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Original article

Three-dimensional reconstruction and morphometric analysis of the mandible in Van cats: A computed tomography (CT) study

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Abstract

This study was carried out to determine the morphometric and volumetric features of the mandible in Van cats by using computed tomography (CT) and a three-dimensional (3D) software program. The study also aimed at presenting the biometrical differences of these measurements between genders. A total of 16 adult Van cats (8 males, 8 females) were used in the study. The cats were anesthetized using a ketamine-xylazine combination. They were then scanned using CT under anesthesia and their images were obtained. The scanned images of the mandible in each cat were used for the reconstruction of a 3D model by using the MIMICS 20.1 (The Materialise Group, Leuven, Belgium) software program. Later, morphometric (17 parameters), volumetric, and surface area measurements were conducted and statistical analyses were carried out. In our morphometric measurements, it was found that TLM (total length of the mandible), PCD (pogonion to coronoid process distance), CAP (length from the indentation between the condyle process and angular process to pogonion), CAC (length from the indentation between the condyle process and the angular process to back of alveole C1), CML (length between C1 - M1), RAH (ramus height), MDM (mandible depth at M1), MHP (height of the mandible in front of P3), and ABC (angular process to back of alveole C1 distance) were greater in male cats; while MWM (mandible width at M1 level) was greater in female cats and was statistically significant ($p<0.05$). The length and height of the mandible were 6.36±2.42 cm and 3.01±1.81 cm in male cats, respectively. On the other hand, in female cats, the length and height of the mandible were 5.89±2.57 cm and 2.71±1.26 cm, respectively. The volume of the mandible was measured to be 7.39±0.93 cm^3 in male cats and 5.40±0.49 cm^3 in female cats. The surface areas were 63.50±5.27 cm^2 in male cats and 52.73±3.89 cm^2 in female cats. In conclusion, in this study, basic morphometric parameters of the mandible in adult Van cats were found by using CT and a 3D modeling program. The differences between male and female cats were also determined in the study.

Key words: computed tomography, mandible, morphometry, three-dimensional reconstruction, Van cat

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Introduction

The lower jaw or mandible is a pair of tabular bones that connect via the symphysis mandibulae (Dursun 2002). In some animals such as cats and dogs, these mandibles do not fully bond even in old age. As a result, upper and lower teeth rows are rooted in a more comfortable way, enabling more efficient cutting and chewing mechanisms (Dyce et al. 2010). Each half of the mandible in cats includes 3 incisors, 1 canine, 2 premolars and 1 molar teeth. In addition, each half of the mandible consists of two parts: the corpus mandibulae (horizontal part) and the ramus mandibulae (vertical part) (Bahadir and Yildiz 2008). The halves of the mandibulae are connected by a synovial joint to the temporal bone on both sides via the articulatio temporomandibularis (Dursun 2002, Bahadir and Yildiz 2008).

Thanks to the current developments in computed tomography and medical imaging techniques, such as various software programs and 3D modeling methods, anatomy teaching has seen many significant improvements. Moreover, many changes have also occurred in clinical diagnosis and surgical treatment planning (Brenton et al. 2007). In particular, in pet animals like cats, as a result of technological advancements in computed tomography and medical imaging techniques, CT is used as a standard in imaging mandibles and peripheral anatomical structures, and in monitoring changes that happen around these structures (Ohlerth and Scharf 2007, Moselhy and Mahdy 2019). By using these imaging techniques and 3D modeling programs, it is easier to determine various pathological malfunctions in the mandible and its surroundings, such as dysplasia in the temporomandibular joint, luxation or subluxation, fractures, and ankylosis, degenerative joint disease, joint infection and neoplasia. These imaging techniques and 3D modeling programs also monitoring of the efficiency of a particular treatment (Ohlerth and Scharf 2007, Wisner and Zwingenberger 2015, Southerden et al. 2018).

Knowing the anatomical properties of the mandible is important for both biomechanical analyses and phylogenetics (Porro et al. 2015). In this respect, Szabelska et al. (2017) argue that understanding the relations between morphological, densitometric and mechanical parameters of the mandible might help reveal metabolic responses, to certain factors, of the skeleton system and bone tissues; these factors include physiological, nutritional, pharmacological, toxicological and environmental factors which affect the bone tissue metabolism. Moreover, knowing the osteometric features of the mandible and measuring these features are also useful for forensic sciences (Rooppakhun et al. 2010, Teodoru-Raghina et al. 2017).

Van cats are an endemic cat species that live around the Van Lake in eastern Turkey. Although, due to their unique physical properties, they have attracted the attention of humans throughout history, their numbers have dramatically decreased in recent years. Therefore, they have been replaced by their crossbreeds (Odabasioglu and Ates 2000, Cak 2017, Yilmaz et al. 2020a). There are a few studies on the osteological properties of this animal (Yilmaz 2018, Yilmaz et al. 2020a,b). In our literature review, no study was found regarding the mandible of Van cats. In this context, this study was therefore conducted to obtain a 3D model of the mandible in Van cats using computed tomography, to measure the morphometric features of the mandible, to compare biometrical differences of these measurements between genders, and to present anatomical reference data regarding mandible morphology.

Materials and Methods

Animals

A total of 16 adult Van Cats (between 3 and 8 years old, 5810 - 8050 gr in weight), 8 male and 8 female, were used in the study. The cats were obtained from the Van Yuzuncu Yil University Van Cat Research and Application Center. They were given drinking water and standard cat food ad libitum until one day before the study. The necessary ethic permission for this study was obtained from the local ethics committee of the Van Yuzuncu Yil University.

Anesthesia

The cats included in the study were numbered and fasted one day before anesthesia. The cats were then anesthetized with a ketamine (15 mg/kg, IM, Ketasol® 10% injectable) - xylazine (1-2 mg/kg, IM, Alfazyne® 2% injectable) combination.

Imaging with computed tomography

For the computed tomography (CT) tests of the Van Cats, 16 cross - sectional multislice CT machines (Somatom Sensation 16; Siemens Medical Solutions, Erlangen, Germany) were used in the Department of Radiology of the Medical Faculty of Van Yuzuncu Yil University. The anesthetized cats were placed on the gantry symmetrically in the prone position. The CT devices were adjusted as follows: KV / Effective mAs / Rotation time (sec) values 120 / 120 / 0.75; gantry rotation period 420 ms; physical detector collimation, 16×0.6 mm; section thickness, 0.5 mm; final section collimation 32×0.63 mm; feed / rotation, 6 mm; Kernel, U90u; increment 0.5 mm; resolution 512×512 pixels. Dosage parameters and scanning were

Table 1. Measurement points and abbreviations of the mandible in Van cats.

Parameter	Abbreviation	Definition
1.	TLM	Total length of the mandible (mm)
2.	PCD	Pogonion (most anterior point on the mandible) to coronoid process distance (mm)
3.	CAP	Length from the indentation between the condyle process and angular process to pogonion (mm)
4.	CBC	Condylar process to back of alveole C_1 distance (mm)
5.	CAC	Length from the indentation between the condyle process and the angular process to the back of alveole C_1 (mm)
6.	PML	P_3-M_1 max length (mm)
7.	MML	M_1 max length (mm)
8.	LPP	P_3-P_4 max length (mm)
9.	CML	C_1-M_1 length between: length between the front of C_1 and the back of M_1 (mm)
10.	RAH	Ramus height: height of the ramus mandibulae (mm)
11.	MDM	Mandible depth at M_1 (mm)
12.	MHP	Height of the mandible in front of P_3 (mm)
13.	ABC	Angular process to back of alveole C_1 distance (mm)
14.	PAD	Pogonion to angular process distance (mm)
15.	MWC	Mandibular width at the back of C_1 alveole (mm)
16.	MWM	Mandible width at M_1 (mm)
17.	MBC	Mandible breadth at coronoid process (mm)
18.	Volume	Volume of the mandible (cm^3)
19.	Area	Surface area of the mandible (cm^2)

performed on the basis of standard protocols found in published literature (Prokop 2003, Kalra et al. 2004). The images obtained were recorded in DICOM format.

3D Reconstruction of the Images and Measurements

The cats were scanned through the CT device under anesthesia and their images were obtained. The scanned images of the mandible in each cat were used for the reconstruction of a 3D model using MIMICS 20.1 (The Materialise Group, Leuven, Belgium). On these reconstructed 3D models of mandibles, osteometric measurements were conducted for 17 different parameters. Morphometric measurements were based on measuring points presented in certain studies in the literature (Von Den Driesch 1976, Onar et al. 1997, Platz et al. 2010, Dayan et al. 2017, Pitakarnnop et al. 2017). Following morphometric measurements, the surface area and volume of the mandible were calculated. The abbreviations regarding osteometric parameters and their definitions are presented in Table 1. The areas on the mandible are presented in Figs. 1, 2, and 3. The Nomina Anatomica Veterinaria (2017) was used as a basis for anatomical terminology. Digital scales (TESS®, RP - LCD) were used for body weight (W) measurements.

Statistical Analysis

Whether measurement averages in this study were normally distributed or not was determined using the via Shapiro-Wilk test ($n<50$). Since it was found that the measurements of the variables were not normally distributed, nonparametric tests were used. For the sample size in the study the 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 provided as mean, standard deviation, minimum and maximum. Gender-related comparisons of the measurements were made using the Mann-Whitney U test. The correlation between measurements, excluding gender-related comparisons, was determined using Spearman correlation coefficients. In the measurements, the level of statistical significance (α) was deemed to be 5%. For all measurements, the SPSS (IBM SPSS for Windows, Ver. 23) statistical package program was used.

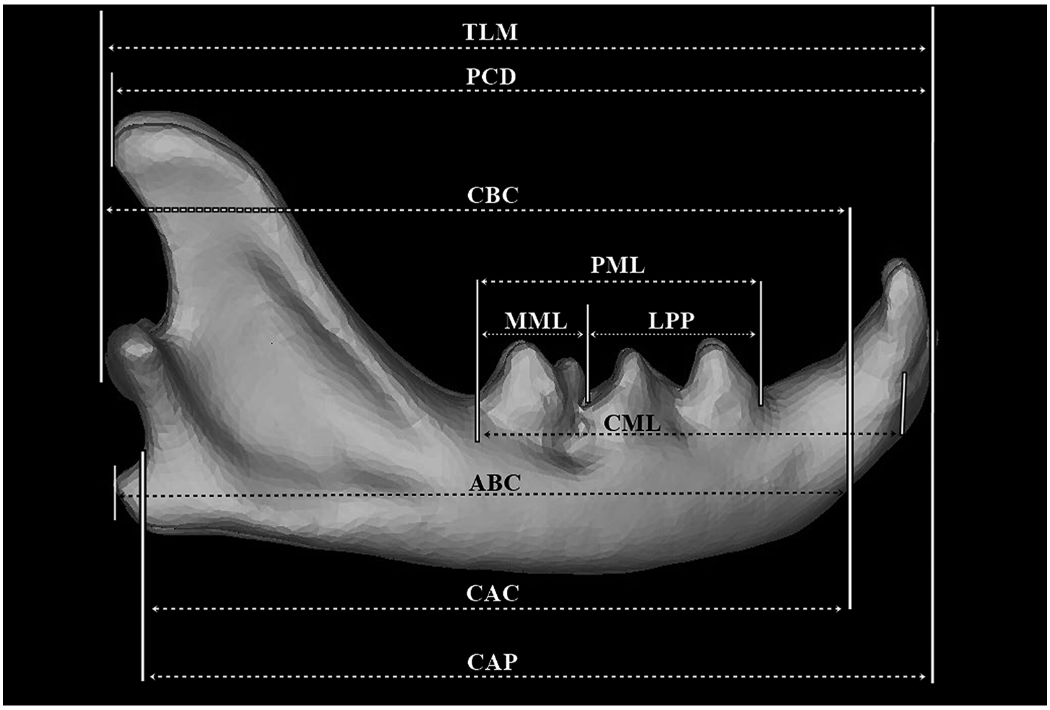

Fig. 1. Measurement points of the mandible variables in Van cats (lateral view-1). TLM: Total length of the mandible, PCD: Pogonion to coronoid process distance, CBC: Condylar process to back of alveole C_1 distance, PML: P_3 – M_1 max length, MML: M_1 max length, LPP: P_3 – P_4 max length, CML: C_1 – M_1 length between, ABC: Angular process to back of alveole C_1 distance, CAC: Length from the indentation between the condyle process and the angular process to the back of alveole C_1, CAP: Length from the indentation between the condyle process and angular process to pogonion.

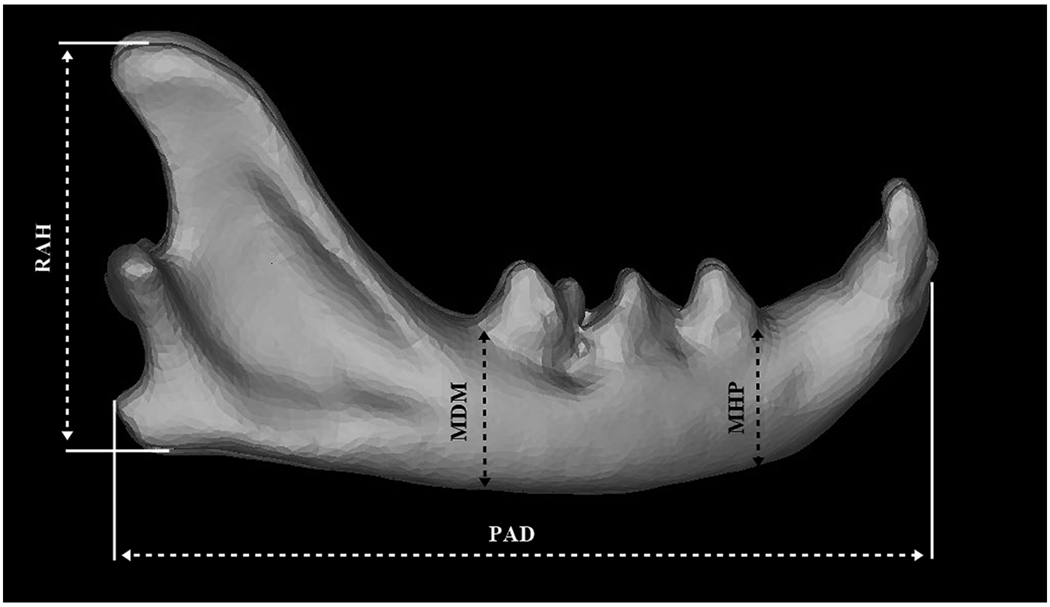

Fig. 2. Measurement points of the mandible variables in Van cats (lateral view-2). RAH: Height of the ramus mandibulae, PAD: Pogonion to angular process distance, MDM: Mandible depth at M_1, MHP: Height of the mandible in front of P_3.

Results

In this study, including volume and surface area measurements, 19 osteometric measurements were carried out. The levels of these morphometric measurements were compared to averages of male and female groups. Differences between genders were determined through statistical analysis. As a result of this analysis, statistically significant differences were found between the measurements of male and female groups ($p<0.05$). The levels of these measurements are presented in Tables 2-4 and Fig. 4.

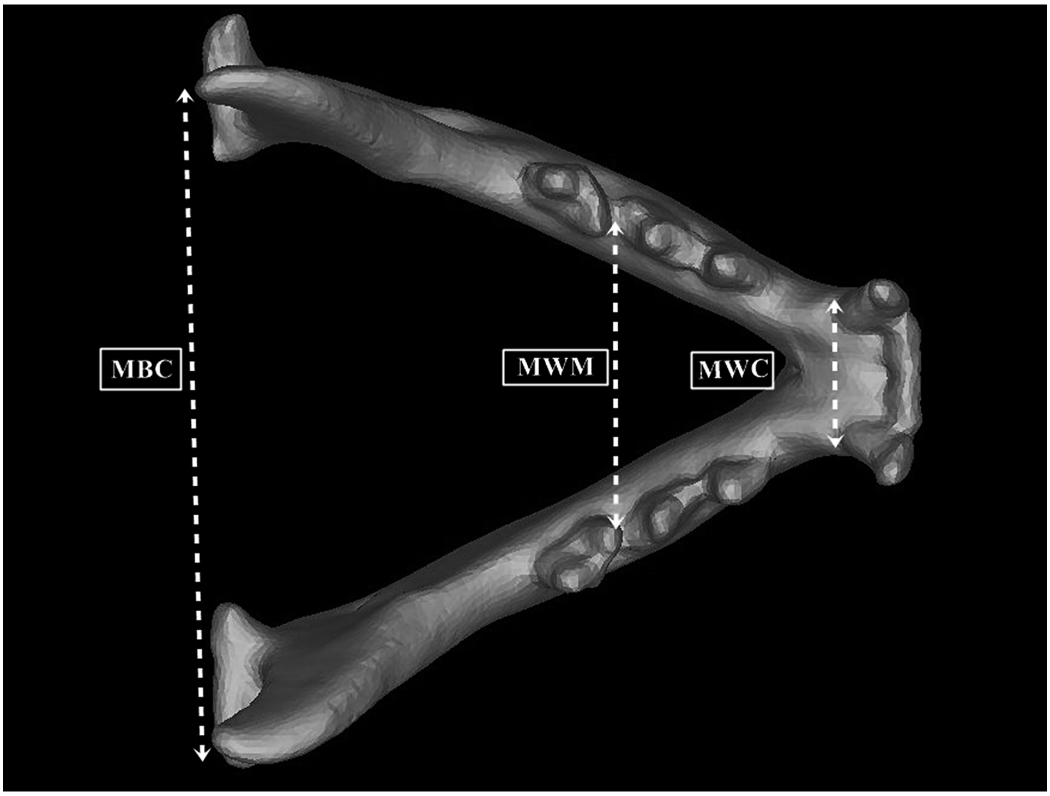

Fig. 3. Measurement points of the mandible variables in Van cats (dorsal view). MWC: Mandibular width at the back of C_1 alveole, MWM: Mandible width at M_1, MBC: Mandible breadth at coronoid process.

In Table 2, morphometric measurements of the mandible are presented according to gender. As seen in the table, measurements of TLM, PCD, CAP, CAC, CML, RAH, MDM, MHP, and ABC were found to be greater in male cats than female cats and were statistically significant ($p<0.05$). However, the width of MWM was found to be greater in female cats than male cats and was statistically significant ($p<0.05$).

In Fig. 4, morphometric measurements of the mandible are presented according to gender. As seen in the graphics, measurements of TLM, PCD, CAP, CBC, CAC, PML, MML, CML, RAH, MDM, MHP, ABC, PAD, MWC, and MBC are greater in male cats while LPP and MWM are greater in female cats.

Volume and surface area of the mandibles in male and female cats were measured separately. Descriptive statistics for these measurements are presented in Table 3. The volume of the mandible in male cats was 7.39±0.93 cm^3 whereas, in female cats, it was 5.40±0.49 cm^3. The surface area of the mandible was 63.50±5.27 cm^2 in male cats and 52.73±3.89 cm^2 in female cats. Therefore, regarding the volume and surface area of the mandibles, differences between male and female cats were found to be statistically significant ($p<0.05$).

In Table 4, the correlations between morphometric measurements of the mandible in both genders are presented. As seen in the table, in male cats, there is a significant positive correlation between age with W, TLM, CBC, CAC, LPP, and ABC levels; between W with TLM, CBC, CAC, LPP, ABC, and MBC levels; between TLM with PCD, CAP, CBC, MDM, and MBC levels; between PCD with CAP, CBC, MDM, and MBC levels; between CAP with CBC, MDM, and MHP levels; between CBC with CAC and MBC levels; between CAC with CML, ABC, PAD, and MBC levels; between PML and MML levels; between LPP and ABC levels; between CML and PAD levels; between RAH and MWC levels; between MDM and MBC levels; between PAD and MBC levels ($p<0.05$). However, between measured levels of MDM and MWM, a significant negative correlation was found at 76.2% ($p<0.05$). On the other hand, in female cats, it was found that there is a significant positive correlation between age and MBC level; between TLM with PCD, CAP, PML, LPP, and PAD levels; between CAP with LPP, ABC, and PAD levels; between CBC and CAC levels; between PML with CML and PAD levels; between LPP with PAD and MBC levels; between MHP and ABC levels ($p<0.05$). However, between age and MWC level, a significant negative correlation was found at 78.1% ($p<0.05$).

Discussion

The morphology of animal bones provides significant data for determining differences between genders

Table 2. Descriptive statistics of the measurements of the mandible in Van cats by gender.

Parameter	Gender	Mean	Std. Dev.	Min.	Max	*p
TLM	Male	63.616	2.417	60.180	67.370	.003
	Female	58.911	2.570	54.020	62.140	
PCD	Male	62.455	2.854	59.040	67.080	.005
	Female	58.208	1.587	55.980	61.060	
CAP	Male	60.456	2.601	57.240	64.800	.002
	Female	55.868	1.564	54.140	58.290	
CBC	Male	54.766	3.266	52.340	61.670	.172
	Female	52.868	.969	51.090	54.460	
CAC	Male	53.565	2.863	50.640	59.020	.002
	Female	49.659	1.399	47.510	51.690	
PML	Male	19.575	1.123	18.030	21.040	.141
	Female	18.525	1.409	16.800	20.670	
MML	Male	7.414	.832	6.210	8.190	.188
	Female	6.926	.190	6.690	7.350	
LPP	Male	11.618	.660	10.640	12.340	.115
	Female	12.095	.594	11.210	12.700	
CML	Male	31.688	1.220	29.550	33.200	.005
	Female	27.689	2.467	24.580	30.880	
RAH	Male	30.141	1.812	27.160	32.440	.005
	Female	27.179	1.259	25.460	28.930	
MDM	Male	11.385	1.167	9.960	13.070	.021
	Female	10.110	.342	9.770	10.880	
MHP	Male	11.532	.849	10.260	12.630	.016
	Female	10.379	.670	9.590	11.610	
ABC	Male	57.990	3.736	53.570	63.420	.001
	Female	51.101	1.550	48.960	52.670	
PAD	Male	58.206	4.708	51.760	64.770	.753
	Female	57.635	1.997	54.250	60.090	
MWC	Male	11.974	.730	10.890	13.130	.052
	Female	11.244	.391	10.730	11.970	
MWM	Male	22.299	2.958	18.710	26.030	.012
	Female	26.618	1.662	24.800	29.380	
MBC	Male	50.397	2.566	46.350	53.890	.462
	Female	49.803	2.270	46.950	53.120	

* $p<0.05$; Mann-Whitney U Test

Table 3. Descriptive statistics of the volume and surface area measurements of the mandible in Van cats by gender.

Parameter	Gender	Mean	Std. Dev.	Min.	Max	*p
Volume	Male	7.39	0.93	6.55	8.92	.001
	Female	5.40	0.49	4.77	6.14	
Area	Male	63.50	5.27	57.25	71.09	.002
	Female	52.73	3.89	45.58	59.68	

* $p<0.05$; Mann-Whitney U Test

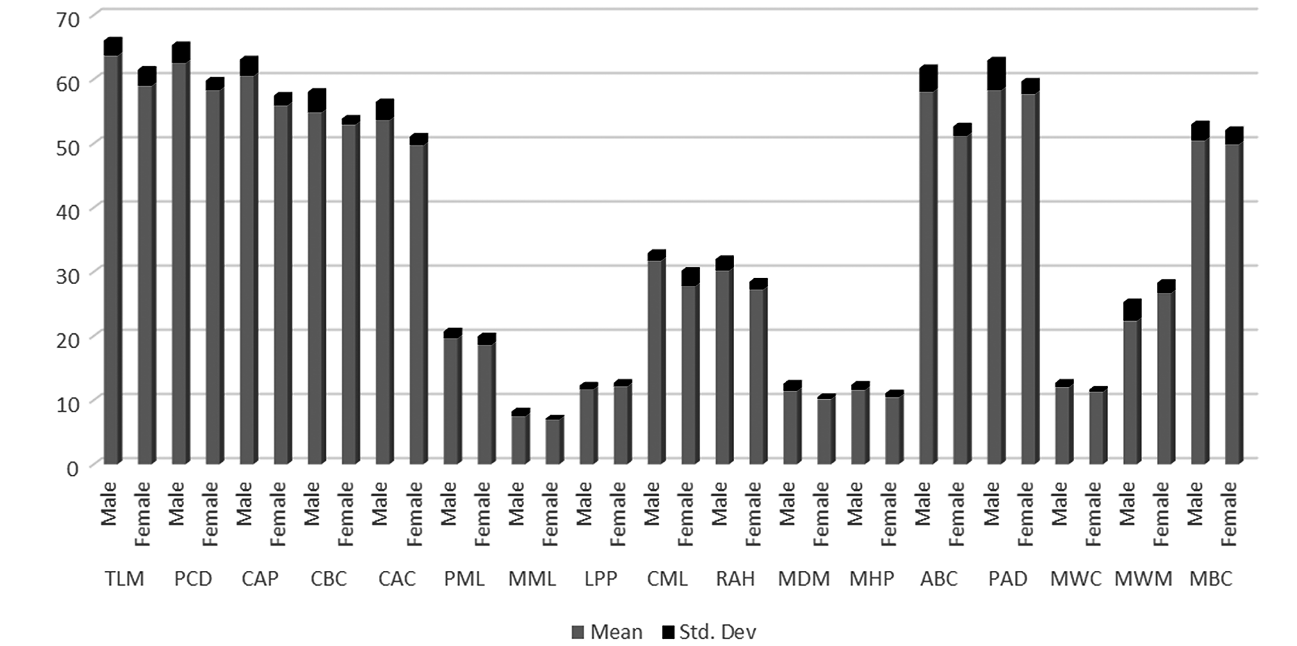

Fig. 4. Distribution of morphometric measurements of mandible in Van cats by gender.

Table 4. Correlation between mandible measurements in Van cats by gender.

↓→		Age (A)	W (kg)	TLM	PCD	CAP	CBC	CAC	PML	MML	LPP	CML	RAH	MDM	MHP	ABC	PAD	MWC	MWM	MBC
Age (A)	r		.390	.244	-.049	.146	-.098	-.244	.634	.123	.488	.537	.293	-.221	-.390	-.049	.293	-.781*	.390	.712*
W (kg)	r	.957**		.000	-.095	-.381	-.119	-.190	.024	.575	-.095	-.143	.333	-.120	.048	-.381	-.333	-.500	.048	.108
TLM	r	.732*	.731*		.714*	.857**	.238	.048	.714*	-.515	.786*	.405	.548	.587	.381	.429	.905**	.190	-.095	.467
PCD	r	.683	.659	.929**		.667	.024	.000	.310	-.383	.595	.143	.167	.527	.286	.095	.571	.500	.000	.587
CAP	r	.683	.707	.976**	.857**		.429	.333	.571	-.527	.881**	.238	.500	.599	.476	.714*	.952**	.333	.000	.503
CBC	r	.781*	.826*	.881**	.905**	.810*		.952**	-.048	-.156	.333	-.190	.190	.228	.571	.524	.310	-.048	-.169	-.060
CAC	r	.732*	.850**	.667	.643	.690	.833*		-.238	.012	.214	-.405	.119	.252	.619	.524	.143	.095	-.524	-.108
PML	r	.244	.347	.024	-.190	.095	.000	.214		-.252	.548	.762*	.310	.443	-.143	.190	.738*	-.238	.095	.539
MML	r	.147	.319	.024	-.180	.108	.060	.311	.958**		-.383	-.539	.156	.036	.108	-.156	-.623	-.216	.323	-.060
LPP	r	.781*	.731*	.500	.381	.452	.595	.571	.452	.371		.238	.619	.287	.333	.595	.857**	.000	.238	.743*
CML	r	.537	.707	.333	.262	.429	.429	.786*	.500	.563	.262		-.262	-.060	-.643	-.262	.476	-.405	-.119	.383
RAH	r	.390	.443	.452	.286	.429	.429	.262	-.143	-.108	.214	.095		.371	.667	.690	.476	.048	.381	.228
MDM	r	.488	.443	.738*	.857**	.714*	.619	.452	-.381	-.395	-.024	.286	.143		.611	.467	.503	.575	-.132	.096
MHP	r	.390	.419	.690	.429	.786*	.452	.476	.357	.371	.524	.262	.262	.214		.714*	.286	.524	-.143	-.156
ABC	r	.732*	.826*	.333	.167	.357	.500	.714*	.500	.503	.714*	.690	.500	-.071	.333		.619	.333	.143	.036
PAD	r	.586	.671	.452	.548	.476	.667	.905**	-.048	.048	.333	.738*	.048	.524	.190	.524		.167	.000	.491
MWC	r	.390	.539	.476	.310	.524	.524	.595	-.048	.084	.214	.452	.857**	.190	.405	.643	.429		.000	-.240
MWM	r	.098	.060	-.357	-.524	-.381	-.238	-.167	.333	.252	.476	-.167	.286	-.762*	-.048	.500	-.310	.119		.419
MBC	r	.683	.755*	.762*	.881**	.690	.929**	.810*	-.119	-.036	.333	.524	.310	.738*	.190	.381	.762*	.452	-.452	

** $p<0.01$; * $p< 0.05$; r: Spearman's rho Nonparametric Correlations Coefficients ↓: MALE. →: FEMALE

and informing various studies such as forensic, developmental, and evolutionary sciences (Pitakarnnop et al. 2017). In this respect, there are many studies that aim to examine differences between genders by using the measurements of the mandible in the fields of humanities (Rooppakhun et al. 2010, Bejdová et al. 2013) and veterinary sciences (Onar et al. 1997, Ince Gezer et al. 2010, Rooppakhun et al. 2010, Akbulut et al. 2014, Remzi et al. 2019, Yilmaz and Demircioglu 2019). Particularly, for small animals such as cats and dogs, medical imaging methods such as CT and 3D modeling programs that have been developed thanks to current technological advancements are widely used in imaging the complex anatomical structure of the mandible and its surroundings, obtaining various osteometric and volumetric measurements, diagnosing malign or pathological structures in the area, and analyzing the efficiency of treatments for these structures (Ohlerth and Scharf 2007, Moselhy and Mahdy 2019). The present study is the first study to determine the morphometric, volumetric, and surface area measurements of the mandible in Van cats by using CT and 3D modeling and to present differences between male and female cats.

In general, when osteometric measurements of the mandible in both humans and animals are compared, males are found to have higher levels than females (Onar et al. 1997, Ince Gezer et al. 2010, Rooppakhun et al. 2010, Akbulut et al. 2014, Pitakarnnop et al. 2017, Remzi et al. 2019, Yilmaz and Demircioglu 2019). Compatible with the findings in the literature, this study has also determined that male cats have higher levels than female cats in 17 out of 19 measurement parameters, including volume and surface area of the mandible in Van cats. Gender distribution of these measurement parameters and descriptive statistics are presented in Fig. 4 and Table 2. In these measurements, it was seen that TLM, PCD, CAP, CAC, CML, RAH, MDM, MHP, and ABC levels were higher in male cats whereas the MWM level was higher in female cats and was statistically significant ($p<0.05$). As a result, it can be concluded that male Van cats have a longer mandible than females.

In a study on Australian Domestic Cats by Saber et al. (2016) it was found that the mean mandibular length and height levels were 6±0.58 and 2.97±0.27 cm in flat-head cats; and 4.43±0.58 and 2.17±0.25 cm in round-head cats, respectively. In a similar study, Monfared (2013) found that the mean mandibular length and height levels of Persian cats were 8.3±1.03 and 3.7±0.59 cm. While Suri et al. (2018) showed that these levels were 4.8 cm and 2.3 cm in Civet cats, Moselhy and Mahdy (2019) found them to be 6.57±0.13 and 3.02±0.11 in domestic cats. On the other hand, Dayan et al. (2017) reported that the mean mandibular length and height levels of the Eurasian Lynx (Lynx lynx), a sub-species of the felidae family, were 9.34±2.98 and 3.89±1.63 cm. In addition, with reference to the differences between genders in domestic cats, Pitakarnopp et al. (2017) revealed that the mean mandibular length and height levels were approximately 6.01 cm and 2.75 cm in male domestic cats and 5.74 cm and 2.61 cm in female domestic cats. In the present study, it was found that the mean mandibular length and height levels of Van cats were 6.36±2.42 cm and 3.01±1.81 cm in male cats and 5.89±2.57 cm and 2.71±1.26 cm in female cats, respectively. Although these levels are generally compatible with the findings in the literature, there are some small differences, which are considered to stem from the age, height, body weight, and race of the cats.

In many studies, it is reported that age and body weight are significant parameters for mandible development and for examining osteometric measurement parameters of the mandible. In these studies, it is also argued that there is a positive correlation between these morphometric measurements and animal age and body weight (Gioso et al. 2001, Mo et al. 2009, Corte et al. 2019). Similarly, in a study by Tymczyna et al. (2012) on 6-month old male pigs (n=27), it was found that there was a positive correlation between body weight and mandible length ($p<0.05$). In the present study, in male cats, a significant positive correlation was seen between age and TLM, CBC, CAC, LPP, and ABC levels. Also, between body weight with TLM, CBC, CAC, LPP, ABC, and MBC levels, a significant positive correlation was observed ($p<0.05$). On the other hand, in female cats, no significant correlation was seen between body weight and morphometric measurements. The correlation between these measurements and body weight was insignificant and mostly negative. Between age and MBC level, a positive correlation was observed ($p<0.05$). Moreover, between age and MWC level, a negative correlation was detected at 78.1% ($p<0.05$). The correlation index between measurement levels of the mandible in male and female Van cats is presented in Table 4.

Thanks to the recent developments in medical imaging techniques and 3D modeling methods, it is easier to measure morphometric properties and volume and surface area in animals. As a result, by obtaining measurements of a related anatomical area, pathological structures can be detected and the efficiency of treatments for these areas can be evaluated (Ohlerth and Scharf 2007, Reynolds et al. 2011, Szabelska et al. 2017). In the present study, the volume and surface area of the mandible in Van cats were measured using CT images and a 3D modeling program (MIMICS 20.1 - The Materialise Group, Leuven, Belgium). In male Van cats, the volume of the mandible was 7.39±0.93 cm^3 while in female cats, the volume was 5.40±0.49 cm^3. The surface area of the mandible was found to be 63.50±5.27 cm^2 in male Van cats and 52.73±3.89 cm^2 in female Van cats. It was determined that these differences between male and female cats were statistically significant ($p<0.05$).

Thanks to medical imaging techniques such as computed tomography, images of an anatomical structure can be obtained in the desired thickness without harming the living creature since it is under anesthesia. In addition, in a digital platform, the osteometric properties, volume, and surface area of these structures can be quickly measured (Brenton 2007, Ohlerth and Scharf 2007). Using 3D software programs, developed in medical imaging areas, anatomical points in the skeleton system can be easily detected. Regardless of the living creature's position, valid and reliable morphometric measurements can be automatically conducted thanks to 3D coordinates (Rooppakhun et al. 2010). As a result, in recent years, CT and 3D software programs have been widely used in the field of veterinary anatomy (Yilmaz et al. 2020a).

In conclusion, in this study, basic morphometric parameters of the mandible in adult Van cats were found by using CT and a 3D modeling program. The differences between male and female cats were also determined in this study. It is thought that the results of the present study can be used as a guide in the evaluation of pathological disorders in the CT images of the Van cat mandible. In addition, through this study, basic anatomical data were obtained that would be beneficial to veterinary physicians in the fields of surgery and clinical practice related to the mandible in these animals.

References

Akbulut Y, Demiraslan Y, Gürbüz I, Aslan K **(2014)** The effect of gender factor on the mandible morphometry in the New Zealand rabbit. FU Sag Bil Vet Derg 28: 15-18.

Bahadir A, Yildiz H **(2008)** Veterinary anatomy: motion system & internal organs, Ezgi Bookselling, Bursa, Turkey, pp 1-90.

Bejdová Š, Krajíček V, Velemínská J, Horák M, Velemínský P **(2013)** Changes in the sexual dimorphism of the human mandible during the last 1200 years in Central Europe. HOMO 64: 437-453.

Brenton H, Hernandez J, Bello F, Strutton P, Purkayastha S, Firth T, Darzi A **(2007)** Using multimedia and web 3D to enhance anatomy teaching. Comput Educ 49: 32-53.

Cak B **(2017)** Turkish Van cat and Turkish Angora cat: a review. J Agric Sci Technol A 7: 151-159.

Corte GM, Hünigen H, Richardson KC, Niehues SM, Plendl J **(2019)** Cephalometric studies of the mandible, its masticatory muscles and vasculature of growing Göttingen Minipigs - a comparative anatomical study to refine experimental mandibular surgery. Plos One 14: e0215875.

Dayan MO, Gürbüz İ, Demiraslan Y, Özgel Ö **(2017)** Craniometric measurements of the male Eurasian Lynx from Turkey. Anim Vet Sci 5: 15-20.

Dursun N **(2002)** Veterinary anatomy I, Medisan Publisher, Ankara, Turkey, pp 42-73.

Dyce KM, Sack WO, Wensing CJG **(2010)** Textbook of veterinary anatomy, 4th ed., Saunders, Elsevier Inc, Missouri, United States, pp 32-99.

Gioso MA, Shofer F, Barros PS, Harvey CE **(2001)** Mandible and mandibular first molar tooth measurements in dogs: relationship of radiographic height to body weight. J Vet Dent 18: 65-68.

Ince Gezer N, Pazvant G **(2010)** Morphometry of the mandible in rats (*Wistar albino*). J Fac Vet Med Istanbul Univ 36: 51-56.

Kalra MK, Maher MM, Toth TL, Hamberg LM, Blake MA, Shepard JA, Saini S **(2004)** Strategies for CT radiation dose optimization. Radiology 230: 619-628.

Mo G, Zotti A, Agnesi S, Finoia MG, Bernardini D, Cozzi B **(2009)** Age classes and sex differences in the skull of the Mediterranean monk seal, Monachus monachus (Hermann, 1779). A study based on bone shape and density. Anat Rec 292: 544-556.

Monfared AL **(2013)** Anatomy of the Persian cat's skull and its clinical value during regional anesthesia. Glob Vet 10: 551-555.

Moselhy A, Mahdy E **(2019)** Comparative three-dimensional computed tomography (CT) scans and anatomical investigation of rabbit (*Oryctolagus cuniculus)* and cat (*Felis domestica*) skull. Slov Vet Res 56: 365-379.

Nomina Anatomica Veterinaria **(2017)** Prepared by the international committes on veterinary gross anatomical nomenclature and authorized by the general assambly of the world association of veterinary anatomists. 6th ed., The Editorial Committee: Hanover (Germany), Ghent (Belgium), Columbia, MO (U.S.A.), Rio de Janeiro (Brazil).

Odabasioglu F, Ates CT **(2000)** Van cats, 1st ed., Selcuk University Printing Office, Konya, Turkey.

Ohlerth S, Scharf G **(2007)** Computed tomography in small animals-basic principles and state of the art applications. Vet J 173: 254-271.

Onar V, Kahvecioğlu O, Mutuş R, Alpak H **(1997)** Morphometric analysis of the mandible in German Shepherd Dogs. Turk J Vet Anim Sci 23: 329-334.

Pitakarnnop T, Buddhachat K, Euppayo T, Kriangwanich W, Nganvongpanit K **(2017)** Feline (*Felis catus*) skull and pelvic morphology and morphometry: gender-related difference? Anat Histol Embryol 46: 294-303.

Platz S, Hertwig S, Jetschke G, Krüger M, Fischer MS **(2011)** Comparative morphometric study of the Slovakian wildcat population (*Felis silvestris silvestris*): evidence for a low rate of introgression? Mamm Biol 76: 222-233.

Porro LB, Rayfield EJ, Clack JA **(2015)** Computed tomography, anatomical description and three-dimensional reconstruction of the lower jaw of Eusthenopteron foordi Whiteaves, 1881 from the Upper Devonian of Canada. Palaeontology 58: 1031-1047.

Prokop M **(2003)** General principles of MDCT. Eur J Radiol 45: S4-S10.

Remzi OA, Caner B, Okan E, Ufuk K, Nuriye ÖK **(2019)** Accuracy and reliability of measurements obtained from 3-dimensional rabbit mandible model: a micro-computed tomography study. Acta Vet-Beograd 69: 192-200.

Reynolds M, Reynolds M, Adeeb S, El-Bialy T **(2011)** 3-D volumetric evaluation of human mandibular growth. Open Biomed Eng J 5: 83-89.

Rooppakhun S, Surasith P, Vatanapatimakul N, Kaewprom Y, Sitthiseripratip K **(2010)** Craniometric study of Thai skull based on three-dimensional computed tomography (CT) data. J Med Assoc Thai 93: 90-98.

Saber A, Cacec T, Gummow B, Johns K **(2016)** Morphometric studies on the skull of the Australian Domestic cat (F. catus) and its clinical implications for regional anesthesia. J Vet Anat 9: 1-24.

Southerden P, Haydock RM, Barnes DM **(2018)** Three dimensional osteometric analysis of mandibular symmetry and morphological consistency in cats. Front Vet Sci 5: 157.

Suri S, Sasan J, Sarma K **(2018)** Gross and morphometrical studies on mandible of Civet cat (*Viverricula indica*). Int J Curr Microbiol Appl Sci 7(10): 229-233.

Szabelska A, Tatara MR, Krupski W **(2017)** Morphological, densitometric and mechanical properties of mandible in 5-month old Polish Merino sheep. BMC Vet Res 13: 12.

Teodoru-Raghina D, Perlea P, Marinescu M **(2017)** Forensic anthropology from skeletal remains to CT scans: a review on sexual dimorphism of human skull. Rom J Leg Med 25: 287-292.

Tymczyna B, Bachanek T, Tatara MR, Krupski W, Tymczyna--Sobotka M, Łuszczewska-Sierakowska I **(2012)** Interrelationships between morphometric, densitometric, and mechanical properties of mandible in 6-month old male pigs. Bull Vet Int Pulawy 56: 177-181.

Von Den Driesch A **(1976)** A guide to the measurement of animal bones from archaeological sites, Peabody Museum Bulletin 1. Cambridge, MA: Harvard University, pp 52-64.

Wisner ER, Zwingenberger AL **(2015)** Atlas of small animal CT and MRI, Willey-Blackwell Publishing, USA, pp 40-68.

Yilmaz O **(2018)** Three-dimensional investigation by computed tomography of the forelimb skeleton in Van cats. Van YYU, Institute of Health Sciences, PhD Thesis, Van, Turkey, pp 1-144.

Yilmaz B, Demircioglu İ **(2019)** Three-dimensional reconstruction and morphometric analysis of the mandible in the Gazelle (*Gazella subgutturosa*): A CT study. J Res Vet Med 38: 65-71.

Yilmaz O, Soyguder Z, Yavuz A, Dundar I **(2020a)** Three--dimensional computed tomographic examination of pelvic cavity in Van Cats and its morphometric investigation. Anat Histol Embryol 49: 60-66.

Yilmaz O, Soyguder Z, Yavuz A **(2020b)** Three-dimensional investigation by computed tomography of the clavicle and scapula in Van cats. Van Vet J 31: 34-41.