

Examining the morphometric features of bulbus oculi in Van cats by using computed tomography and magnetic resonance imaging

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Received date: 25.08.2020 - Accepted date: 10.12.2020

Abstract: This study was conducted to obtain the morphometric and volumetric measurements of bulbus oculi of Van cats, growing around the city of Van in Turkey and named after here, by using computed tomography (CT) and magnetic resonance imaging (MRI), and to reveal the biometric differences of these measurement values between the sexes. A total of 16 adult Van cats including 8 females and 8 males were used in the study. The animals were anesthetized with the combination of xylazine and ketamine. The anesthetized animals were scanned by using CT and MRI devices and their images were obtained. Then, the morphometric and volumetric measurements of bulbus oculi were calculated from these images using the software (Syngo CT Software) in the workstation and their statistical analysis was performed. Upon the examination of the morphometric and volumetric analysis results, it was determined that while W (bodyweight) and ACL (Left Anterior Chamber) values were higher in male cats, DVLL (Dorsoventral length of the left lens) value was higher in female cats. These differences between the sexes were statistically significant ($P<0.05$). The volumetric measurement values of bulbus oculi and lens were determined to be averagely $4.60 \pm 0.27 \text{ cm}^3$ and $0.67 \pm 0.09 \text{ cm}^3$, respectively. In conclusion, the statistical differences of biometric values of bulbus oculi between male and female Van cats were determined by using CT and MRI. It is thought that the present study would contribute to the ophthalmological applications and the students receiving anatomy education.

Keywords: Bulbus oculi, computed tomography, magnetic resonance imaging, morphometry, Van cat.

Van kedilerinde bulbus oculi'nin bilgisayarlı tomografi ve manyetik rezonans görüntüleme ile morfometrik özelliklerinin incelenmesi

Özet: Bu çalışma, Türkiye'de Van ili yöresinde yetiştirilen ve ismini buradan alan Van kedilerinde bulbus oculi'nin bilgisayarlı tomografi (BT) ve manyetik rezonans görüntüleme (MRG) ile morfometrik ve volümetrik ölçülerini elde etmek ve bu ölçüm değerlerinin cinsiyetler arasındaki biyometrik farklılıklarını ortaya koymak amacıyla yapıldı. Çalışmada 8 dişi, 8 erkek olmak üzere toplam 16 adet erişkin Van Kedisi kullanıldı. Hayvanlar ketamin-ksilazin kombinasyonu ile anesteziye alındı. Anestezi altındaki hayvanlar BT ve MRG cihazı ile taranarak görüntüleri elde edildi. Daha sonra bu görüntülerden iş istasyonundaki yazılım programı (Syngo CT Software) kullanılarak bulbus oculi'nin morfometrik ve volümetrik ölçümleri hesaplandı ve istatistiksel analizi yapıldı. Morfometrik ve volümetrik analiz sonuçlarına bakıldığında, W (vücut ağırlığı) ve ACL (sol ön kamera) değerlerinin erkek kedilerde; DVLL (sol lens'in dorsoventral uzunluğu) değerinin ise dişi kedilerde daha yüksek olduğu tespit edildi. Cinsiyetler arasındaki bu farkların istatistik olarak önemli düzeyde olduğu gözlemlendi ($P<0,05$). Bulbus oculi ve lens'e ait volümetrik ölçüm değerleri sırasıyla ortalama $4,60 \pm 0,27 \text{ cm}^3$ ve $0,67 \pm 0,09 \text{ cm}^3$ olarak belirlendi. Sonuç olarak, Van kedilerinde bulbus oculi'nin biyometrik değerlerinin istatistiksel olarak erkek ve dişiler arasındaki farklılıkları BT ve MRG kullanılarak tespit edildi. Sunulan çalışmanın bu kedilerle ilgili oftalmolojik uygulamalara ve anatomi eğitimi alan öğrencilere katkı sağlayacağı düşünülmektedir.

Anahtar sözcükler: Bilgisayarlı tomografi, bulbus oculi, manyetik rezonans görüntüleme, morfometri, Van kedisi.

Introduction

Van cats have attracted great interest in recent years due to its unique physical characteristics and especially being included in the endangered species. Being growing around the city of Van in Turkey and named after here,

Van cats are known for their eye colors (their eyes may be amber or blue or they have heterochromia), triangular-shaped head, soft coat on their bodies, fluffy tail, love of swimming and grooming, intelligence, and superior

learning ability. Van cats are an important source of the cultural wealth of the region (21).

The eye is a sense organ that can receive and process light stimuli from the surrounding environment and transmit them to the visual cortex of the central nervous system by converting them into an electrical signal by anatomic and physiological mechanisms (10). Being the organ of sight, the eye consists of bulbus oculi (the eyeball) and organa oculi accessoria (accessory organs of the eye). Bulbus oculi, which has an active role in sight, forms the optic structure of the eye. Bulbus oculi, which is situated in orbit, has a three-layered structure including tunica fibrosa bulbi (sclera and cornea), tunica vasculosa bulbi (choroidea, corpus ciliare, and iris), and tunica interna bulbi (retina) (9). Bulbus oculi varies among animal species and breeds in terms of shape and size. In general, when the domestic mammals are listed based on their body sizes, cats have the biggest bulbus oculi, which is followed by the dog, horse, cattle, and pig, respectively (18).

The technological advancements in the computer-aided medical imaging fields such as computed tomography and magnetic resonance imaging as well as three-dimensional modeling and various software programs enable to determine of the features of many anatomic structures in human or animal bodies, and evaluation easily any pathological change in these structures (2, 39). These imaging methods provide a perfect morphological detail in imaging of the eye and relevant (peripheral) complex anatomic structures particularly in small pets such as cats and dogs (7, 22). Also, the ocular and periocular benign and malignant aggressive tumors, orbital neoplasia, various inflammation cases, cystic structures, traumas, fractures, and foreign bodies in the region can be identified easily by means of CT, MRI, and the three-dimensional reconstruction software. Briefly, they are commonly used in diagnosing eye and orbital diseases and evaluating the diagnosis and treatment activities in veterinary medicine (7, 38).

Various studies concerning the anatomic and morphometric features of bulbus oculi have been conducted on horses (13, 24), cattle (13, 27), pigs (13), camels (16), sheep (8, 11), goats (23), various dog breeds (4, 25, 30, 37), and cats (3, 5, 19) from domestic mammals. However, no study has been found on the bulbus oculi in Van cats in the literature reviews. This study was conducted to provide the imaging of anatomic structures of bulbus oculi of Van cats by using computed tomography and magnetic resonance imaging, obtain its morphometric and volumetric measurements, and reveal the biometric differences of these measurement values between the sexes.

Materials and Methods

Animal materials: In the study, a total of 16 adult Van cats (between 3 and 8 years old, the average bodyweight (W) 4.91 kg for males and 3.60 kg for females), eight females and eight males, were used. The cats were obtained from Van Yüzüncü Yıl University Van Cat Research and Application Center. Ad libitum cat feed and drinking water were provided to these cats until the day before the study. This study was approved by the Van Yüzüncü Yıl University Animal Experiments Local Ethics Committee.

Anesthesia: The cats included in the study were numbered, and were not provided any feed starting the day before the study. Then, the cats were anesthetized with xylazine (1 - 2 mg / kg, IM, Alfazyme® 2 % injectable) - ketamine (15 mg / kg, IM, Ketazol® 10 % injectable) combination.

Imaging with computed tomography: For the computed tomography (CT) tests of the Van Cats, a 16-section multi-sequential computed tomography (CT) device (Somatom Sensation 16; Siemens Medical Solutions, Erlangen, Germany) was used in the Department of Radiology of Medicine Faculty of Van Yüzüncü Yıl University. A disposable sheet was placed onto the gantry of the device, and the cats were laid onto this sheet head-first in a prone position to achieve symmetry. The device parameters for the CT scan were adjusted as follows: Section thickness, 0.5 mm; physical detector collimation, 16 × 0.6 mm; feed/rotation, 6 mm; kernel, U90u; final section collimation, 32 × 0.63 mm; KV/rotation time (sec) values/effective mAs, 120/0.75/120; gantry rotation period, 420 ms; increment, 0.5 mm; resolution, 512 × 512 pixels. Scanning and dosage parameters were performed in accordance with standard protocols found in published literature (15, 28). The images obtained were recorded in the DICOM format.

Magnetic resonance imaging (MRI): The Van cats being ready for the study were laid in prone position under anesthesia and they were scanned by MRI. The T1 - weighted sagittal data obtained from the MRI device was used for image analysis. MRI parameters were adjusted as follows; the field of view of 16 cm, the repetition time of 19.2 milliseconds, echo time of 9.5 milliseconds, flip angle of 30°, resolution of 512 x 512 pixels, the resolution range of 0.31 x 0.31 mm², and the section thickness of 1 mm. The obtained axial images were transferred to the workstation (Leonardo, Siemens Medical Solutions, Erlangen, Germany) for processing in DICOM format.

Measurements: Then, using the software in the workstation (Syngo CT Software) on these obtained images, the morphometric measurements obtained from the axial, and coronal sections were obtained from CT measurements and the morphometric measurements obtained from sagittal sections were obtained from T1-

weighted MRI images as they were more demonstrative. On the other hand, the volumetric measurements were obtained by sectioning both bulbus oculi and lens from the outer border in all sections respectively from anterior to posterior in axial CT sections, obtaining colored images by means of the special software and then calculating the common volumetric data of all the sections. Figure 1, 2, 3,

and 4 shows the morphometric and volumetric measurement points of the bulbus oculi of Van cats. All measurements were made from the widest part of the bulbus oculi and lens. The morphometric and volumetric measurements of the points on the bulbus oculi were determined in Table 1.

Table 1. The measurement points of the bulbus oculi and the abbreviations.

Abbreviation	Explanation
ABR	Axial (anterior- posterior) length of the right bulbus oculi (cm)
ABL	Axial (anterior- posterior) length of the left bulbus oculi (cm)
MLBR	Mediolateral length of the right bulbus oculi (cm)
MLBL	Mediolateral length of the left bulbus oculi (cm)
DVBR	Dorsoventral length of the right bulbus oculi (cm)
DVBL	Dorsoventral length of the left bulbus oculi (cm)
ALR	Axial (anterior- posterior) length of the right lens (cm)
ALL	Axial (anterior- posterior) length of the left lens (cm)
MLLR	Mediolateral length of the right lens (cm)
MLLL	Mediolateral length of the left lens (cm)
DVLR	Dorsoventral length of the right lens (cm)
DVLL	Dorsoventral length of the left lens (cm)
ACR	Right Anterior Chamber (Anterior-posterior distance of the anterior chamber, from the cornea to the rostral border of the lens) (cm)
ACL	Left Anterior Chamber (Anterior-posterior distance of the anterior chamber, from the cornea to the rostral border of the lens) (cm)
PCR	Right Posterior Chamber (Anterior-posterior distance of the posterior chamber, from the caudal aspect of the lens to internal surface of the bulbus oculi of the posterior segment) (cm)
PCL	Left Posterior Chamber (Anterior-posterior distance of the posterior chamber, from the caudal aspect of the lens to internal surface of the bulbus oculi of the posterior segment) (cm)
VLR	Volumetric value of the right lens (cm ³)
VLL	Volumetric value of the left lens (cm ³)
VBR	Volumetric value of the right bulbus oculi (cm ³)
VBL	Volumetric value of the left bulbus oculi (cm ³)



Figure 1. Measurement points of the bulbus oculi in Van cats (axial CT image). DVBR: Dorsoventral length of the bulbus oculi; MLBR: Mediolateral length of the bulbus oculi; DVLR: Dorsoventral length of the lens; MLLR: Mediolateral length of the lens.

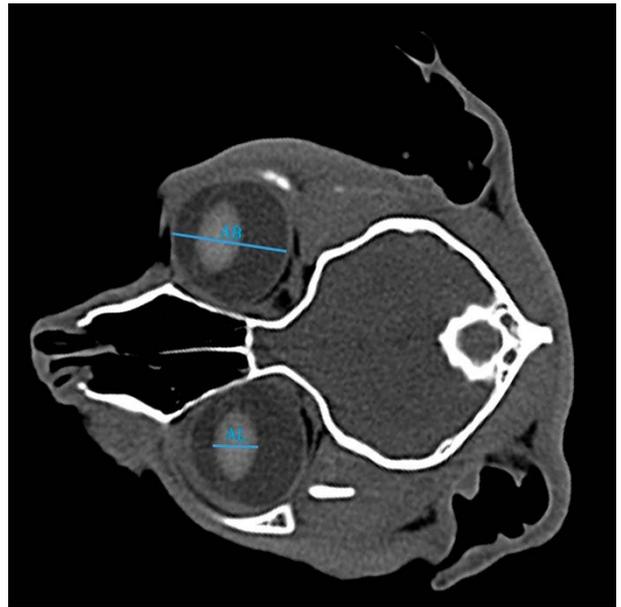


Figure 2. Measurement points of the bulbus oculi in Van cats (coronal CT image). AB: Axial (anterior - posterior) length of the bulbus oculi; AL: Axial (anterior - posterior) length of the lens.

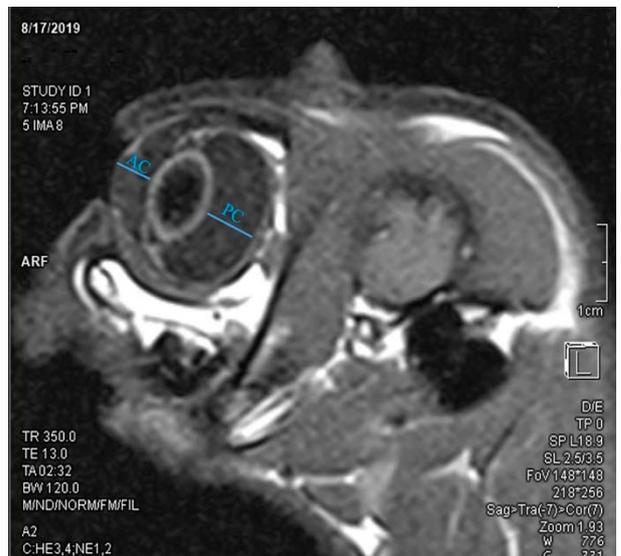


Figure 3. Measurement points of the bulbus oculi in Van cats (sagittal T1-weighted MRI image). AC: Anterior Chamber; PC: Posterior Chamber.



Figure 4. The process of calculating the volume value of the lens (VL) and the bulbus oculi (VB) in Van cats.

Nomina Anatomica Veterinaria was used as terminology in the study (20). Digital scales (TESS[®], RP - LCD) were also used for bodyweight (W) measurements.

Statistical analysis: Whether measurement averages in this study were normally distributed or not was controlled via the Shapiro-Wilk test ($n < 50$). Since it was found that measurements of the variables were not normally distributed, nonparametric tests were used. For the sample size in the study; G*Power statistics program (ver.3.1.9.4) was used. In the calculation, the power of the test was 95 % and the type-1 error was 5 %. Accordingly, it was appropriate to have a minimum of 8 cats in each group. Descriptive statistics for measurements in the study are communicated as mean, standard deviation, minimum, and maximum. Gender-related comparisons of the measurements were made through the Mann-Whitney U

test. The correlation between measurements, excluding gender-related comparisons, was determined by Spearman correlation coefficients. In measurements, the level of statistical significance (α) was deemed to be 5 %. For all measurements, SPSS (IBM SPSS for Windows, Ver. 23) statistical package program was used.

Results

The morphometric and volumetric measurement values obtained from bulbus oculi by using CT and MRI were analyzed statistically in order to determine the differences between male and female groups in terms of continuous variables. Statistically significant differences between the measured values of the bulbus oculi were recorded ($P < 0.05$). Tables 2-4 show the measured values.

Table 2. Morphometric and volumetric measurement values of the bulbus oculi according to gender.

	Gender	N	Median	Mean	Std. Dev.	Min.	Max.	*P
A	Male	8	4.50	5.00	2.00	3.00	8.00	1.000
	Female	8	4.50	5.00	2.00	3.00	8.00	
W (kg)	Male	8	5.00	4.91	0.60	4.10	6.00	0.002
	Female	8	3.40	3.60	0.48	3.10	4.30	
VLR	Male	8	0.70	0.68	0.11	0.47	0.79	0.399
	Female	8	0.64	0.65	0.08	0.52	0.76	
VLL	Male	8	0.73	0.68	0.11	0.50	0.77	0.171
	Female	8	0.63	0.62	0.09	0.44	0.71	
ALR	Male	8	0.97	0.96	0.04	0.86	0.99	0.288
	Female	8	0.95	0.94	0.05	0.83	0.99	
MLLR	Male	8	1.12	1.12	0.05	1.05	1.20	0.833
	Female	8	1.12	1.10	0.06	1.01	1.17	
DVLR	Male	8	1.07	1.08	0.04	1.03	1.16	0.092
	Female	8	1.14	1.15	0.09	0.99	1.27	
ALL	Male	8	0.97	0.95	0.06	0.84	1.03	0.792
	Female	8	0.96	0.94	0.05	0.85	0.99	
MLLL	Male	8	1.10	1.11	0.04	1.05	1.18	0.596
	Female	8	1.13	1.13	0.07	1.02	1.23	
DVLL	Male	8	1.09	1.08	0.03	1.03	1.11	0.013
	Female	8	1.13	1.15	0.08	1.00	1.28	
VBR	Male	8	4.72	4.69	0.12	4.49	4.81	0.248
	Female	8	4.52	4.57	0.43	4.07	5.44	
VBL	Male	8	4.70	4.70	0.13	4.54	4.86	0.172
	Female	8	4.46	4.53	0.40	4.16	5.34	
ABR	Male	8	2.19	2.20	0.09	2.05	2.38	0.156
	Female	8	2.15	2.14	0.08	2.00	2.23	
MLBR	Male	8	2.11	2.08	0.08	1.93	2.16	0.102
	Female	8	2.04	2.01	0.10	1.81	2.10	
DVBR	Male	8	2.09	2.07	0.06	1.94	2.13	0.636
	Female	8	2.09	2.07	0.11	1.86	2.21	
ABL	Male	8	2.19	2.19	0.10	2.01	2.33	0.493
	Female	8	2.16	2.16	0.08	2.05	2.28	
MLBL	Male	8	2.07	2.06	0.07	1.97	2.14	0.429
	Female	8	2.05	2.02	0.10	1.83	2.13	
DVBL	Male	8	2.10	2.09	0.03	2.04	2.13	0.460
	Female	8	2.07	2.05	0.09	1.88	2.13	
ACL	Male	8	0.46	0.46	0.03	0.40	0.49	0.026
	Female	8	0.41	0.42	0.02	0.39	0.46	
ACR	Male	8	0.44	0.44	0.04	0.39	0.51	0.167
	Female	8	0.42	0.42	0.03	0.39	0.48	
PCL	Male	8	0.78	0.78	0.03	0.74	0.83	0.314
	Female	8	0.79	0.80	0.03	0.78	0.86	
PCR	Male	8	0.79	0.80	0.04	0.75	0.88	0.205
	Female	8	0.77	0.77	0.04	0.71	0.84	

* $P < 0.05$; Mann-Whitney U test.

Table 3. Correlation between the morphometric and volumetric measurement values of the bulbus oculi in the male cats. (n=8).

	A	W(kg)	VLR	VLL	ALR	MLLR	DVLR	ALL	MLLL	DVLL	VBR	VBL	ABR	MLBR	DVBR	ABL	MLBL	DVBL	ACL	ACR	PCL	PCR	
W (kg)	r	.957**																					
VLR	r	-.321	-.297																				
VLL	r	-.300	-.245	.840**																			
ALR	r	.500	.405	-.728*	-.850**																		
MLLR	r	.244	.335	.337	.122	-.122																	
DVLR	r	.712*	.614	-.552	-.466	.552	.180																
ALL	r	.515	.373	-.648	-.798*	.957**	.012	.614															
MLLL	r	.350	.442	.383	.200	-.125	.903**	.000	.000														
DVLL	r	.450	.565	-.049	-.100	.200	.854**	.479	.258	.725*													
VBR	r	.049	.084	-.169	-.220	.244	.690	.419	.371	.464	.805*												
VBL	r	.195	.156	-.265	-.366	.390	.619	.407	.575	.537	.659	.881**											
ABR	r	.785*	.705	-.594	-.761*	.749*	.252	.699	.795*	.270	.393	.252	.491										
MLBR	r	.172	.151	.800*	.687	-.331	.216	-.295	-.289	.405	.012	-.299	-.287	-.271									
DVBR	r	.638	.596	.315	.049	.233	.491	.096	.313	.712*	.368	.012	.228	.470	.681								
ABL	r	.750*	.638	-.543	-.750*	.800*	.268	.700	.871**	.275	.400	.317	.561	.982**	-.209	.515							
MLBL	r	.344	.422	.564	.565	-.184	.383	-.211	-.181	.626	.344	-.060	-.060	-.127	.855**	.729*	-.098						
DVBL	r	.667	.715*	.287	.296	.086	.542	.218	.127	.716*	.617	.193	.248	.673	.806*	.806*	.272	.897**					
ACL	r	.864**	.733*	-.488	-.580	.642	.217	.806*	.733*	.235	.346	.193	.434	.945**	-.127	.497	.938**	-.061	.329				
ACR	r	.302	.278	-.112	-.050	-.164	.528	.420	.037	.478	.403	.430	.577	.408	-.266	.086	.352	-.167	.093	.485			
PCL	r	.683	.659	-.036	-.317	.317	.405	.180	.371	.610	.268	-.071	.238	.743*	.240	.814*	.708*	.323	.482	.687	.344		
PCR	r	.515	.464	-.770*	-.945**	.847**	-.036	.458	.807*	.000	.147	.120	.359	.886**	-.500	.223	.859**	-.337	-.061	.721*	.130	.587	

**P<0.01; *P<0.05; r: Spearman's rho Nonparametric Correlations Coefficients.

Table 4. Correlation between the morphometric and volumetric measurement values of the bulbus oculi in the female cats. (n=8).

	A	W(kg)	VLR	VLL	ALR	MLLR	DVLR	ALL	MLLL	DVLL	VBR	VBL	ABR	MLBR	DVBR	ABL	MLBL	DVBL	ACL	ACR	PCL	PCR			
W(kg) r	.390																								
VLR r	.195	.190																							
VLL r	.442	.407	.922**																						
ALR r	.025	.192	-.192	-.048																					
MLLR r	.393	-.072	.347	.542	.193																				
DVLR r	.519	-.120	.542	.679	.182	.897**																			
ALL r	-.123	-.036	-.719*	-.482	.476	.241	-.048																		
MLLL r	.663	-.036	.443	.596	.145	.777*	.933**	-.108																	
DVLL r	.687	.024	.539	.687	.139	.747*	.939**	-.187	.988**																
VBR r	.342	.071	.476	.671	-.060	.862**	.819*	.132	.731*	.731*															
VBL r	.488	.167	.524	.743*	-.060	.886**	.843**	.072	.755*	.766**	.976**														
ABR r	.146	.119	-.190	-.048	.898**	.287	.313	.395	.347	.048	.024	.024													
MLBR r	.642	.241	-.289	-.176	-.133	-.079	-.055	-.097	.248	.188	-.193	-.096	.145												
DVBR r	.732*	-.048	-.071	.108	-.323	.323	.434	.024	.635	.599	.429	.452	-.048	.615											
ABL r	-.195	.286	-.095	.108	.659	.371	.145	.683	-.072	-.060	.310	.286	.405	-.554	-.429										
MLBL r	.859**	.240	-.108	.084	-.223	.193	.248	-.078	.500	.464	.156	.263	.036	.903**	.850**	-.479									
DVBL r	.810*	.168	-.395	-.157	-.006	.120	.139	.223	.343	.307	.012	.120	.132	.806*	.778*	-.263	.904**								
ACL r	-.691	.036	.048	.042	.115	.164	-.104	.388	-.339	-.345	.277	.169	-.060	-.756*	-.602	.699	-.758*	-.733*							
ACR r	-.148	.482	.277	.273	.370	.115	-.024	-.127	-.030	-.042	-.036	.000	.398	.030	-.542	.277	-.194	-.376	.323						
PCL r	-.182	.457	.304	.313	.440	.070	-.077	-.032	-.274	-.217	-.114	-.025	.165	-.359	-.774*	.571	-.466	-.440	.436	.732*					
PCR r	.196	.192	-.299	-.205	.548	-.169	.006	.175	.265	.229	-.156	-.216	.755*	.394	.240	-.036	.259	-.295	-.345	.091	-.293				

**p<0.01; *p<0.05; r: Spearman's rho Nonparametric Correlations Coefficients.

Table 2 shows morphometric and volumetric measurements of the bulbus oculi according to sex. Accordingly, it was determined that W and ACL values were higher in the male cats compared to the female cats. In addition, DVLL values were higher in the female cats compared to the male cats. These differences were statistically significant ($P < 0.05$). No statistically significant difference was determined between the other average measurement values of bulbus oculi based on sex ($P > 0.05$).

Table 3 shows the correlation between the morphometric and volumetric measurement values of bulbus oculi in the male cats. Accordingly, a positive significant correlation was determined between age with W, DVLR, ABR, ABL, and ACL measurement values, between bodyweight with DVBL and ACL measurement values; between VLR with VLL and MLBR measurement values; between ALR with ALL, ABR, ABL, and PCR measurement values; between MLLR with MLLL and DVLL measurement values; between DVLR with ACL measurement value; ALL with ABR, ABL, ACL, and PCR measurement values; between MLLL with DVLL, DVBR, and DVBL measurement values; between DVLL and VBR measurement value; between VBR and VBL measurement value; between ABR with ABL, ACL, PCR measurement values; between MLBR with MLBL measurement value; between DVBR with MLBL, DVBL, and PCL measurement values; between ABL with ACL, PCL, and PCR measurement values; between MLBL and DVBL measurement value; between ACL and PCL measurement value ($P < 0.05$). On the other hand, there was a negative significant correlation between VLR with ALR and PCR measurement values; between VLL with ALR, ALL, ABR, ABL, and PCR measurement values ($P < 0.05$).

Table 4 shows the correlation between the morphometric and volumetric measurement values of bulbus oculi in the female cats. Accordingly, a positive significant correlation was determined between age with DVBR, MLBL, and DVBL measurement values; between VLR and VLL measurement value; between VLL and VBL measurement value; between ALR and ABR measurement value; between MLLR with DVLR, MLLL, DVLL, VBR, and VBL measurement values; between DVLR with MLLL, DVLL, VBR, and VBL measurement values; between MLLL with DVLL, VBR, and VBL measurement values, between DVLL with VBR and VBL measurement values; between VBR and VBL measurement value; between ABR and PCR measurement value; between MLBR with MLBL, DVBL, and ACL measurement values; between DVBR with MLBL and DVBL measurement values; between MLBL and DVBL measurement value; and between ACR and PCL measurement value ($P < 0.05$). However, a negative significant correlation was determined between VLR and

ALL measurement value; between DVBR and PCL measurement value; between ACL with MLBL and DVBL measurement values ($P < 0.05$).

Discussion and Conclusion

The medical imaging methods such as A-mode Ultrasonography, B-mode Ultrasonography, Computed tomography, and magnetic resonance imaging are commonly used in imaging eye and the relevant complex anatomic structures, obtaining morphometric and volumetric measurement values from these images, and interpreting pathological conditions (19, 30, 31, 36). This study is the first attempt to determine the morphometric and volumetric values of the right-left bulbus oculi using CT and MRI in Van cats and reveal the biometric differences of these values between males and females.

No statistically significant differences were observed in the ocular biometric measurement values obtained from the various planes of the right and left eyes of some animals such as domestic cats (36), Persian cat (19), mesocephalic and dolichocephalic dogs (6), Saanen goats (29), Guinea pigs (40), rabbits (34), and Striped Owls (32). In this study, it was observed that ACL measurement values were higher in the male cats compared to the female cats. In addition, DVLL measurement values were higher in the female cats compared to the male cats. These differences were statistically significant ($P < 0.05$). No statistically significant difference was determined between the other mean measurement values of the right and left bulbus oculi based on sex ($P > 0.05$). It was observed that other findings of bulbus oculi other than ACL and DVLL measurement values were compatible with the literature data. In addition, in the study by Schiffer et al. (31), no statistical difference was found between the right and left axial bulbus oculi length measurement values and they reported based on the differences between sexes that this measurement value was significantly longer in male dogs compared to female dogs.

Gilger et al. (12), determined that the mean values of axial bulbus oculi length, anterior chamber depth, and axial lens thickness were 20.91 ± 0.53 mm, 5.07 ± 0.36 mm, and 7.77 ± 0.23 mm, respectively, in the ocular biometric measurements performed in 20 mixed-breed cats with clinically normal characteristics. Vosough et al. (36), determined that the mean values of axial bulbus oculi length, anterior chamber depth, axial lens thickness, and posterior chamber depth of the right and left eyes were approximately 17.1 ± 0.1 mm, 3.9 ± 0.1 mm, 5.0 ± 0.1 mm, and 7.0 ± 0.1 mm, respectively, in the ocular morphometric examinations performed with 6 healthy female domestic shorthair cats. Mirshahi et al. (19), determined that these values were 20.7 ± 1.0 mm, 4.1 ± 0.7 mm, 7.7 ± 0.5 mm, and 8.2 ± 0.4 mm, respectively, in

the ocular morphometric examinations of 40 healthy Persian cats. In this study, it was observed that these values were approximately 21.7 ± 0.1 mm, 4.3 ± 0.03 mm, 9.6 ± 0.8 mm, and 7.8 ± 0.3 mm, respectively. It was considered that these differences observed between the morphometric measurement results of the mean values of axial bulbus oculi length, anterior chamber depth, axial lens thickness, and posterior chamber depth were due to the age, length, and breed characteristics of cats.

The studies have revealed that there is a correlation between body length and ocular size in humans (26) and dogs (6). However, in the present study, the ocular morphometric characteristics were assessed with bodyweight rather than body length. Accordingly, a positive, statistical correlation was determined between bodyweight and DVBL and ACL measurement values in male cats. Also, no significant correlation was observed between the ocular parameters and bodyweight in females. However, Hollis et al. (13), reported that there was a positive correlation between bodyweight and all the ocular structures except for lens and anterior chamber depth in horses.

In the study by Larsen (17), it was stated that the size of the eye developed and increased approximately until the age of 13 in humans. Also, Ribeiro et al. (29), reported that all the ocular parameters increased until the age of 549 days in Saanen goats. In the study conducted by Tuntivanich et al. (35), during the postnatal development period of dogs by using ultrasound they determined that the axial bulbus oculi increased until the 52nd week. In the study conducted by Mirshahi et al (19), with Persian cats, they determined that there was a positive correlation between age and posterior chamber depth. In the present study, a positive significant correlation was determined between age and W, DVLR, ABR, ABL, and ACL measurement values in the male cats and between age and DVBR, MLBL, and DVBL measurement values in the female cats. Also, Tables 3 and 4 show the correlation between the other measurement values of ocular structures in male and female Van cats.

Eye volume is quite important in terms of some ocular diseases such as microphthalmus, buphthalmus (congenital glaucoma), and macrophthalmus (1). Especially in pets such as cats and dogs, eye volume can be calculated using various software developed from CT and MRI images (1, 3, 14, 30). In this study, the volumetric measurement values of bulbus oculi and lens in healthy Van cats were determined to be averagely 4.60 ± 0.27 cm³ and 0.67 ± 0.09 cm³, respectively.

Using computed tomography and magnetic resonance imaging, the images with the appropriate thickness of the relevant anatomic structure can be obtained without giving any bodily harm to animals under anesthesia (33, 39). Additionally, imaging various

anatomic structures morphologically, interpreting them and the morphometric and volumetric measurements of these anatomic structures can be easily performed (7, 22, 38). Due to these properties, these imaging methods are increasingly and commonly used in the field of veterinary anatomy recently together with the computer-aided technological developments (2, 39).

Consequently, the statistical differences between the male and female Van cats in terms of bulbus oculi biometric values were determined using CT and MRI. It is predicted that this study would guide the ophthalmological applications related to Van cats and the students receiving anatomy education. Also, it is thought that this study would significantly contribute to the scientific studies about the eye in Van cats.

Financial Support

This research received no grant from any funding agency/sector.

Ethical Statement

This study was approved by Van Yüzüncü Yıl University Animal Experiments Local Ethics Committee (the decision no: 2020 / 02 and date: 27. 02. 2020).

Conflict of Interest

The authors declared that there is no conflict of interest.

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