Craniometric Investigation and Radiographic Anatomy of the Red Fox (*Vulpes vulpes*) Skull

Yeşim Aslan Kanmaz[1]*, Saime Betül Baygeldi[1], Sadık Yılmaz[1]

[1]Fırat University, Faculty of Veterinary Medicine, Department of Anatomy, ELAZIG, Turkey

*Corresponding: yesim.aslan@firat.edu.tr

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Abstract

Morphometric analyses used for skull measurements are an important tool for determining sexual dimorphism and evaluating taxonomy and morphological structure. In recent years, this has led to the emergence of radiographic imaging methods that are frequently used in addition to traditional measurement techniques and allow the skull to be evaluated with the help of imaging techniques. In this study, it was aimed to measure the various dimensions of the skulls observed on radiographs and measured morphometrically and to present numerical data using the measurements. Four adult male red fox skulls were used in the study. Digital callipers were used for craniometric measurements. Morphometric measurements were based on 18 measurement points. The mean and standard deviation of craniometric measurements were determined. Radiographic images were taken ventrodorsally and laterolaterally and the necessary anatomical parts were marked on the image. The highest value of total length (TL) was 139.22±0.55 mm and the smallest value of height of foramen magnum (HFM) was 13.19±0.02 mm. As a result of the analyses, it was determined that the skulls of red foxes have some similarities with other carnivores as well as some unique anatomical features. This study can be used in different disciplines such as anatomy, morphology and osteoarchaeology in the taxonomic determination of carnivore species and thus may contribute to further studies on the red fox. In addition to morphometric measurements, radiographic imaging of the red fox for the first time is very important in terms of establishing an important data bank for breed identification.

Keywords: *Craniometry, radiography, skull, Vulpes vulpes*

INTRODUCTION

The red fox (*Vulpes vulpes*) belongs to the order Carnivora. They have one of the most widespread geographical ranges among carnivores and are found in Europe, Asia, North Africa and North America (Wilson & Reeder, 2005). Carnivores are highly variable in size, diet, social behaviour and movements (Kruuk, 2002). This variability is also reflected in the size and shape of the skull (Tamlin et al., 2009). Therefore, the morphological structure of the skull is affected by factors such as individual characteristics, genetics, environmental effects, growth and sex (Tamlin et al., 2009).

Anatomical studies play an important role in increasing the biological knowledge of breeds, which can then be used in different ways in health and biological fields such as surgical applications and phylogenetic, taxonomic and evolutionary studies (Atasoy et al., 2014; Brombini et al., 2018; Brünner et al., 2002; Erdoğan et al., 2012; Erolin, 2019). The skull is the main component of the skeleton, showing taxonomic relationships and providing information on changes that cause selection in animals (Gündemir et al., 2020). Craniometry forms the basis of clinical and surgical studies (Chariker et al., 2012). Similarly, the different holes of the skull have clinical importance in regional anesthesia around the head (İlgün & Özkan, 2015; İlgün et al., 2021). Traditional craniometric analyses are an important study tool for evaluating the morphological structure of the skull (Karan et al., 2005; 2006; Karan & Yılmaz, 2015; 2016). However, the radiographic imaging method, which is frequently used in recent years and allows the skull to be evaluated with the help of imaging techniques, helps to determine morphological variations with morphometric analyzes (Tejavathi et al., 2017; Uzuner et al., 2016; Yilmaz et al., 2024).

In this study, it was aimed to measure the various dimensions of the skulls measured morphometrically and observed on radiographs and to present numerical data using the measurements. It is expected that it will allow comparison of skulls in terms of size and shape among carnivores and will provide a literary contribution to further studies to be carried out with this species in the future.

MATERIALS AND METHODS

In this study, 4 adult male red fox skulls, which were previously brought dead from nature by students (with the permission of the General Directorate of Nature Conservation and National Parks of the Ministry of Agriculture and Forestry with the number E-21264211-288.04-14713474) and whose skeletons were exhibited in our anatomy museum, were used. The dead animals were firstly subjected to maceration procedures by removing the skin and muscles, which is a routine dissection process, and made ready for craniometric measurements.

Digital callipers were used for craniometric measurements of the skull. The morphometric measurements were based on 18 measurement points (Von den Driesch, 1976). The measurement points are listed in Table 1 with their descriptions.

The radiography device (Varian medical systeme X-RAY PRODUCTS, RAD-14) at Fırat University Animal Hospital was used for radiographic images. Radiographic images of the skulls were taken as dorso-ventral, vento-dorsal and laterolateral. The images were transferred to the computer and the necessary anatomical parts were marked on the image.

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RESULTS

The skull of each fox was radiographically visualised. Then, the parameters defined in Table 1 were measured on the skull. The highest value of total length (TL) was 139.22±0.55 mm and the smallest value of height of foramen magnum (HFM) was 13.19±0.02 mm. The mean and standard deviation of the craniometric measurements of the red tics are shown in Table 2 and the points where the craniometric measurements were taken are shown in Figures 1 and 2. Radiographic images were taken ventrodorsal and laterolateral (figure 3).

DISCUSSION

In our study, the skulls of red foxes in the vicinity of Elazığ province were analysed by morphometric methods. In the literature review, it was determined that there were morphometric (Dobrowolska et al., 2017; Munkhzul et al., 2018; Onar et al., 2005) and geometric morphometric (Gürbüz et al., 2022; Kistner et al., 2021) studies on the skulls of foxes obtained from various regions at different times. However, no study was found in which the skulls of red foxes in Turkey were analysed by radiographic morphometric method. Therefore, considering that morphological structures are affected by environmental

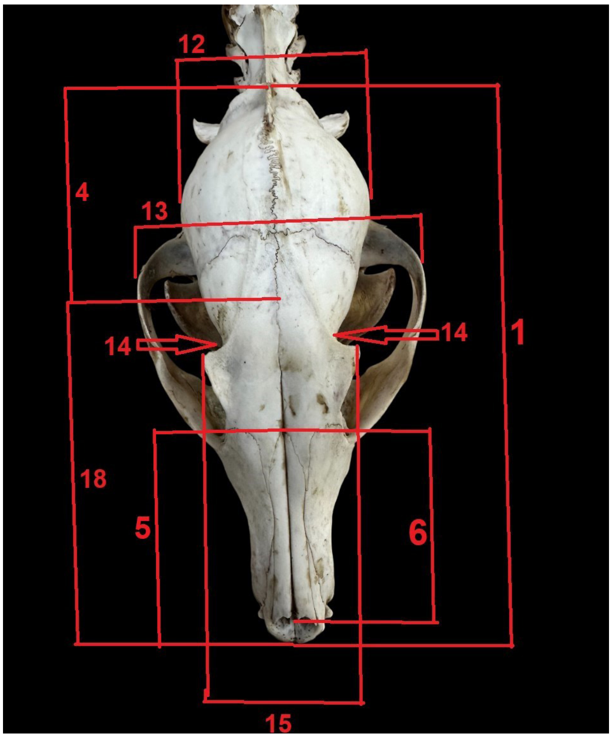

Figure 1. *Showing the craniometric measurement points of the dorso-ventral image of the red fox skull.*

Figure 2. *Showing the craniometric measurement points of the ventro-dorsal image of the red fox skull.*

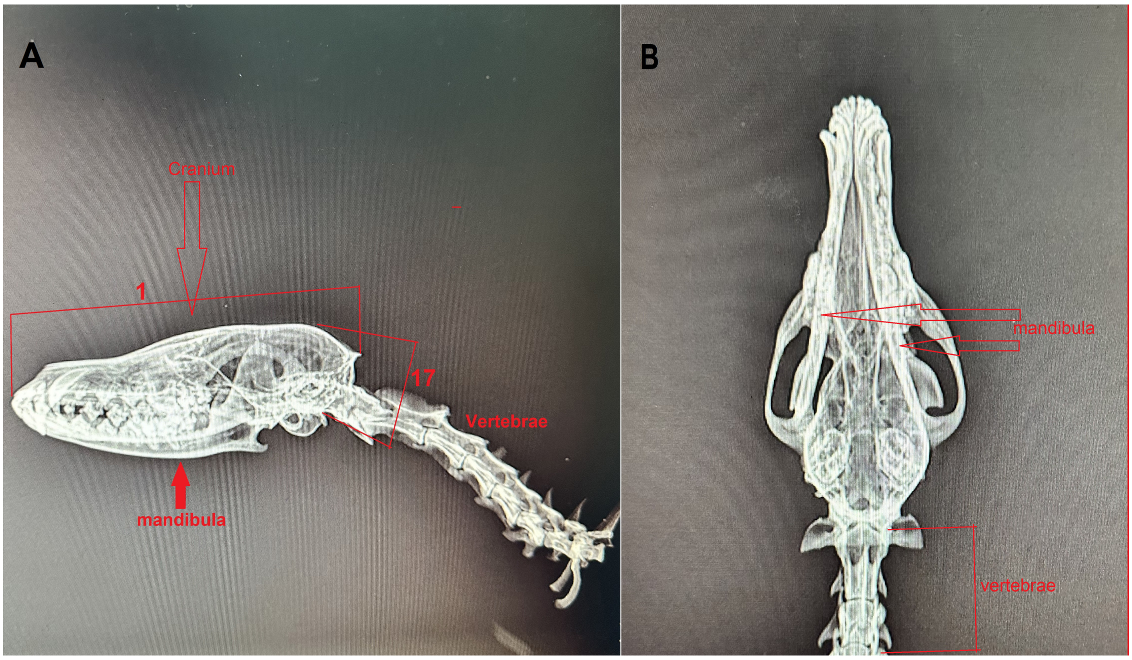

Figure 3. *Radiographic image of the red fox skull (A: latero-lateral direction B: ventro-lateral direction).*

Table 1: *Abbreviations and descriptions of skull craniometric measurement points (Von den Driesch, 1976).*

No	Abrevi-ation	Definition
1	TL	Total length
2	CBL	Condylobasal length
3	BL	Basal length
4	UNL	Upper Neurocranium length
5	VL	Viscerocranium length
6	GLN	Greatest length of the nasals
7	PL	Palatal length
8	GMB	Greatest mastoid breadth
9	GBOC	Greatest breadth of the occipital condyles
10	GBFM	Greatest breadth of the foramen magnum
11	HFM	Height of the foramen magnum
12	GNB	Greatest neurocranium breadth
13	ZB	Zygomatic breadth
14	LBS	Least breadth of skull
15	FB	Frontal breadth
16	GPB	Greatest Palatal breadth
17	SH	Skull height
18	FL	Facial Length

Table 2: *Skull craniometric measurements and standard deviation values.*

No	Abreviation	Average of measure-ments (mm) (4 male red foxes)	Standard deviation (±)
1	TL	139. 22	0.55
2	CBL	131.20	0.76
3	BL	125.98	0.84
4	UNL	61.14	0.75
5	VL	64.76	0.82
6	GLN	46.56	0.56
7	PL	67.74	0.63
8	GMB	48.76	0.63
9	GBOC	13.36	0.26
10	GBFM	15.00	0.39
11	HFM	13.19	0.02
12	GNB	41.77	0.50
13	ZB	67.49	1.07
14	LBS	25.85	0.80
15	FB	33.76	0.73
16	GPB	36.82	0.92
17	SH	36.46	1.00
18	FL	91.07	0.22

factors, the skulls of red foxes in Elazığ were examined in this study. However, this study has some limitations (sex difference, etc.) due to the biometric data and small number of materials.

It has been reported that most of the cranial morphometric measurements in mammalian species are used for sex determination (Travaini et al., 2000). However, in a morphometric study conducted by Pitakarnnop et al., (2017), it was determined that there was no statistically significant difference in cranial parameters measured between male and female on 38 domestic cat skulls to determine sexual dimorphism between the sexes. However, in some studies (Farhadinia et al., 2014; Shukla et al., 2003), it was reported that although the animals were adults, morphometric measurements of the skull could not be used in sexual dimorphism and varied according to age and body weight. In our study, since all of the animals collected from the nature were males, sex discrimination could not be analysed. However, in a study by Travaini et al., (2000), it was determined that male foxes had a larger skull structure than females. The TL, BL, PL values in our study were in parallel with the values of adult male foxes used in this study.

In a morphological study on 111 red fox skulls, Parsons et al., (2020) found that the skulls of foxes living in urban and rural areas were different in shape. In their study (Parsons et al., 2020), they stated that habitat and sex greatly affect the shape of the skull. In addition, Gürbüz et al. (2022), using different reference points and a limited sample, found no significant difference in the geometric analysis of the dorsal appearance between the sexes shown in the consensus graph. In our study, a limited number of red foxes from around the province of Elazığ were used and it was determined that the skull measurements of the adult foxes used were parallel in size.

Craniometric measurements are used to define breeds and to determine variations within breeds (Karimi et al., 2011; Saber et al., 2016; Yalçın & Kaya, 2010). In the literature (Khosravi et al., 2012), the condylobasal length of the grey wolf was reported as 215.76±12.22 mm and the basal length measurement as 206.79±11.13 mm. In a study on Aksaray Malaklı dog (Güzel et al., 2023), condylobasal length was 245.17±2.21 mm and basal length was 222.80±4.64 mm and it was found to be longer than grey wolf. In our study, the condylobasal length of the red fox skull was 131.20±0.76 mm and the basal length was 125.98±0.84 mm on average and it was found to be smaller than the canids depending on species and breed distinction.

İlgün and Özkan, (2015) reported GIHO length as 31.06±1.15 mm and GBFM length as 20.09±2.05 mm in Kangal dogs. In Aksaray Malaklı dogs (Güzel et al., 2023), both GIHO length 26.96±2.51 mm and GBFM length 18.71± 0.61 mm were found to be shorter than Kangal dogs. Kaloyianni, (2022) reported that the highest total length measurement point (TL) was 180 mm in border terrier dogs, 195 mm in boxer dogs, 256.5 mm in Doberman dogs, 202 mm in dogo argentine dogs and 243.5 mm in wolves. The total length of the Malaklı dog (Güzel et al., 2023) was found to be 277.11 mm. In our study, TL length was 139.22±0.55 and it was found to be shorter than the dog breeds. Christiansen, (2008) reported the skull length as 268.97+12.2mm in female lions, 317.67+19.0mm in males, 259.47+13.9mm in females and 291.97+21.4mm in male tigers. In our study, it was determined that the skull was quite small according to canine species.

Onar et al., (2002) found the skull length as 193.90 mm in a 120-day-old dog and measured the cheek width as 95.40 mm in a study on German shepherd dogs. In the Malaklı dog (Güzel et al., 2023), the skull length at the measurement points was determined to be 277.11 mm and the cheek width as 91.50 mm. In a study conducted by Urosevic et al., (2021) on Aksaray Malaklı dogs, the total length was reported as 200.64 ± 1.68 mm in males and 160.75 ± 0.86 mm in females. Atasoy et al., (2014) reported that the head length of Aksaray Malaklı dogs was 300.92±0.24 mm in females and 320.98±0.18 mm in males, and the face length was 110.80±0.15 mm in females and 120.55±0.09 mm in males. Güzel et al., (2023) calculated the total length as 260.41±1.75 mm and 270.71±8.49 mm in females and males, respectively, and the face length as 140.18±087 mm and 140.46±1.21 mm. According to the measurement results in our study, the total length was measured as 139.22±0.55 mm in male red foxes.

CONCLUSION

In conclusion, in this study, the cranial morphometric features and radiographic images of the red fox were examined. This study can be used in different disciplines such as anatomy, morphology and osteoarchaeology in the taxonomic determination of carnivore species and thus contribute to further studies on the red fox. In addition to the morphometric measurements of the red fox, the examination of radiographic imaging for the first time will contribute to the establishment of an important data bank for the breed definition of this study.

Conflict of Interest

There is no conflict of interest in this study.

Financial Disclosure

There is no financial support for this study.

Author contributions

Motivation / Concept: YAK, SBB; Design: YAK; Control/Supervision: SY; Data Collection and / or Processing: YAK; Analysis and /or Interpretation: YAK, SBB, SY.

Availability of data and materials

Data and materials may be used subject to the author's permission.

Ethics Committee document

This study was approved by the Fırat University-HADYEK local ethics committee on 15.10.2024 with number 17.10.2024-28157. Permission E-21264211-288.04-14713474 was obtained from the General Directorate of Nature Conservation and National Parks of the Ministry of Agriculture and Forestry.

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