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Research Article

Evaluation of Morphological Variations in Tympanic Portion of Temporal Bone in Dogs

Semra ÇINAR[1*], Figen SEVİL-KİLİMCİ[1], Mehmet Erkut KARA[1]

[1]*Department of Anatomy, Faculty of Veterinary Medicine, Aydin Adnan Menderes University, Aydin, Turkey*

ABSTRACT

In this study, it was aimed to examine the relationship between the morphometric-geometric features of the external acoustic meatus, tympanic bulla, and auditory tube and the cranium shape, age, gender, and race characteristics in the os temporale region in terms of the clinical-anatomical approach to the outer ear and middle ear regions of the dog's skull. A total of 110 dogs' skulls were used. The bones were photographed in three different views with the camera. The morphometric data on the skull, angle measurements, and index values related to them were calculated in obtained images. Auditory tube angle and external acoustic meatus angle were found to differ statistically among the age groups. In addition, it was determined that the index values of bulla tympanica, except for the height index, showed statistical differences among age groups. When the angle measurements and index values of the skulls of male and female animals were examined, it was determined that other index values did not differ between female and male dogs, except for the external acoustic meatus angle. As a result, it can be said that age and skull type is more effective than gender in the positioning of the tympanic region in dogs. The results of this research are supportive information that can be used in both clinical and zooarchaeological studies on the tympanic bulla region on dogs.

Keywords: Bulla tympanica, dog, morphometry, temporal bone, tuba auditiva

Köpeklerde Temporal Kemiğin Pars Tympanica'sındaki Morfolojik Varyasyonların Değerlendirilmesi

ÖZET

Bu çalışmada, köpeklerin kafatasının dış kulak ve orta kulak bölgelerine anatomik yaklaşım ve klinik açıdan meatus acusticus externus, bulla timpanica ve tuba auditiva'nın morfometrik-geometrik özellikleri ile os temporale bölgesindeki kafatası şekli, yaş, cinsiyet ve ırk özellikleri arasındaki ilişkinin incelenmesi amaçlanmıştır. Çalışmada toplam 110 adet köpek kafatası üzerinde çalışılmıştır. Kemiklerin üç farklı yönde fotoğrafları çekildi. Elde edilen görüntülerde kafa ile ilgili bazı morfometrik veriler, açı ölçümleri ve bunlara ilişkin indeks değerleri hesaplandı. Tuba auditiva açısı ve meatus acusticus externus açısı yaş grupları arasında istatistiksel olarak farklılık görüldü. Ayrıca bulla timpanika indeks değerlerinin boy indeksi dışında yaş grupları arasında istatistiksel olarak farklılık gösterdiği belirlendi. Dişi ve erkek hayvanların kafataslarının açı ölçümleri ve indeks değerleri incelendiğinde, meatus acusticus externus açısı dışındaki diğer indeks değerlerinin dişi ve erkek hayvanlar arasında farklılık göstermediği belirlendi. Sonuç olarak köpeklerde timpanik bölgenin pozisyonunda, yaş ve kafa tipinin cinsiyetten daha etkili olduğu söylenebilir. Bu araştırmanın sonuçları köpeklerde bulla timpanica bölgesi ile ilgili hem klinik hem de zooarkeolojik çalışmalarda kullanılabilecek destekleyici bilgilerdir.

Anahtar kelimeler: Bulla tympanica, köpek, morphometi, temporal kemik, tuba auditiva

***Corresponding Author:** Semra ÇINAR, Department of Anatomy, Faculty of Veterinary Medicine, Aydin Adnan Menderes University, Aydin, Turkey. e-mail: veterinariansemra@gmail.com

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Introduction

Morphometric studies of the skull can be done to determine species, race or sex characteristics (Onar, 1999; Onar and Gunes, 2003; Schmidt et al., 2011), as well as to form the basis of clinical approaches in various regions (Fox, 1964; Schmidt et al., 2011; Schmidt et al., 2013) is important. One of the most common ailments of dogs seen in veterinary medicine is ear disease. About 15%-20% of all canine patients have ear problems, which can range from mild erythema to severe otitis media (Louis, 2004). The temporal bone, which participates in the formation of a part of the lateral and base wall of the cavum cranii, is an important bone in terms of clinical applications, as some important vessels and nerves pass through it, articulates with the mandible, and forms the bony roof of the ear. In the middle of pars tympanica of the os temporale external hole of the meatus acoustics externus osseous is located. External acoustic meatus (external ear canal) is a tubular path which it is extending from concha auriculare to membrana tympanica and obliquely in dog (Evans, 1993; König, 2007; Njaa et al., 2012). The membrana tympanica at the end of external acoustic meatus is located at an angle of approximately 45 degrees to the horizontal central axis of the external acoustic meatus in dogs, however, this angle may differ according to dog breeds (Njaa et al., 2012). External acoustic meatus is closed in newborn kittens and puppies. For this reason, although newborn puppies can perceive some sounds, they cannot hear them properly. Generally, the external ear canal opens between the 6th and 14th days and the puppies begin to hear in the 3rd week after they are born (Samsar and Akın, 2006). Bony enlargement called tympanic bulla located on the ventral aspect of the pars tympanica is a structure that contains the middle ear (Bahadır and Yıldız, 2004). The space in the middle ear is called tympanic cavity and this space is in conjunction with the pharynx through the auditory tube (Eustachian tube). Since the position of the osseous roof of the external auditory canal, mastoid part of middle ear, and auditory tube, which is the functional unit of the ear, is related to various clinical approaches. Many studies are conducted on the morphometric and geometric features of the region (Mann et al., 1979; Albiin, 1984; Djeric and Savic, 1985; Sadler-Kimes et al., 1989; Kemaloğlu et al., 1996; Judkins and Li, 1997; Sırıkçı et al., 2001). In clinical applications, position of the external auditory canal for otoscope application and location of the tympanic membrane during cleaning of the ear canal must be taken into account (Njaa et al., 2012). For example, the dorso-rostral border of the external acoustic meatus and the shape of the zygomatic process of the os temporale and the angle of the skull to the long axis may show variations in different skull types of dogs. This is important in terms of placing the autoendoscope deeper during video otoscope use in procedures such as myringotomy (Njaa et al., 2012). In addition, regarding the angle of the external auditory canal with the tympanic annulus; provides an advantage in washing the external ear, inserting and passing the catheter into the horizontal ear canal, and collecting the washing solution and serum physiology without damaging the tympanic membrane (Njaa et al., 2012). Auditory tubeposition is considered to be the main cause of middle ear inflammations (Mawson, 1974; Kemaloğlu et al., 1996). The po sition of the Tympanic bulla and auditory tube changes depending on age (Takeuchi ve ark., 1980; Bluestone and Doyle, 1988; Kemaloğlu et al., 1996)

Due to the common middle ear inflammations in children, there are many studies on this subject both in humans and animals (Sadler-Kimes, 1989; Judkins and Li, 1997). For this reason, os temporale measurements and their ratios to ossa cranii measurements have gained importance. Considering the changes in development process of the studied measurements, it is seen that the os temporale continues to develop together with the ossa faciei until it reaches maturity (Takeuchi ve ark., 1980) and it has been revealed that the growth process of the skull significantly affects function of the auditory tube (Mann et al., 1979). In these studies, change in the shape, size and position of the auditory tube with age was also investigated (Mann et al., 1979; Takeuchi et al., 1980; Todd and Martin, 1988).

In literature review on the subject, detailed data on various ear diseases in dogs and temporal bone morphometry, which is important in terms of examination, and variations of this region depending on race, age, gender, and skull shape were not found. In this study, it was aimed to examine the relationship between the morphometric and geometric features of the external acoustic meatus, tympanic bulla and auditory tube and the cranium shape, age, and gender characteristics in the os temporale region in terms of the clinical-anatomical approaches to the outer ear and middle ear regions of the dog's skull.

Materials and Methods

In this study, dog skull bones obtained from the archive of Adnan Menderes University Veterinary Faculty Anatomy Department Osteometry Laboratory were used. A total of 110 dogs (48 female, 59 male, 3 non-gendered) were studied. In the absence of age records of the animals (n:16), the approximate age of the animals was determined according to the condition of their teeth and sutures (Dyce et al. 2002; Thrall and Robertson, 2011; Mihelic et al., 2013; Schmidt et al., 2013). Accordingly, animals with an approximate age range of 1.5 months to 168 months were used.

In order to demonstrate the reliability of the method, the cranium of a randomly selected dog was photographed five times and all measurements were taken repeatedly on these five images of the same skull to calculate the coefficients of variation (Özdamar, 2004).

After checking the validity and reliability of the measurement method, photographic images of the bones, which were placed on a flat platform with the

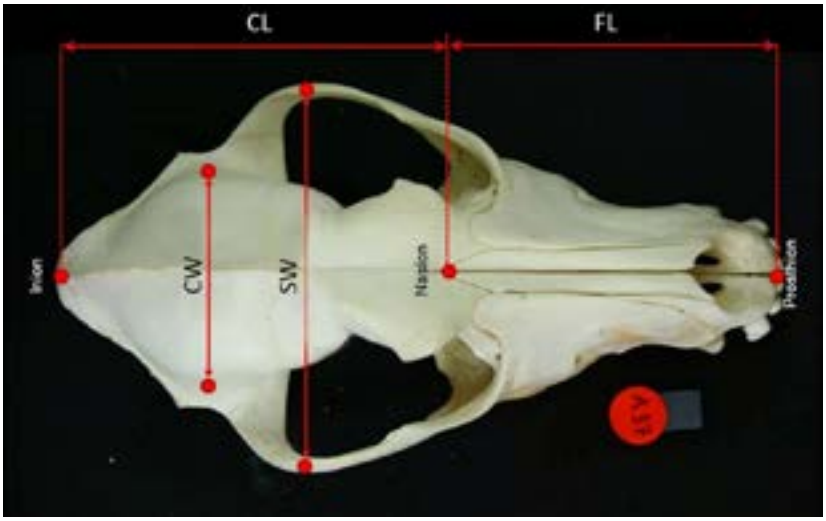

Figure 1. Dorsal view of the skull and the measurements

Figure 2. Lateral view of the skull and the measurements

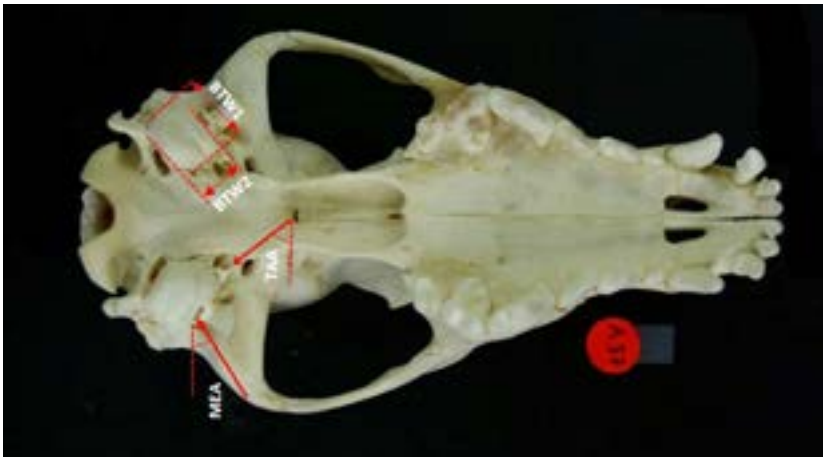

Figure 3. Basal view of the skull and the measurements

help of play dough, were taken from the dorsal, lateral and basal face with a Canon EOS 350D camera. A ruler was placed during photographing for calibration of the images. Photographs were taken perpendicular to the bone and focusing on the midpoint of the bone for all positions. All obtained photos were transferred to the computer in ".jpeg" format. After calibration of the transferred images in the "ImageJ" program, all the measurements of skull bones were taken using necessary commands in the "ImageJ" program", whose reference points were already defined. (Figure 1-3, Table 1).

Statistical analyzes were performed with the SPSS 19.0 program, and normal distribution of the data was checked with the "Shapiro-Wilk test". In age and gender groups, an intergroup comparison was checked for independent variables by t-test. The results were checked with the Mann-Whitney test, which is a non-parametric test for parameters that did not show normal distribution, and the significant (p) values were written according to the results of this test. Pearson correlation analysis method was used to determine whether there was a correlation between the cranium index values in the bones used and the index and angle values obtained from the pars tympanica region the data were presented as the number of animals in the group (n), mean value (MV), and standard deviation (SD) in tables. The significance level in the study was accepted as $p<0.05$. Checking the reliability of the measurement method, the coefficient of variation (%CV) of measurements was calculated using the formula, "(standard deviation/mean value) x 100" (Özdamar, 2004).

Results

When the coefficients of variation calculated for the measurement method in the study were examined, the lowest coefficient of variation was found to be 0.18% in facial length and skull width measurements, and the highest coefficient of variation was 1.96% in the measurement of auditory tube angle.

Angle measurements and index values of the young and adult age groups are presented in Table 2. Auditory tube angle and external acoustic meatus angle were found to differ statistically between two groups. In addition, it was determined that the index values of bulla tympanica, except for the height index, showed statistical differences among age groups.

Angle measurements and index values of the skulls of male and female animals are presented in Table 3. According to these results, it was determined that other index values did not differ between female and male animals, except for the external acoustic meatus angle.

Table 1. Identification of abbreviations in the study

	Parameter		Method	Source
Lenght Values (mm)	Facial length	FL	Between nasion and prosthion	EVANS (1993)
	Cranial length	CL	Between Inion and nasion	EVANS (1993)
	Cranial width	CW	The widest interparietal width	EVANS (1993)
	Cranial height	CH	Lateral side from base of occipital condyle to highest point of head	EVANS (1993)
	Skull width	SW	The widest interzygomatic distance	EVANS (1993)
	Skull length	SL	FL+CL	EVANS (1993)
	Width of Bulla tympanica 1	BTW1	The largest diamater of the Bulla tympanica	DRIESCH (1976)
	Width of Bulla tympanica 2	BTW2	The narrowest diamater of Bulla tympanica	DRIESCH (1976)
	Heigth of Bulla tympanica	BTH	The distance between the upper border of the porus acusticus externus and the ground contacting part of the bulla tympanica	-
Angle Values (°)	Angle of tuba auditiva	TAA	Angle of tuba auditiva with transversal plane	-
	Angle of meatus acusticus externus	MEA	The angle between ventral border of porus acusticus externus and the transversal axis	ALBIIN (1984)
Index Values (%)	Skull index	SI	SW x 100 /SL	EVANS (1993)
	Cranial index	CI	CW x 100 /CL	EVANS (1993)
	Facial index	FI	SW x 100 /FL	EVANS (1993)
	Width of Bulla tympanica 1 index	BWI1	BTW1x100/SL	-
	Width of Bulla tympanica 2 index	BWI2	BTW2x100/SW	-
	Heigth of Bulla tympanica index	BHI	BTHx100/CH	-

Table 2: Angular measurements and calculated index values of the skulls of animals in different age groups

	Young		Adult		p
Angular values (°)	**N**	**MV±SD**	**N**	**MV±SD**	
Angle of tuba auditiva	39	43.81±7.38	69	53.50±5.65	**0.000*** **
Angle of meatus acusticus externus	39	48.34±5.32	69	45.75±5.86	**0.021***
Index values (%)					
Skull index	41	57.90±4.09	69	56.38±9.51	**0.004****
Cranial index	41	75.69±10.02	69	57.90±10.67	**0.000*** **
Facial index	41	156.67±27.05	69	126.69±26.80	**0.000*** **
Width of bulla tympanica 1 index	41	16.86±4.411	69	12.28±1.34	**0.000*** **
Width of bulla tympanica 2 index	41	13.44±4.02	69	8.93±1.10	**0.000*** **
Heigth of bulla tympanica index	41	19.17±4.76	69	20.92±2.09	0.114

p<0.05 * , p<0.01 , p<0.001*****

The correlation coefficients between cranial index values and angle values measured from the pars tympanica region are presented in Table 4. In particular, it was observed that there was a correlation between the angle of the auditory tube and the all skull indices. External acoustic meatus angle was found to have correlation only with bulla tympanica indices

Discussion

Before starting the study, five images were taken from the skull of an animal to the demonstrate reliability of the method used and the measurements taken, and all measurements were taken again from these images. It is seen that the highest coefficient of variation was 1.96% in the angle of Tuba auditiva. According to these data, since all coefficients were below 5% value, it was seen that the measurement method used in the study was reliable (Özdamar 2004).

When index values of the tympanic bulla measurements were examined, it was noted that the width and length of the bulla were larger compared to the skull size in young animals, but the height ratio did not change with age. In addition, it was determined that the angle of the auditory

Table 3: Angular measurements and calculated index values of the skulls of animals of different sexes

	FEMALE		MALE		
Angular values (o)	**N**	**MV±SD**	**N**	**MV±SD**	**p**
Angle of tuba auditiva	48	49.83±6.79	57	50.03±8.80	0.616
Angle of meatus acusticus externus	48	45.48±4.73	57	47.77±6.51	**0.040***
Index values (%)					
Skull index	48	57.22±10.94	59	56.77±4.63	0.608
Cranial index	48	66.57±15.02	59	62.92±12.37	0.201
Facial index	48	137.43±31.1	59	138.95±30.36	0.735
Width of bulla tympanica 1 index	48	14.21±2.51	59	13.87±4.41	0.066
Width of bulla tympanica 2 index	48	10.83±2.62	59	10.47±3.98	0.146
Heigth of bulla tympanica index	48	20.78±3.23	59	19.83±3.63	0.176

p<0.05 *

Table 4: Correlation coefficients between cranial index values and the angle values on the pars tympanica

	SI	CI	FI	BWI1	BWI2	BHI
TAA	**-0,273****	**-0,581****	**-0,524****	**-0,454****	**-0,528****	**0,265****
MEA	-0,120	0,127	0,061	**0,220***	**0,212***	-0,110

p<0.01**

tube with the transversal plane was approximately 18% higher in adults than in young animals. The angle that the porus acusticus externus makes with the transversal axis is approximately 5% greater in young animals than in adults. In this case, it is seen that the long axis of the tympanic bulla rotates more rostro-medially in the horizontal plane depending on age. While the suturae-shaped sections of the occipital bone, which largely surround the tympanic bone sections in the skull posteriorly and laterally, are mostly closed by the age of six months, the sphenoid bone and associated synchondrosis type junctions anteriorly close after one year of age (Evans, 1993; Thrall and Robertson, 2011; Schmidt et al., 2013). Since the facial bones continue to grow at the front during these periods, it can be said that the position of the tympanic bone may show age-related changes in this way.

Studies of sexual dimorphism in the closure of skull sutures have shown that differences in suture closure can be seen in both male and female (Sahni et al., 2005; Vijay et al., 2013; Alhadi et al., 2019). Since differences between males and females occur at different points in the life cycle, a gender-related difference in the position of tympanic region can also be expected due to differences in suture closure. However, according to the results of this study, it was determined that other angle and index values did not differ between female and male animals, except for a small difference in the external acoustic meatus angle in the dog.

It has been stated that the closure time of synchondrosis type unions, which has the most important effect on the longitudinal growth of the skull-shape, may vary according to the skull-shape type or race (Schmidt et al., 2013). The auditory tube angle measurement is approximately the angle of the tympanic bulla long axis with the transversal plane. It can be said that the long axis of tympanic bulla may be more medially oriented in dogs with longer head type, as this angle has negative correlations with skull indices. In addition, the medial position of the tympanic bulla increases as the bulla height increases.

The most important limitation of this study is the insufficient exact age information of the animals. For this reason, animals estimated under one year of age, which are considered to be young, could not be divided into subgroups. The neurocranium (cranium) region of the skull, in which it is located in the temporal bone, has largely completed its development and this region changes less. However, the splanchnocranium (facies) region adjacent to the temporal bone develops and changes much more rapidly until about one year of age (Evans, 1993; Thrall and Robertson, 2011; Schmidt et al., 2011). Therefore, if the younger group could be further divided into subgroups, age-related changes could be seen more prominently. In addition, due to the lack of pedigree records of all dogs used, breed-related evaluations could not be made. Instead, skull indices were used to evaluate head type-related changes.

In conclusion, it can be said that age and skull type is more effective than gender in the position of the tympanic region in dogs. The results of this research are supportive information that can be used in both clinical and zooarchaeological studies on the tympanic bulla region in dogs.

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Conflict of interest

The authors declare that they have no conflict of interest in this study.

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