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Anatomical structure of the orbits of the European beaver (*Castor fiber*)

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SUMMARY

Understanding the specifics of the orbit of each species is a fundamental and crucial step in the development of veterinary ophthalmology. This article describes the bone structure, foramina piercing the bones, and shape of the orbit in the European beaver (*Castor fiber*). Additionally, a morphometric analysis of the orbit was conducted, measuring its height, width, and depth, and the orbital index was calculated. A total of 27 skulls of this species were used for the study. The average length and depth of the orbit were shown to be greater in females, while the average width was comparable in both sexes. Males, however, had a higher average orbital index. These differences, assessed with a t-test, were shown to be statistically significant. These results are the first step towards developing reference values for the European beaver for the dimensions determined in this study.

KEY WORDS: European beaver, orbit, orbit morphometry, orbital index

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INTRODUCTION

The skull is an attribute of Craniata or Craniota, which include vertebrates and hagfish, animals that have developed many advanced features. The skull is a highly specialized part of the skeleton, differing from other parts in that it is the seat of the brain, the initial segments of the digestive apparatus with taste receptors, and the respiratory apparatus with olfactory receptors, as well as sensory organs: sight, hearing, and balance. Accordingly, the skull is logically divided into the bones of the neurocranium (cranium) and the bones of the viscerocranium (facies) (NAV 2017). A characteristic structure unique to the skull is the sinuses – hollow spaces between bone plates lined with mucous membranes and filled with air (Lutnicki 1986). An essential structure of the skull is the orbit, which provides solid protection for the eyeball (the organ of vision). The shape of the orbit resembles a cone with an open base and multiple openings in its walls. These openings provide connectivity between the eyeball and the cranial cavity (cavum cranii) via blood vessels and nerves (Turvey and Golden 2012).

The more complex anatomical structure of the skull compared to other skeletal elements reflects its numerous protective functions. Hence, the morphological features of the skull are also very useful for taxonomic purposes. For many animal species, there is as yet no detailed description of structure of the orbit, including the topography of the bones, together with a morphometric analysis. Authors of publications on the subject focus on humans (Sękara et al. 2013) and animals kept by humans: dogs (Klaumann et al. 2018), horses (Coroleucă et al. 2020), and pigs (Kyllar et al. 2016).

The lack of such studies in wild animals inspired this research on the European beaver (*Castor fiber*). This species and the Canadian beaver (*Castor canadensis*) are the only representatives of the beaver family (Castoridae). The European beaver is considered the largest rodent inhabiting Eurasia: it can reach a length of up to 110 cm and a body weight up to 30 kg. Beginning in the early 20th century, the destructive activities of humans caused a continuous decline in the population of this species, to the extent that in the post-war years, only about 130 individuals could be found in Poland. Remedial actions, such as the establishment of a beaver farm at the Experimental Station of the Polish Academy of Sciences in Popielno and research conducted at the former Agricultural University in Poznań to restore beavers to their natural habitats, were highly successful. These scientific achievements and the legal status of the European beaver have significantly contributed to the increase in its population (Marciniszyn-Jedeszko et al. 2016). The species' lack of sexual dimorphism expressed by differences in body size and coat colour, apart from the obvious differences in the structure of the sexual organs, prompts the search for other anatomical features that allow for sex determination in this species.

The aim of this study is a morphological analysis of the orbits of the European beaver, including their length, width, and depth. The measurement results were analysed in an attempt to provide answers regarding the symmetry of the orbits and the issue of sexual dimorphism.

MATERIALS AND METHODS

The study material consisted of 27 skulls of adult European beavers (14 females and 13 males) obtained in Greater Poland. The beaver skulls were prepared using the enzymatic maceration method in an aqueous solution of Persil powder for 30 days at a temperature of 40°C. Then the specimens were disinfected and bleached in a 4% hydrogen peroxide solution and dried. Macroscopic examination was conducted to identify the bones constituting the orbit, its shape, and the foramina perforating its walls. The height, width, and depth of each orbit were measured with a calliper to within 0.01 mm. The results were summarized in a table in Excel, which was used to calculate the average of each of these dimensions and the orbital index (orbital width/orbital height x 100%) for individual specimens. Additionally, the average and standard deviation for each of these dimensions and of the orbital index were calculated for males and females separately. A t-test was also performed to calculate the p-value for the orbital index of males and females. To demonstrate the presence or absence of sexual dimorphism in beavers, the t-test was performed for the male and female orbital index. As only the orbital index was analysed with the t-test, the effect of the age of the animals on the orbital metric parameters was not taken into account. Similarly, the significance of differences in the asymmetry of orbital dimensions (right and left sides in males and females) was tested. The nomenclature used was according to the *Nomina Anatomica Veterinaria* (2017).

RESULTS AND DISCUSSION

The available literature provides information on the taxonomy, population numbers, habitats, and general anatomical structure of European beavers. However, there is a lack of detailed studies of specific regions or structures of the body, which would allow for a better understanding of this species and comparison with other animals.

The margin of the orbit of the European beaver has an open ring structure; its caudal edges do not connect, forming a gap slightly shorter than the width of the entire orbit. The lateral wall of the orbit is made up of the maxillary and zygomatic bones (Fig. 1), while the medial wall consists of the sphenoid, frontal, and maxillary bones. In beavers, unlike other animals, the orbit has no distinct upper and lower vaults, but rather an anterior and posterior wall (rostral and caudal). This is due to the characteristic, very flat shape of the skull, which is an adaptation to the semi-aquatic lifestyle of these mammals. The rostral wall of the beaver's orbit is formed by the lacrimal and maxillary bones, while the caudal wall is formed by the sphenoid, palatine, and – to a small extent – the temporal bone. The temporal bone is also involved in the formation of the orbit in horses, but is absent in cattle and pigs. The beaver and horse orbits differ in the form of the ring that makes up their margins. In horses, the orbital margin forms a closed ring, whereas in beavers, as in pigs and carnivores, the ring is open.

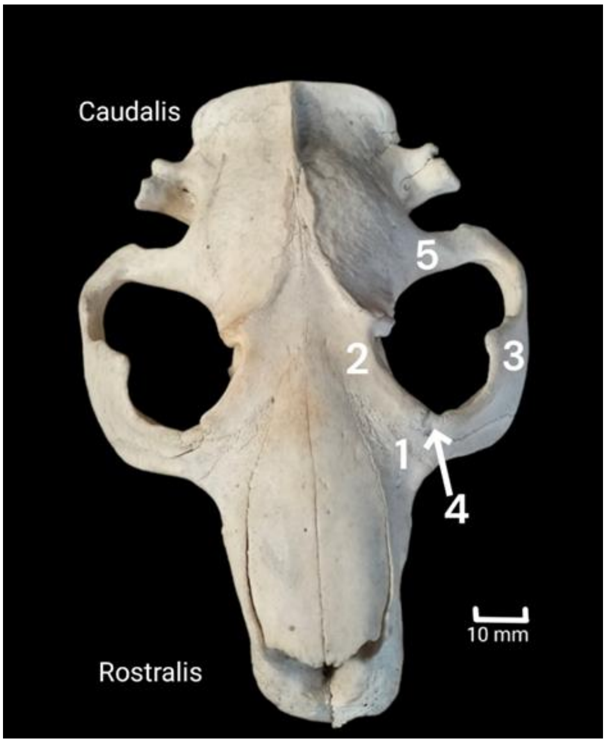

Figure 1. Skull of the European beaver, dorsal view. 1. Maxilla 2. Frontal bone 3. Zygomatic bone 4. Lacrimal bone 5. Temporal bone

In the medial corner of the beaver's orbit, as in pigs (Krysiak et al. 2012), there is no lacrimal sac fossa, but only a lacrimal foramen, which drains excess tears through the nasolacrimal duct into the nasal cavity. In the rostral-medial part of the beaver's orbit are the maxillary foramen, the sphenopalatine foramen, and the caudal palatine foramen (Fig. 2). These lead to the infraorbital canal, the nasal cavity, and the greater palatine canal, respectively. These structures are located in a relatively shallow pterygopalatine fossa, as in carnivores. The caudal-medial wall of the orbit has openings that provide connectivity with the cranial cavity. From top to bottom, these are the ethmoidal foramen, optic canal, orbitorotundum foramen, rostral alar foramen, and caudal alar foramen. Additionally, the alar canal is located between the orbitorotundum foramen and the caudal alar foramen.

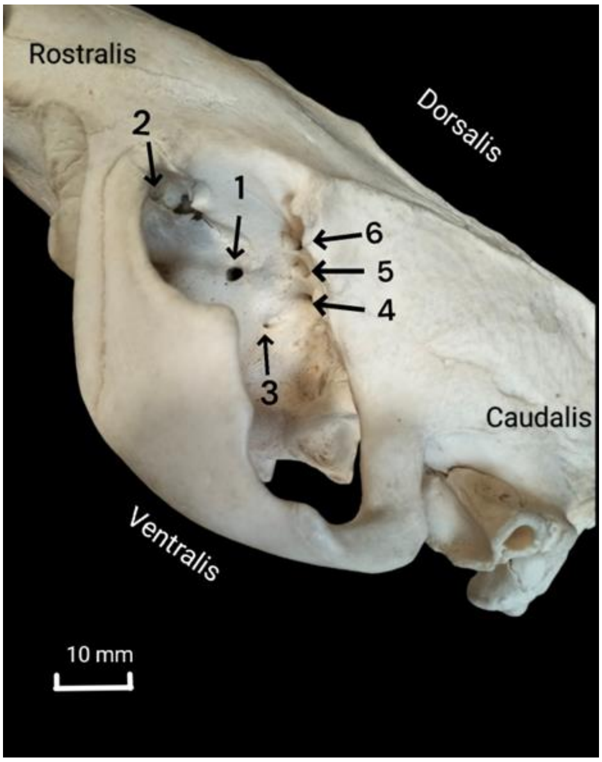

Figure 2. Left orbit with zygomatic arch in the European beaver. 1. Infraorbital foramen 2. Lacrimal foramen 3. Palatine foramen 4. Orbital foramen 5. Optic canal 6. Ethmoid foramen

Publications on the orbit have described its bone structure, general shape, and perforating foramina (Krysiak et al., 2012). In veterinary practice, information on the morphometry of the orbit – its dimensions and proportions – are also essential to performing procedures or surgeries in the orbital region. Although wild animals are less frequently patients in veterinary clinics, our research included aspects of the beaver's orbital morphometry.

The results of the morphometric analysis did not show significant differences in the size of the orbits on the right and left sides of individual specimens – the p-value for these values was over 0.9, indicating that the differences are statistically insignificant. The longest orbit measured 30.37 mm (male, right side), and the shortest was 19.68 mm (male, left side). The widest orbit belonged to a female and measured 24.28 mm, while the narrowest was 17.85 mm in a male. The deepest orbit was 38.41 mm (male), and the shallowest was 22.51 mm (male).

Table 1.
Mean dimensions of the orbit and orbital index in male and female European beaver

	Male	Female
Length	24,71±3,865	26,25 ±1,908
Width	21,28 ±2,275	21,39±1,262
Depth	30,88±5,540	32,00 ±4,297
Orbital index	86,82±5,081	81,66±4,0161

The average width was comparable in both sexes, while the average length and depth were greater in females (Table 1). According to Choudhary et al. (2018), the average length, width, and depth of the orbit in goats (*Capra hircus*) were 36.2±0.1 mm, 32.9±0.1 mm, and 43.2±0.1 mm in the right orbit, and 37.1±0.2 mm, 34.0±0.1 mm, and 44.3±0.2 mm in the left orbit. Additionally, these animals had a higher orbital index on the left side (91.64) than on the right (90.88). For beavers, this index was 84.02 on the right and 84.23 on the left. The average orbital index in female beavers was 81.659, which was lower than in males, where the index reached 86.821. Moreover, the p-value for these values was <0.05, indicating that the differences in the orbital index between males and females are statistically significant. These numerical data suggest that they may be related to the shape of the orbit, which is slightly more rounded in males than in females. Thus, the differences in the orbital index can serve as an indicator for sex determination in these animals. It is noteworthy that the standard deviation of each dimension was higher in males, suggesting greater individual variability in this group than in females.

In humans, knowledge of orbital anatomy and proportions is particularly important for forensic purposes, in which anthropometry – a research method involving the comparison of various body dimensions or parts – is used. This method makes it possible to determine information such as an individual's age, sex, or ethnic origin based on remains. Kaplanoglu et al. (2014) demonstrated that anthropometric differences in orbits depend on sex, whereas age has no impact. According to these authors, orbital width and height are greater in males. In contrast, our study on beavers showed the opposite, with larger dimensions observed in females. Sękara et al. (2013) also confirmed that sex can be identified based on orbital dimensions, although their research considered the thickness of the supraorbital margin. It can be assumed that morphometric studies of beaver orbits may be useful for determining their sex or age. Detailed knowledge of orbital anatomy is crucial for clinical purposes, serving as a foundation for complex surgical procedures on organs located in the orbital region (Wallin-Håkansson and Berggren 2017). Clinical needs have led to numerous studies of the skull and orbit in dogs. Based on these studies, dogs have been divided into three groups according to skull shape and muzzle length: brachycephalic, mesocephalic, and dolichocephalic. Morphological diversity of the skull also results in variability within the orbit, making certain breeds more susceptible to specific eye diseases. An example is exophthalmos or lagophthalmos (the inability to completely close the eyelids) in brachycephalic dogs, which have a shallow orbit (Gelatt, 2008). Yoichiro Ichikawa et al. (2024) found that the average depth of the orbit in brachycephalic dogs was 25.80 ± 4.20 mm. The average orbital depth in beavers is 32.0 ± 4.30 mm in females and 30.88 ± 5.54 mm in males, similar to the measurement in mesocephalic dogs (31.90 ± 6.50 mm). Thus, like mesocephalic dogs, beavers are not susceptible to diseases associated with excessively protruding eyes, which are common in brachycephalic dogs.

In anthropology, humans are also classified on the basis of skull shape according to the orbital index. There are three categories: megaseme (large), mesoseme (intermediate), and microseme (small). The first category is characteristic of 'yellow' races (except for Eskimos), with an orbital index equal to or greater than 89 (Anthony et al. 1997). The second category includes individuals with an orbital index between 89 and 83, typical of European races. The last group includes black individuals, with an orbital index lower than 83 (Igbigbi and Ebite 2010). However, studies conducted on X-rays of Malawians aged 18 to 73 years showed that the average orbital index was 96.03 in women and 94.35 in men (Igbigbi and Ebite 2010). This categorizes them as megaseme, like Chinese individuals (Patnaik et al. 2001). No similar geographical correlation has been studied or described in animals.

CONCLUSIONS

The orbit of the European beaver was shown to consist of seven bones classified as cranium and facies, forming an open ring. Additionally, similarly to horses, the temporal bone is involved in the structure of the orbit in beavers. However, the absence of upper and lower vaults was observed, with anterior and posterior walls present instead. All openings in the walls are analogous to those described in other species. Analysis of the dimensions of beaver orbits revealed statistically significant differences between individuals of different sexes – females had greater mean length and depth, while the average orbital index was higher in males. These differences may be useful in determining the sex of these animals based on detailed skull structure. Moreover, the differences observed in dimensions between the right and left orbits do not indicate asymmetry, as they are not statistically significant. Given the preliminary nature of this study, future observations should be conducted on a larger group of animals, with precise determination of age and its inclusion in the statistical analysis.

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