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ANATOMIC AND CRANIOMETRIC FACTORS IN DIFFERENTIATING ROE DEER (*CAPREOLUS CAPREOLUS*) FROM SHEEP (*OVIS ARIES*) AND GOAT (*CAPRA HIRCUS*) SKULLS

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Abstract – This study was carried out to investigate the bony structures relevant to skull of roe deer, sheep and goat. The skull of five sheep weighing 45-50 kg, three goat weighing 50-60 kg and five roe deer weighing 20-25 kg were used in this study. Macerations of the cranium were performed by the boiling method. The skull of the roe deer was notably similar to that of sheep with the presence of external lacrimal fossa, and to the goat with due to the presence of two points (lateral and medial) on the septal process and a significant fissure formed between the nasal, lacrimal, frontal and maxillary bones. In addition to these similarities, the formations which were specific to the roe deer were structures such as the number and position of the lacrimal foramen and presence of an uncertain muscular tubercle in the basilar portion of the occipital bone. In addition, the craniometric parameters specific to the roe deer's skull were determined as the zygomatic, interorbital, neurocranium and nasal lengths.

Key words: Craniometric parameters, determinative anatomic factors, roe deer, skull

INTRODUCTION

The cranial bones consist of the neurocranium surrounding organs such as the brain and ear, and the viscerocranium including structures such as the tongue, mouth and nose (Nickel et al., 1986). Organs in viscerocranium are the start-point of the respiratory and digestive systems; therefore these parts form an entrance gate to external pathogens and increase the importance of the region (König and Liebich, 2007). The shape of the skull skeleton varies between species due to lifestyle (Nickel et al., 1986). Therefore, the anatomy of the skull should be known in detail in clinical and surgical approaches. The holes and bone processes on the skull are quite important in regional anesthesia of the head. Until now, the skull anatomy has been studied in many mammalian species. Skull morphology is significantly different among species, so there have been numerous comparative morphological studies of the skull anatomy in many of the mammalian species (Yalçin and Arslan, 2009; Atalar and Temizer, 2009; Karan et al., 2005) In particular, in small ruminants the morphological structures and geometrical measurements of the skull bones have been examined to detect the distinguishing features of these species. The morphological structures and geometrical measurements of the skull bones have been used for species determination in ruminants in particular (Sarma, 2006; Yalçin and Kaya, 2009; Yalçin and Lök, 2009; Karimi et al., 2011).

In the literature, studies related to the general character and ecology of roe deer (Antoine et al., 1996) and variations of the skull bones of the roe deer living in Western Siberia (Sheremetyeva and Sheremetyev, 2008) and Central Europe (Aragon et al., 1998) are found. But there is no study where the specific bony elements of the roe deer skull have been determined and compared with the other small ruminants. Therefore, the present study is the first study of the difference in craniometric factors between roe deer, sheep and goat. The results obtained will help to fill the current literature deficiency in species differentiation for anatomists and archaeologists and contribute to surgeons working in this field.

MATERIALS AND METHODS

In this study, the skulls of five adult roe deer (*Capreolus capreolus*), three goats (*Capra hircus*) and five sheep (*Ovis aries*) were examined. Roe deer belong to the Capreolinae subfamily of the Cervidae family that belong to the Ruminantia subgroup were admitted to the clinics of our faculty having died from firearm injuries or traffic accidents. Their weight varied between 20 and 25 kg. The heads of three goats, with an average weight of 50-60 kg, belonging to Caprinae subfamily of Bovidae family of Ruminantia subgroup, and 5 sheep (Ovis aries) with an average weight of 45-50 kg belonging to Ovinae subfamily of the same family, were obtained from a slaughterhouse.

The heads were boiled to examine the specific bony elements. All bones from the dorsal, lateral, ventral and cranial cavity belonging to the skulls of the three species were macroanatomically examined. In addition, craniometric measurements were performed based on the parameters used by Sheremetyeva and Sheremetyev (2008) (Fig. 1). These measurements were analyzed via one-way ANOVA. Additionally, linear dendrogram analyses were used to reveal morphometric differences visually (Table 1-2). The parameters that were taken from the species compared, and specific for roe deer, are presented in Fig. 2. Existing anatomical similarities and differences between the skulls of the species were detected and evaluated. Photographs were taken by an Olympus C-5060 digital camera. The craniometric measurements were taken using a Mitutoyo Digital Caliper. Nomina Anatomica Veterinaria (2005) was utilized for denominating anatomical terms in the study.

RESULTS

Although the skulls of species (roe deer, sheep and goat) belonging to different families of the Ruminantia subgroup used in the study seemed similar at first glance, partial differences were determined when they were examined macroanatomically. When the results were evaluated by linear dendrogram analysis of the craniometric measurements, the most characteristic differences for roe deer skull were detected in the zygomatic, interorbital, neurocranium and nasal lengths; and these differences are presented in Fig. 2. In the macroscopic inspection, the dorsal, lateral, ventral and cranial cavity of the skulls were examined as to detect specific bony structures.

Determinative osseous factors in dorsal and lateral inspection

The lacrimal foramen had one hole in the orbital surface of the lacrimal bone in the sheep (Fig. 3, a) and goat (Fig. 4, a). This was observed as two holes, dorsal and ventral, in the facial surface of the lacrimal bone in the roe deer (Fig. 5, a). The fossa of the lacrimal sac (fossa sacci lacrimalis) in the orbital surface of the lacrimal bone in the roe deer (Fig. 5, b) and sheep (Fig. 4, b) was not present in the goat. While the lacrimal fossa located on the facial surface of the lacrimal bone was present in the sheep (Fig. 3, b) and roe deer (Fig. 5, c), this structure was not detected in the skull of the goat. The rostrocaudal length of the external lacrimal fossa was 11.95±0.06 mm in roe deer, 20.20±0.54 mm in sheep ($p<0.01$) and the dorsoventral length was 9.84±0.3 mm in roe-deer and 15.41±1.3 mm in sheep.

A fissure that was surrounded by the maxilla, lacrimal, frontal, nasal bones and covered by cartilage was detected in the roe deer (Fig. 5, d) and goat (Fig. 4, c). However, such a structure was not found in the sheep. The rostrocaudal length of this fissure was 16.71±0.37 mm in the roe deer, and 21.19±1.91 mm in the goat; the dorsoventral length of this fissure was 9.67±0.41 mm in the roe deer and 7.61±0.41 mm in the goat.

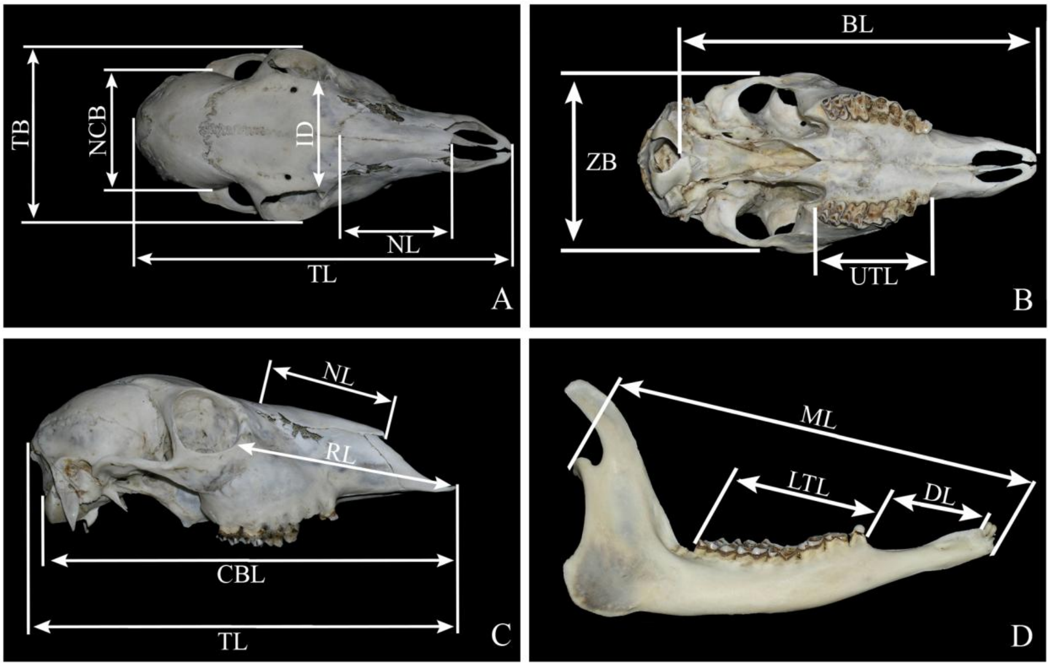

Fig.1. The parameters used in craniometric measurements (Sheremetyeva and Sheremetyev, 2008).
TL: total length, CBL: condylobasal length, BL: basal length, TB: total breadth, ZB: zigomatic breadth, ID: interorbital distance, RL: rostrum length, NL: nasal length, UTL: upper tooth row length, NCB: neurocranium breadth, ML: mandible length, LTL: lower tooth row length, DL: diastema length.

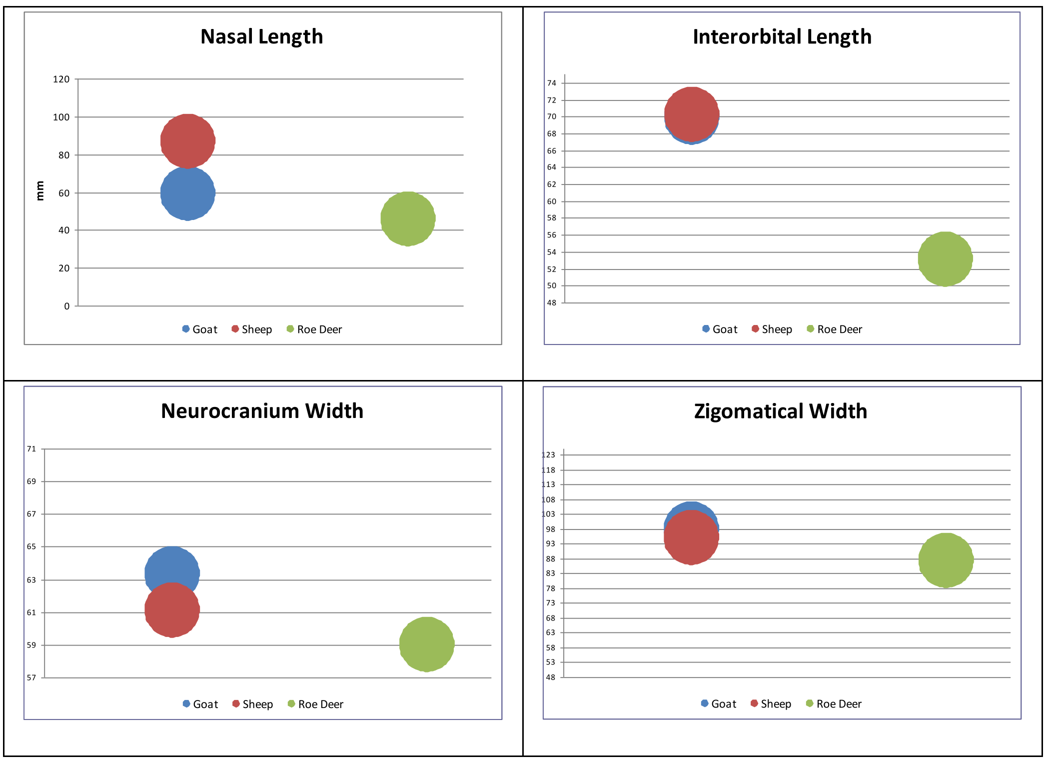

Fig. 2. Parameters taken from species compared and specific for roe-deer.

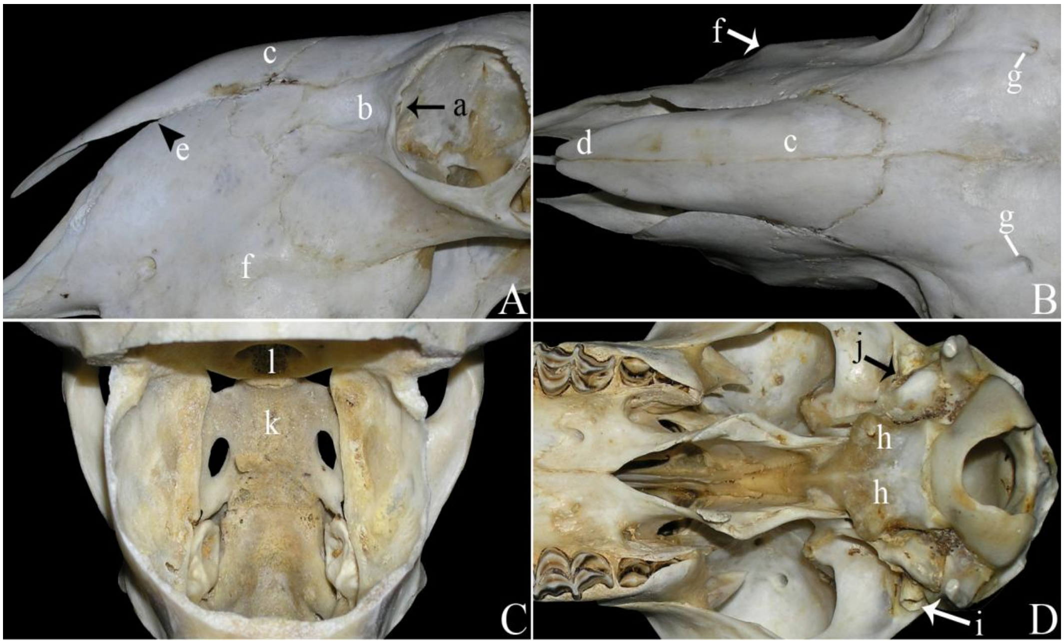

Fig. 3. Lateral view (A), Dorsal view (B), Cavum cranii (C), Ventral view (D) of sheep cranium
a: foramen lacrimale, b: fossa lacrimalis externa, c: fascies externa of os nasale, d: proc. septalis of os nasale, e: the incisur composed of nasal process of the incisive, the nasal bone and maxilla f: tuber faciale, g: foramen supraorbitale, h: tuberculum musculare, i: porus acusticus externus, j: proc. styloideus, k: fossa hypophysialis, l: sulcus chiasmatis.

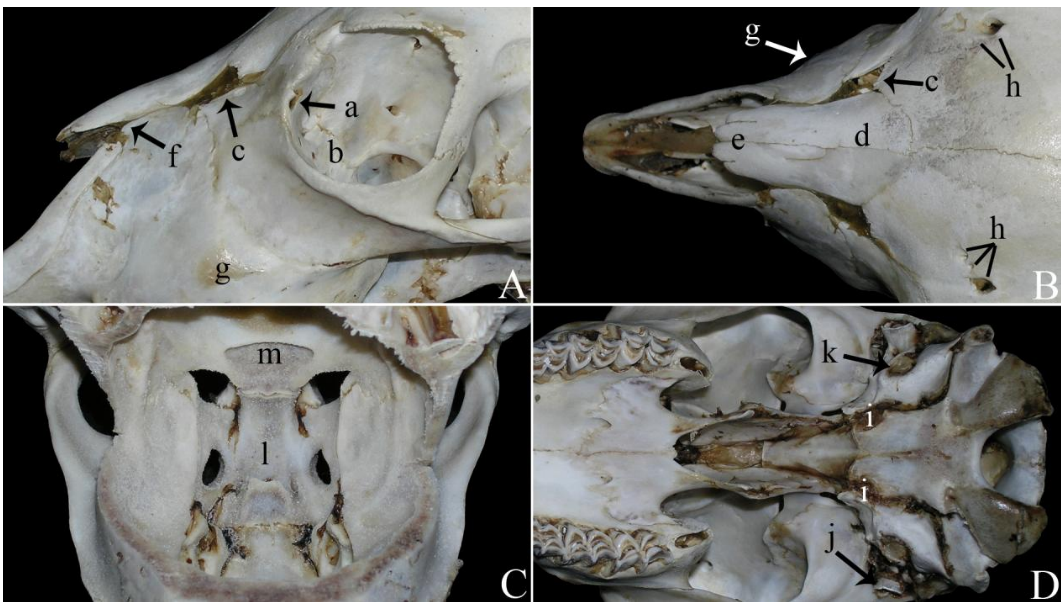

Fig. 4. Lateral view(A), Dorsal view (B), Cavum cranii (C), Ventral view (D) of goat cranium
a: foramen lacrimale, b: fossa sacci lacrimalis, c: A fissure which was surrounded by the maxilla, lacrimal, frontal, nasal bones, d: fascies externa of os nasale, e: proc. septalis of os nasale, f: the incisur composed of nasal process of the incisive, the nasal bone and maxilla, g: tuber faciale, h: foramen supraorbitale, i: tuberculum musculare, j: porus acusticus externus, k: proc. styloideus, l: fossa hypophysialis, m: sulcus chiasmatis.

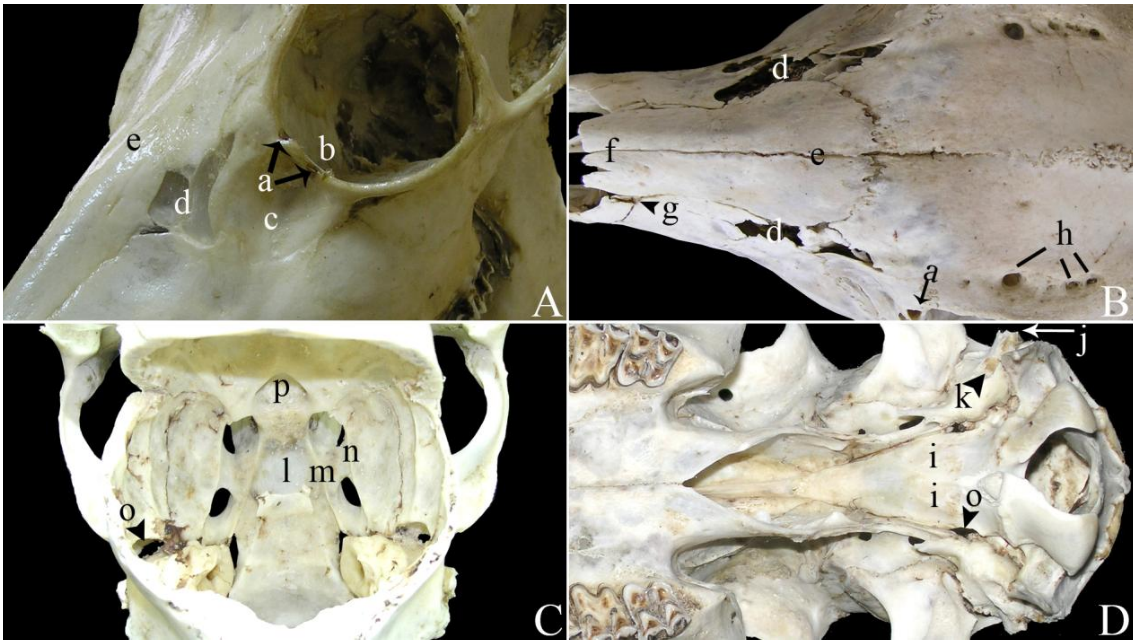

Fig. 5. Lateral view(A), Dorsal view (B), Cavum cranii (C), Ventral view (D) of Roe deer cranium
a: foramen lacrimale, b: fossa sacci lacrimalis, c: fossa lacrimalis externa, d: A fissure which was surrounded by the maxilla, lacrimal, frontal, nasal bones, e: fascies externa of os nasale, f: proc. septalis of os nasale, g: the incisur composed of nasal process of the incisive and the nasal bone, h: foramen supraorbitale, i: tuberculum musculare, j: porus acusticus externus, k: proc. styloideus, l: fossa hypophysialis, m: a distinctive crest located between carotid groove and nn. ophtalmici et maxillaries groove, n: lateral edge of sulcus nn. ophtalmici et maxillaries o: retroarticular foramen, p: sulcus chiasmatis.

It was observed that the caudal side of the external surface of the nasal bone was convex in the sheep (Fig. 3, c), flat in the roe deer (Fig. 5, e) and concave in the goat (Fig. 4, d). It was determined that the septal process of both the nasal bones had a single edge in the sheep (Fig. 3, d) whereas it had two edges as the lateral and medial in the roe deer (Fig. 5, f) and goat (Fig. 4, e). The medial edge was longer in the goat and the lateral edge was longer in the roe deer.

It was detected that the nasal process of the incisive bone joined with the nasal bone in the roe deer (Fig. 5, g) and with the maxilla in the sheep (Fig. 3, e) and goat (Fig. 4, f). The facial tuber in the corpus of the maxilla was very significant in the sheep (Fig. 3, f) and goat (Fig. 4, g), but not seen in the roe deer.

The dorsoventral length of the maxillary foramen located in the pterygopalatine fossa was 12.74±0.62 mm in the sheep, 5.38±1.82 mm in the goat and 3.74±0.07 mm in the roe deer; the rostrocaudal length was 8.13±0.32 mm in the sheep, 2.21±0.58 mm in the goat and 2.29±0.09 mm in the roe deer ($p<0.01$).

The supraorbital foramen in the medial side of the supraorbital border of the frontal bone was determined as a hole in the sheep (Fig. 3, g), generally one and sometimes two or three holes in the goat (Fig. 4, h) and three or four holes in the roe deer (Fig. 5, h). The supraorbital foramen opened into the orbita with a short channel in the sheep. In the goats, the supraorbital foramen localization on the caudal of the holes was biggest and opened into the orbita with a long L-shaped channel. Furthermore, the supraorbital foramen situated in the rostra of the holes, in the roe deer, was biggest hole and opened into the orbita directly with the other holes. The supraorbital groove was extended in a rostral direction only in the sheep and goat and in a rostral and caudal direction in the roe deer.

Table 1. Linear dendrogram analyses of morphometric values of roe deer, sheep and goat craniums.

Traits		N	Means±Stderr	Min	Max	P Value
TB	roe deer	5	85.07±0.39 B	84.01	86.49	0.0141
	sheep	5	105.37±4.29A	90.69	113.16	
	goat	3	97.2±8.1 AB	87.36	113.43	
NCB	roe deer	5	60.11±0.41C	59.01	61.04	0.0001
	sheep	5	62.57±0.41B	61.12	63.54	
	goat	3	67.19±1.42A	65.3	69.98	
TL	roe deer	5	196.19±2.65A	188.15	204.76	0.1486
	sheep	5	215.89±6.06A	203.69	238.42	
	goat	3	216.67±17.21A	195.44	250.76	
NL	roe deer	5	53.8±2.38C	45.81	58.83	<.0001
	sheep	4	89.88±1.1A	86.7	91.7	
	goat	3	64.14±5.91B	56.12	75.69	
ID	roe deer	5	57.66±1.99B	53.09	64.77	0.0008
	sheep	5	71.11±0.39A	70.26	72.25	
	goat	3	77.98±5.72A	69.97	89.08	
ZB	roe deer	5	89.74±0.67B	87.31	91.41	0.0128
	sheep	5	100.97±2.40A	94.91	107.51	
	goat	3	106.25±7.05A	97.94	120.29	
BL	roe deer	5	171.53±2.47A	166.24	179.57	0.2683
	sheep	5	189.78±5.69A	172.34	207.58	
	goat	3	186.2±19.28A	163.78	224.58	
UTL	roe deer	3	56.94±1.8A	55.11	60.56	0.3693
	sheep	5	63.14±3.59A	49.37	69.72	
	goat	3	55.22±6.03A	47.98	67.2	
RL	roe deer	5	101.82±3.91B	92.23	113.58	0.0385
	sheep	5	126.38±5.48A	109.54	140.19	
	goat	3	112.39±11.11AB	98.72	134.41	
CBL	roe deer	5	187.38±3.86B	180.54	201.79	0.0071
	sheep	5	211.28±4.74A	194.35	221.78	
	goat	3	192.61±5.09B	184.85	202.21	

Table 2. Linear dendogram analyses of morphometric values of roe deer, sheep and goat mandibulae.

Traits		N	Means±Stderr	Min	Max	P Value
ML	roe deer	8	152.46±0.79B	150.23	157.54	0.0034
	sheep	10	176.41±3.81A	163.51	200.73	
	goat	6	165.95±8.57BA	150.09	193.76	
LTL	roe deer	8	64.42±1.14A	61.52	70.78	0.1076
	sheep	10	62.61±2.01BA	55.76	76.25	
	goat	6	55.25±5.43B	46.16	72.59	
DL	roe deer	8	39.26±0.82A	35.37	42.63	0.6720
	sheep	10	37.41±1.27A	29.66	43.17	
	goat	6	38.3±2.64A	32.12	49.28	

*A,B,C, no significant differences between group means bearing the same letter.

While the parietal planum of the parietal bone was rectangular in the sheep and goat, it was triangular in the roe deer.

Determinative osseous factors in the ventral and cranial cavity inspection

The muscular tubercle found in the basilar portion of the occipital bone was quite significant in the sheep (Fig. 3, h). This structure was slightly significant in the goat (Fig. 4, I) whereas it was unclear in the roe deer (Fig. 5, i).

The direction of the external acoustic pore situated in the lateral part of the external acoustic meatus in the tympanic portion of the temporal bone was caudodorsal in the roe deer (Fig. 5, j) and lateral in the goat (Fig. 4, j) and sheep (Fig. 3, i). It was observed that the styloid process which appeared in the petrosal portion of the temporal bone was at a middle level of the lateral side of the tympanic bulla in the sheep (Fig. 3, j) and goat (Fig. 4, k) and in between the ventral side of the jugular process and the caudal side of the tympanic bulla in the roe deer (Fig. 5, k).

It was observed that the hypophysial fossa in the basisphenoid bone in the cranial cavity was a distinctive pit (fossa) in the roe deer (Fig. 5, 1) when compared with the sheep (Fig. 3, k) and goat (Fig. 4, 1). There were two grooves in the lateral side of the hypophysial fossa in the investigated species. These grooves, called the carotid groove and nn. ophtalmici et maxillaries groove which is located near the sella turcica, were separated by a distinctive crest (Fig. 5, m) in the roe deer. Also, in the roe deer, the lateral edge of the nn. ophtalmici et maxillaries groove (Fig. 5, n) ended on the cranial edge of the petrous portion of the temporal bone. The same edge was extended to the internal surface of the occipital squama in the sheep and goat. Therefore, while the rostral surface of the petrous portion of the temporal bone was not seen in the sheep and goat, it was rather significant in the roe deer. Besides, in the roe deer, the retroarticular foramen (Fig 5, o) was connected with the cranial cavity from the dorsal of the lateral edge of the above-mentioned groove. It was observed that this foramen was connected with the temporal fossa in the sheep and goat.

The shape of the chiasmatic groove situated on the internal surface of the presphenoidal portion of the sphenoid bone was oval in the sheep (Fig. 3, 1) and goat (Fig. 4, m) and triangular in the roe deer (Fig. 5, p).

DISCUSSION

Craniometric measurements are used for the identification of species and detection of intra-species variations (Yalçin and Kaya, 2009; Karimi et al., 2011; Sheremetyeva and Sheremetyev, 2008). In this study, the craniometric parameters specific to the roe deer's skull were determined as the zygomatic, interorbital, neurocranium and nasal lengths. These parameters were similar to the measurements of the skull of the roe deer living in northern and southern Primorye in Russia and has been reported in the literature (Sheremetyeva and Sheremetyev, 2008).

The numbers of supraorbital foramen and position of the supraorbital groove have been reported in the literature (Sarma 2006; Nickel et al., 1986). It was observed that the number of the supraorbital foramen was 1 in the sheep and 1 or sometimes 2-3 in the goat in this study. While this situation complies with the literature (Sarma 2006; Nickel et al., 1986), the presence of 3 or 4 supraorbital foramen in the roe deer was a significant difference. The large number of these holes indicates that the number of nerves passing from these apertures may be large. Therefore, strict attention should be given to regional nerve-extension anesthesia in the roe deer. The supraorbital groove with extension only in the rostral direction of the supraorbital foramen in the sheep and goat was similar to the literature (Nickel et al., 1986). However, in the roe deer, this groove was extended in both rostral and caudal direction of the supraorbital foramen.

It has been reported that the anatomic structures called canine fossa in the pig (Nickel et al., 1986) and external lacrimal fossa in the sheep (Nickel et al., 1986, Dursun, 2008; Yalçin and Lök, 2009) are present on the facial surface of the lacrimal bone. The external lacrimal fossa, an important differentiation factor between sheep and goat skulls, was also seen in the roe deer.

Nickel et al. (1986) have reported that the septal process presented on each half of the nasal bone ends with only a medial point in pig, sheep and horse, the lateral point in dog and cat; and with two points situated on the lateral and medial in the cow and goat. In the present study, it was determined that the septal process had single point ending on the medial side in the sheep and two points as lateral and medial in the roe deer and goat. There were differences between the length of the lateral and medial points in the roe deer and goat. While the medial point was longer than the lateral point in the goat, the lateral point was longer than the medial point in the roe deer. The length of the medial point of the septal process in the goat complied with that reported by Shawull et al. (2011).

In the present study, a significant fissure called as the nasolacrimal fissure by Popesko and the frontomaxillolacrimal fissure by George (2001), was observed between the nasal, lacrimal, maxilla and frontal bones in the roe deer and goat. Although George (2001) stated that this fissure is covered only by skin, it was determined that the same fissure was covered by cartilage in this study. Nickel et al. (1986) have reported that there is a notch (called the incisura nasoincisiva) between the incisive and nasal bones in the pig, cow and horse and between the nasal, incisive and maxillary bones in small ruminants. While in sheep and goat the formation of this notch was similar to that determined in small ruminants, in the roe deer, it was similar to the cow, horse and pig. The facial tubercle that is used and defined as a perceivable bone structure in regional anesthesia, was very significant in the sheep and goat complying with the literature (Yalçin and Lök, 2009); but in the roe deer, no such tubercle was seen.

In conclusion, the skull of the roe deer was similar to that of sheep due to the presence of the external lacrimal fossa, and to the goat by having two points (lateral and medial) on the septal process and a significant fissure formed between the nasal, lacrimal, frontal and maxillary bones. In addition to these similarities, the formations that were specific to the roe deer were present**.** These structures were detected as the number and position of the lacrimal foramen, the presence of an uncertain muscular tubercle in the basilar portion of the occipital bone, the caudodorsal direction of the external acoustic pore, position in between the ventral side of the jugular process and the caudal side of the tympanic bulla of the styloid process, visibility of the rostral surface of the petrous portion of the temporal bone and connection with the cranial cavity of the retroarticular foramen.

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