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MORPHOMETRIC ANALYSIS OF THE FORAMEN MAGNUM OF BYZANTINE DOGS EXCAVATED IN ISTANBUL YENIKAPI AT THE SITE OF THEODOSIUS HARBOUR

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ABSTRACT

This study presents the results of morphometric analysis of a total of 473 skulls ascribed to adult animals were sufficiently complete to allow the measurement of their foramen magnum; and for 472 of them the foramen magnum index could be calculated. The dorsal notch was only seen in the group of mesocephalic dogs where about 17% of all skulls exhibited this feature. The average length of the dorsal notch was found to be 2.59 mm. Not a single skull in the dolichocephalic dog group showed any sign of a dorsal notch. The results of this study show that the dorsal notch in the foramen magnum widely seen dogs of the Middle Ages, and point to a morphological variation.

KEYWORDS: foramen magnum, Byzantine dogs, Theodosius harbour, Yenikapı-Istanbul

INTRODUCTION

Yenikapı is the most important transfer station on the European side of Istanbul connecting the subway system (Metro) with the Marmaray project which links both sides of the city with a rail tunnel under the Bosporus (Onar et al., 2013a) (Fig.1). During the construction work at Yenikapı a large number of antique shipwrecks and animal skeletons were discovered. In the light of these important finds, organised excavations began as early as 2004 with the permission of the Ministry of Culture, General Directorate of Cultural Heritage and Museums, and under the guidance of the Archaeological Museum.

Figure1. Yenikapı Excavation area

In Byzantine times the Theodosius harbour was used as an urban dumping ground for discarded objects, organic waste, food as well as dead domestic stock and wasted work animals. Over centuries animal skeletons, broken bones, teeth and horns accumulated at the bottom of the harbour to form an enormous archive. Radiocarbon dating shows that the animal remains from the Theodosius harbour cover a period of more than one millennium from the Early Byzantium (4th century AD) to the Late Byzantium Period (15th century AD) (Onar et al., 2008). The remains represent a wealthy archive of human-animal relationships in Constantinople.

The foramen magnum in dogs varies in size and shape and has been reported to exhibit important variations both between breeds and individual animals (De Lahunta, 1983). The transversal diameter of the foramen magnum tends to be the larger dimension in most cases, however, in some dog skulls breadth and height have been found to be equal (Sisson, 1975). Irregularities observed in the foramen magnum's shape and dimensions have been defined as malformation (Colter, 1981) and are considered serious problems in veterinary science (Chrószcz et al., 2006; Janeczek et al., 2008). The dorsal notch or expansion of the foramen magnum, reported as occipital dysplasia, is congenital and has been proposed as a clinical indicator of acquired neurological illnesses (Colter, 1981; De Lahunta, 1983). Other researchers point to the fact that such a relationship with neurological problems is rare, and come to the conclusion that the clinical significance of an extended foramen magnum is questionable (Hoerlein, 1978; Wright, 1979; Simoens et al., 1994a). In recent studies this finding has been qualified as normal morphological variation, in particular in brachycephalic dog breeds, rather than a pathological malformation (Simoens et al., 1994a, 1994b). A relationship between an expanded foramen magnum and neurological problems has primarily been reported for small and medium-size brachycephalic breeds (De Lahunta, 1983) but similar findings have also been reported for some small dog breeds (Parker and Park, 1974; Hoerlein, 1978; Wright, 1979), Beagle (Watson et al., 1989; Simoens et al., 1994b), Doberman Pinschers (Simoens et al., 1994b), and German shepherd dog' puppies (Onar et al., 1997). While the dorsal notch of the foramen magnum has been interpreted as a morphological variation in Beagle, Pekingese and Doberman Pinschers (Watson et al., 1989; Simoens et al., 1994a, 1994b), in German shepherd dog' puppies it was considered a pathologic malformation (Onar et al., 1997).

The dorsal notch or expansion of the foramen magnum in dogs is usually not covered by a bone but a membrane. The dorsal notch has been explained as the result of incomplete ossification of the ventro-median part of the supraoccipital bone, and has been considered a variation of the regular morphology of the supraoccipital bone (De Lahunta, 1983).

Among all domesticated species, the dog has established the closest relationship with humans in all parts of the world (Harris, 1993; Stein and Rowe, 1993). Dog breeds exhibit a wide range of phenotype variations, with the Greyhound accepted to be the oldest of their common ancestors. These dolichocephalic dogs are characterised by their slim build and long legs, and have been rather extensively bred as far back in time as Old Egypt (Evans, 1993). The Romans are credited with being the first to record the functions and characteristics of dog breeds and of having established the first systematic. The Romans also discovered that selective breeding did not only have an impact on the animals' appearance but also on their capabilities and behaviour (Evans, 1993).

While a number of archaeozoological studies provide information about the phenotype variations in dog breeds (Bökönyi, 1974; Harcourt, 1974; Onar, 2005; Onar et al., 2002; Onar and Belli, 2005) studies on congenital and acquired illnesses with importance for veterinarians are rather rare. Paleopathological data relating to the dorsal notch or expansion of the foramen magnum, which are frequently observed in small and medium-size brachycephalic breeds (De Lahunta, 1983; Simoens et al., 1994a) and some small breeds (Wright, 1979; Hoerlein, 1978; Parker and Park, 1974), have only recently been reported in studies about Iron Age dogs (Janeczek et al., 2008). Besides that, a number of studies on paleopathology have reported detailed findings going beyond occipital dysplasia (Harcourt, 1971; Wijgaarden-Baker and Krauwer, 1979; Baker and Brothwell, 1980; Warren, 2000; Bathurst and Barta, 2004; Teegen, 2005; Baxter, 2007).

The construction work in connection with the Metro rail network and the Marmaray project on the European side of Istanbul, in particular the excavations for the underground station Yenikapı, have yielded numerous dog skulls from Byzantine times (Onar et al., 2008; 2012; 2013a; 2013b). This study is dedicated to the morphometry of their foramen magnum and the examination of the dorsal notch.

MATERIALS AND METHODS

During the construction of the Yenikapı underground station on the European side of Istanbul as part of the Metro rail network and the Marmaray project which connects the European and the Asian part of the city via a tunnel link under the Bosporus straits a large number of dog skulls from Byzantine times were unearthed (Onar et al., 2008; 2012; 2013a; 2013b); they form the material basis of this study. In a previous typological evaluation the collection of 500 dog skulls was classified into dolichocephalic and mesocephalic types (Onar et al., unpublished data; Onar et al., 2012). Some of them had to be excluded because parts of the occipital bone were either missing or fractured. A total of 473 skulls ascribed to adult animals were sufficiently complete to allow the measurement of their foramen magnum; and for 472 of them the foramen magnum index could be calculated. Five measurements were taken in the occipital region of every skull (Von den Driesch, 1976; Simoens et al., 1994a, 1994b; Onar et al., 1997, 2002; Onar, 1999). For seven craniometric measurements and five index values we made use of a previous study (Onar et al., 2012). The foramen magnum index was calculated from correspondent pairs of maximum breadth (greatest breadth of the foramen magnum) and height (height of the foramen magnum)

values (Simoens et al., 1994a; 1994b; Onar et al., 1997, 2002; Janeczek et al., 2008).

Foramen magnum index (FMI)= height of the foramen magnum x 100 / Greatest breadth of the foramen magnum

The following measurements for the occipital region were obtained. They are also shown in Fig. 2.

Greatest breadth of the bases of the processes jugulars (GBPJ); Greatest breadth of the foramen magnum (GBFM); Height of the foramen magnum (HFM); Height of the occipital triangle (HOT); Length of the dorsal notch (LDI).

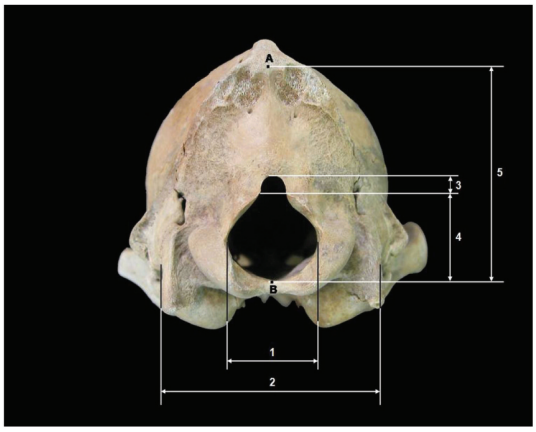

Figure 2. Occipital region measures of Yenikapı dogs
Occipital view:
A. akrokranion; B. basion; 1. greatest breadth of the foramen magnum (GBFM); 2. greatest breadth of the bases of the processes jugulars (GBPJ); 3. length of the dorsal notch (LDI); 4. height of the foramen magnum (HFM); 5. height of the occipital triangle (HOT).

RESULTS

The measurements of the occipital region (GBPJ, GBFM, HFM, HOT, LDI) of a total of 473 skulls were taken. They are summarized in table 1 for dolichocephalic and mesocephalic dogs respectively.

The skulls belong to adult dogs. The foramen magnum index for mesocephalic dogs was found to be larger than for dolichocephalic dogs; however, the difference was not of statistical significance. The dorsal notch was only seen in the group of mesocephalic dogs where about 17% of all skulls exhibited this feature. The average length of the dorsal notch was found to be 2.59 mm. Not a single skull in the dolichocephalic dog group showed any sign of a dorsal notch.

The foramen magnum index could be calculated for a total of 472 skulls; one skull had to be excluded due to a fracture in the occipital region. The calculated index value for the dolichocephalic group was 80.58 and for the mesocephalic group 83.00. In Table 2 the foramen magnum index values of both

Table 1. Craniometric measures (mm) of the Yenikapı Byzantine dogs according to the typological classification

Type		TL*	VCL*	GNB*	ZB*	CL*	GMB*	GBOC*	GBPJ	GBFM	HFM	HOT	LDI
	n	13	13	15	13	15	14	14	14	14	14	14	-
Dolichocephalic	Mean	189.56	100.63	55.28	101.12	100.03	65.31	37.76	49.94	19.87	15.95	45.84	-
	SD	28.024	14.897	7.126	11.554	15.782	8.123	4.971	6.684	2.530	1.850	6.251	-
	n	366	358	461	369	403	444	459	449	458	459	446	78
Mesocephalic	Mean	169.63	83.99	54.69	95.70	93.39	59.83	34.09	46.35	17.87	14.80	42.09	2.59
	SD	21.916	11.849	3.333	9.803	11.302	6.365	4.053	5.341	1.958	1.683	4.693	1.041

*: These values were taken from Onar et al.,[2]. Total length (TL), akrokranion-prosthion; viscerocranial length (VCL), nasion-prosthion; greatest neurocranium breadth (GNB), euryon-euryon; zygomatic breadth (ZB), zygion-zygion; cranial length (CL), akrokranion-nasion; greatest mastoid breadth (GMB), otion-otion; greatest breadth of the occipital condyles (GBOC); greatest breadth of the bases of the processes jugulars (GBPJ); greatest breadth of the foramen magnum (GBFM); height of the foramen magnum (HFM); height of the occipital triangle (HOT); length of the dorsal notch (LDI).

Table 2. The indices of the Yenikapı Byzantine dogs according to the typological classification

Type		SI*	CI*	FI*	LLI-2*	LWI-2*	LWI-4*	FMI
	N	12	15	12	13	12	15	14
Dolichocephalic	Mean	54.25	56.39	102.49	0.98	1.85	1.83	80.58
	SD	4.295	10.770	8.745	0.030	0.144	0.345	5.890
	N	318	400	302	323	318	400	458
Mesocephalic	Mean	57.13	59.06	115.66	1.12	1.76	1.70	83.00
	SD	3.649	4.807	9.231	0.070	0.112	0.136	6.381

*: These values were taken from Onar et al.,[2]. Skull index (SI), ZB x 100/TL ; Cranial index (CI), GNB x100/CL ; Facial index (FI), ZB x 100/VCL; Length-length index-2 (LLI-2), CL/VCL; Length-width index-2 (LWI-2), TL/ZB; Length-width index-4 (LWI-4), CL/GNB; Foramen magnum index (FMI).

typological groups are related to their skull index values.

The foramen magnum index difference between the dolichocephalic and the mesocephalic group was examined with the Student-T test and found to be of no statistical significance.

If was found that some of the mesocephalic dog skulls did not only exhibited a dorsal notch but also a hole in the supraoccipital region (Fig. 2). However, only the dorsal notch was a frequently seen feature.

Figure 3. The occipital view of mesocephalic skulls of adult Yenikapı Byzantine dogs. Notice the wide variation in size and shape of the foramen magnum

DISCUSSION AND CONCLUSION

A dorsal expansion or notch of the foramen magnum has been reported for small and medium-size brachycephalic dog breeds (De Lahunta, 1983; Simoens et al., 1994a). Of the Byzantine dogs excavated at Yenikapı 97% are of the mesocephalic type which according to craniometric measurements (Onar et al., 2012) are assumed to be of light- and medium-size build (Onar et al., unpublished data). One in five of these dogs exhibits a dorsal notch in the foramen magnum; this high incidence rate points rather to a morphological feature than a pathological malformation. Taking into account that some of the examined animals were of an advanced age when they died indicates that the dorsal notch is not age-dependent. This leads us to the conclusion that the existence of this morphological feature was in no way involved in the animals' death. Besides that no concrete findings point to such an involvement. In adult and juvenile Pekingese dogs, which belong to the brachycephalic type, no statistically significant relation could be established between their height and the foramen magnum index which has led researchers to the conclusion that the dorsal notch in the foramen magnum is a mere morphological feature (Simoen et al., 1994a). In a study on dogs with shoulder heights of 33-41 cm (Alderton, 1993), a study on breed classification based on shoulder height (Wijngaarden-Bakker and Ijzereff, 1977) and a study of medium-sized mesocephalic

Beagles (Evans, 1993) high rates of dorsal notch incidences have been reported for otherwise clinically normal dogs. Consequently the appearance of the dorsal notch has been interpreted as a normal morphological variation and not an anomaly (Watson et al., 1989). A similar study has been conducted again on Beagles as well as on Doberman pinschers (Simoens et al., 1994b). Again the conclusion of the researchers was that the finding is a morphological variation and no malformation of the foramen magnum. In this study 17% of mesocephalic Byzantine dogs from Yenikapı, which are assumed to have been of light- and medium-size (Onar et al., unpublished data), exhibit the dorsal notch. We interpret this finding as a normal morphological variation like the one reported by Watson for Beagles (Watson et al., 1989).

In the skulls of dogs belonging to the dolichocephalic group examined in this study we could not detect any sign of a dorsal notch. This may be due to the relative low number of skulls of this type found at Yenikapı and to the fact that the dorsal notch is more prevalent in meso- and brachycephalic dog breeds (Watson et al., 1989; Simoens et al., 1994a). No brachycephalic dog skulls have been found at Yenikapı (Onar et al., 2012). However, the results of this study and of previous research show that the dorsal notch in the foramen magnum widely seen in present day dog breeds, in particular meso- and brachycephalic breeds (Watson et al., 1989; De Lahunta, 1983; Simoens et al., 1994a,), can already be found both in Iron Age dogs (Janeczek et al., 2008) and in dogs of the Middle Ages. These findings point to a morphological variation.

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