Dog Behavior, 3-2022, pp. 47-54 • DOI 10.4454/db.v8i3.167

Wolf and German shepherd dog skull: morphometric changes due to domestication

Alessandra Coli[a], Davide Prinetto[a], Elisabetta Giannessi[a]

[a] *Department of Veterinary Sciences, University of Pisa, Viale delle Piagge, 2, 56124, Pisa, Italy*

Abstract: A morphometrical investigation between Italian wolves' skulls and German Shepherd dogs skulls was carried out to study if the domestication process can determine craniometric changes induced by the different way of life between the wild ancestor and the present domestic dog. By the comparative evaluation of morphometrical data from 8 wolf and 8 German Shepherd skulls, all obtained from Navone taxidermy laboratory (https://www.tassidermia.com/), the Authors found that wolf skulls are larger in 78% of the craniometrics variables, in accordance with strong and fast use of masticatory muscles, necessary for predation. From morphological and morphometrical point of view, less marked nasal "frontal stop", shorter and wider skull, larger orbital angle and a coronoid process with dorsal side facing caudally are the features that most characterize the wolf skull and that change during the domestication process. Of particular interest is the lower morphometrical parameters of canine and carnassial teeth in German Shepherd dog jaw respect to wolf jaw, probably related to a different approach to food, and a larger nasal opening of German Shepherd dog skull, probably related to an aesthetic characteristic. The reduction of craniometric parameters which mainly concern the dorsal part of the skull could be attributed to a decrease of brain volume caused by domestication process, attributable to a reduction of the limbic system.

Key Words: skull, domestication, morphometry, wolf, German Shepherd dog.

* *Corresponding Author*: alessandra.coli@unipi.it

Introduction

The wolf belongs to the Canidae family whose main morphological characters are longest dental row, large number of teeth (42), long tail, digitigrade limbs and four fingers in the hind limb. Of all wild species of canine family, the wolf (*Canis lupus L., 1758*) is the largest animal and is the second largest predator in Europe, after the brown bear.

The wolf is considered to be the wild ancestor of the domestic dog (*Canis lupus familiaris L., 1758*). Some wolf subspecies have currently been defined with great accuracy based mainly on morphometric investigations and applying new molecular genetic techniques (Pilgrim et al., 2018): today there are 5 subspecies of the North American continent (*arctos*, *occidentalis*, *nubilus*, *baileyi* and *lycaon*) and 4 Eurasian ones (*albus*, *communis*, *cubanensis* and *pallipes*). Some authors (Nowack, 2003) also recognize the subspecies *Canis lupus laniger* for the Chinese wolf. As for the Italian wolf, Altobello (1921) distinguished it from the populations of other European wolves, considering it a subspecies of the gray wolf (*Canis lupus*) and calling it *Apennine wolf*. Recent genetic investigations have confirmed this line by elevating the *Apennine wolf* to a subspecies (*Canis lupus italicus*), thus distinguishing it from the remaining population of European wolves by morphological and genetic features (Ciucani et al., 2019).

Currently the wolf distribution affects the whole Apennine chain with branches in Lazio and Tuscany, with a total population estimated at 400-500 individuals. Unfortunately, today there is a continuous anthropogenic persecution at the local level: the number of killings is estimated at 50-70 individuals/year (Apollonio et al., 2004). For many decades it was thought that the first dogs entered human history when our ancestors decided to bring wolf cubs to their camps, feed and raise them. This hypothesis was supported by K. Lorenz, who in his book "*And man met the dog*" (1950) suggests the theory of direct adoption (the dog derives from wolves taken from the mother, raised by man and made to reproduce). Where and when this animal domestication took

Submitted, 09/14/2023
Accepted, 09/29/2023

place remains surprisingly inaccurate (Larson et al., 2012), but most scientists agree that it took thousands of years and scientific reality showed that it was not man who sought the wolf, transforming him into a dog, but the exact opposite: the wolf approached human settlements to eat the remains of meals, losing fear of man over time, and making itself tameable (Gazzano, 2013). It is therefore a process of "self-domestication" where wolves and men have shared an ecological niche, allowing the wolf to become domesticable, changing behavioural and morphological levels in the "proto-dog". In this way, generation after generation, the animal would gradually become accustomed to contact with humans until evolving into a dog and supporting humans in their work (Driscoll & Macdonald, 2010). The theory of the "proto-dog" is also confirmed by means of palaeontological study of bone finds. Indeed, the bones can show the morphological modifications by the domestication process: the first findings associated with the domestic dog date back to 14,000 years ago, when bones of the primitive *Canis familiaris* were found in a Pleistocene archaeological excavation in a human burial. However, results based on the study of mitochondrial DNA have suggested that the domestication process can be traced back as early as 40,000 years ago (Ding et al., 2012).

From the literature, the skull anatomy represents a notable parameter of differentiation determined by the process of domestication. Wolf skull can reach a length of about 23-27 cm (taken from incisive teeth to occipital condyles) and a width of about 15-18 cm (taken between two zygomatic processes) (Ciucci & Boitani, 1998). The dog skull has a different length in relation to the breed: Chihuahua breed skulls has very small dimensions (10 cm in length), Saint Bernard breed skull has very large width (Evans, 1993).

Figure 1. Dog frontal stop (dog skulls, Veterinary Anatomy Museum, University of Pisa)

Wolf skull is characterized by a long splanchnocranium, a strongly ossified neurocranium with large and robust zygomatic processes and a particularly developed external sagittal crest, into which the temporal muscle is inserted (Ciucci & Boitani, 1998). The orbital angle (acute angle by the intersection between the straight-line tangent to the top of the skull and the tangent line to the zygomatic process) is a parameter of distinction between wolf and dog skulls, especially to differentiate animals of similar size (e.g. *German Shepherd dog*). This angle is of great importance for the distinction between the two types of animals: it measures between 40°-45° in the wolf, and 53°-60° in dogs (Studer, 1901). This measure indicates the great development of wolf chewing muscles, attached between the considered bones.

The wolf tympanic bulla is large, convex and spherical, unlike that of dog which appears more atrophied, small and compressed. The "frontal stop" between the nasal and frontal bones is one of the main features that helps in identification: in wolf skull we find a more elusive frontal nose angle than that of the dog, which has a more marked "frontal stop" (Fig. 1).

The wolf dental formula for an adult subject (I 3/3, C 1/1, Pm 4/4 and M 2/3, for a total of 42 teeth) is the same of an adult dog. The canines are very developed. In the group of premolar and molar teeth the "feral" or "carnassial" teeth stands out, which are much less developed in dog than in wolf (Severtsov et al., 2016). Some anatomical features cannot be explained by artificial selection: the shape of the coronoid process of dog jaw (on which the temporal and masseter muscles are inserted) is typically curved backwards along the branch ascendant, unlike what is observed in the wolf skull (Olsen & Olsen, 1977) (Fig. 2).

The purpose of this study was carry out a morphometrical investigation of wolf and German Shepherd dog skulls to observe the craniometric changes induced by the domestication process. This work also aims to validate the existence of variables significantly useful for the differentiation of the skulls belonging to these two specimens, described in the literature.

Figure 2. Difference in the coronoid processes of dog (up) and wolf (down) jaw (skulls from Navone taxidermy laboratory, drawings copyright ©Davide Prinetto)

Materials and methods

In this work, 8 wolf and 8 German Shepherd dog skulls were evaluated from Navone taxidermy laboratory of Alessandro Trucco (Chieri, Torino) (https://www.tassidermia.com/). The wolf skulls were taken from specimens sent to the laboratory for osteological preparation and subsequent museal exhibition. These wolf skulls were taken from bodies brought in taxidermy laboratory following their random retrieval. The dog skulls were taken from animals admitted to veterinary hospitals, euthanized for non-curable pathology, not involving the skeleton, and with the informed consent of the owners. The decision to evaluate German Shepherd dog breed is due to the body shape similar to that of the wolf. All the animal bodies were placed in the appropriate area dedicated to preparation.

The skulls subjected to the evaluations belong to adult specimens. Eighteen craniometric measurements were carried out on the 16 skulls included in this work, indicated by the alphabetic letters (Table 1).

Table 1. Craniometric measurements

A	distance between the extremity of sagittal crest and parietal bone
B	nasal bone length
C	distance between sagittal crest end and oral end of incisor bone
D	distance between oral end of nasal bone and incisive bone
E	distance between sagittal crest and zygomatic process of frontal bone
F	distance between two zygomatic processes of frontal bone
G	distance between zygomatic arches
H	distance between left and right P4-M1
I	distance between lateral ends of tympanic bullae
L	distance between outer extremes of M2
M	distance between outer edge of tympanic bulla and outer edge of zygomatic bone
N	palate length
O	distance between oral part of incisive bone and oral part of ipsilateral tympanic bulla
P	canine tooth length
Q	height skull (excluding jaw)
R	width of nasal cavity opening
S	height of nasal cavity opening
T	carnassial tooth length (last upper Pm4)

These parameters taken into account were chosen for their simplicity of identification and interpretation. The measurements were made using a tape measure, a calibre and a compass for measuring distances between points. The results are reported in centimetres.

Statistical analysis

The statistical analysis of the data was carried out using a Microsoft Excel worksheet. The collected data were summarized as mean value (±SD).

Results

The results obtained from the measurements made on wolf and German Shepherd dog skulls showed in Table 2.

Table 2. Mean values (± DS) of the single measurement's parameters

	Wolf skull	Dog skull
A	7.3 (0.6)	6.1 (0.4)
B	7.9 (0.1)	5.8 (0.2)
C	25.1 (0.7)	21.5(0.6)
D	3.9 (0.3)	3.3 (0.2)
E	10.2(0.6)	10.8 (0.5)
F	6.3 (0.3)	6.6 (0.3)
G	13.4 (0.3)	11.8 (0.4)
H	7.1 (0.5)	7 (0.3)
I	6.3(0.2)	5.7 (0.1)
L	6.8 (0.2)	6.1 (0.2)
M	3.3 (0.2)	3.1 (0.3)
N	12 (0.2)	11.8 (0.2)
O	16,2 (0.2)	15.5 (0,3
P	3.3 (0.2)	2 (0.1)
Q	8.2 (0.2)	8.7 (0.2)
R	2.5 (0.1)	2.6 (0.1)
S	2 (0.2)	2.3 (0.1)
T	1.6 (0.1)	0.9 (0.1)

Wolf skulls are larger in 78% of the variables, graphically visible in Fig. 3.

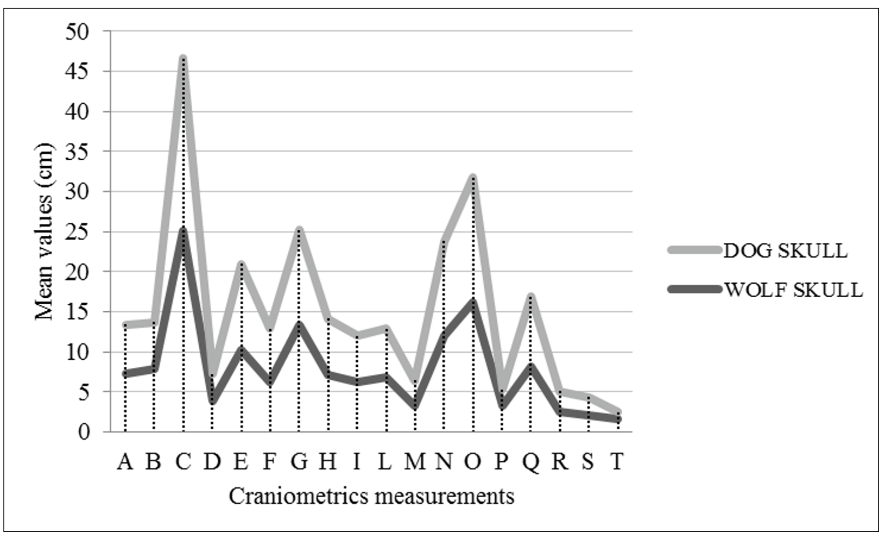

Figure 3. Mean values of craniometric measurements

These data are in agreement with further studies in which some disparities between the craniometric dimensions of wolf and dog are described. Indeed, wider and stronger zygomatic processes and a well-developed sagittal crest have been identified in the wolf skull, allowing a strong and fast closing of the jaw by temporal muscle, necessary for predation.

Furthermore, from Table 2 it is also highlightable a significant difference in craniometrics measurement B and C which are greater in wolf skull. These results might depend on the presence of a less marked "frontal stop" between nasal and frontal bone in wolf skull compared to that of German Shepherd dogs, in which it is present more markedly.

Of particular importance are the results obtained from parameter E, F and Q which detect a slight increase in size in German Shepherd dog skull. These results might support the morphological and morphometric differences most frequently reported in literature and used to distinguish dogs from wolves' skulls: shorter and wider skull, larger orbital angles and coronoid process with the dorsal side facing caudally.

Significant differences are also noted in the jaw measurements, due to the different morphometry of the teeth: in German Shepherd dog jaw parameters P and T are lower than those measured in wolf jaw. This result might be attributed to different eating habits. Indeed, feral teeth are also called "carnassial teeth" because they are particularly sharp, necessary for laceration of tendons and large pieces of meat.

The parameters S and R are also larger in German Shepherd dog skull. In literature this particular feature finds no attention: it has been hypothesized that it may simply be an aesthetic feature.

Thus, although the morphological changes induced by the domestication process are less pronounced than in other dog breeds (Evans, 1993), the slight diversification in the shape of German Shepherd dog skull compared to that of wolf might have multiple reasons, including also specific selective inputs. Another possible explanation for the onset of these changes is given by the domestication process which leads to a decrease in the brain volume (Kruska, 1988): in particular, there is an acute reduction of the limbic system, a crucial component in the fight and flight responses. It seems plausible that the domestication process has therefore reduced those inner anatomical areas of the brain that inhibit contact and collaboration with humans in the wolf. This reduction, quantified in an average value of 30%, is considered one of the most important factors in the changes in the morphology of the modern dog skull. This hypothesis is also supported by the results of the largest experiment on domestication ("*Russian foxes of Novosibrisk*") (Trut et al., 2009), in which important skull reductions is associated with the only selection criterion used in this study (the choice of the most docile subjects for each generation).

Conclusions

This work suggested that, in order to differentiate wolf and German Shepherd dog skulls, it is necessary to carry out a series of complete morphological and morphometrical investigations, since there is not a single significant parameter useful for this investigation. In wolf skull almost all of the parameters considered show larger measurements. In particular the *nasal bone length*, the *distance between the extremity of sagittal crest and oral extremity of the incisive bone of the jaw* and *the tooth morphometry* proved to be valuable features in differentiating a wolf skull from a German Shepherd dog skull. The size of the neurocranium was also useful for this discriminating: indeed, from the results it is pointed out that in the German Shepherd dog the neurocranium is dimensionally wider but shorter, in accordance with some studies of literature (Zeder, 2012) that refer the skull short length to the reduction in development of the rhinencephalon during domestication. This work also highlighted how morphological and morphometrical changes induced by the domestication process (Schoenebeck & Ostrander, 2013) are less pronounced in German Shepherd dog than in other dog breeds. This might be attributable to the phenomenon of neotenic pedomorphism, i.e. the conservation in adult dogs of morphological and behavioural traits typical only of different juvenile stages of wolf development, as a result of the selection processes in German Shepherd dog breed. The morphometrical differences between the two types of specimens might derive also from the different types of life: dog is integrated into the human being's world and does not need to kill for autonomous survival. This behaviour leads to a reduced brain capacity and a resultant change in morphology ok the skull. Since these conclusions are valid only for the small group of subjects included in this work, further studies are needed to validate these conclusions.

References

1. Altobello G.C.E. 1921. Mammiferi (Fauna dell'Abruzzo e del Molise), Colitti (ed.), Campobasso.
2. Apollonio M., Mattioli L., Scandura M., Mauri L., Gazzola A., Avanzinelli E. Wolves in the Casentinesi Forests: insight for wolf conservation in Italy from a protected area with a rich wild prey community. Biological Conservation. 120 (2): 253-264; 2004 https://doi.org/10.1016/j.biocon.2004.02.021
3. Ciucani M.M., Palumbo D., Galaverni M., Serventi P., Fabbri E., Ravegnini G., Angelini S., Maini E., Persico D., Caniglia R. Cilli E. Old wild wolves: ancient DNA survey unveils population dynamics in Late Pleistocene and Holocene Italian remains. Peer J. 7, e6424; 2019; https://doi.org/10.7717/peerj.6424
4. Ciucci P., Boitani L. 1998. Il lupo: elementi di biologia, gestione, ricerca. Istituto nazionale per la fauna selvatica "Alessandro Ghigi". Documenti tecnici, 23, Ozzano dell'Emilia (Bologna).
5. Ding Z.L., Oskarsson M., Ardalan A., Angleby H., Dahlgren L.G., Tepeli C., Kirkness E., Savolainen P., Zhang Y.P. Origins of domestic dog in southern East Asia is supported by analysis of Y- chromosome DNA. Heredity (Edimb.). 2012; 108 (5): 507-514. https://doi.org/ 10.1038/hdy.2011.114
6. Driscoll C.A., Macdonald D.W. Top dogs: wolf domestication and wealth. J Biol. 2010; 9(2)10: 1-6. https://doi.org/10.1186/jbiol226
7. Evans H.E. 1993. Miller's Anatomy of the dog, third edition, W.B Saunders Company, USA.
8. Gazzano A., 2013. A nostra immagine e somiglianza, la creazione del cane e delle sue doti mentali e emotive. In: Irene, (ed.). Emotività Animali. Ricerche e discipline a confronto, Andreozzi, M. Castignone, S., Massaro, A., S147-154. https://doi.org/10.7359/663-2013gazz
9. Kruska D. 1988. Mammalian domestication and its effect on brain structure and behavior. In Intelligence and evolutionary biology, 211-250. Berlin, Heidelberg: Springer Berlin Heidelberg.
10. Larson G., Karlsson E.K., Perri A., Webster M.T., Ho S.Y.W., Peters J., Stahl P.W., Piper P.J., Lingaas F., Fredholm M., Comstock K.E., Modiano J.F., Schelling C., Agoulnik A.I., Leegwater P.A., Dobney K., Vigne J.D., Vilà C., Andersson L., Lindblad-Toh K. Rethinking dog domestication by integrating genetics, archaeology and biogeography. Proc. Natl. Acad. Sci. USA. 109(23): 8878-83; 2012. https://doi.org/10.1073/pnas.1203005109
11. Lorenz K., 1950. E l'uomo incontrò il cane, Adelphi (ed.), Milano.
12. Nowack R.M., 2003. Wolf evolution and taxonomy. In: Mech & Boitani (Ed.). Wolves. behaviour, ecology, and conservation. University of Chicago Press, USA, 239-258.
13. Olsen J.S., Olsen J.W. The Chinese Wolf, Ancestor of New World Dogs. Science. 197: 533-535; 1977. https://doi.org/10.1126/science.197.4303.533
14. Pilgrim K., Engkjer C., Schwartz M. 2018. Genetic analysis summary and preliminary population genetic evaluation of wolves (Canis lupus) in the Italian Alps in 2014-2018. In: Marucco et al. Lo Status della popolazione di lupo sulle Alpi Italiane e Slovene 2014-2018, Relazione tecnica, Progetto LIFE 12 NAT/IT/00080 WOLFALPS-Azione A4 e D1.
15. Severtsov A.S., Kormylitsin A.A., Severtsova E.A., Yatsuk I.A. Functional differentiation of teeth in the wolf (Canis lupus, Canidae, Carnivora), Biology Bulletin. 43: 1271-1280; 2016. https://doi.org/10.1134/S1062359016110133
16. Schoenebeck, J.J., Ostrander J.A. The genetics of canine skull shape variation. Genetics. 193: 317-325; 2013. https://doi.org/10.1534/genetics.112.145284

17. Studer T. 1901. Die prähistorischen Hunde in ihrer Beziehung zu den gegenwärtig lebenden Rassen. Zurcher und Furrer ed., Zurich, 1-154.
18. Trut L., Oskina I., Kharlamova A. Animal evolution during domestication: the domestic fox as a model. BioEssays. 31: 349-360; 2009. https://doi.org/10.1002/bies.200800070
19. Zeder M.A. The Domestication of Animals. Journal of Anthropological Research. 68 (2): 161-190; 2012. https://doi.org/10.1080/00988157.1982.9977605

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Individual contributions

Alessandra Coli: Director of Veterinary Anatomy Museum, concept and design of the study; interpretation of the data.

Davide Prinetto: interpretation of the data.

Elisabetta Giannessi: concept and design of the study; interpretation of the data.

Cranio di lupo e di pastore tedesco: cambiamenti morfometrici dovuti alla domesticazione

Alessandra Coli, Davide Prinetto, Elisabetta Giannessi

Dipartimento di Scienze Veterinarie, Università di Pisa, Viale delle Piagge, 2, 56124, Pisa, Italia

Sintesi

È stata condotta un'indagine morfometrica tra crani di lupi italiani e crani di pastore tedesco per studiare se il processo di domesticazione può determinare cambiamenti craniometrici indotti dal diverso modo di vivere tra l'antenato selvatico e l'attuale cane domestico. Dalla valutazione comparativa dei dati morfometrici di 8 teschi di lupo e 8 di pastore tedesco, tutti ottenuti dal laboratorio di tassidermia di Navone (https://www.tassidermia.com/), gli Autori hanno scoperto che i crani di lupo sono più grandi nel 78% delle variabili craniometriche, in accordo con l'uso forte e veloce dei muscoli masticatori, necessari per la predazione. Dal punto di vista morfologico e morfometrico, "stop frontale" nasale meno marcato, cranio più corto e più largo, angolo orbitale maggiore e processo coronoideo con la faccia dorsale rivolta caudalmente sono le caratteristiche che maggiormente caratterizzano il cranio del lupo e che cambiano durante il processo di addomesticamento. Di particolare interesse sono i parametri morfometrici dei denti canini e carnassiali nella mascella del pastore tedesco rispetto a quella del lupo, probabilmente legati ad un diverso approccio al cibo, e un'apertura nasale più grande del cranio del pastore tedesco, probabilmente legata ad una caratteristica estetica. La riduzione dei parametri craniometrici che riguardano principalmente la parte dorsale del cranio potrebbe essere attribuita ad una diminuzione del volume cerebrale causata dal processo di addomesticamento, imputabile ad una riduzione del sistema limbico.