Research Article

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The occipital area in medieval dogs and the role of occipital dysplasia in dog breeding

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Abstract: An investigation was carried out on 42 dog skulls from the early medieval period. The skulls were excavated in Wrocław, Poland, and in Novgorod and Moscow, Russia. Craniometric measurements were taken. On the basis of the basion-ethmoid measurement, the shoulder height was estimated. The foramen magnum height and width were measured and the foramen magnum index was calculated. The foramen magnum was typical in shape, and any occipital dysplasia signs observed were in the skulls. The results of the investigation, in comparison to other investigations of modern breeds and archaeozoological material, suggest that occipital dysplasia is not a pathology but rather a morphological variation connected with intentional dog breeding that can occur as a result of inbreeding.

Key words: Occipital dysplasia, foramen magnum, archaeozoology, craniometry, skull

Introduction

The foramen magnum (*foramen magnum*) and the occipital bone (*os occipitale*) have been the objects of scientific investigations because of their morphological variability and clinical importance (1-4). In humans and animals, anomalies of the foramen magnum and the occipital bone can lead to neurological signs (5-10). Occipital hypoplasia is certainly a pathology, but the role of occipital dysplasia inspires controversy. Occipital dysplasia occurs in some modern breeds like the Yorkshire terrier, Beagle, and Papillon, but it was also recorded in 7 dogs from ancient Urartu and in 2 dogs from the Roman period in England (11,12). Information about dorsal notch occurrence has come only from modern dogs, and there is no proof of occipital dysplasia in dogs from the Neolithic, La Tene, medieval, and other periods. It is possible that the dorsal notch presence is not generally connected with domestication, but rather with the genetic pool narrowing during the breeding process. In this study, dog skulls from medieval Wrocław, Novgorod, and Moscow were investigated.

Materials and methods

The investigation was carried out on 12 skulls from early medieval Wrocław (group 1), 15 skulls from early medieval Novgorod (group 2), and 15 skulls from early medieval Moscow (group 3).

Subsequent craniometric measurements were taken: skull length (prosthion-acrocranion), facial length 2 (prosthion-nasion), cranial length (nasion-acrocranion), maximum zygomatic width (zygion-

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zygion), maximum width of neurocranium (euryon-euryon), maximal width of foramen magnum, height of foramen magnum (basion-opisthion), maximal width of the occipital condyles, maximal width between the bases of jugular processes, basicranial axis (basion-synsphenion), internal cranial dimension (basion-ethmoid), maximal width between the bases of jugular processes (otion-otion), and height of the occipital triangle (acrocranion-basion) (Figures 1-4) (12-15). The basion-tubercula muscularia dimension was also introduced for this study. The measurements taken were the basis for the length-width index 2, length-length index 2, and foramen magnum index calculations. Following the methods of Wyrost and Kucharczyk (16) and Chrószcz et al. (17), the shoulder height was estimated. During statistical analysis, the parameter mean values and standard deviations (SD) were calculated. The variation severity was analyzed using analysis of variance (ANOVA).

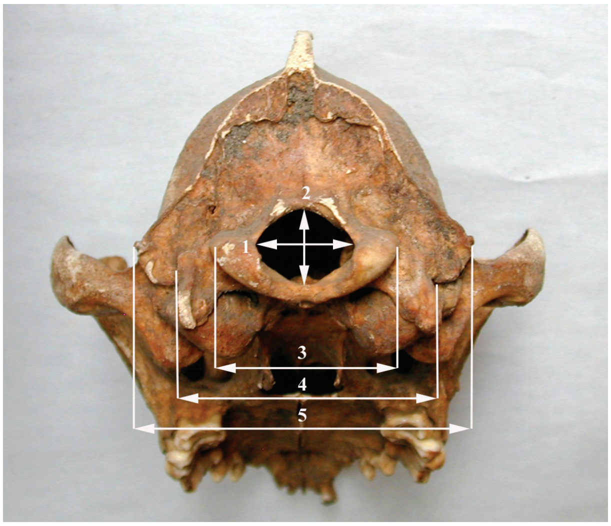

Figure 1. Craniometric measurements: 1) height of the foramen magnum, 2) maximal width of the foramen magnum, 3) maximal width of the occipital condyles, 4) maximal width between the bases of jugular processes, 5) greatest width above base of jugular process.

Figure 2. Craniometric measurements: 1) skull length, 2) facial length 2, 3) cranial length, 4) maximum zygomatic width, 5) maximum width of neurocranium.

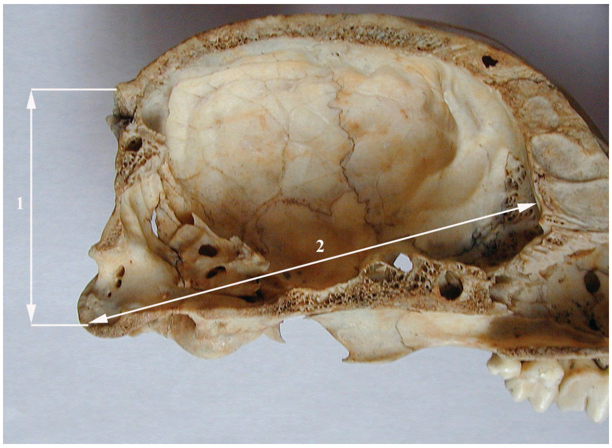

Figure 3. Craniometric measurements: 1) height of occipital triangle, 2) internal cranial dimension.

Figure 4. Craniometric measurements: 1) basion-tubercula muscularia dimension, 2) basioccipital length.

Results

Analysis of the dentition and skull sutures proved that all investigated individuals were adults. On the basis of the length-width index 2 and length-length index 2, all dogs' skulls were classified as mesocephalic in type (13,18). The occipital bone was well developed and its morphology was characteristic for dogs. There were no significant differences in the measurements of the *basioccipitale* between investigated groups. The foramen magnum in all dogs was typical in shape, without dorsal notch occurrence. The value of the osteometric data of the skulls, as well as mean values and SDs, are given in Table 1. The mean values of shoulder height are shown in Table 2. The mean value of shoulder height in group 1 was 51.57 cm; in group 2, it was 51.76 cm; and in group 3, it was 49.18 cm (Table 3). The standard deviation of the height values in all groups proved the height diversity of the dogs. A dorsal notch (occipital dysplasia) was not observed in any investigated skull. The mean value of the foramen magnum index in group 1 was 78.79, in group 2 was 76.34, and in group 3 was 80.0 (Table 2). There was no significant different ($P \leq 0.05$) between the foramen magnum indices of the groups.

Discussion

The malformations of the foramen magnum and occipital bone and their clinical importance are commonly investigated in modern dog breeds (9,10,19). The normal build of the foramen magnum and occipital bone plays a significant role in correct cerebrospinal fluid (CSF) circulation. The obstruction of CFS can result in the development of syringomyelia, fluid-containing cavities that develop in the spinal cord. In veterinary medicine, the most common cause of syringomyelia is occipital bone hypoplasia (9). It is possible that basioccipital and supraoccipital bone malformations cause the diminution of caudal cranial fossa volume. As a result, the vermis goes through the foramen magnum and the spinal cord moves dorsally (10). The role of occipital dysplasia is not clear. Watson et al. (20) stated that the dorsal notch is a morphological variation caused by the supraoccipital bone ossification differences, and occipital dysplasia occurs when the ventromedial portion of the developing supraoccipital bone fails to ossify. Marin-Padilla (21) suggested that occipital dysplasia occurs because of an early paraxial mesodermal insufficiency. Rusbridge and Knowler (9) described

Table 1. Craniometric results (mm).

group	SL	FL 2	CL	MOC	MJP	MWN	MZW	BA	GWJP	BTM	HOT
1.	185. 37 SD 8.91	94.66 SD 11.84	101.8 SD 8.32	37.07 SD 3.89	48.37 SD 3.31	56.06 SD 2.21	94.01 SD 9.46	46.17 SD 5.96	62.98 SD 4.27	26.89 SD 4.26	45.44 SD 2.67
2.	192.0 SD 10.95	96.26 SD 6.78	104.47 SD 6.22	37.29 SD 3.89	51.46 SD 2.91	56.49 SD .01	105.98 SD 8.17	46.92 SD 4.09	65.48 SD 4.72	29.34 SD 2.77	46.64 SD 3.36
3.	163.87 SD 45.86	88.71 SD 12.57	96.63 SD 11.95	34.76 SD 5.18	45.98 SD 6.5	54.37 SD 3.99	101.58 SD 8.9	42.73 SD 6,96	60.61 SD 7.19	25.21 SD 2.73	45.12 SD 5.14

SL: skull length, FL 2: facial length 2, CL: cranial length, MOC: maximal width of the occipital condyles, MJP: maximal width between the bases of jugular processes, MWN: maximum width of neurocranium, MZW: maximum zygomatic width, BA: basicranial axis, GWJP: greatest width above base of jugular process, BTM: basion-tubercula muscularia dimension, HOT: height of occipital triangle.

Table 2. Measurements of foramen magnum (mm) and foramen magnum index.

Group	Maximal width of foramen magnum	Height of foramen magnum	Foramen magnum index
1	18.51 SD 1.16	14.56 SD 1.42	78.79
2	19.42 SD 1.31	14.79 SD 1.18	76.34
3	17.84 SD 2.18	14.16 SD 1.1	80.44

Table 3. Internal cranial dimension (mm) and shoulder height (cm) of the dogs.

Group	Internal cranial dimension	Shoulder height
1	87.47 SD 6.88	51.57 (max 65.38, min 43.32) SD 6.7
2	81.66 SD 7.38	51.76 (max 63.34, min 33.69) SD 7.5
3	79.12 SD 7.29	49.18 (max 59.44, min 39.37) SD 7.41

the dorsal notch in the skull of a 10-year-old Cavalier King Charles spaniel with serious neurological signs. Both occipital dysplasia and occipital hypoplasia were observed in this dog. The King Charles spaniel and other toy dogs are predisposed to this disease (22). Wright (23) radiographically observed this formation in dogs without neurological signs, but Parker and Park (7,24) found dorsal notches in dogs with neurological symptoms. Onar et al. (15) did not observe a dorsal notch in the German shepherd dog. Janeczek et al. (19) described the dorsal notch in an 8-month-old Papillion. Watson et al. (20) observed dorsal notches in 33 of 36 skulls investigated from the Beagle. In all cases, the dorsal notch was covered by a fibrous membrane. No neurological symptoms were observed in these animals. These authors stated that the dorsal notch occurred more often in brachycephalic skulls and was not a pathological but rather a morphological variation. The existence of a fibrous membrane in the supraoccipital region in American Staffordshire terrier newborns was proven by Chrószcz et al. (17). Wielądek and Kupczyńska (25) observed dorsal notches in all 3 investigated Yorkshire terriers of various ages, but there were significant neurological symptoms in only 1 of them. Simoens et al. (26) observed dorsal notches in the Pekingese, Doberman, and Beagle, but not in the German shepherd dog. In the opinion of Simoens et al. (26), the dorsal notch is not a pathology, but rather a structural form of the foramen magnum. Dobermans, according to Brehm et al. (13), belong to the category of dolichocephalic dogs, and, according to Watson et al. (26), the probability of dorsal notch occurrences should be low. However, Simoens et al. (4) observed this formation in 7 of 9 skulls investigated. Rusbridge and Knowler (9) stated that occipital dysplasia is not a functional problem. In their opinion, the membrane covering the supraoccipital defect allows for a dynamic expansion and less severe obstruction of CSF movement through the foramen magnum. As a consequence, it is possible that syringomyelia could develop more slowly, resulting in later onset signs.

Dogs with occipital hypoplasia and occipital dysplasia potentially may have a milder progression of clinical signs than those with only occipital hypoplasia. It is also unclear if the fibrous membrane covering the lack of occipital bone has sufficient resistance to protect the central nervous system. This structure is a developmental remnant that was not replaced by bone tissue in the perinatal physiological ossification process. The hypothesis of Rusbridge and Knowler (9) is interesting, but suggests clearly that the dorsal notch is not a physiological creation.

The mean value of the foramen magnum index in American Staffordshire terrier newborns is 106.82 (17). Onar et al. (15) described the foramen magnum index in German shepherd puppies as 92.76. Simoens et al. (4) estimated the mean value of the foramen magnum index in the Pekingese at 93.4. In this study, the mean value of the foramen magnum index was 78.79-80.44. The minimal value of the foramen magnum was 68.4 in the dogs from Moscow. This index in dogs with occipital dysplasia is approximately 45 (20). Simoens et al. (26) proved that the foramen magnum had a large size variability and was not related to animal age in the Beagle, Pekingese, Doberman, and German shepherd dog. Onar et al. (15) proved the correlation between age and the size of the foramen magnum in German shepherd puppies. Investigations carried out on archaeozoological material from the Iron Age found dorsal notch occurrence in 7 skulls from 48 investigated (12). The dorsal notch was seen only in dogs from the Urartian fortress of Van-Yoncatepe. In the same study, no dorsal notch was seen in dogs from the Scythian castle of Bielskoje. The Urartian dogs were used in watching, herding, and hunting. This proved the geographic and environmental factors in dog breeding and utilization. Animal selection aimed for strong, male, large dogs developed for the above uses. In these dogs, close affinity (genetic similarity) occurred in some cases, such as oligodontia and enamel hypoplasia. The majority of the identified male skeleton remains proved the greater importance of this sex in dog use, both inside and outside the fortress (27). We can state that the dogs of Van-Yoncatepe were the object of an intentional breeding process. Reliefs from Mesopotamia strongly support the thesis of advanced dog breeding in Urartu, as well. Another 2 dogs with occipital dysplasia were described by Grimm (11) in archaeozoological material dating back to the Roman period. The occurrence of occipital dysplasia in these dogs can be connected with Great Britain's occupation by the Romans. It is known that various dog types existed in the Greco-Roman world (28,29). In our study, no dorsal notch was seen in dogs from Novgorod, Moscow, or Wrocław. In these dog remains, archaeozoological analysis showed widespread exterior differences such as animal size. The lack of close genetic affinity signs (e.g., no oligodontia or enamel hypoplasia) can suggest that there were no dog-breeding practices in medieval Novgorod, Wrocław, or Moscow. It seems to be true that occipital dysplasia is a foramen magnum morphological variation, but its occurrence strongly implies directional and intentional dog-breeding praxis. In other words, the reproduction of these animals was not supervised. In this situation, inbreeding could be only incidental.

The results of archaeozoological investigations suggest that occipital dysplasia occurred in domestic dogs in the Iron Age. Dorsal notch occurrence is probably related to intentional dog breeding, as in Urartu. Proof of this hypothesis is the commonly observed occipital dysplasia and occipital hypoplasia in modern breeds.

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