<td>OVERALL</td>
<td>6.41 ± 0.10</td>
<td>6.44 ± 0.07</td>
<td></td>
</tr>
</tbody>
</table>

Not significant at both $P \geq 0.05$ and $P \geq 0.01$

Fig. 7: LT in dolichocephalic skull group
Average echobiometric parameters for LT of both right and left eyes for groups 1, 2, 3 and 4 were $6.39 \pm 0.15$ mm, $6.49 \pm 0.02$ mm, $6.31 \pm 0.12$ mm and $6.50 \pm 0.14$ mm, respectively. Overall average findings for right and left eye of all age groups were $6.41 \pm 0.10$ mm and $6.44 \pm 0.07$ mm, respectively. There was no statistically significant difference between parameters of right and left eyes within all respective age groups for LT (both at $P > 0.01$ and $P > 0.05$). Difference in average parameters for LT was statistically insignificant among age groups as well sex of the dog (both at $P > 0.01$ and $P > 0.05$).

(III) Vitreous chamber depth (VCD): (Table – 4, Fig. – 8)

Vitreous chamber depth (VCD) findings of echobiometric parameters for dolichocephalic skull group were $9.68 \pm 0.04$ mm for right eye while $8.93 \pm 0.04$ mm for left eye in group 1 (male between 15 days to 1.5 years). For group 2 (female between 15 days to 1.5 years) VCD was $8.96 \pm 0.09$ mm for right eye and $8.85 \pm 0.05$ mm for left eye. While for group 3 (male 1.5 years onwards) right and left eye VCD values were $9.34 \pm 0.87$ mm and $9.80 \pm 0.83$ mm, respectively. Group 4 (female 1.5 years onwards) VCD values were $9.76 \pm 0.04$ mm and $9.23 \pm 0.43$ mm, for right and left eye, respectively.

Average echobiometric parameters for VCD of both right and left eyes for groups 1, 2, 3 and 4 were $9.30 \pm 0.22$ mm, $8.91 \pm 0.05$ mm, $9.57 \pm 0.50$ mm and $9.49 \pm 0.23$ mm, respectively. Overall average findings of VCD for right and left eye of all age groups were $9.44 \pm 0.20$ mm and $9.20 \pm 0.22$ mm, respectively. There was no statistically significant difference between parameters of right and left eyes within all respective age groups for VCD (both at $P > 0.01$ and $P > 0.05$). Difference in average parameters for VCD was statistically insignificant among age groups as well sex of the dog (both at $P > 0.01$ and $P > 0.05$).

(IV) Axial globe length (AGL): (Table – 5, Fig. – 9)

Axial globe length (AGL) findings for dolichocephalic skull group were $20.14 \pm 0.05$ mm for right eye while $19.72 \pm 0.28$ mm for left eye in group 1 (male between 15 days to 1.5 years). For group 2 (female between 15 days to 1.5 years) AGL was $19.82 \pm 0.02$ mm for right eye and $19.84 \pm 0.26$ mm for left eye. While for group 3 (male 1.5 years onwa-
Table 4: VCD (mm) in dolichocephalic skull group

<table>
<thead>
<tr>
<th>Group</th>
<th>Right Eye (Mean ± SE)</th>
<th>Left Eye (Mean ± SE)</th>
<th>Overall (Mean ± SE)</th>
</tr>
</thead>
<tbody>
<tr>
<td>GROUP 1</td>
<td>9.68 ± 0.04</td>
<td>8.93 ± 0.04</td>
<td>9.30 ± 0.22</td>
</tr>
<tr>
<td>GROUP 2</td>
<td>8.96 ± 0.09</td>
<td>8.85 ± 0.05</td>
<td>8.91 ± 0.05</td>
</tr>
<tr>
<td>GROUP 3</td>
<td>9.34 ± 0.87</td>
<td>9.80 ± 0.83</td>
<td>9.57 ± 0.50</td>
</tr>
<tr>
<td>GROUP 4</td>
<td>9.76 ± 0.04</td>
<td>9.23 ± 0.43</td>
<td>9.49 ± 0.23</td>
</tr>
<tr>
<td>OVERALL</td>
<td>9.44 ± 0.20</td>
<td>9.20 ± 0.22</td>
<td></td>
</tr>
</tbody>
</table>

Not significant at both P ≥ 0.05 and P ≥ 0.01

Fig. 8: VCD in dolichocephalic skull group
Table 5: AGL (mm) in dolichocephalic skull group

<table>
<thead>
<tr>
<th></th>
<th>Right Eye (Mean ± SE)</th>
<th>Left Eye (Mean ± SE)</th>
<th>Overall (Mean ± SE)</th>
</tr>
</thead>
<tbody>
<tr>
<td>GROUP 1</td>
<td>20.14 ± 0.05</td>
<td>19.72 ± 0.28</td>
<td>19.92 ± 0.17</td>
</tr>
<tr>
<td>GROUP 2</td>
<td>19.82 ± 0.02</td>
<td>19.84 ± 0.26</td>
<td>19.83 ± 0.10</td>
</tr>
<tr>
<td>GROUP 3</td>
<td>19.59 ± 1.32</td>
<td>19.98 ± 1.47</td>
<td>19.79 ± 0.82</td>
</tr>
<tr>
<td>GROUP 4</td>
<td>20.12 ± 0.47</td>
<td>20.08 ± 0.26</td>
<td>20.10 ± 0.22</td>
</tr>
<tr>
<td>OVERALL</td>
<td>19.92 ± 0.28</td>
<td>19.90 ± 0.29</td>
<td></td>
</tr>
</tbody>
</table>

Not significant at both P ≥ 0.05 and P ≥ 0.01

Fig. 9: AGL in dolichocephalic skull group
rds) right and left eye AGL values were 19.59 ± 1.32 mm and 19.98 ± 1.47 mm, respectively. Group 4 (female 1.5 years onwards) AGL values were 20.12 ± 0.47 mm and 20.08 ± 0.26 mm for right and left eye, respectively.

Average echobiometric parameters for AGL of both right and left eyes for groups 1, 2, 3 and 4 were 19.92 ± 0.17 mm, 19.83 ± 0.10 mm, 19.79 ± 0.82 mm and 20.10 ± 0.22 mm, respectively. Overall average findings of AGL for right and left eye of all groups were 19.92 ± 0.28 mm and 19.90 ± 0.29 mm, respectively. There was no statistically significant difference between parameters of right and left eyes within all respective age groups for AGL (both at P > 0.01 and P > 0.05). Difference in average parameters for AGL was statistically insignificant among age groups as well sex of the dog (both at P > 0.01 and P > 0.05).

(B) Mesocephalic Skull Group

(I) Aqueous chamber depth (ACD): (Table – 6, Fig. – 10)

Echobiometric findings for mesocephalic skull group of various parameters were compared between right and left eyes as well as among age groups also. In group 1 (male between 15 days to 1.5 years) ACD was 2.75 ± 0.56 mm for right eye while 2.64 ± 0.66 mm for left eye. For group 2 (female between 15 days to 1.5 years) ACD was 3.82 ± 0.33 mm for right eye and 4.12 ± 0.12 mm for left eye. While for group 3 (male 1.5 years onwards) right and left eye ACD values were 3.92 ± 0.29 mm and 4.09 ± 0.22 mm, respectively. Group 4 (female 1.5 years onwards) ACD values were 4.04 ± 0.17 mm and 4.19 ± 0.16 mm for right and left eye, respectively.

Average echobiometric parameters for ACD of both right and left eyes for groups 1, 2, 3 and 4 were 2.69 ± 0.39 mm, 3.97 ± 0.17 mm, 4.00 ± 0.18 mm and 4.11 ± 0.11 mm, respectively. Overall average findings for right and left eye of all groups were 3.71 ± 0.19 mm and 3.82 ± 0.21 mm, respectively. There was no statistically significant difference between parameters of right and left eyes within all respective age groups for ACD. Difference in average parameters of ACD for group 1 (male from 15 days to 1.5 years) from other age groups was statistically significant (at P > 0.01 highly significant and at P > 0.05 significant) while difference among group 2, group 3 and group 4 average parameters was statistically
### Table 6: ACD (mm) in mesocephalic skull group

<table>
<thead>
<tr>
<th>Group</th>
<th>Right Eye (Mean ± SE)</th>
<th>Left Eye (Mean ± SE)</th>
<th>Overall (Mean ± SE)</th>
</tr>
</thead>
<tbody>
<tr>
<td>GROUP 1</td>
<td>2.75 ± 0.56</td>
<td>2.64 ± 0.66</td>
<td>2.69_a ± 0.39</td>
</tr>
<tr>
<td>GROUP 2</td>
<td>3.82 ± 0.33</td>
<td>4.12 ± 0.12</td>
<td>3.97_b ± 0.17</td>
</tr>
<tr>
<td>GROUP 3</td>
<td>3.92 ± 0.29</td>
<td>4.09 ± 0.22</td>
<td>4.00_b ± 0.18</td>
</tr>
<tr>
<td>GROUP 4</td>
<td>4.04 ± 0.17</td>
<td>4.19 ± 0.16</td>
<td>4.11_b ± 0.11</td>
</tr>
<tr>
<td>OVERALL</td>
<td>3.71 ± 0.19</td>
<td>3.82 ± 0.21</td>
<td></td>
</tr>
</tbody>
</table>

Values sharing the same letters of superscripts in column indicate that there was no statistically significant difference among parameters of age groups (P > 0.05). Different letters of superscripts in a column indicates statistically significant difference among parameters of age groups (P < 0.05). (At P ≥ 0.01 Highly significant).

![Fig. 10: ACD in mesocephalic skull group](image-url)

*Fig. 10: ACD in mesocephalic skull group*
insignificant from each other (both at \( P > 0.01 \) and \( P > 0.05 \)).

(II) **Lens thickness (LT):** (Table – 7, Fig. – 11)

Lens thickness (LT) data recorded using B-mode ultrasound for mesocephalic skull group were \( 5.58 \pm 0.57 \) mm for right eye while \( 5.54 \pm 0.56 \) mm for left eye in group 1 (male between 15 days to 1.5 years). For group 2 (female between 15 days to 1.5 years) LT was \( 6.52 \pm 0.37 \) mm for right eye and \( 6.69 \pm 0.05 \) mm for left eye. While for group 3 (male 1.5 years onwards) right and left eye LT values were \( 6.71 \pm 0.17 \) mm and \( 6.79 \pm 0.17 \) mm, respectively. Group 4 (female 1.5 years onwards) LT values were \( 6.74 \pm 0.16 \) mm and \( 6.67 \pm 0.17 \) mm, for right and left eye, respectively.

Average echobiometric parameters for LT of both right and left eyes for groups 1, 2, 3 and 4 were \( 5.56 \pm 0.37 \) mm, \( 6.61 \pm 0.16 \) mm, \( 6.75 \pm 0.11 \) mm and \( 6.71 \pm 0.11 \) mm, respectively. Overall average findings for right and left eye of all groups were \( 6.46 \pm 0.17 \) mm and \( 6.47 \pm 0.17 \) mm, respectively. There was no statistically significant difference between parameters of right and left eyes within all respective age groups for LT (both at \( P > 0.01 \) and \( P > 0.05 \)).

Difference in average parameters of left and right eye for LT of group 1 was statistically significant from group 3 and group 4 (both at \( P > 0.01 \) and \( P > 0.05 \), highly significant and significant, respectively). Difference of group 2 average parameters from group 1, group 3 and group 4 was not statistically significant (both at \( P > 0.01 \) and \( P > 0.05 \)). Average parameters of group 3 also did not differ statistically significant from group 2, and group 4 (both at \( P > 0.01 \) and \( P > 0.05 \)).

(III) **Vitreous chamber depth (VCD):** (Table – 8, Fig. – 12)

Vitreous chamber depth (VCD) findings of echobiometric parameters for mesocephalic skull group were \( 7.92 \pm 0.36 \) mm for right eye while \( 8.05 \pm 0.30 \) mm for left eye in group 1 (male between 15 days to 1.5 years). For group 2 (female between 15 days to 1.5 years) VCD was \( 7.91 \pm 0.82 \) mm for right eye and \( 8.18 \pm 1.04 \) mm for left eye. While for group 3 (male 1.5 years onwards) right and left eye VCD values were \( 9.34 \pm 0.21 \) mm and \( 9.46 \pm 0.20 \) mm, respectively. Group 4 (female 1.5 years onwards) VCD
Table 7: LT (mm) in mesocephalic skull group

<table>
<thead>
<tr>
<th></th>
<th>Right Eye (Mean ± SE)</th>
<th>Left Eye (Mean ± SE)</th>
<th>Overall (Mean ± SE)</th>
</tr>
</thead>
<tbody>
<tr>
<td>GROUP 1</td>
<td>5.58 ± 0.57</td>
<td>5.54 ± 0.56</td>
<td>5.56a ± 0.37</td>
</tr>
<tr>
<td>GROUP 2</td>
<td>6.52 ± 0.37</td>
<td>6.69 ± 0.05</td>
<td>6.61ab ± 0.16</td>
</tr>
<tr>
<td>GROUP 3</td>
<td>6.71 ± 0.17</td>
<td>6.79 ± 0.17</td>
<td>6.75b ± 0.11</td>
</tr>
<tr>
<td>GROUP 4</td>
<td>6.74 ± 0.16</td>
<td>6.67 ± 0.17</td>
<td>6.71b ± 0.11</td>
</tr>
<tr>
<td>OVERALL</td>
<td>6.46 ± 0.17</td>
<td>6.47 ± 0.17</td>
<td></td>
</tr>
</tbody>
</table>

Values sharing the same letters of superscripts in column indicate that there was no statistically significant difference among parameters of age groups (P > 0.05). Different letters of superscripts in a column indicates statistically significant difference among parameters of age groups (P < 0.05). (At P ≥ 0.01 Highly significant).

Fig. 11: LT in mesocephalic skull group
### Table 8: VCD (mm) in mesocephalic skull group

<table>
<thead>
<tr>
<th></th>
<th>Right Eye (Mean ± SE)</th>
<th>Left Eye (Mean ± SE)</th>
<th>Overall (Mean ± SE)</th>
</tr>
</thead>
<tbody>
<tr>
<td>GROUP 1</td>
<td>7.92 ± 0.36</td>
<td>8.05 ± 0.30</td>
<td>7.98&lt;sup&gt;a&lt;/sup&gt; ± 0.22</td>
</tr>
<tr>
<td>GROUP 2</td>
<td>7.91 ± 0.82</td>
<td>8.18 ± 1.04</td>
<td>8.04&lt;sup&gt;ab&lt;/sup&gt; ± 0.55</td>
</tr>
<tr>
<td>GROUP 3</td>
<td>9.34 ± 0.21</td>
<td>9.46 ± 0.20</td>
<td>9.46&lt;sup&gt;b&lt;/sup&gt; ± 0.14</td>
</tr>
<tr>
<td>GROUP 4</td>
<td>8.10 ± 0.59</td>
<td>8.53 ± 0.45</td>
<td>8.32&lt;sup&gt;b&lt;/sup&gt; ± 0.36</td>
</tr>
<tr>
<td>OVERALL</td>
<td>8.44 ± 0.28</td>
<td>8.68 ± 0.24</td>
<td></td>
</tr>
</tbody>
</table>

Values sharing the same letters of superscripts in column indicate that there was no statistically significant difference among parameters of age groups (P > 0.05). Different letters of superscripts in a column indicates statistically significant difference among parameters of age groups (P < 0.05). (At P ≥ 0.01 Not significant).

**Fig. 12: VCD in mesocephalic skull group**
values were $8.10 \pm 0.59$ mm and $8.53 \pm 0.45$ mm for right and left eye, respectively.

Average echobiometric parameters for VCD of both right and left eyes for groups 1, 2, 3 and 4 were $7.98 \pm 0.22$ mm, $8.04 \pm 0.55$ mm, $9.46 \pm 0.14$ mm and $8.32 \pm 0.36$ mm, respectively. Overall average findings of VCD for right and left eye of all groups were $8.44 \pm 0.28$ mm and $8.68 \pm 0.24$ mm, respectively. There was no statistically significant difference between parameters of right and left eyes within all respective age groups for VCD (both at $P > 0.01$ and $P > 0.05$).

Difference in average parameters of left and right eye for VCD of group 1 from group 3 and group 4 was statistically significant (at $P > 0.05$). Difference of group 2 average parameters from group 1, group 3 and group 4 was not statistically significant (both at $P > 0.01$ and $P > 0.05$). Average parameters of group 3 also did not differ from group 2, and group 4 (both at $P > 0.01$ and $P > 0.05$).

(IV) Axial globe length (AGL): (Table – 9, Fig. – 13)

Axial globe length (AGL) for mesocephalic skull group was $16.58 \pm 1.33$ mm for right eye while $16.48 \pm 1.51$ mm for left eye in group 1 (male between 15 days to 1.5 years). For group 2 (female between 15 days to 1.5 years) AGL was $19.55 \pm 0.70$ mm for right eye and $19.48 \pm 0.86$ mm for left eye. While for group 3 (male 1.5 years onwards) right and left eye AGL values were $20.02 \pm 0.46$ mm and $20.18 \pm 0.42$ mm, respectively. Group 4 (female 1.5 years onwards) AGL values were $18.89 \pm 0.54$ mm and $19.24 \pm 0.38$ mm for right and left eyes, respectively.

Average echobiometric parameters for AGL of both right and left eyes for groups 1, 2, 3 and 4 were $16.53 \pm 0.94$ mm, $19.51 \pm 0.45$ mm, $20.10 \pm 0.30$ mm and $19.07 \pm 0.32$ mm, respectively. Overall average findings of AGL for right and left eye of all groups were $18.83 \pm 0.46$ mm and $18.98 \pm 0.47$ mm, respectively. There was no statistically significant difference between parameters of right and left eyes within all respective age groups for AGL (both at $P > 0.01$ and $P > 0.05$).

Average parameters of left and right eyes for VCD of group 1 differed from group 2 and group 3 but it was statistically significant (at $P > 0.05$). Difference in average parameters of group 4 from group 1, group 2
**Table 9: AGL (mm) in mesocephalic skull group**

<table>
<thead>
<tr>
<th>Group</th>
<th>Right Eye (Mean ± SE)</th>
<th>Left Eye (Mean ± SE)</th>
<th>Overall (Mean ± SE)</th>
</tr>
</thead>
<tbody>
<tr>
<td>GROUP 1</td>
<td>16.58 ± 1.33</td>
<td>16.48 ± 1.51</td>
<td>16.53 ± 0.94</td>
</tr>
<tr>
<td>GROUP 2</td>
<td>19.55 ± 0.70</td>
<td>19.48 ± 0.86</td>
<td>19.51b ± 0.45</td>
</tr>
<tr>
<td>GROUP 3</td>
<td>20.02 ± 0.46</td>
<td>20.18 ± 0.42</td>
<td>20.10b ± 0.30</td>
</tr>
<tr>
<td>GROUP 4</td>
<td>18.89 ± 0.54</td>
<td>19.24 ± 0.38</td>
<td>19.07ab ± 0.32</td>
</tr>
<tr>
<td>OVERALL</td>
<td>18.83 ± 0.46</td>
<td>18.98 ± 0.47</td>
<td></td>
</tr>
</tbody>
</table>

Values sharing the same letters of superscripts in column indicate that there was no statistically significant difference among parameters of age groups (P > 0.05). Different letters of superscripts in a column indicates statistically significant difference among parameters of age groups (P < 0.05). (At P ≥ 0.01 Highly significant).

**Fig. 13: AGL in mesocephalic skull group**
and group 3 was statistically insignificant (both at P > 0.01 and P > 0.05). Average parameters of group 2 also differed statistically insignificant from group 3, and group 4 (both at P > 0.01 and P > 0.05).

(C)  Brachycephalic Skull Group

Echobiometric findings for brachycephalic skull group for various parameters were compared for right and left eye as well among age groups also are as followed:

(I)  Aqueous chamber depth (ACD): (Table – 10, Fig. – 14)

In brachycephalic skull group ACD values for group 1 (male between 15 days to 1.5 years) were 2.97 ± 0.38 mm for right eye while 2.81 ± 0.43 mm for left eye. For group 2 (female between 15 days to 1.5 years) ACD was 3.82 ± 0.33 mm for right eye and 4.12 ± 0.12 mm for left eye. While for group 3 (male 1.5 years onwards) right and left eye ACD values were 3.90 ± 0.19 mm and 4.06 ± 0.15 mm, respectively. Group 4 (female 1.5 years onwards) ACD values were 4.05 ± 0.12 mm and 4.06 ± 0.14 mm for right and left eye, respectively.

Average echobiometric parameters for ACD of both right and left eyes for groups 1, 2, 3 and 4 were 2.35 ± 0.35 mm, 3.76 ± 0.25 mm, 4.38 ± 0.39 mm and 3.99 ± 0.24 mm, respectively. Overall average findings for right and left eye of all groups were 3.71 ± 0.19 mm and 3.82 ± 0.21 mm, respectively. There was no statistically significant difference between parameters of right and left eyes within all respective age groups for ACD.

Difference in average parameters of left and right eyes for ACD of group 1 from group 3 was statistically significant (at P > 0.01 highly significant and at P > 0.05 significant). Difference of average parameters of group 2 and group 4 was statistically insignificant from each other and from group 1 and group 3 (both at P > 0.01 and P > 0.05).

(II)  Lens thickness (LT): (Table – 11, Fig. – 15)

Lens thickness (LT) data recorded using B-mode ultrasound for brachycephalic skull group were 5.09 ± 0.18 mm for right eye while 5.49 ± 0.25 mm for left eye in group 1 (male between 15 days to 1.5 years). For group 2 (female between 15 days to 1.5 years) LT was 5.86 ± 0.38 mm for right eye and 6.36 ± 0.27 mm for left eye. While for group 3 (male 1.5 years onwards) right and left eye LT values were 6.02 ± 0.54 mm and
Table 10: ACD (mm) in brachycephalic skull group

<table>
<thead>
<tr>
<th></th>
<th>Right Eye (Mean ± SE)</th>
<th>Left Eye (Mean ± SE)</th>
<th>Overall (Mean ± SE)</th>
</tr>
</thead>
<tbody>
<tr>
<td>GROUP 1</td>
<td>2.97 ± 0.38</td>
<td>2.81 ± 0.43</td>
<td>2.35\textsuperscript{a} ± 0.35</td>
</tr>
<tr>
<td>GROUP 2</td>
<td>3.82 ± 0.33</td>
<td>4.12 ± 0.12</td>
<td>3.76\textsuperscript{ab} ± 0.25</td>
</tr>
<tr>
<td>GROUP 3</td>
<td>3.90 ± 0.19</td>
<td>4.06 ± 0.15</td>
<td>4.38\textsuperscript{b} ± 0.39</td>
</tr>
<tr>
<td>GROUP 4</td>
<td>4.05 ± 0.12</td>
<td>4.06 ± 0.14</td>
<td>3.99\textsuperscript{ab} ± 0.24</td>
</tr>
<tr>
<td>OVERALL</td>
<td>3.74 ± 0.14</td>
<td>3.79 ± 0.15</td>
<td></td>
</tr>
</tbody>
</table>

Values sharing the same letters of superscripts in column indicate that there was no statistically significant difference among parameters of age groups (P > 0.05). Different letters of superscripts in a column indicates statistically significant difference among parameters of age groups (P < 0.05). (At P ≥ 0.01 Highly significant).

Fig. 14: ACD in brachycephalic skull group
Table 11: LT (mm) in brachycephalic skull group

<table>
<thead>
<tr>
<th></th>
<th>Right Eye (Mean ± SE)</th>
<th>Left Eye (Mean ± SE)</th>
<th>Overall (Mean ± SE)</th>
</tr>
</thead>
<tbody>
<tr>
<td>GROUP 1</td>
<td>5.09 ± 0.18</td>
<td>5.49 ± 0.25</td>
<td>5.16$^a$ ± 0.13</td>
</tr>
<tr>
<td>GROUP 2</td>
<td>5.86 ± 0.38</td>
<td>6.36 ± 0.27</td>
<td>5.94$^{ab}$ ± 0.24</td>
</tr>
<tr>
<td>GROUP 3</td>
<td>6.02 ± 0.54</td>
<td>6.52 ± 0.17</td>
<td>5.98$^{ab}$ ± 0.36</td>
</tr>
<tr>
<td>GROUP 4</td>
<td>6.72 ± 0.15</td>
<td>6.66 ± 0.13</td>
<td>6.72$^b$ ± 0.21</td>
</tr>
<tr>
<td>OVERALL</td>
<td>6.25 ± 0.18</td>
<td>6.30 ± 0.12</td>
<td></td>
</tr>
</tbody>
</table>

Values sharing the same letters of superscripts in column indicate that there was no statistically significant difference among parameters of age groups (P > 0.05). Different letters of superscripts in a column indicates statistically significant difference among parameters of age groups (P < 0.05). (At P ≥ 0.01 Highly significant).

Fig. 15: LT in brachycephalic skull group
6.52 ± 0.17 mm, respectively. Group 4 (female 1.5 years onwards) LT values were 6.72 ± 0.15 mm and 6.66 ± 0.13 mm for right and left eye, respectively. Average echobiometric parameters for LT of both right and left eyes for groups 1, 2, 3 and 4 were 5.16 ± 0.13 mm, 5.94 ± 0.24 mm, 5.98 ± 0.36 mm and 6.72 ± 0.21 mm, respectively.

Overall average findings for right and left eye of all groups were 6.25 ± 0.18 mm and 6.30 ± 0.12 mm, respectively. There was no statistically significant difference between parameters of right and left eyes within all respective age groups for LT (both at P > 0.01 and P > 0.05).

Difference in average parameters of left and right eyes for LT of group 1 from group 4 was statistically significant (at P > 0.01 highly significant and at P > 0.05 significant). Difference in average parameters of group 2 and group 3 was statistically insignificant in between and from group 1 and group 4 (both at P > 0.01 and P > 0.05).

(III) Vitreous chamber depth (VCD): (Table – 12, Fig. – 16)

Vitreous chamber depth (VCD) findings of echobiometric parameters for brachycephalic skull group were 8.25 ± 0.56 mm for right eye while 8.19 ± 0.19 mm for left eye in group 1 (male between 15 days to 1.5 years). For group 2 (female between 15 days to 1.5 years) VCD was 9.17 ± 0.62 mm for right eye and 8.62 ±0.52 mm for left eye. While for group 3 (male 1.5 years onwards) right and left eye VCD values were 9.54 ± 0.42 mm and 9.44 ± 0.15 mm, respectively. Group 4 (female 1.5 years onwards) VCD values were 8.81 ± 0.32 mm and 8.84 ± 0.26 mm for right and left eye, respectively.

Average echobiometric parameters for VCD of both right and left eyes for groups 1, 2, 3 and 4 were 8.14 ± 0.30 mm, 9.11 ± 0.31 mm, 9.63 ± 0.32 mm and 9.27 ± 0.16 mm, respectively. Overall average findings of VCD for right and left eyes of all groups were 8.84 ± 0.23 mm and 8.84 ± 0.14 mm, respectively. There was no statistically significant difference in right and left eyes within all respective age groups for VCD (both at P > 0.01 and P > 0.05).

Difference in average parameters of left and right eye for VCD of group 1 from group 3 was statistically significant (at P > 0.05 significant).
### Table 12: VCD (mm) in brachycephalic skull group

<table>
<thead>
<tr>
<th>Age Groups</th>
<th>Right Eye (Mean ± SE)</th>
<th>Left Eye (Mean ± SE)</th>
<th>Overall (Mean ± SE)</th>
</tr>
</thead>
<tbody>
<tr>
<td>GROUP 1</td>
<td>8.25 ± 0.56</td>
<td>8.19 ± 0.19</td>
<td>8.14ab ± 0.30</td>
</tr>
<tr>
<td>GROUP 2</td>
<td>9.17 ± 0.62</td>
<td>8.62 ± 0.52</td>
<td>9.11ab ± 0.31</td>
</tr>
<tr>
<td>GROUP 3</td>
<td>9.54 ± 0.42</td>
<td>9.44 ± 0.15</td>
<td>9.63ab ± 0.32</td>
</tr>
<tr>
<td>GROUP 4</td>
<td>8.81 ± 0.32</td>
<td>8.84 ± 0.26</td>
<td>9.27ab ± 0.16</td>
</tr>
<tr>
<td>OVERALL</td>
<td>8.84 ± 0.23</td>
<td>8.84 ± 0.14</td>
<td></td>
</tr>
</tbody>
</table>

Values sharing the same letters of superscripts in column indicate that there was no statistically significant difference among parameters of age groups (P > 0.05). Different letters of superscripts in a column indicates statistically significant difference among parameters of age groups (P < 0.05). (At P ≥ 0.01 Not significant).

![Fig. 16: VCD in brachycephalic skull group](chart.png)
Table 13: AGL (mm) in brachycephalic skull group

<table>
<thead>
<tr>
<th></th>
<th>Right Eye (Mean ± SE)</th>
<th>Left Eye (Mean ± SE)</th>
<th>Overall (Mean ± SE)</th>
</tr>
</thead>
<tbody>
<tr>
<td>GROUP 1</td>
<td>15.80 ± 1.03</td>
<td>16.56 ± 0.72</td>
<td>15.87&lt;sup&gt;a&lt;/sup&gt; ± 0.65</td>
</tr>
<tr>
<td>GROUP 2</td>
<td>18.76 ± 1.49</td>
<td>19.65 ± 0.65</td>
<td>18.69&lt;sup&gt;b&lt;/sup&gt; ± 0.78</td>
</tr>
<tr>
<td>GROUP 3</td>
<td>19.96 ± 0.46</td>
<td>20.12 ± 0.23</td>
<td>20.18&lt;sup&gt;b&lt;/sup&gt; ± 0.23</td>
</tr>
<tr>
<td>GROUP 4</td>
<td>19.54 ± 0.33</td>
<td>19.58 ± 0.25</td>
<td>20.05&lt;sup&gt;b&lt;/sup&gt; ± 0.32</td>
</tr>
<tr>
<td>OVERALL</td>
<td>18.84 ± 0.46</td>
<td>18.95 ± 0.31</td>
<td></td>
</tr>
</tbody>
</table>

Values sharing the same letters of superscripts in column indicate that there was no statistically significant difference among parameters of age groups (P > 0.05). Different letters of superscripts in a column indicates statistically significant difference among parameters of age groups (P < 0.05). (At P ≥ 0.01 Highly significant).

Fig. 17: AGL in brachycephalic skull group
Difference in average parameters of group 2 and group 4 was statistically insignificant in between and from group 1 and group 3 (both at \( P > 0.01 \) and \( P > 0.05 \)).

(IV) **Axial globe length (AGL):** (Table – 13, Fig. – 17)

Axial globe length (AGL) for brachycephalic skull group was 15.80 ± 1.03 mm for right eye while 16.56 ± 0.72 mm for left eye in group 1 (male between 15 days to 1.5 years). For group 2 (female between 15 days to 1.5 years) AGL was 18.76 ± 1.49 mm for right eye and 19.65 ± 0.65 mm for left eye. While for group 3 (male 1.5 years onwards) right and left eye AGL values were 19.96 ± 0.46 mm and 20.12 ± 0.23 mm, respectively. Group 4 (female 1.5 years onwards) AGL values were 19.54 ± 0.33 mm and 19.58 ± 0.25 mm, for right and left eye, respectively.

Average echobiometric parameters for AGL of both right and left eyes for groups 1, 2, 3 and 4 were 15.87 ± 0.65 mm, 18.69 ± 0.78 mm, 20.18 ± 0.23 mm and 20.05 ± 0.32 mm, respectively. Overall average findings of AGL for right and left eye of all groups were 18.84 ± 0.46 mm and 18.95 ± 0.31 mm, respectively. There was no statistically significant difference between parameters of right and left eyes within all respective age groups for AGL (both at \( P > 0.01 \) and \( P > 0.05 \)).

Difference of average parameters of group 1 (male from 15 days to 1.5 years) from other age groups was statistically significant (at \( P > 0.01 \) highly significant and at \( P > 0.05 \) significant) while among group 2, group 3 and group 4 it was statistically insignificant (both at \( P > 0.01 \) and \( P > 0.05 \)).

2. **COMPARISON OF ECHOBIOMETRIC PARAMETERS AMONG DIFFERENT SKULL GROUPS:**

Echobiometric findings of aqueous chamber depth, lens thickness, vitreous chamber depth and axial globe length for dolichocephalic, mesocephalic and brachycephalic skull group were compared between right and left eye within skull groups along with their averages among skull groups. Combined overall averages of right eye and left eye for all three skull groups were also compared.
(I) **Aqueous chamber depth (ACD) among skull groups:** (Table – 14, Fig. – 18)

In dolichocephalic skull group ACD findings were 4.17 ± 0.16 mm for right eye while 4.01 ± 0.18 mm for left eye. For mesocephalic skull group ACD was 3.71 ± 0.19 mm for right eye and 3.82 ± 0.21 mm for left eye. While for brachycephalic skull group values of ACD for right and left eye were 3.54 ± 0.34 mm and 3.52 ± 0.36 mm, respectively.

Average echobiometric parameters for ACD of both right and left eyes for dolichocephalic, mesocephalic and brachycephalic skull group were 4.09 ± 0.12 mm, 3.76 ± 0.14 mm and 3.53 ± 0.23 mm, respectively. Overall average findings for right and left eye of all skull groups were 3.76 ± 0.14 mm and 3.78 ± 0.14 mm, respectively.

There was no statistically significant difference between parameters of right and left eyes in all respective skull groups for ACD. Difference in the overall average values of right and left eye of all three skull groups was also not statistically significant. Difference in the average parameters of right and left eye of ACD for all respective skull groups was also not statistically significant from each other (both at P > 0.01 and P > 0.05).

(II) **Lens thickness (LT) among skull groups:** (Table – 15, Fig. – 19)

Lens thickness (LT) parameters in dolichocephalic skull group were 6.41 ± 0.09 mm for right eye while 6.45 ± 0.07 mm for left eye. For mesocephalic skull group LT was 6.47 ± 0.17 mm for right eye and 6.47 ± 0.17 mm for left eye. While for brachycephalic skull group values of LT for right and left eye were 5.88 ± 0.24 mm and 6.02 ± 0.26 mm, respectively.

Overall average echobiometric parameters for LT of both right and left eyes for dolichocephalic, mesocephalic and brachycephalic skull group were 6.43 ± 0.06 mm, 6.47 ± 0.12 mm and 5.95 ± 0.17 mm, respectively. Average findings for right and left eye of all skull groups were 6.29 ± 0.12 mm and 6.34 ± 0.12 mm, respectively. There was no statistically significant difference between parameters of right and left eyes in all respective skull groups for LT.

Difference in the average values of right and left eye for all three skull groups was also not statistically significant. Parameters of LT for brachycephalic skull group differed from dolichocephalic skull group and
Table 14: ACD (mm) among skull conformation groups

<table>
<thead>
<tr>
<th>Skull Groups</th>
<th>Right Eye (Mean ± SE)</th>
<th>Left Eye (Mean ± SE)</th>
<th>Overall (Mean ± SE)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dolichocephalic</td>
<td>4.17 ± 0.16</td>
<td>4.01 ± 0.18</td>
<td>4.09\textsuperscript{a} ± 0.12</td>
</tr>
<tr>
<td>Mesocephalic</td>
<td>3.71 ± 0.19</td>
<td>3.82 ± 0.21</td>
<td>3.76\textsuperscript{a} ± 0.14</td>
</tr>
<tr>
<td>Brachycephalic</td>
<td>3.54 ± 0.34</td>
<td>3.52 ± 0.36</td>
<td>3.53\textsuperscript{a} ± 0.23</td>
</tr>
<tr>
<td>OVERALL</td>
<td>3.76 ± 0.14</td>
<td>3.78 ± 0.14</td>
<td></td>
</tr>
</tbody>
</table>

Values sharing the same letters of superscripts in column indicate that there was no statistically significant difference among parameters of skull groups \((P > 0.05)\). Different letters of superscripts in a column indicates statistically significant difference among parameters of skull groups \((P < 0.05)\). \((At\ P \geq 0.01\ Not\ significant)\).

Fig. 18: ACD among skull groups
Table 15: LT (mm) among skull conformation groups

<table>
<thead>
<tr>
<th>Skull Groups</th>
<th>Right Eye (Mean ± SE)</th>
<th>Left Eye (Mean ± SE)</th>
<th>Overall (Mean ± SE)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dolichocephalic</td>
<td>6.41 ± 0.09</td>
<td>6.45 ± 0.07</td>
<td>6.43b ± 0.06</td>
</tr>
<tr>
<td>Mesocephalic</td>
<td>6.47 ± 0.17</td>
<td>6.47 ± 0.17</td>
<td>6.47b ± 0.12</td>
</tr>
<tr>
<td>Brachycephalic</td>
<td>5.88 ± 0.24</td>
<td>6.02 ± 0.26</td>
<td>5.95a ± 0.17</td>
</tr>
<tr>
<td>OVERALL</td>
<td>6.29 ± 0.12</td>
<td>6.34 ± 0.12</td>
<td></td>
</tr>
</tbody>
</table>

Values sharing the same letters of superscripts in column indicate that there was no statistically significant difference among parameters of skull groups (P > 0.05). Different letters of superscripts in a column indicates statistically significant difference among parameters of skull groups (P < 0.05). (At P ≥ 0.01 Not significant).

Fig. 19: LT among skull groups
mesocephalic skull group though it was not statistically significant at the level of P > 0.01 but significant at the level of P > 0.05.

(III) Vitreous chamber depth (VCD) among skull groups: (Table – 16, Fig. – 20)

Vitreous chamber depth (VCD) parameters in dolichocephalic skull group were 9.44 ± 0.20 mm for right eye while 9.20 ± 0.23 mm for left eye. For mesocephalic skull group VCD was 8.44 ± 0.28 mm for right eye and 8.68 ± 0.24 mm for left eye. While for brachycephalic skull group values of VCD for right and left eye were 9.07 ± 0.27 mm and 8.88 ± 0.25 mm, respectively.

Average echobiometric parameters for VCD of both right and left eyes for dolichocephalic, mesocephalic and brachycephalic skull group were 9.32 ± 0.15 mm, 8.56 ± 0.18 mm and 8.97 ± 0.18 mm, respectively. Overall average findings for right and left eye of all skull groups were 8.82 ± 0.18 mm and 8.85 ± 0.15 mm, respectively. There was no statistically significant difference between parameters of right and left eyes in all respective skull groups for VCD. Difference in the overall average values of right and left eye for all three skull groups was also not statistically significant. Average parameters of right and left eye of VCD for dolichocephalic skull group differed from mesocephalic skull group statistically at P > 0.05 while difference in parameters of brachycephalic skull group from dolichocephalic skull group and mesocephalic skull group was not statistically significant (both at the level of P > 0.01 and P > 0.05).

(IV) Axial globe length (AGL) among skull groups: (Table – 17, Fig. – 21)

Values of axial globe length in dolichocephalic skull group were 19.92 ± 0.28 mm for right eye while 19.91 ± 0.29 mm for left eye. For mesocephalic skull group AGL was 18.83 ± 0.46 mm for right eye and 18.98 ± 0.47 mm for left eye. While for brachycephalic skull group values of AGL for right and left eyes were 18.53 ± 0.72 mm and 18.57 ± 0.69 mm, respectively. Average echobiometric findings for AGL of both right and left eyes for dolichocephalic, mesocephalic and brachycephalic skull group were 19.91 ± 0.19 mm, 18.91 ± 0.32 mm and 18.55 ± 0.49 mm,
Table 16: VCD (mm) among skull conformation groups

<table>
<thead>
<tr>
<th>Skull Groups</th>
<th>Right Eye (Mean ± SE)</th>
<th>Left Eye (Mean ± SE)</th>
<th>Overall (Mean ± SE)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dolichocephalic</td>
<td>9.44 ± 0.20</td>
<td>9.20 ± 0.23</td>
<td>9.32&lt;sup&gt;b&lt;/sup&gt; ± 0.15</td>
</tr>
<tr>
<td>Mesocephalic</td>
<td>8.44 ± 0.28</td>
<td>8.68 ± 0.24</td>
<td>8.56&lt;sup&gt;a&lt;/sup&gt; ± 0.18</td>
</tr>
<tr>
<td>Brachycephalic</td>
<td>9.07 ± 0.27</td>
<td>8.88 ± 0.25</td>
<td>8.97&lt;sup&gt;ab&lt;/sup&gt; ± 0.18</td>
</tr>
<tr>
<td>OVERALL</td>
<td>8.82 ± 0.18</td>
<td>8.85 ± 0.15</td>
<td></td>
</tr>
</tbody>
</table>

Values sharing the same letters of superscripts in column indicate that there was no statistically significant difference among parameters of skull groups (P > 0.05). Different letters of superscripts in a column indicates statistically significant difference among parameters of skull groups (P < 0.05). (At P ≥ 0.01 Not significant).

Fig. 20: VCD among skull groups
respectively. Average findings for right and left eye of all skull groups were 18.98 ± 0.31 mm and 19.07 ± 0.31 mm, respectively. There was no statistically significant difference between parameters of right and left eyes in all respective skull groups for AGL as well their overall averages also did not differ from each other statistically. Difference in the overall average values of right and left eye for all three skull groups was also not statistically significant. Difference observed among average parameters of right and left eye of AGL between dolichocephalic and mesocephalic; mesocephalic and brachycephalic skull group was not statistically significant both at the level of P > 0.01 and P > 0.05.
### Table 17: AGL (mm) among skull conformation groups

<table>
<thead>
<tr>
<th>Skull Groups</th>
<th>Right Eye (Mean ± SE)</th>
<th>Left Eye (Mean ± SE)</th>
<th>Overall (Mean ± SE)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dolichocephalic</td>
<td>19.92 ± 0.28</td>
<td>19.91 ± 0.29</td>
<td>19.91\textsuperscript{b} ± 0.19</td>
</tr>
<tr>
<td>Mesocephalic</td>
<td>18.83 ± 0.46</td>
<td>18.98 ± 0.47</td>
<td>18.91\textsuperscript{ab} ± 0.32</td>
</tr>
<tr>
<td>Brachycephalic</td>
<td>18.53 ± 0.72</td>
<td>18.57 ± 0.69</td>
<td>18.55\textsuperscript{a} ± 0.49</td>
</tr>
<tr>
<td><strong>OVERALL</strong></td>
<td>18.98 ± 0.31</td>
<td>19.07 ± 0.31</td>
<td></td>
</tr>
</tbody>
</table>

Values sharing the same letters of superscripts in column indicate that there was no statistically significant difference among parameters of skull groups (P > 0.05). Different letters of superscripts in a column indicates statistically significant difference among parameters of skull groups (P < 0.05). (At P ≥ 0.01 Not significant).

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**Fig. 21: AGL among skull groups**

![Graph showing AGL among skull groups](image-url)
2. Review of literature

Schiffer et al., (1982) evaluated 32 eyes of 17 clinically normal dogs using A-mode ultrasonography and biometric measurements were recorded for intraocular structures. Dimensions measured in the study were; the distance from the anterior cornea to the anterior lens surface, the lens thickness, the distance from the posterior lens surface to the retina, and the distance from the anterior cornea to the retina. No statistical difference was observed between the total axial length of the right eye and left eye. However, a significant increase of the total axial length of the eye in the male over that in the female dog (P less than 0.05) was observed.

Gelatt et al., (1983) performed A-scan ultrasonographic biometry on Miniature Schnauzer pups and adults with congenital cataracts and microphthalmia. The globe and lens were smaller than normal in the cataractous eyes, as ascertained in the study. Comparisons of clear lens of Miniature Schnauzers and normal Beagles with the cataractous Miniature Schnauzers showed that the affected globes and cataractous lenses were reduced 10% to 20% in their antero-posterior lengths. Congenital microphakic cataract was the main reason of the microphthalmia in the study.

Cottrill et al., (1989) described the normal B-scan ultrasonographic anatomic features of the eye and orbit of mesocephalic and dolichocephalic dogs. Measurements from mid-cornea to anterior lens surface, lens thickness, vitreous body (posterior lens surface to retina), and axial globe length were performed. The B-scan measurements of mid-cornea to anterior lens surface, lens thickness, and vitreous body were significantly different from direct measurements; however, there was no significant difference between B-scan and direct measurements of axial globe length. There was no significant difference observed in between A-scan and B-scan measurements. These findings of the study suggested that A-scan and B-scan measurements were similar and B-
scan measurements were reasonably accurate for axial globe determination. The axial globe length of dolichocephalic dogs was found significantly longer than that of mesocephalic dogs. In both mesocephalic and dolichocephalic dogs the axial globe length of male and female dogs was not significantly different. No significant difference was found in the axial globe length of right and left eyes in mesocephalic or dolichocephalic dogs.

Gaiddon et al., (1991) determined axial length by the use of A-scan ultrasonography on both eyes of dogs of various breeds, sizes and ages. Mean axial length of the globe was 20.43 ± 1.48 mm which was not related to age or sex of the dogs but was found significantly greater (P = 0.047) in dogs of larger breeds.

Ekesten (1994) performed A-scan ultrasonography of 40 healthy Samoyeds aged between 2 to 5 years. Twenty five dogs were sedated before the ultrasound examination and mydriasis and cycloplegia were induced in all dogs. To calculate intra-subject variance (measurement error) and true inter-subject variance (true biological variation) five consecutive A-scans were taken on each eye and were compared. Biological variation in both sedated and unsedated dogs was found to be of the same magnitude. In sedated dogs the sizes of the measurement errors were all within an acceptable range.

Ekesten and Torràng (1995) recorded parameters for ocular biometry in 52 Samoyeds of 2 months to 13 years of age without intraocular or systemic diseases using A-scan ultrasonography. Results of the study were interpreted and concluded that age-related changes mainly in lens thickness caused a shallow anterior chamber. It was also suggested that this may be of importance for development of a relative pupillary block and primary angle-closure glaucoma in the Samoyeds.

Soares et al., (1998) performed two dimensional real-time ultrasonography using 7.5 MHz mechanical sector fluid offset transducer by corneal contact method on 20 normal eyes of 10 dogs and 55 eyes of
30 dogs having ocular opacity. All the examinations were carried out without sedation or anaesthesia, only the cornea received a topical ophthalmic anesthetic and the eyelids were held open manually. Both the vertical and horizontal planes were used to examine the eyes. The ultrasonographic characteristics of the eye in normal dogs were found compatible with reports of previous studies. Use of 7.5 MHz mechanical sector fluid offset transducer and the two-dimensional real-time ultrasonography showed a satisfactory adaptability to the evaluation of the intra-ocular structures in dogs.

Mutti et al., (1999) investigated 75 Labrador Retrievers for diagnosis of naturally occurring vitreous chamber based myopia and observed a significant negative correlation between refractive error and vitreous chamber depth (Spearman $r = — 0.42; P < 0.001$). Myopic eyes of the Labrador Retrievers had an elongated vitreous chamber depth (10.87 ± 0.34 mm for myopic eyes, 10.02 ± 0.40 mm for non-myopic eyes; $P < 0.0001$). A significant quadratic association between lens thickness and vitreous chamber depth ($P < 0.005; R^2 = 0.11$) was found indicating that thinner lens occurred at both shorter and longer vitreous chamber depths.

Gonçalves et al., (2000) performed a real-time ultrasonic biometry on 60 ocular globes of 30 healthy dogs with the objective of getting distance measurement of intra-ocular structures. Dogs were restrained in sternal recumbency and measurements were taken from cross-sectional sagittal image using 7.5 MHz transducer of a mechanical sector scanner without use of flotation pad. The averages of measurements were 3.90 ± 0.70 mm for distance between the mid cornea and anterior lens capsule (D1); 6.10 ± 1.20 mm for lens thickness (D2); 10.50 ± 1.00 mm for lens diameter (D3); 9.10 ± 0.40 mm for vitreous chamber depth (D4) and 18.80 ± 0.90 mm for mid cornea to retina. No significant difference was observed among the right and left eyes except D1.

Svaldeniene et al., (2000) measured canine eye ball axis in sagittal, horizontal and vertical planes using ultrasonography for the estimation of the measurements and their connections to the canine skull size. The
horizontal axis of canine eye ball was found to be the longest and the saggital axis was found to be the shortest. No statistically reliable differences were observed between male and female, left and right eye ball, orbit and skull dimensions. The height of orbit was observed 2.72 ± 0.18 cm in the left eye and 2.68 ± 0.18 cm in the right eye.

Paunksnis et al., (2001) examined 28 mix breed dogs of different ages using A-scan ultrasonography and found that parameters of the eye such as the lens thickness, vitreous thickness and saggital eyeball axis increased with age. The lens thickness was measured from 2.10 to 3.10 mm in the age group of 10 – 15 days (group 1), from 2.20 to 4.20 mm in the age group of 5 – 20 days (group 2), from 2.30 to 4.70 mm in the age group of 2 – 4 months (group 3) and from 4.70 to 6.80 mm in the adults (group 4). The vitreous thickness varied from 4.80 to 5.50 mm, from 4.60 to 5.70 mm, from 6.10 to 8.70 mm and from 7.6 to 9.7 mm respectively in age groups. Saggital eyeball axis ranged from 10.10 to 11.40 mm, from 9.50 to 10.90 mm, from 13.30 to 18.50 mm and from 18.50 to 20.60 mm respectively in the age groups. The parameters of the left and right eye differed insignificantly in the study.

Sampaio et al., (2002) performed a keratometric and biometric study using A-mode ultrasonography on 120 dogs of either sex that were clinically healthy and free from ophthalmic diseases and reported that body weight of dogs was restricted to 10 kg, since the size of the dogs can interfere with the size of intraocular structures.

Williams (2004) determined axial lens thickness, anterior chamber depth and axial globe length in canine eyes with normal lenses and in eyes with immature, mature, congenital, posterior polar and diabetic cataracts. B-mode ultrasonography was performed in 50 normal dogs and as a pre-phacoemulsification screening procedure in 100 dogs with cataract. Difference in the axial globe lengths was not statistically significant between groups apart from the smaller globes in younger dogs with congenital cataract. Axial lens thickness in diabetics (8.40 ± 0.90 mm) was found statistically significantly different from the lens thickness in
normal eyes (6.70 ± 1.00 mm), eyes with immature cataract (6.40 ± 0.80 mm) and eyes with mature cataract (7.40 ± 0.90 mm) although these groups while varying in thickness were not statistically significantly different from each other. Anterior chamber depth was statistically significantly reduced in eyes with diabetic cataract (2.90 ± 0.10 mm) from that in normal eyes (3.80 ± 0.10 mm), eyes with immature cataract (3.50 ± 0.10 mm) and eyes with mature cataract (3.20 ± 0.60 mm) while, difference in chamber depth were not statistically significant from each other in the reported study.

Boroffka (2005) performed transabdominal ultrasonography to visualise the development of intraocular structures of both eyes of four different fetuses in each of two pregnant beagles. Postnatally, the development of both eyes of 11 pups of 4 beagles was visualised with B-mode ultrasonography. Biometric measurements of the eyes of the fetuses and pups were obtained using B-mode ultrasonography i.e. the length of the eye, the depth of cornea, the anterior chamber, the lens (anteroposterior depth and equatorial diameter) and the vitreous body when these structures could be identified ultrasonographically. In all fetuses the eyes with lens, vitreous body, hyaloid artery, and scleroretinal rim could be clearly identified from day 37 of pregnancy. Postnatally also the cornea, anterior chamber, iris, ciliary body, and optic disc were visible ultrasonographically. In the study, biometric measurements revealed both pre- and postnatally a continuous growth of the depth of the eye, anterior chamber, lens (anteroposterior depth and equatorial diameter) and vitreous body.

Boroffka et al., (2006) assessed the intra-observer and inter-observer repeatability of ocular biometric measurements obtained by means of high-resolution B-mode ultrasonography using 10.5 MHz linear array transducer in 6 Beagles dogs without ocular abnormalities. Intra-observer and inter-observer repeatability was found highest for larger measurements in the study such as depth of the eye and depth of the anterior chamber. Results were suggestive of that most measurements of
intraocular distances and structures obtained by means of high-resolution B-mode ultrasonography had acceptable intra-observer and inter-observer repeatability. The percentage difference between observations for smaller measurements was reported to be high.

Mieres et al., (2007) quantitatively evaluated ocular structures using ultrasound and determined if there was a correlation between the size of ocular structures and the dolichocephalic canine head. Thirty ophthalmologically healthy dolichocephalic dogs were examined by B-mode ultrasonography using 7.5 MHz transducer. Quantitative measurements of the lens width and antero-posterior depth of the anterior chamber, lens, vitreous chamber and globe were taken. No significant differences ($P > 0.05$) were found between measurements obtained from the left and right eye. Mean (cm) ± standard error (SE) was measured in all ocular structures and were reported to be as followed: antero-posterior depth of the anterior chamber (0.30 ± 0.01), anteroposterior depth of the lens (0.76 ± 0.01), width of the lens (1.50 ± 0.02), vitreous chamber depth (0.89 ± 0.01) and antero-posterior depth of the globe (1.94 ± 0.02). A large correlation between head length and both the antero-posterior depth of the anterior chamber and the globe ($r = 0.71$ in both cases) was found.

Tuntivanich et al., (2007) documented the development of axial globe length (AGL) in normal mesocephalic cross-bred dogs between 2 and 52 weeks of age and determined a relationship between AGL and age, and derived an equation to predict AGL in normal mesocephalic cross-bred dogs. The AGL of 20 normal mesocephalic cross-bred dogs were measured at 12 time points from 2 to 52 weeks of age using B-scan ultrasonography. The AGL (mean ± SEM) increased from $12.65 ± 0.18$ mm at 2 weeks of age to $19.52 ± 0.18$ mm at 52 weeks of age. A linear model of natural logarithmic-transformed value of AGL (mm) and age (week) was established for the mesocephalic cross-bred dogs. Side (left or right eye) and gender correlation with development of AGL was not found to be of statistical significance.
Vosough et al., (2008) measured the optical long axis in 12 healthy mixed-breed dogs including 6 males and 6 females using a 5–12 MHz linear trapezoid transducer. Eyes were evaluated and the normal optical long axis through a line between the cornea and the optic disc in three-dimensional images were measured. The mean ± SD optical axis were 20.70 ± 0.90 mm in males and 26.30 ± 0.60 mm in females (P < 0.05). No significant differences between the measurements of left and right eyes were observed.

Beserra et al., (2009) used 31 healthy mongrel dogs (10 males and 21 females) from 8 months to 7 years of age weighing 1.5 to 28 kg for study. Fronto-occipetal (FOD) and bizygomatic (BZD) diameters were measured using a caliper. The ophthalmologic transpalpebral B-mode ultrasonography (US) was performed to measure the ocular bulbi structures, as follows: The corneal thickness (D1), distance between cornea and anterior lens capsule (D2), distance between cornea and posterior lens capsule (D3), lens thickness (D4), lens diameter (D5), lens area (D6), distance between posterior lens capsule and retina (D7), distance between anterior lens capsule and retina (D8) and the distance between cornea and retina (D9). FOD and BZD affected the measures of the internal structures of bony orbit except for D4 i.e. lens thickness. The Lineal Regression Analysis between the measures of the internal oculars structures and FOD and BZD was found to be statistically significant for D1, D2, D3, D4, D5, D6, D7, D8 and D9 in the study.

Martins et al., (2010a) evaluated 15 male and female dogs aging 8 to 14 years affected with different stages of cataract using mode A and mode B ultrasonography, simultaneously and observed that the values obtained for axial diameter of the eyes, anterior chamber, lens, and vitreous chamber were respectively, 19.22 mm, 2.35 mm, 7.94 mm, and 8.94 mm. Diabetic cataractous lenses were found to be larger (8.90 mm), compared to mature cataractous lenses (8.12mm). Lens with immature cataract were found smaller in dimension than those with mature and diabetic cataracts.
Silva et al., (2010) evaluated the changes in the thickness of various eye structures in male and female English Cocker Spaniel dogs with and without non-diabetic cataracts. Sixteen dogs with cataracts (32 eyes) and 7 normal dogs (14 eyes) older than eight years were selected for the study. Simultaneously both A- and B-mode ultrasonography was performed with a 10MHz transducer. Mean and standard deviations of various ocular structures for dogs with and without cataracts were; anterior chamber: 3.04 ± 0.83 mm, 3.37 ± 1.04 mm; lens: 6.82 ± 1.12 mm, 7.06 ± 0.48 mm; vitreous: 10.06 ± 0.75 mm, 9.52 ± 0.71 mm and axial length: 19.91 ± 1.10 mm, 19.96 ± 1.05 mm respectively. Statistically significant differences were not observed for ocular measurements between right and left eyes, males and females, as well as in eyes with and without cataract (P > 0.05).

Feliciano et al., (2013) evaluated 10 Poodle dogs of varied ages and presenting cataracts using B-mode ultrasound. The ultrasound examination allowed the evaluation of the sonographic anatomy of the eye and measurement of the axial thickness of the lens (ATL). Values found for ATL were 5.89 ± 1.05 mm for the right eye (OD) and 6.07 ± 1.32 mm for the left eye (OS).

Toni et al., (2013) established mean values for intraocular structures in the dogs of different skull conformations and analysed the differences, if any. In this study, 30 dogs were selected and distributed into three groups according to skull conformation i.e. group 1 (G1) was composed of brachycephalic dogs, group 2 (G2) was composed of mesocephalic dogs and group 3 (G3) was composed of dolichocephalic dogs. Simultaneously, A and B-mode ultrasound was performed for obtainment of measurements relating to anterior chamber depth (D1); lens thickness (D2); vitreous chamber depth (D3); and the axial length of the eye (D4). No statistical significant differences were observed when comparing left and right eyes of dogs within the same skull conformation group (p > 0.05). Differences were observed when comparing D3 and D4 between groups G2 and G3 (p < 0.05). It was concluded that skull conformation of
brachycephalic dogs did not influence intraocular measurement values when compared to dolichocephalic and mesocephalic dogs. Skull conformation of dolichocephalic dogs showed an influence in values of vitreous chamber and the complete length of the eye when compared to mesocephalic dogs.

Boillot at el., (2014) performed the ocular biometry in 28 Eurasier dogs. They assigned the dogs into four groups: young males, young females (1 to 3 years old), adult males and adult females (4 to 8 years old) and measured the axial globe length (AGL) from the corneal epithelial surface to the inner retinal surface. The study revealed a significant inverse correlation between intraocular pressure (IOP) and axial globe length suggested that a decrease in AGL might lead to an increase in IOP.

Tavana and Peighambarzadeh, (2014) performed transcorneal ultrasonographic scanning of left and right eyes of 10 dogs (5 male and 5 female) using a 7.5 - 10 MHz transducer. Measurements of the ocular structures were obtained and qualitative ultrasonographic findings of the eyes were described. Mean ± standard deviation of the anterior-posterior length of the eye axis, thickness of the lens and depth of the anterior chamber were 19.41 ± 0.78 mm, 5.71 ± 0.45 mm and 8.63 ± 0.35 mm, respectively.

Kobashigawa et al., (2015) evaluated the ophthalmic parameters in 48 eyes of 24 male and female Shih Tzu dogs aged from 2 to 4 years, weighing between 5 and 10 kg. Recorded axial length of the ocular globe was 20.26 ± 0.13 mm; lens thickness was 6.62 ± 0.03 mm; anterior chamber depth was 4.06 ± 0.11 mm and vitreous chamber depth was 9.56 ± 0.05 mm respectively.
INTRODUCTION
REVIEW OF LITERATURE
MATERIALS AND METHODS
RESULTS
DISCUSSION
SUMMARY
LITERATURE CITED
ABSTRACT
(English and Hindi)
ANNEXURE 1
6. SUMMARY

Ultrasonography is a relatively easy, safe, non-invasive and inexpensive examination method which can be used in diagnosis of ocular and orbital disorders as complementary to routine ophthalmic examinations. Ultrasonography affords the benefit of providing a complete cross-sectional view of the globe. The ocular ultrasonography is indicated whenever opacity of the transmitting media of the eye prevents a complete ophthalmic examination. Situations that prevent normal examination include lid problems (e.g., severe edema, partial or total tarsorrhaphy), keratoprosthesis, corneal opacities (e.g., scars, severe edema), hyphema, hypopyon, miosis, pupillary membranes, dense cataracts, or vitreous opacities (e.g., hemorrhage, inflammatory debris).

There are very less studies undertaken on the normal echo-morphometric measurements of ocular structures in dogs of different skull conformations hence data regarding this are scarce. So, obtaining these measurements could be a benchmark to diagnose some of the diseases and eye problems of the dogs causing changes in these parameters. Transcorneal ultrasonographic scanning of 74 eyes of 37 healthy dogs of 11 different breeds and either sexes between 15 days to 1.5 years and 1.5 years onwards was performed without any sedation, anaesthesia or analgesia in present study.

Diagnostic B-scan permits topographical examination of the eye and characterise the location, size, shape, echotexture, consistency, insertion and relationship to neighbouring structures of any eye tumour mass. Other indications involve biometric measurements of intraocular and orbital structures and determination of axial eye length for power calculations of artificial lens for intraocular lens replacement surgery. Ocular biometry is also useful tool for the assessment of abnormalities such as phthisis bulbi, microphthalmia, pseudoexophthalmia, sclera ectasia, congenital glaucoma, enophthalmos, buphthalmos or exophthalmos due to the presence of retrobulbar masses, retinal detachment, tumors, hemorrhages and foreign bodies.
Qualitative echo-biometric findings of the eyes were described and measurements of the ocular structures i.e. aqueous chamber depth (ACD), lens thickness (LT), vitreous chamber depth (VCD) and axial globe length (AGL) were obtained by 5-14 MHz linear transducer at 4 cm scanning depth with suitable gain (55%).

The globes were examined in a sagittal plane as per standard described models. Optimal B-scan sonogram along the central optic axis enabled visualisation of the cornea, aqueous chamber, anterior lens capsule, posterior lens capsule, vitreous chamber and posterior ocular wall. Statistically non-significant (P ≥ 0.05 and P ≥ 0.01) differences were observed in all parameters of left and right eyes of male as well as female dogs within and among all skull conformation groups.

Observations of ACD was 4.09 ± 0.12 mm, 3.76 ± 0.14 mm and 3.53 ± 0.23 mm; LT was 6.43 ± 0.06 mm, 6.47 ± 0.12 mm and 5.95 ± 0.17 mm; VCD was 9.32 ± 0.15 mm, 8.56 ± 0.18 mm and 8.97 ± 0.18 mm; AGL was 19.91 ± 0.19 mm, 18.91 ± 0.32 mm and 18.55 ± 0.49 mm, respectively for dolichocephalic, mesocephalic and brachycephalic skull groups.

There were no statistically significant differences in all four parameters of dolichocephalic skull group whereas for mesocephalic and brachycephalic skull groups statistically significant differences were present in all four parameters among age groups. When all four parameters were compared statistically significant (P ≤ 0.05) differences were observed in lens thickness, vitreous chamber depth and axial globe length among skull conformation groups while differences in right and left eye were statistically non-significant (P ≥ 0.05 and P ≥ 0.01).

The present study provides an inside echo-morphometric view of the inner ocular structures in healthy eyes of dogs of different skull conformations. Knowledge of the ultrasonographic appearance and normal dimensions of the eye would serve as a basis for ultrasonographic examinations when ocular disease may have caused alterations in the dimensions and appearance of intraocular structures.