1.5 The Skull Shape of *Canis lupus*. A Study of Wolf and Dog Cranial Morphology

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Abstract

The aim of this research is to analyse craniomandibular features in contemporary wolves and dogs in order to study evolutionary changes that are assumed to be related to domestication. We compared these modern canids with four fossils from different Upper Pleistocene (Grotta Romanelli, Terrasses de la Riera dels Canyars) and Holocene (Portalón) sites of the Mediterranean region. The specimens were analysed using both traditional and geometric (2D) morphometric techniques. Our results characterise wolves' greater mandible size (dental series), greater cranial width and length, and less elongated snout.

Keywords: domestication, *Canis lupus*, morphometry, skull, Pleistocene.

1 Introduction

The *Canis* domestication process is riddled with controversy (Müller 2002: 34–39) and the classification of the wolf-like canids remains uncertain (Boudadi-Maligne and Escarguel 2014: 80–81). Dogs/wolves have a deeper relationship with humans than any other mammal, and the origins of dogs are interesting to a very wide audience. Various morphological methods have illuminated the process of domestication and, recently, so have ancient DNA analyses of Pleistocene wolf-dogs (Germonpré *et al.* 2009: 473–74, 2015: 261–62). Lindblad-Toh *et al.* (2005) studied the structure of the haplotype and the phylogeny of the dog, to observe the relationship with the domestication of the dog. However, it is not so simple to genetically distinguish proto-dogs from contemporary wolf populations by genomic sequences (Druzhkova *et al.* 2013: 5; Thalmann *et al.* 2013: 873–74). After many years of intense DNA work, morphology is still the best witness of dog origins from wolves.

Research based on morphometric studies (Drake and Klingenberg 2010, 2017; Germonpré *et al.* 2009, 2012, 2015, 2017; Janssens *et al.* 2016; Morey 2014; Sardella *et al.* 2014) reveal morphological differences between dogs and wolves. Drake and Klingenberg (2010) analyse, in 106 breeds of domestic dogs, cranial diversity using geometric morphometry. The variation observed in the skulls, with respect to its length, forehead and neurocranium, is also found in the wolf, which these authors interpret as changes already occurring before domestication. In the archeo-paleontological record, complete skulls are not always recovered in good condition, therefore we also studied mandibles because they also show distinct morphology (Drake *et al.* 2017; Germonpré *et al.* 2015). Dogs are characterised by a shorter snout, a more pronounced forehead area and a wide palate (Germonpré *et al.* 2009: 481; Sablin and Khlopachev 2002: 796; Morey and Jeger 2015: 427) and, therefore, we propose these features diagnose domestic animals. The shortening of the snout in dogs implies a strong mandible and well-developed carnassial (P^4 and M_1) (Germonpré *et al.* 2009: 481). A skull of short length (condyle-basal length) is also identified as a typical feature of paleolithic dogs (Germonpré *et al.* 2012: 196). Another criterion that is used as evidence of domestication is the crowding of teeth due to the absence of diastema (or shortening of the snout) (Germonpré *et al.* 2015: 276). Similarly, metric data indicate that the mandibles of paleolithic dogs are shorter. In addition, they present a high frequency of very close premolars with cusps oriented towards the posterior mandibular region (the coronoid process) (Germonpré *et al.* 2015: 277).

Skulls and mandibles are complex biological forms with diet-related adaptations that respond quickly to selective pressures. One way to compare the morphologies of dogs, wolves and their kin is through different morphometric techniques: traditional and geometric. Combining both, it is possible to obtain a more complete morphometric analysis and also a comparison between techniques and their effectiveness in extracting morphological information in the study of the bone. Traditional morphometry basically describes simple changes in size and shape as mathematic regressions (allometries), which then focus on specific areas of variability. Multivariate data processes have enjoyed continuous improvement from the late 20th Century through to the present. Measured variables have been subjected to increasingly powerful factorial analysis, with current geometric morphometry (2D) that allows more complex observation of changes of shape, through building visual representations of morphological variation (Zelditch *et al.* 2004: 2). For this, anatomically homologous landmarks are located in 2D space for all analysed specimens. In geometric morphometry, the shape is defined as 'all the geometric information that remains when the location, scale and rotational effects are filtered from an object' (Kendall 1977: 428). By performing Multivariate techniques like Principal Components Analysis (PCA), variability can be represented numerically and graphically. PCA is a method to simplify descriptions of variation among individuals and make them easier to interpret (Zelditch *et al.* 2004: 156). As a result, PCA converts the original variables into a set of new variables, Principal Component (PC). PCs are linear combinations of the original variables and uncorrelated with each other. Wireframe graphs allow for better visualisation of changes in shape, connecting landmarks by straight lines. Two graphs are generated, one with the initial shape (or average form of the study samples) and another with the final shape (Klingenberg 2013: 19).

In this research, skulls and mandibles of modern Iberican wolves (*Canis lupus signatus*) and dogs (*Canis lupus familiaris*) are studied using the techniques described above. We analyse the morphological features most useful in differentiating wolf-like canids and characterise them in descriptive visual and numerical terms. In addition, in this work a preliminary analysis is carried out with a fossil sample of Paleolithic dogs and Pleistocene wolves from the Mediterranean region (Grotta Romanelli, Terrasses de la Riera dels Canyars and Portalón). This material is complete and well preserved and provides a base for future projects where the fossil record sample will be expanded.

Grotta Romanelli is a Late Pleistocene site located in the region of Apulia (Southern Italy) (Bertè 2013: 156; Sardella *et al.* 2014: 180). In this research we analysed the skull of a wolf from Level G (dated at 69 ka to 40 ka ±3250 years by Fornaca-Rinaldi and Radmilli, 1968) of '*terre rosse*', interpreted by Blanc (1928) as an eolian deposit. El Portalón de Cueva Mayor (Sierra de Atapuerca, Burgos, Spain), dated at 30 ka to 1000 BP years (Carretero *et al.* 2008: 74), is one of the most important archaeo-paleontological sites of the Meseta. The material analysed in this work corresponds to two mandibles of paleolithic dogs of the Bronze Age level. Broadly speaking, the Bronze Age layer is constituted by greyish silt-clay and sandy sediments, clasts, organic matter and coals (Carretero *et al.* 2008: 71; Pérez-Romero *et al.* 2016: 3–4). Terrasses de la Riera dels Canyars is a Pleistocene site located near Gavà (Barcelona) in an abandoned gravel pit dated to 39.6 ka cal BP (Daura *et al.* 2013: 26–27). The lithological sequence described in this site corresponds to coarse-grained fluvial deposits. We analysed a skull and a mandible of a Pleistocene wolf.

Our results suggest that wolves are characterised by a greater size of the mandible (dental series length), a greater cranial width-length and less elongation of the snout.

2 Material and methods

2.1 Material

We studied 41 modern skulls of *Canis l. signatus* and *Canis l. familiaris*. Furthermore, we analysed fossil material from different Pleistocene and Holocene sites (Table 1). All this material is well preserved. In order to study *Canis lupus* from Grotta Romanelli (Level G) we used the high quality pictures figured in Sardella *et al.* (2014: 183, fig.

Table 1. Material (modern and fossil specimens) studied.

Modern material	41 specimens: 21 Iberian wolves and 20 dogs		
Fossil material	**Material**	**Site**	**Age**
	1 Pleistocene wolf (skull) - P3580	Grotta Romanelli (GR)	69–40 ± 3250 ka[1]
	1 Pleistocene wolf (skull and mandible) - TC'07.M242401 (mandible) - TC'07.N231644 (skull)	Terrasses de la Riera dels Canyars (TC)	39.6 ka cal BP[2]
	2 Paleolithic dogs (mandibles) - CMIA8.51.1 - CMIA6.48.4	El Portalón de Cueva Mayor (ATP)	Middle Bronze Age

[1] Sardella *et al.* (2014: 183, fig. 3); [2] Daura *et al.* (2013: 26)

3). In this publication, the skull can be analysed in all the anatomical views (dorsal, ventral, lateral, frontal and caudal) and thus can be included in our comparative study. For the study of the Pleistocene wolf from Terrasses de la Riera dels Canyars we also analysed pictures figured in Daura *et al.* (2013: 40, fig. 11) and additional photos.

The modern material studied is stored at different museums and institutions: Museo Nacional de Ciencias Naturales (MNCN, Madrid), Laboratorio de Evolución Humana (LEH) from University of Burgos (UBU), Museo de Anatomía Comparada de Vertebrados (MACV, Complutense University of Madrid) and Facultad de Veterinaria of the Complutense University of Madrid (UCM). We used size as a criterion to select the skulls of dogs, thus controlling for allometry by selecting those of similar size to wolves.

2.2 Methods

2.2.1 Traditional morphometric

For traditional analysis we followed Driesch (1976: 42–45, 60–61) using a digital caliper to the nearest 0,01 mm. We measured 25 variables on mandibles and 27 on skulls: we focused both on specific areas like the dental series (especially the carnassial and canine) and on generalised measures of the mandible (such as length, height of the body and height of the vertical ramus). We also measured several different cranio-facial (frontal bone, snout) and neurocranial chords. We used *STATISTICA* (version 12.5) to perform the factorial analyses of principal components. Finally, we studied the differences and variability of wolves and dogs with scatterplots.

2.2.2 Geometric morphometric

For geometric (2D) morphometric analysis we took photographs of all the specimens. Skulls and mandibles were carefully placed on a base, always in the same position to obtain accurate results.

We selected several landmarks from different regions of skulls and mandibles (Tables 2–4 and Figure 1) and analysed them using tpsDig2 (version 2.3; Rohlf 2017). The landmarks chosen were previously-defined anatomic homologous points (Zelditch *et al.* 2004: 24) that allow a better analysis of the shape. Bookstein (1991: 63–65) describes three types of landmarks: Type I (classic craniometric points/discrete juxtapositions of tissue, for example, points of contact between bones), Type II (points of maximal curvature) and Type III (extreme points). In this study, most of the landmarks digitised are of Type I and II given their more conventional biological meaning.

We used *MorphoJ* (version 1.06d; Klingenberg 2011) to perform several analyses. We carried out a Procrustes superimposition to homogenise the data (Rohlf and Marcus 1993: 130). This consisted of translating, scaling and rotating landmark configurations to eliminate information unrelated to shape (Zelditch *et al.* 2004: 113). We thus excluded size differences, location and orientation differences, and then transformed the original landmarks in Procrustes space, generating new analagous points. Secondly, a PCA was applied to reduce dimensionality of the data and to simplify its representation. Finally, for a better display of the shape changes we used wireframe graphs. With these graphs we observed the differences and variability between both types of canids.

3 Results

3.1 Traditional morphometry

We performed a factorial analysis of the mandibles, analyzing 25 variables. We obtained two factors that represent 85.56% of the total variance. The first factor provides the highest proportion of the variability and explains 77.71% of the total variance, while the second factor explains 7.85%. The more significative variables in Factor 1 are those related to measurements that express the length and height of the mandibles, and dental series length. The more relevant variables from Factor 2 are the molar row (M_1-M_3) and the carnassial length (M_1). Figure 2A shows both factors with visible graphical discrimination between wolves and dogs.

For the skulls we performed a factorial analysis, where we analysed 27 variables. We obtained three factors that represent 72.42% of the total variance. Factor 1 (56.14%) and Factor 2 (10.18%) are graphically represented in Figure 2B. The most significative variables from Factor 1 are measurements related to dental series length (Prostion-M^2, P^1-P^4, etc.) and measurements of skull length. The most relevant variables from Factor 2 are measurements related to the frontal bone and muzzle breadth. Factor 2 does not discriminate between wolves and dogs, but it provides morphological details. Factor 3 only represents 6.10% of the total variance, not providing relevant information.

3.2 Geometric morphometry

A PCA for the mandibles was performed. We analysed the first four Principal Components (PC) because they show the maximum shape variation, with 75.06% of the total variance. However, only PC1 (37.98%) discriminates between wolves and dogs and is the one that better analyses the shape variation. By observing the landmarks in the wireframe of PC1, PC2, PC3 and PC4 (6.9%), we selected PC1 *vs.* PC4 (Figure 3A) to analyse mandibular differences. Given the variation of the shape observed in the PC1 wireframe, the final

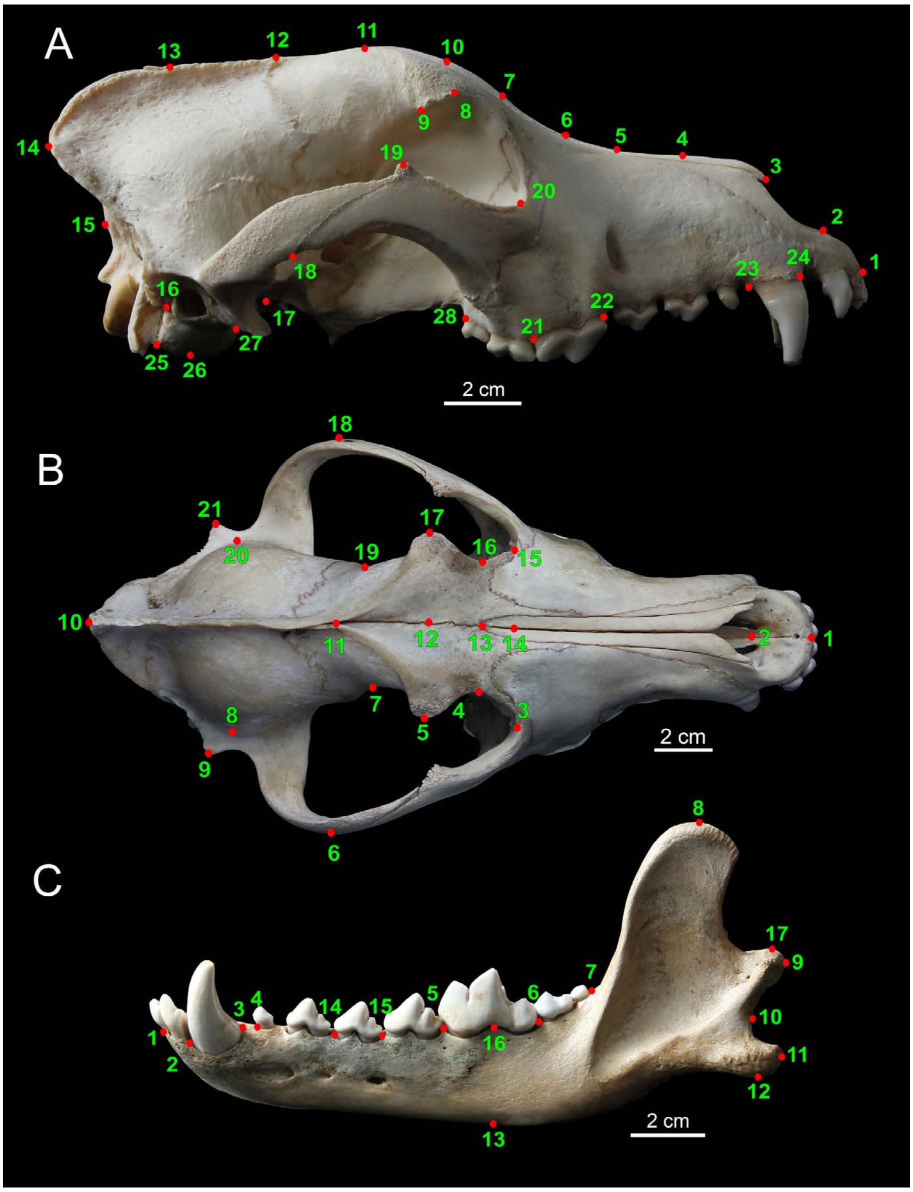

Figure 1. Position of the landmarks in the skull in lateral view (A), in dorsal view (B) and the mandible (C).

Table 2. Position and type of landmarks placed on mandibles. (Definitions according to Driesch 1976: 60–61).

Landmark	Position	Type
1	Infradentale: the most prominent median point at the oral border of the alveoli of the incisors	I
2–3	Alveolus of the canine (oral-aboral points)	I
4	Oral point of the alveolus of the first premolar (P_1)	I
5–6	Alveolus of the carnassial (M_1) (oral-aboral points)	I
7	Aboral point of the third molar (M_3)	I
8	Coronion: the highest point of the coronoid process	I
9	Midpoint of the condylar process	II
10	Point between the condylar process and the angular process	II
11	Midpoint of the angular process	II
12	Basal point of the angular process	II
13	Midpoint at the base of M_1	II
14–15	Alveolus of the third premolar (P_3) (oral-aboral points)	I
16	Basal border of body mandible (below M_1)	II
17	Higher point of the condylar process	II

Table 3. Position and type of landmarks placed on skull (dorsal view). (Definitions according to Driesch 1976: 42–45).

Landmark	Position	Type
1	Prosthion: the medial point of the line joining the most oral points of the premaxillae	I
2	Rhinion: the median point of the line joining the most oral points of the nasals	I
3–15	Lacrimal	I
4–16	Entorbitale: the naso-medial indentation of the orbit that corresponds with the most lateral point of the braincase	I
5–17	Ectorbitale: the most lateral point of the frontal bone on the occipital side of the orbit	I
6–18	Zygion: the most lateral point of the zygomatic arch	I
7–19	Frontostenion: point at the postorbital constriction	I
8–20	Euryon: the most lateral point of the braincase	I
9–21	Otion: the most lateral point of the mastoid region	I
10	Acrocranion: the most aboral point on the vertex of the skull in the median plane	I
11	Point between parietal and frontal bones	I
12	Frontal midpoint between Ectorbitale-Ectorbitale	I
13	Nasion: the median point of the naso-frontal suture	I
14	Point in the nasal bone between oral border of the orbits (median)	I

Table 4. Position and type of landmarks placed on skull (lateral view). (Definitions according to Driesch 1976: 42–45).

Landmark	Position	Type
1	Prosthion: the medial point of the line joining the most oral points of the premaxillae	I
2	Lowest point of the nasal opening (at the clivus), at the height of I^3	III
3	Most anterior point of the nasal bone	III
4–5	Curvature of the nasal bone	II
6	Midpoint of the nasal bone at the level of the infraorbital	II
7	Nasion: the median point of the naso-frontal suture	I
8	Higher point of the orbit	I
9	Ectorbitale: the most lateral point of the frontal bone on the occipital side of the orbit	I
10	Midpoint- in the frontal bone- at the height of the ectorbitale	I
11	Most posterior point of the frontal (before the beginning of the sagital crest)	II
12	Coronal Suture (that separates the parietal bones and the frontal bone)	I
13	Origin of the external sagittal crest	II
14	Acrocranion: the most aboral point on the vertex of the skull in the median plane	I
15	Midpoint of the occipital bone	III
16	Point joining the postorbital process and the tympanic bullae	II
17	Point at the base of the skull (on basioccipital)	III
18	Temporal process of the zygomatic bone	I
19	Frontal process of the zygomatic bone	I
20	Oral point of the orbit	I
21–22	Alveolus of the carnassial (P^4) (aboral and oral point)	I
23–24	Alveolus of the canine (aboral-oral points)	I
25	Aboral point of the tympanic bullae	II
26	Midpoint of the bullae tympanic base	II
27	Oral point of tympanic bullae	II
28	Aboral point of the second molar (M^2)	I

FIGURE 2A

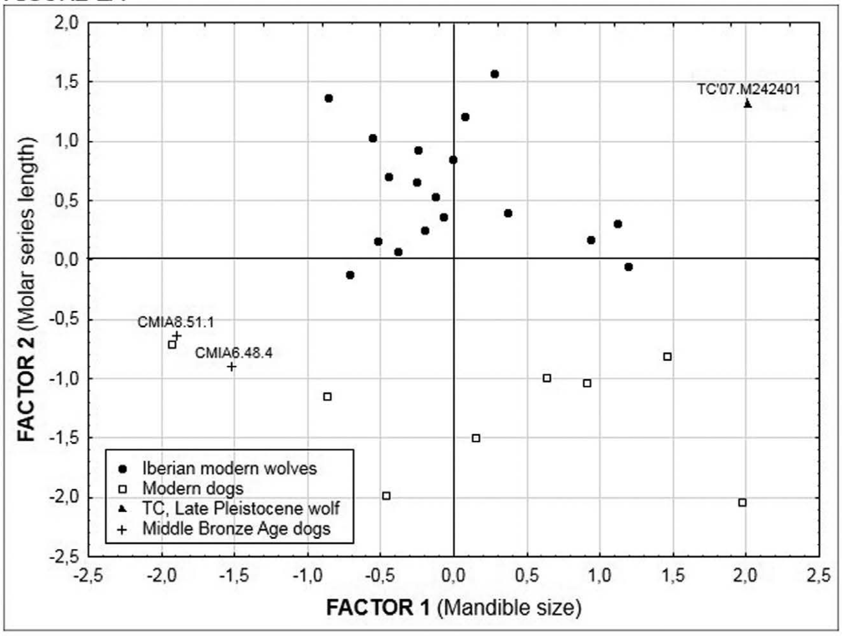

FIGURE 2B

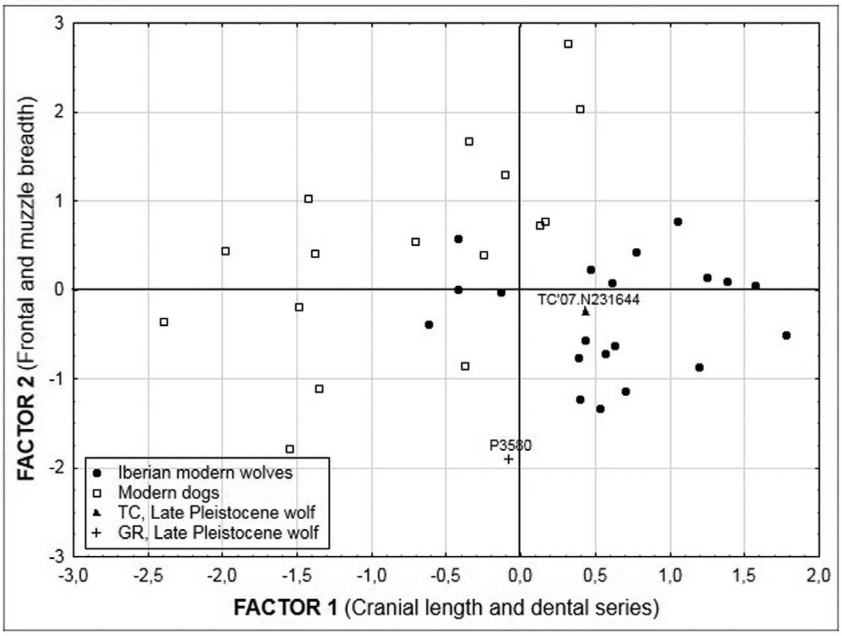

Figure 2. Scatterplots that analyse the mandible variables (2A): Factor 1 (size: length and height of the mandible and dental series length) *vs.* Factor 2 (molar series length) and the skull variables (2B): Factor 1 (cranial length and dental series) *vs.* Factor 2 (frontal and muzzle breadth).

shape reflects a mandible with a greater ascending ramus height, oriented towards the aboral, and a lesser molar series length. The shape of PC4 reflects a more elongated mandible with a lesser mandibular height (lesser ascending ramus height and lesser mandibular body height). In Figure 3A, PC1 shows a wider dispersion of dogs, presenting the more positive values of the PCA and PC4 shows some overlapping of dogs and wolves but also displays differences.

For the skulls we carried out a PCA, analyzing the variation of the shape in dorsal view and lateral view. From the dorsal view PCA, PC1 *vs.* PC3 (PC1: 32.90% and PC3: 13.6%) were selected (Figure 3B) because these are the ones that better express the shape differences. Given the variation of the shape observed in the PC1 wireframe, the final shape reflects a skull with a greater skull length and a less frontal bone breadth. The shape of PC3 reflects a skull with a lesser neurocranium (cranium) and postorbital constriction breadth. In Figure 3B, PC3 discriminates wolves and dogs. From the lateral view PCA, we selected PC1 *vs.* PC2 (Figure 3C), which explain 42.79% of the total variance (25.07% and 17.72% respectively). The shape of PC1 reflects the landmarks located in the snout that show greater variation, as a result of lesser facies height. The shape of PC2 reflects greater variability in the cranium. The PC1 (Figure 3C) suggests two groups

FIGURE 3A

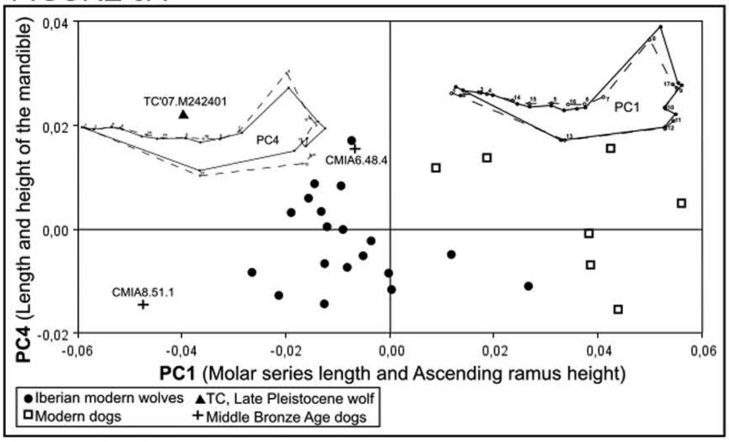

FIGURE 3B

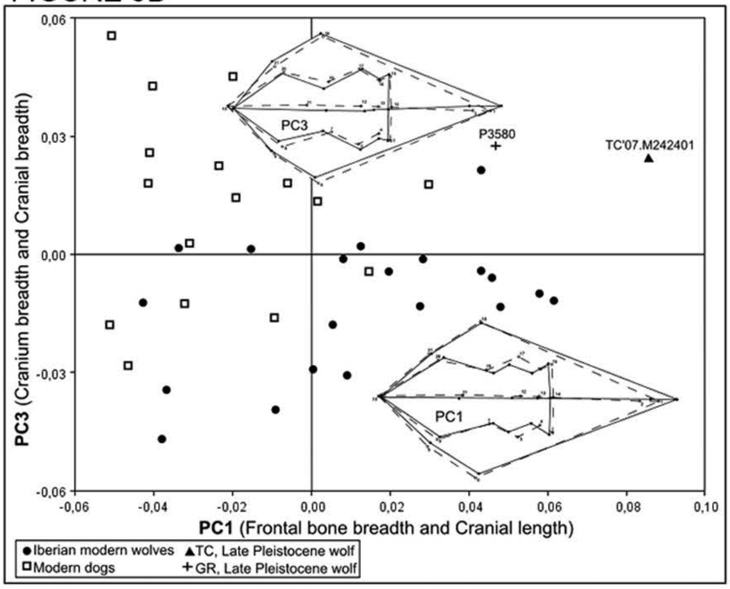

FIGURE 3C

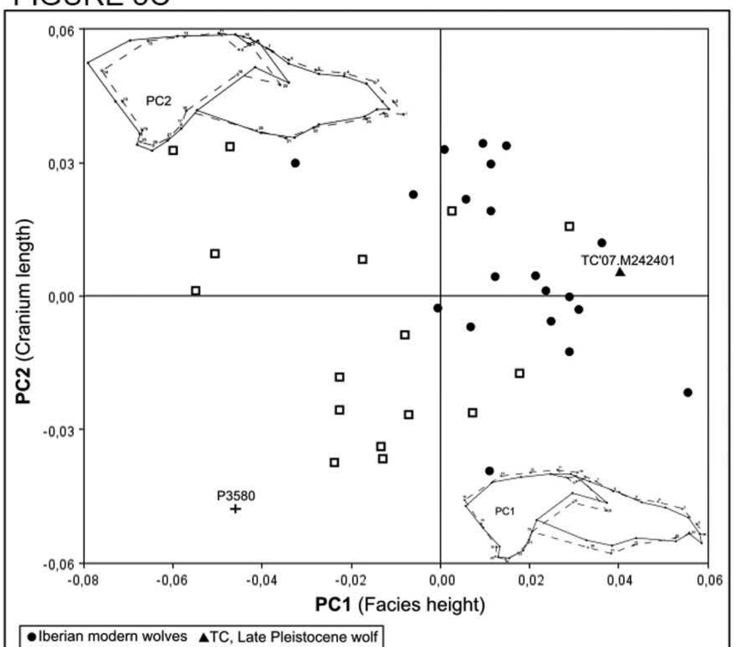

Figure 3. PCA that analyse the mandible landmarks (3A): PC1 (Molar series and ascending ramus height) *vs.* PC4 (Length and height of the mandible), the skull landmarks in dorsal view (3B): PC1 (Frontal bone breadth and Cranial length) *vs.* PC3 (Cranium breadth and Cranial breadth-at postorbital constriction) and the skull landmarks in lateral view (3C): PC1 (Facies height) *vs.* PC2 (Cranium length).

are distinguished. However, in PC2 they overlap.

4 Discussion

First we analysed the shape variations on the modern *Canis* according to the results obtained with the traditional (TM) and geometric morphometry (GM). Then we incorporated the study of fossil specimens to the morphology variation discussion.

4.1 Traditional morphometry

Considering the results obtained in the factorial analysis of the mandibles (Figure 2A), Factor 1 is positively dominated by the general size of the mandible, that is, by length and height of the mandible and dental series length. Therefore, we interpret the positive values of Factor 1 as larger mandibles. In this case, there is no clear separation between dogs and wolves. From the most important variables in Factor 2, we can deduce that molar series length, especially by the size of the carnassial (M_1), is the one with the greatest burden on this factor. In other words, the most positive values (the modern wolves) in this axis are interpreted as individuals with larger molar series.

Analyzing the skulls' graph (Figure 2B), positive values in Factor 1 display a greater cranial length and dental series (snout and facial length). Most modern wolves fall into positive Factor 1 values, indicating that they have an elongated snout. In Factor 2, which expresses frontal and muzzle width, there is greater dispersion of dogs and wolves, but in general, it seems to indicate that dogs have greater frontal and muzzle

Table 5. Mandible features.

Mandible Features	Iberian Modern Wolves	Modern Dogs	TC'07.M242401 (Wolf-TC)	CMIA8.51.1 (Dog-ATP)	CMIA6.48.4 (Dog-ATP)
Mandible size and dental series length	Greater	Lesser	Greater	Lesser	Lesser
Molar series length (carnassial size)	Greater	Lesser	Greater	Lesser	Lesser
Ascending Ramus height	Lesser	Greater	Lesser	Lesser	Medium

Table 6. Skull features.

Skull Features	Iberian Modern Wolves	Modern Dogs	P3580 (Wolf-GR)	TC'07.N231644 (Wolf-TC)
Snout elongation (cranial length)	Greater	Lesser	Medium	Greater
Dental series length	Greater	Lesser	Greater	Greater
Cranium breadth	Greater	Lesser	Greater	Greater
Facies height	Lesser	Greater	Greater	Lesser
Cranial breadth (at postorbital constriction)	Greater	Lesser	Greater	Greater
Frontal bone breadth	Lesser	Greater	Lesser	Lesser
Muzzle breadth	Lesser	Greater	Lesser	Lesser

width. Even the largest wolves, do not show great frontal and muzzle width.

4.2 Geometric morphometry

We analysed the shape variation of the mandibles with PC1 and PC4 (Figure 3A) and their respective wireframe. In PC1, the greatest variation appears in the molar series (especially by a larger size of the carnassial) and the coronoid process. Therefore, the positive values in PC1 are characterised by a greater ascending ramus height (coronoid process oriented towards aboral) and a shorter molar series length, in this case, it corresponds to the modern dogs. In the wireframe of PC4, a shape variation in the length and height of the mandible is observed. Dogs and wolves seem to overlap in this component, showing little differences between them.

We analysed the PCA of the skulls in the dorsal view (Figure 3B). The specimens located with positive values of PC1 are characterised by a greater cranial length (more snout elongation) and lesser frontal bone width. In general, most wolves falling into more positive values of PC1 display those characteristics. Whereas the dogs, located with negative values of PC1, display opposite features. Skulls with positive correlations in PC3, in general, are characterised by a lesser cranium breadth and a lesser cranial breadth (breadth in the postorbital constriction). Therefore, *a priori*, dogs would have a lesser cranium breadth and a lesser cranial breadth since they are placed in more positive values of this component. Whereas the wolves display the opposite traits.

Finally, we analysed the skulls in the side view (Figure 3C). Observing the wireframe, the positive values in PC1 are characterised by representing skulls of specimens with a lesser facies height, in this case, the wolves. With respect to PC2, skulls that have more positive values of this component are characterised by a greater cranium length; however, this component does not clearly discriminate between wolves and dogs.

4.3 Morphological differences between dogs and wolves. A comparison with fossil records from three ancient sites

We have summarised in two tables the analyses of shape reflected through the different methods (TM and GM) regarding the most significant differences between modern wolves and dogs. The results obtained from the mandible analysis (Table 5) suggest that wolves are distinguished by a greater mandible size and a greater dental series length (especially the carnassial) and a lower ascending ramus height. Dog's skulls (Table 6) are distinguished by a lesser degree of snout elongation, a lower dental series length, and a lower width of the cranium. The muzzle and frontal bone of the skulls of the dogs studied are wider.

Finally, we carried out a preliminary study comparing modern canids with two Pleistocene wolves and two Paleolithic dogs. The Pleistocene wolf from Canyars (TC) is larger than the average modern wolves and yields undoubtful wolf craniomandibular features. The skull from Grotta Romanelli (P3580) is classified as a wolf by Sardella *et al.* (2014: 186), who performed a biometric study including several canid remains

(GR), and wolves from the Middle-Late Pleistocene of Apulia, revealing a wide overlap between *C. lupus* and *C. mosbachensis*. However, they concluded that the general morphology and proportions of the wolf from GR fall within the variability of *C. lupus*. Also, they argue that the small size of the GR specimen can be explained as southern wolves are smaller than northern wolves. Sardella *et al.* (2014: 190, 2018: 256) description of GR canids is: slender muzzle, short palatal area, tooth crowding, rounded neurocranium with a gently sloping forehead and low sagittal and nuchal crests, and reduced tympanic bullae. In our results, P3580 is characterised by a greater dental series length, greater cranium, and cranial breadth, in addition to a lesser frontal bone and muzzle breadth. All these features are present in modern wolves. This fossil has an average lengthening of the snout when compared to the rest of the wolf specimens. Furthermore, modern wolves present a smaller facies compared to this specimen.

The mandibles of paleolithic dogs are smaller and morphologically yield a lesser dental series size (especially a lesser carnassial size), than modern dogs. The paleolithic dog from Portalón (CMIA6.48.4) shows a slight 'crowding of the premolars', a feature that differentiates domestic dogs (Germonpré *et al.* 2015: 276). The chronology of this site (Middle Bronze Age) supports this evidence.

5 Conclusions

This work analyses the distinctive features observed in skulls and mandibles from wolves and dogs, by combining two morphometry methods (traditional and geometric) reinforcing the efficiency of the analyses. Both methods are useful for clarifying morphological differences between the two canids, however applying geometric morphometry, more complex changes can be observed. The results obtained from the mandibles analysed suggest that wolves are distinguished by a greater size of the mandible and a greater length of the dental series (specially the carnassial) and lower ascending ramus height. The dogs' skulls are distinguished by a lesser degree of snout elongation, lower dental series length and lower width of the cranium. Both snout and forehead of the dogs' sample studied, are wider.

The sample of modern wolves needs to be enlarged for a better knowledge of its variability. Although in this study we have selected the most complete fossil material available, fossils are usually incompletely preserved. The fossil collections we are studying (Portalón, Canyars, among other Pleistocene and Holocene sites) include an important number of fragmentary material that, nevertheless preserve important information on the undamaged regions. We will focus our research on the analysis of fossil remains of *Canis lupus* (especially dogs) which are damaged from excavations (sometimes consumed by humans) and this excludes them from studies, as they miss a complete set of variables to perform statistical analyses. We propose to focus the morphometric study on informative regions of mandible and maxilla (more likely to survive) that, as derived from the current study, have demonstrated to preserve valuable information to discriminate between dogs and wolves.

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