

Obliteration study of lambdatic and obelionic region sutures in ruminant, carnivores and hominids

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ABSTRACT

The morphology of Orce cranial fragment VM-0 is contrasted with the fronto-parietal region in artiodactyls, and the obelionic region in carnivores and primates including hominids. Sutural development at obelion is compared in those taxa throughout the growth period up to the onset of sutural obliteration, and ontogenetic differences between non-primates and primates lead us to conclude that the configuration in VM-0 more resembles that found in hominids than in artiodactyls or carnivores. Moreover, cranial capacity for VM-0 is estimated at >470cm³, comparable to Plio-Pleistocene hominids, but greater than in young equids.

Key words: Skull, Orce, Lower Pleistocene.

RESUMEN

La morfología del fragmento craneal de Orce (VM-0) se contrasta con la región fronto-parietal de los artiodáctilos y con la región obélica de los carnívoros y primates incluyendo los homínidos. Se compara en estos taxones, el desarrollo de las suturas en esta región a lo largo del periodo de crecimiento hasta que ocurre la obliteración de las mismas. Las diferencias ontogenéticas entre no primates y primates nos permiten concluir que la anatomía de VM-0 es más próxima a los homínidos que a la de los artiodáctilos y carnívoros. Se estima que la capacidad craneana de VM-0 tiene que ser > 470 cm³, comparable a la de los homínidos del Plio-Pleistoceno y mayor que la de los équidos juveniles.

Palabras clave: Cráneo, Orce, Pleistoceno inferior.

Introduction

Orce cranial fragment VM-0 was found in 1983 at the Lower Pleistocene site of Venta Micena and classified as human (Gibert, Agustí & Moyà, 1983). However, in 1987 Agustí and Moyà revised their view, reassigning it to a juvenile equid (in papers which more reflect opinion than new findings), both because of an allegedly “coronal” suture (notwithstanding its distal situation in the fragment) and its small internal occipital crest (Agusti J., Moyà 1987; Moyà J., Agustí, 1989; Moyà & Köhler, 1997). However, any “coronal” attribution of the suture is readily rebutted by anatomical arguments and, anyway, small internal occipital crests have been described in human skulls (Campillo, 1989, 1998, 1999, 2002, 2003;

Campillo & Barceló, 1989; Campillo D., Gibert, 1996; Campillo *et al.*, 2003; García Olivares *et al.*, 1989, Gibert, 1986, 2004, 2005; Gibert *et al.*, 1983, 1989a, b, c, 1992a, b; 1993, 1994a, b, 1995, 1998a, b, 1999a, b, c, d; 2001; 2002, 2003; 2005) (fig. 3).

Moreover, fossil protein analyses of bones from Venta Micena separate VM-0 and other hominid specimens from equid and bovid remains (Borja, 1999; Borja *et al.*, 1992, 1995, 1997; García-Olivares *et al.*, 1989; Lowenstein, 1995; Lowenstein *et al.*, 1999, Torres *et al.*, 2002). In particular, Borja *et al.* (1997) published the reactivity of bison anti-albumin antiserum with VM-0 which gave negative results, whereas the same antiserum gave positive results when tested on two bovids from Venta Micena (VM-01653 and VM-01577) and anatomical comparisons

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Fig. 1.—Skull anatomy of *Equus burcheli*, *Homo sapiens* and *Panthera leo*. 1) *Equus burcheli* (7 months). 2) *Homo sapiens* (1 month). 3) *Panthera leo* (7 months). P, parietals; O, occipital; L, lambda; B, bregma.

with artiodactyls and perissodactyls exclude the likelihood of VM-0 being a ruminant (Gibert 1986; Gibert *et al.*, 1989a, c, 2002a, b). Neither anatomical nor immunological studies demonstrate that VM-0 should be assigned to equids or bovids.

New anatomical research presented here is based on changes observed at the obelionic region during growth in humans and other large mammals and differential growth here during postnatal ontogenesis is found to be a distinctively human characteristic. Furthermore, cranial capacity in VM-0 is demonstrably closer to human rather than other mammalian values.

Materials, methods and theoretical considerations

Sources and inventory numbers of juvenile, infant and newborn specimens principally are given in table 1. Biological age is based on museum data-bases, supplemented in some cases by our observations on dental eruption. Cranial capacity was determined directly using small gramineae seeds whose volume was subsequently measured in a graduated cylinder. “Excel” was used to draw up graphs. Non-human specimens (table 1) are from Barcelona’s Zoology Museum (MZB), the Autonomous University of Barcelona’s (UAB), Veterinary Faculty (not included in table 1), the Laboratory of Comparative Anatomy in Paris (LAP), the University of Hamburg (UH). Human remains are from the Autonomous University of Barcelona’s Anthropology Unit. We gratefully acknowledge data provided by the Conservator of Barcelona’s Zoological, Dr. Filella. Tomographs were carried out by Dr. X. Roura of the Autonomous University of Barcelona’s Veterinary Faculty.

VM-0 has two sutures that come together at a point, as well as very wide longitudinal and transverse arcs (figs. 1, 2, 4). Broad-

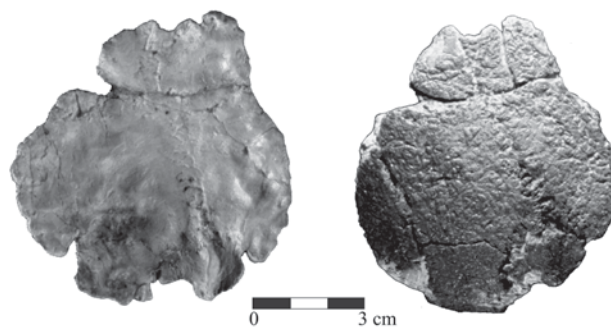


Fig. 2.—VM-0. left, internal face. Right, external face.

ly speaking, similar features are seen in the bregmatic and fronto-parietal region of artiodactyl skulls and the obelionic region of hominid, carnivore and equid skulls. With regard to the former, if the point where the VM-0 sutures come together is presumed to be bregma, then VM-0 has longitudinal and transverse arcs that put it in a category on its own. With regard to obelionic comparisons, matters are complicated by the need to take into consideration, not only the biological age at which obliteration occurs in lambdoid and occipital sutures (and, for contrast, coronal sutures), but also, both increases in cranial capacity during ontogenesis, and anatomical changes in the external surface at obelion during that period, in taxa such as equids, bovids, cervids, carnivores, and lagre primates (including hominids).

Anatomical description of VM-0

The cranial fragment VM-0 (fig. 1) is a small portion of a cranial vault, with a maximum coronal width of 76 mm and sagittal length of 80 mm, that includes lambda and comprises two posterior fragments of the right and left parietal bones (the right fragment being almost twice the size of the left), part of the sagittal suture (visible on both external and internal bony tables), and the apex of the occipital squame (separated from the parietal fragments by parts of clearly recognizable right and left lambdoid sutures). The surface of the outer table is somewhat eroded, like many other fossils from Venta Micena, and a few fracture lines are visible, though there are no signs of bony regeneration. VM-0 is not deformed (except perhaps beyond the most anterior fracture, although any displacement there is of trivial significance) (fig. 3). The specimen provides enough anatomical elements to enable reliable conclusions to be drawn when compared to other mammals. In fact, none of the studies of Agustí & Moyà (1987), Moyà & Agustí (1989), Moyà & Köhler (1997) or Martínez-Navarro (2002) claim that the specimen is deformed.

Table 1.—Sources and inventory numbers of juvenile, infant and newborn specimens principally

Number	Family	Spece	Sex and Age
MZB, 94-0714	Bovidae	<i>Ammotragus lervi</i>	female, young
MZB, 91-0109	Bovidae	<i>Antilope cervicapra</i>	male, juvenile
MZB, 47-3	Bovidae	<i>Antilope cervica</i>	young
MZB, 94-0667	Bovidae	<i>Bison bison</i>	juvenile
MZB, 96-0966	Bovidae	<i>Bison bonasus</i>	male, young
MZB, 94-1185	Bovidae	<i>Boselaphus tragocamelu</i>	young
MZB, 94-0477	Bovidae	<i>Bos taurus</i>	young
MZB, 94-1065	Bovidae	<i>Bubalus bubalis</i>	female, young
MZB, 91-0120	Bovidae	<i>Capra pyrenaica</i>	juvenile
MZB, 93-0003	Bovidae	<i>Hipotragus niger</i>	female, young
MZB, 93-0004	Bovidae	<i>Hipotragus niger</i>	female, young
MZB, 92-0232	Bovidae	<i>Kobus ellipsyprimus</i>	juvenile
MZB, 300-1	Bovidae	<i>Kobus defessa</i>	adult
MZB, 31-0286	Bovidae	<i>Ovis musimon</i>	juvenile
MZB, 94-0433	Bovidae	<i>Ovis musimon</i>	young
MZB, 96-0484	Bovidae	<i>Ovis musimon</i>	juvenile
MZB, 95-0346	Bovidae	<i>Ovis musimon</i>	male, young
MZB, 98-1330	Bovidae	<i>Rupicapra rupicapra</i>	juvenile
MZB, 99-0880	Bovidae	<i>Rupicapra rupicapra</i>	male, young
MZB, 94-1256	Bovidae	<i>Tragelaphus orix</i>	male, young
MZB, 94-0424	Bovidae	<i>Tragelaphus spekei</i>	male, young
MZB, 92-0094	Bovidae	<i>Tragelaphus strepsiceros</i>	female, young
MZB, 95-0400	Cervidae	<i>Capreolus capreolus</i>	female, young
MZB, 96-0691	Cervidae	<i>Capreolus capreolus</i>	new-born
MZB, 96-0690	Cervidae	<i>Capreolus capreolus</i>	male, new-born
MZB, 95-0601	Cervidae	<i>Cervus dama</i>	female, young
MZB, 94-0899	Cervidae	<i>Cervus elaphus</i>	male, young
MZB, 94-0995	Cervidae	<i>Cervus elaphus</i>	male, young
MZB, 94-1061	Cervidae	<i>Cervus elaphus</i>	female, young
MZB, 94-1062	Cervidae	<i>Elaphurus davidianus</i>	young
MZB, 94-1064	Cervidae	<i>Elaphurus davidianus</i>	female, young
MZB, 94-1366	Cervidae	<i>Elaphurus davidianus</i>	male, young
MZB, 6-4	Cervidae	<i>Elaphurus davidianus</i>	young
MZB, 94-1154	Cervidae	<i>Elaphurus davidianus</i>	young
MZB, 94-0765	Felidae	<i>Acinonyx jubatus</i>	male, young
MZB, 94-1176	Felidae	<i>Felis concolor</i>	young
MZB, 94-0762	Felidae	<i>Lynx canadiensis</i>	female, young
MZB, 94-1206	Felidae	<i>Lynx lynx</i>	female, young
MZB, 82-7033	Felidae	<i>Panthera leo</i>	new-born
MZB, 94-0649	Felidae	<i>Panthera leo</i>	juvenile
MZB, 92-0005	Felidae	<i>Panthera tigris</i>	juvenile
MZB, 82-6994	Felidae	<i>Panthera tigris</i>	juvenile
MZB, 82-0388b	Felidae	<i>Panthera tigris</i>	juvenile
MZB, 97-0294	Felidae	<i>Panthera tigris</i>	female, young
MZB, 91-0169	Felidae	<i>Panthera uncia</i>	female, young
MZB, 99-1097	Felidae	<i>Panthera uncia</i>	juvenile
MZB, 92-0096	Ursidae	<i>Ursus arctos</i>	young
MZB, 82-0388a	Ursidae	<i>Ursus maritimus</i>	juvenile
UH, 7476	Equidae	<i>Equus sp.</i>	young
UH, 5444	Equidae	<i>Equus hemionus onager</i>	young
UH, 6933	Equidae	<i>Equus przewalskii</i>	male, juvenile
LAP, 313	Equidae	<i>Equus sp.</i>	young
LAP, 72	Equidae	<i>Equus sp.</i>	young
MZB, 95-1160	Equidae	<i>Equus burchelli</i>	young
MZB, 95-0410	Equidae	<i>Equus burchelli</i>	young
MZB, 94-1229	Equidae	<i>Equus burchelli</i>	young
MZB, 94-1159	Equidae	<i>Equus burchelli</i>	young
MZB, 94-1363	Cercopithecidae	<i>Cercocebus torquatus</i>	male, young
MZB, 98-0014	Cercopithecidae	<i>Colobus guereza</i>	male, young
MZB, 91-0316	Cercopithecidae	<i>Papio leucophaeus</i>	female, young
MZB, 96-0411	Cercopithecidae	<i>Papio sphinx</i>	female, young

Table 1.—Sources and inventory numbers of juvenile, infant and newborn specimens principally (*continuación*)

Number	Family	Specie	Sex and Age
MZB, 94-0642	Pongidae	<i>Gorilla gorilla</i>	male, juvenile
MZB, 82-0544	Pongidae	<i>Gorilla gorilla</i>	young
MZB, 82-0547	Pongidae	<i>Gorilla gorilla</i>	young
MZB, 94-0358	Pongidae	<i>Pongo pygmaeus</i>	young
MZB, 84-9394	Hominidae	<i>Homo sapiens sapiens</i>	new-born
UAB, N.B.I.	Hominidae	<i>Homo sapiens sapiens</i>	juvenile
UAB, M2	Hominidae	<i>Homo sapiens sapiens</i>	juvenile
UAB, SA 850	Hominidae	<i>Homo sapiens sapiens</i>	juvenile
UAB, SA 861	Hominidae	<i>Homo sapiens sapiens</i>	juvenile
UAB, SA 863	Hominidae	<i>Homo sapiens sapiens</i>	juvenile
UAB, SA 864	Hominidae	<i>Homo sapiens sapiens</i>	juvenile
UAB, SA 865	Hominidae	<i>Homo sapiens sapiens</i>	juvenile
UAB, SA 866	Hominidae	<i>Homo sapiens sapiens</i>	juvenile
UAB, SA 868	Hominidae	<i>Homo sapiens sapiens</i>	juvenile
UAB, TG3	Hominidae	<i>Homo sapiens sapiens</i>	juvenile
UAB, Binidelfa	Hominidae	<i>Homo sapiens sapiens</i>	juvenile

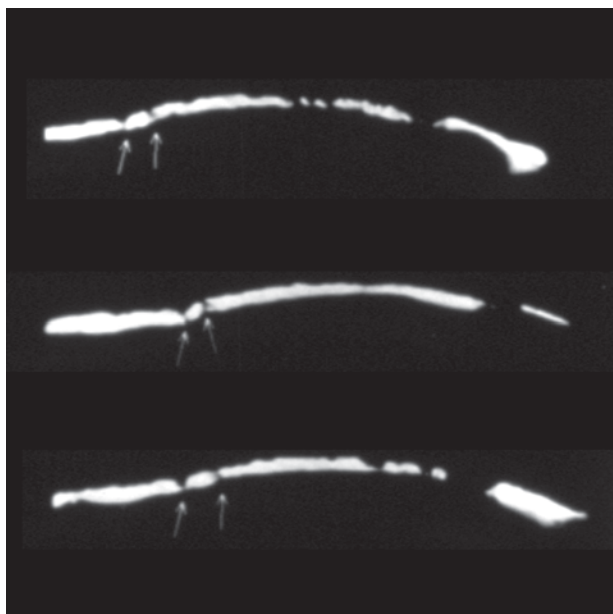


Fig. 3.—Longitudinal tomography of VM-0 into lambda and two millimeter, left and right. Broken in diastal portion is interpreted by Moyá and Agustí as coronal suture.

Ruminant comparisons

Morphology of the external aspect of the parietal and bregmatic regions of the ruminant

Male bovid horns and cervid antlers are associated with fusion of the parietal bones such that obliteration of the sagittal suture takes place at birth or soon afterwards (*e.g.* immature type specimens of *Elaphurus davidianus* MZB 94-1062, *Rupicapra rupicapra*

MZB 98-1330, *Bison bison* MZB 94-0667 and *Bos taurus* MZB 94-0477); obliteration of the sagittal suture had commenced proximally and terminated distally in a young female barely a few months old of *Rupicapra rupicapra* (MZB 98-1330), and in all cases studied commencement of obliteration in coronal and lambdoid sutures followed commencement of obliteration in the sagittal suture. A more or less developed crest appears by only a few months of age in cervid and bovid parietals (fig. 4).

The complexity of the indentations of the coronal and interfrontal sutures is variable and the angle that these form with reference to bregma also varies, between 85 and 145 degrees (Gibert *et al.*, 1989a, table 5). In terms of its complexity, the interfrontal suture can be divided into a shorter part (less than half its total length) which offers a complexity similar to that of the coronal suture (fig. 1; *cf.* Gibert *et al.*, 1989a, figs. 57 and 58), and a longer part which is straight. Following attainment of the juvenile stage in cervids the interfrontal suture is aligned along a visible crest (fig. 4). Supraorbital foramina lie medially on the frontal bones and give rise to anteriorly-directed supraorbital grooves. Medial to the supraorbital foramina the frontal bones lose their lateral convexity and become flattened in the coronal plane, tending to become depressed where the complexity of the interfrontal suture gives way to straightness (fig. 4). At bregma the frontal coronal or transverse arc is strongly curved, though between 5 and 10 mm from bregma it changes its form such that curvature is maintained only in the midline and on either side of the interfrontal suture, undergoing an inflexion that renders it almost flat



Fig. 4.—Skull anatomy of african bovidae female (*Boselaphus tragocamelos*, MZB 94-0389) left, and cervidae female (*Cervus elaphurus davidianus* MZB 94-1062) right. 1) Foramina supraorbital. 2) Bregma. 3) Coronal suture. 4) Interfrontal suture; F, Frontal bones; S, Supraorbital grooves; P, Parietal bones; O, Zygomatic bone.

towards the extremes (figs. 1, 4). The transverse curvature near bregma is inflected at the level of cervid and bovid supraorbital foramina.

Morphology of the internal table at the bregmatic region in bovids and cervids

Sutures on the internal table of bovid and cervid skulls become obliterated near bregma before they do so laterally, and their pattern tends to become simpler. Bovid frontals display well-formed sinuses throughout the bone, even in infants, most particularly in horned genera such as *Bos*, *Bubalus*, *Bison* and *Tragelaphus*. In juveniles and adults of *Kobus* and *Boselaphus* (whose females lack horns) major sinuses lie posterior to the orbital foramina (figs. 1, 4). Juvenile and adult cervid frontals have sinuses in the same region as bovids. In bovids grooves are visible on the internal table beneath the interfrontal suture (fig. 4) whilst in cervids there is marked thickening here in both juveniles and adults.

Comparison with modern artiodactyls

The bregmatic region is thick in modern artiodactyls skulls, including infant specimens (table 2). The thickness of VM-0 is commensurable only with infant cervids, whilst being differentiated from them by VM-0's larger dimensions (fig. 5). Any similarity

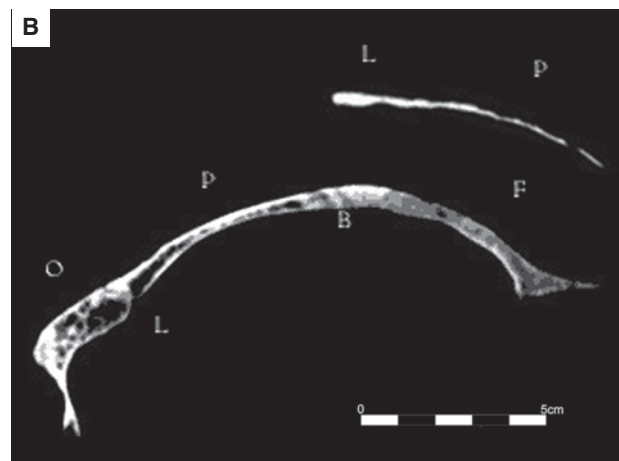
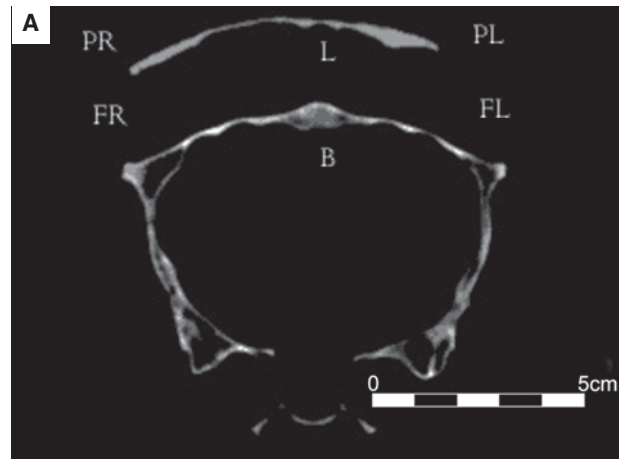


Fig. 5.—A) Transversal section of VM-0 (superior) and juvenile cervidae (*Elaphurus davidianus* MZB 94-1154). B) Longitudinal section juvenile cervidae (*Elaphurus davidianus* MZB 94-1154. L, Lambda; PR, Right parietal bone; PL, Left parietal bone; SS, Sagittal groove; FR, Right frontal bone; FL, Left frontal bone; B, Bregma.

between the external table of VM-0 and artiodactyls is confined to the form of coronal and interfrontal sutures, which might otherwise be confused with VM-0's lambdoid and sagittal sutures (*cf.* Gibert *et al.*, 1989a, b). As can readily be seen from figures 1 and 5,6 the morphology of VM-0 is not comparable with the bregmatic region of bovids or cervids because their frontal regions, in both juvenile and adult specimens, exhibit significant alterations of curvature at the level of the supraorbital foramina, from 5 to 10 mm away from bregma in the coronal plane. Owing to presence of sinuses in infant, juvenile and adult specimens of *Bos*, *Bubalus* and *Bison*, VM-0 cannot be compared to those genera, nor probably with their fossil ancestors either. Neither can VM-0 be compared with bovids such as *Bosela-*

Table 2.—Skull thickness of different specimens and its sex and age

Number	Family	Spece	Sex and Age	Density	
				A	B
MZB, 94-1065	Bovidae	<i>Bubalus bubalis</i>	female, young	15-17	16
MZB, 2000-0063	Bovidae	<i>Bubalus depressicornis</i>	male, adult	10-12	11
MZB, 2000-0636	Bovidae	<i>Bubalus depressicornis</i>	female, adult	7-12	9
MZB, 2001-0009	Bovidae	<i>Bubalus depressicornis</i>	female, young	5-12	5
MZB, 92-0094	Bovidae	<i>Tragelaphus strepsiceros</i>	female, young	5-6	5
MZB, 94-0667	Bovidae	<i>Bison bison</i>	juvenile	1-19	18
MZB, 94-1364	Cervidae	<i>Elaphurus davidianus</i>	adult	8-12	10
MZB, 94-1061	Cervidae	<i>Elaphurus davidianus</i>	female, young	4-6	6
MZB, 94-1064	Cervidae	<i>Elaphurus davidianus</i>	female, young	5-7	5
U H, 6933	Equidae	<i>Equus precevalski</i>	juvenile	1-6	
U H, 5444	Equidae	<i>Equus hemionus</i>	juvenile	1-5	
MZB, 94-0649	Felidae	<i>Pantera leo</i>	juvenile	2-5	

A) Maximum-minimum thickness obelionic region. B) Thickness at bregma. The thickness is expressed in mm.

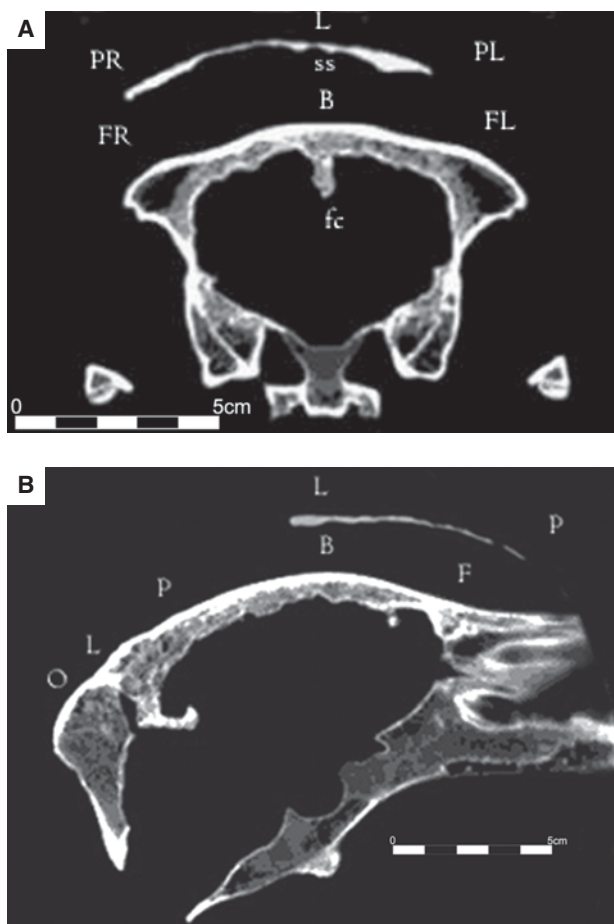


Fig. 6.—A) Transversal section of VM-0 (superior) and african bovidae female *Boselaphus tragocamelos*, MZB 94-0389. L, Lambda; PR, Right parietal bone; PL, Left parietal bone; SS, Sagittal groove; FR, Right frontal bone; FL, Left frontal bone; B, Bregma; fc, Falx cerebri. B) Longitudinal section of VM-0 (superior) and african bovidae female *Boselaphus tragocamelos*, MZB.

phus, *Kobus*, or similar genera, nor with cervids, which exhibit sinuses behind orbital foramina in juvenile and adult specimens (figs. 1, 4, 5, 6).

The anatomy of the external table of artiodactyls frontal bones is markedly different from that presented by VM-0, as is demonstrated by anatomical comparisons using computerized tomography. The presence of sinuses in the frontals of infants, juveniles and adults of some bovids, and in juvenile and adult cervids, excludes VM-0 from these groups.

The thickness of the bregmatic region in bovids, even in infant specimens, is much greater than that of VM-0. Infant cervids exhibit a similar thickness to that of VM-0, but their transverse (coronal) and longitudinal (sagittal) curvatures are markedly different, as are the differences in size

Age of sutural obliteration at obelion in carnivores, equides and primates

Carnivores and equides

Tickness of obelic region in young of carnivores and equides is similar of VM-0 (table 2).The obelionic region is elongated and rounded in infants and juveniles of both groups, and quite different from hominids, as may be seen by comparison a new-born *Homo sapiens sapiens* with juvenile *Equus burchelli* and *Panthera leo* specimens (fig. 1). We have published detailed anatomical comparison of the obelionic region in equids, hominids and VM-0 (Gibert *et al.*, 1989a-c, 1995, 1998a, 1999b, 2002) (fig. 7) and we confine our

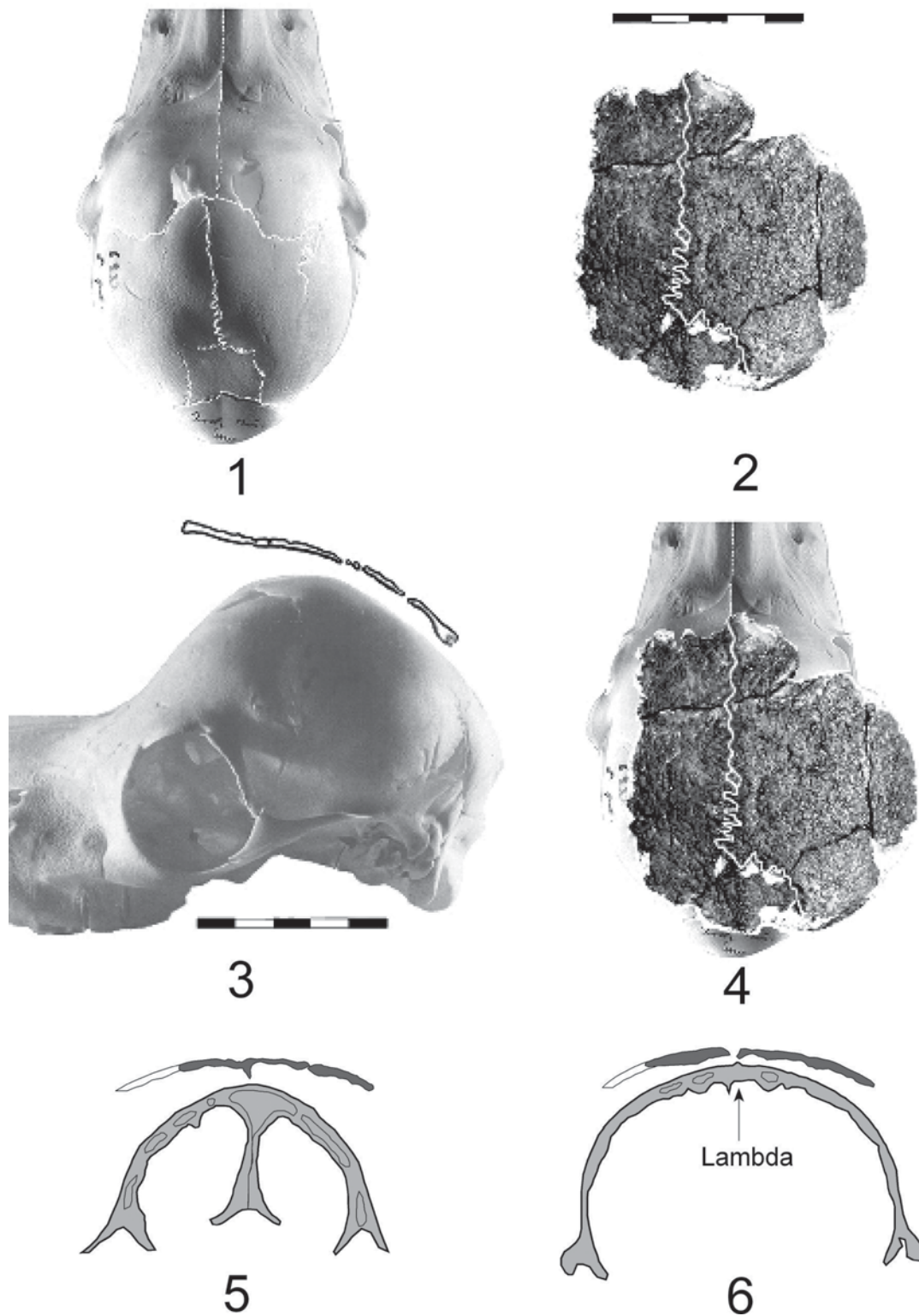


Fig. 7.—Comparison between juvenile equus skull and the skull fragment of Venta Micena in oclusal view (1-4) and in profile (5-6). 1) Juvenile Equus skull (0-3 months). 2) Skull fragment VM-0. 3 and 4) Longitudinal and oclusal superposition of the skull fragment VM-0 on the juvenile Equus skull (0-3 month). 5 and 6) Transversal superposition of the VM-0 fragment on the juvenile Equus skull (7 month). (5, Section in lambda; 6, Section 5 mm behind lambda).

selves here to sutural obliteration at obelion. In carnivores sutural sagittal obliteration begins at around 7-8 months. At 5 months it was still not obliterated in *Ursus arctos* (MZB 92-0096), *Panthera leo* (MZB 94-0649) and *P. uncia* (MZB91-0197), whereas at 7-8 months it had begun in *P. tigris* (MZB 97-0294) together with sagittal crest formation. Occipital crests are present from birth in carnivores (thus, *P. tigris* MZB 82-0388).

In equids sagittal sutural obliteration begins at around 8-9 months. It was still not obliterated on the external cranial surface in 2-to-5-month-old specimens (UH 7476, 5444, 6933), but a 9-month-old specimen of *Equus burchelli* (MZB 94-1160) shows obliteration of the middle part of the suture and onset of external sagittal crest formation. As in carnivores, coronal sutural obliteration follows that of the sagittal suture. In some specimens (e.g. MZB 94-1160) sagittal sutural obliteration begins earlier on the inner than on the outer surface of the skull. At obelion, the order of closure in equids begins with the sagittal suture, followed by the interfrontal suture, then by the coronal sutures, and finally the lambdoid sutures. In carnivores, sagittal sutural closure occurs first, but we have not been able to determine the subsequent sequence.

Primates

In Primates, unlike other mammals, sagittal sutural closure takes place very late. We have never seen it obliterated in any specimens designated as "young" in museum catalogues. It was still open in a 5-year-old *Colobus gerezza* (MZB 98-0014), an allegedly "young" *Gorilla gorilla* (MZB 82-547) with a cranial capacity of 400 cm³ well on the way to that of adults (475 cm³), and similarly "young" specimens of *Colobus torquatus* (MZB 94-1363), *Mandrillus sphinx* (MZB 96-0411) and *Papio leucocephalus* (MZB 91-0316). Nowadays, in human beings sagittal sutural closure can begin at age 13 even though cerebral growth may continue till age 20.

Increase in brain volume during growth

Primates differ, then, from bovids, cervids, carnivores and equids, in all of which sagittal sutural obliteration has begun by 7-9 months after birth. Sutural closure sets severe limits to brain growth, whereas retardation of closure may allow it to con-

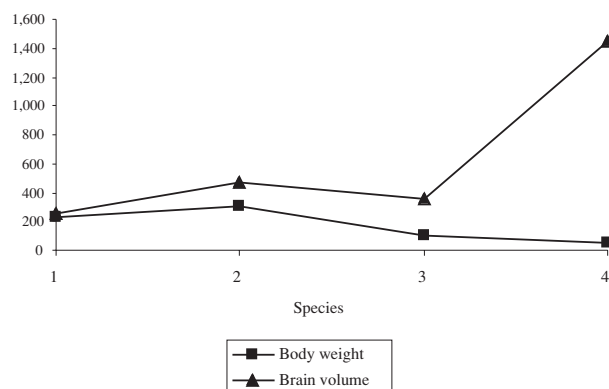


Fig. 8.—Comparison of body weight (kg) with brain volume (cm³) in adults of different taxa. 1) *P. Tigris*. 2) *E. Burchelli*. 3) *G. Gorilla*. 4) *H. sapiens sapiens*.

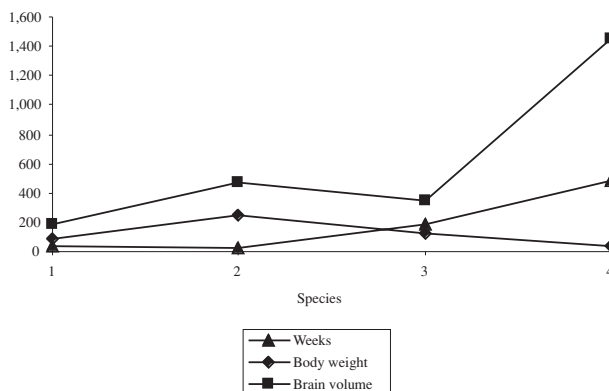


Fig. 9.—Comparison of body weight (kg) with brain volume (cm³) at the time of sagittal sutural closure in adults of different taxa (expressed in weeks after birth). 1) *P. Tigris*. 2) *E. Burchelli*. 3) *G. Gorilla*. 4) *H. sapiens sapiens*.

tinue growing. There is a fundamental difference here between non-Primates and Primates, and between non-human primates and humans. In non-primates mammals brain mass is proportional to body mass, whereas in hominids there is an allometrical relation. Comparison of body weight (kg) with brain volume (cm³) in adults of *P. tigris*, *E. burchelli*, *G. gorilla* and *H. sapiens sapiens* (fig. 8) shows the well-known disproportionate size, in our species, of the brain in relation to the body. When we consider those relationships at the time of sagittal sutural closure (fig. 9), the difference is particularly marked; thus whereas the suture closes earliest in *P. tigris*, followed a few weeks later by the heavier *E. burchelli*, in Primates it is much delayed, and

most particularly so in our species of course. If we now consider monthly increments in body mass and brain volume, it is noteworthy that whereas both have ceased by 18-20 months in the first two species (fig. 10), spectacular differences are seen in human beings (figs. 11, 12) because the allometrical increase of brain size with regard to body mass separates our growth curve from the growth curves of *P. tigris* and *E. burchelli* – not to mention the much longer time over which our brain continues to grow, of course. Representing the three values as a percentage index for each of the three taxa over their ontogenetic growth, the same differences stand out that appeared in the previous graphs: exponential growth during early months becomes asymptotic afterwards, whether in *P. tigris* (fig. 13a) or *E. burchelli* (fig. 13b), whereas continuous values are seen in *H. sapiens sapiens* (fig. 13c). In short, the time elapsed between birth and sagittal sutural closure is proportional to brain size, and the longer the time, the greater is its size.

The VM-0 sagittal suture

There is general agreement in the published literature that VM-0 corresponds to an obelionic region of a mammalian skull in which the sagittal suture has not undergone obliteration (Agustí & Moyà, 1987; Campillo, 1989, 1999; Gibert, 1986; Campillo & Gibert, 1996; Gibert *et al.*, 1983, 1989a-c, 1998a, 1999a, b; Moyà & Agustí, 1989). From considerations explained above, comparison is admissible only with bovids and cervids under 2 months old or carnivores and equids under 9 months old. However, comparison with carnivores and equids shows VM-0 to have greater dimensions and quite different arcs around obelion (figs. 1, 7); corroborating earlier comparisons with equids: Gibert *et al.*, 1998a, b, 1999b). The comparisons highlight a brain size for VM-0 well in excess of the 470 cm³ of 9-month-old equids when their sagittal sutural closure begins or an adult equid value of 500 cm³. Taking into account infantile features and thinness of VM-0 (Campillo, 1989; Gibert *et al.*, 1989a-c) it can be deduced that growth was incomplete. Notwithstanding allegations to the contrary (Agutí & Moyà, 1987, Moyà & Agustí, 1989), VM-0 does not present a partly closed coronal suture; indeed, were there to have been a partly closed equid coronal suture the sagittal suture would have been utterly and completely obliterated, which is obviously not the case!

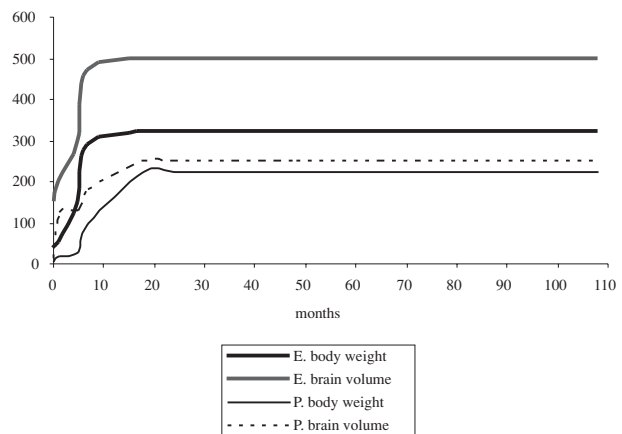


Fig. 10.—Comparison of body weight (kg) and brain volume (cm³) with months after birth between *P. Tigris* and *E. Burchelli*.

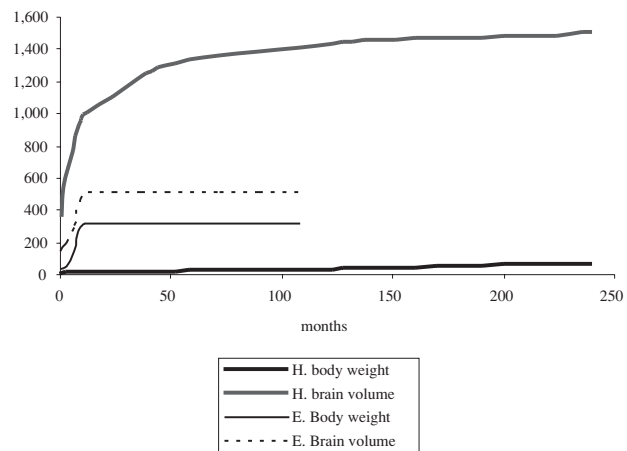


Fig. 11.—Comparison of body weight (kg) and brain volume (cm³) with months after birth between *E. Burchelli* and *H. sapiens sapiens*.

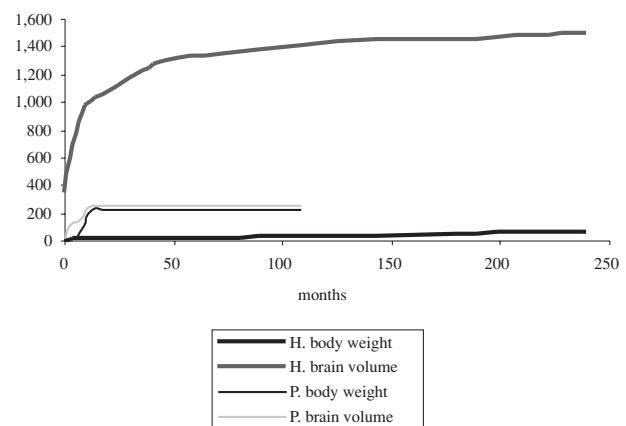
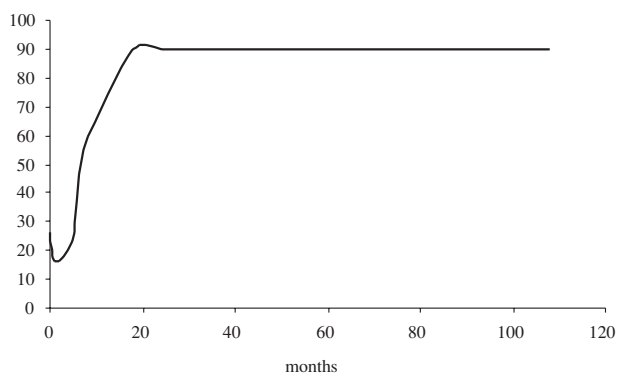
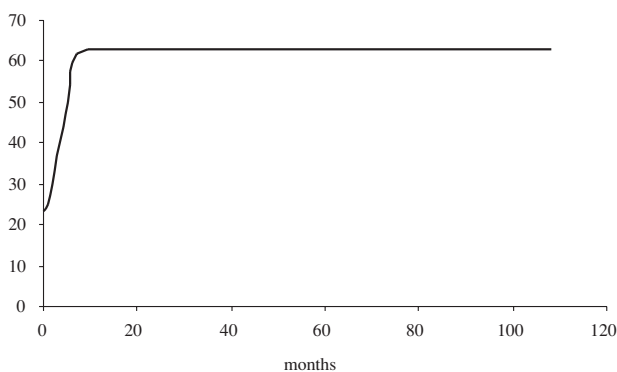


Fig. 12.—Comparison of body weight (Kg) and brain volume (cm³) with months after birth between *H. sapiens sapiens* and *P. Tigris*.



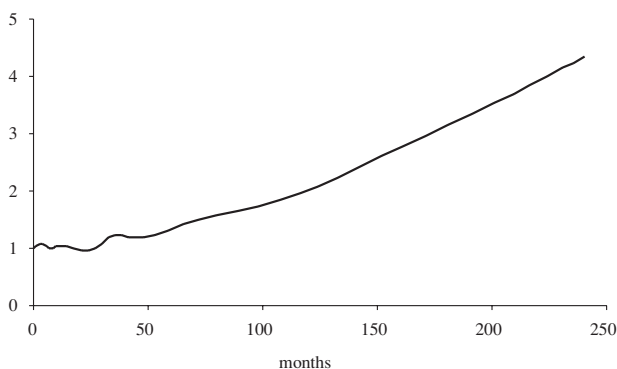
A

— Body weight/Brain
volume x 100



B

— Body weight/Brain
volume x 100



C

— Body weight/Brain
volume x 100

Fig. 13.—Representation of the three previous values as a percentage index (body weight/brain volume x 100) for each of the three taxa over their ontogenetic growth: A) *P. tigris*, B) *E. burchelli*, C) *H. sapiens sapiens*.

Conclusions

1. The Lower Pleistocene Venta Micena (Orce, Granada, Spain) cranial fragment (Gibert *et al.*, 1983) is incompatible with artiodactyls, carnivores and equids.

2. Lack of sutural obliteration in the obelionic region of VM-0 implies the fossil formed part of a large-brained skull.

3. That volume had to be larger than that (470 cm³) of equids when their sagittal suture begins to close.

4. Infantile features of VM-0 (Campillo, 1989; Gibert *et al.*, 1989a-c) lead to an inescapable conclusion that, at the time of death, its skull contained a large brain that was still growing in a manner comparable to that of the human brain, and plausibly capable of attaining an eventual size similar to that (625 cm³) -also from the Eurasian Lower Pleistocene- of Dmanisi (D-2282) in the Georgian Republic.

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References

- Agustí, J. and Moyà S. (1987). Sobre la identidad del fragmento craneal atribuido a *Homo* sp. de Venta Micena (Orce Granada). *Estudios Geol.*, 42: 538-443.
- Arques J. M., Gibert J. (2002). Fractal Análisis And Its Applications In Human Palaeontology. *Hum. Evol.* 17: 45-53.
- Borja, C. (1999). Estudio de proteínas en fósiles. In (J. Gibert *et al.* Edit.): *The hominids and their environment in the middle and lower Pleistocene of Europe and Asia*. Museo de Prehistoria y Paleontología "J. Gibert", Orce (Granada), 49-64.
- Borja, C. and García-Olivares, E. (1995). Detection and characterisation of proteins in fossils from Venta Micena and Cueva Victoria by immunological methods. Abstracts International Conference on Human Palaeontology (Orce, Granada), 26.
- Borja, C., García Pacheco, J. M., Ramírez-López, J. P. and García-Olivares, E. (1992). Cuantificación y caracterización de la albúmina fósil en el cráneo de Orce. In (J. Gibert, Ed.): *Presencia humana en el Pleistoceno Inferior de Granada y Murcia*. Museo de Prehistoria y Paleontología "J. Gibert", Orce (Granada), 415-424.

- Borja, C., García Pacheco, J. M., García-Olivares, E., Scheuenstuhl, G. & Lowenstein, J. M. (1997). Immunospecificity of albumin detected in 1.6 million-year-old fossils from Venta Micena in Orce, Granada, Spain. *Am. J. Phys. Anthropol.*, 103: 433-441.
- Campillo, D. (1989). Study of the Orce man. In (J. Gibert, D. Campillo & E. García-Olivares, Edit.): *Los restos humanos de Orce y Cueva Victoria*. Sabadell: Inst. Paleontología "Dr. M. Crusafont". Diputació de Barcelona, 187-220.
- Campillo, D. (1998). Morfoloogical *endocranium* variability, secondary of the *encephalon* increase. *Arch. Esp. Morfol.*, 3: 133-151.
- Campillo, D. (1999). Réplica a las objeciones de tipo anatómico, en que algunos autores fundamentan que el fósil VM0 exhumado en Venta Micena (Orce, Granada), no pertenece al Género Homo. In (J. Gibert *et al.* Edit.): *The Hominids and their environment during the lower and middle Pleistocene of Eurasia*. Museo de Prehistoria y Paleontología "J. Gibert", Orce (Granada), 75-82.
- Campillo, D. (2002). El cráneo infantil de Orce. *Edicions Bellaterra*. Barcelona.
- Campillo, D. (2003). El Hombre de Orce (VM-0) en el 2001. *Antropología y Biodiversidad*. Ediciones Bellaterra S. L., 96-104.
- Campillo, D., Barceló, J. A. (1989). Morphometric study of the internal surface of the squama occipitalis. In (J. Gibert, D. Campillo and E. García-Olivares, Edit.): *Los restos humanos de Orce y Cueva Victoria*. Sabadell: Inst. Paleontología "Dr. M. Crusafont". Diputació de Barcelona, 109-186.
- Campillo, D. and Gibert, J. (1996). El hombre de Orce. *Investigación y Ciencia*, 234: 64-69.
- Campillo, D., Rovira, M., Sánchez-Sánchez, J. A., Vila, S., Gibert, J., Gibert, L. (2003). Radiographical Study of Fragment of Venta Micena (VM-0) (Orce, Granada, Spain). *Hum. Evol.*, 18: 131-146.
- García-Olivares, E., Gallardo, J. M., Martínez, F., Borja, C., García-Olivares, D. (1989). Detección y caracterización de proteínas fósiles en el cráneo de Orce. *Los restos humanos de Orce y Cueva Victoria*. Sabadell: Inst. Paleontología "Dr. M. Crusafont". Diputació de Barcelona, 225-228.
- Gibert, J. (1986). El yacimiento de Venta Micena (Orce, Granada): su importancia, acción antrópica y características paleoantropológicas del fragmento de cráneo de *Homo* sp. *Actas del Congreso "Homenaje a Luis Siret"*, 37-49.
- Gibert J. (2004). El hombre de Orce. *Edit. Almuzara*. Córdoba.
- Gibert, J., Agustí, J. and Moyà, S. (1983). Fragmento craneal atribuido a *Homo* sp. de Venta Micena (Orce, Granada). *Paleontol. Evolució*. Publicación especial. Sabadell: Inst. Paleontología "Dr. M. Crusafont".
- Gibert, J., Ribot, F., Ferrández, C., Martínez, B. and Ruz, C. (1989a). Diagnósis diferencial del fragmento de cráneo de *Homo* sp. del yacimiento de Venta Micena (Orce, Granada). In (J. Gibert, D. Campillo and E. García-Olivares, Edit.): *Los restos humanos de Orce y Cueva Victoria*. Publicacions de l'Institut de Paleontologia "Dr. M. Crusafont", Sabadell, 31-108.
- Gibert, J., Ribot F., Ferrández, C., Martínez B., Caporicci R. (1989b). Características diferenciales entre el fragmento de cráneo de *Homo* sp de Venta Micena (Orce, Granada) y los équidos. *Estudios Geol.*, 45: 121-128.
- Gibert, J., Campillo D., Caporicci R., Ribot, F., Ferrández C., Martínez, B. (1989c). Anatomical study: comparison of the hominid craneal fragment from Venta Micena (Orce, Spain) with fossil and extant mammals. *Hum. Evol.*, 4: 283-305.
- Gibert, J., Martínez, B. (1992a). Human presence and anthropic action in the S.E. of Iberian Peninsula during the Lower Pleistocene. *Rev. Esp. Paleontol.* Extra, 59-70.
- Gibert, J., Malgosa, A., Sánchez, F., Martínez, B., Walker, M., Ribot, F. (1992b). Nuevos restos humanos en los yacimientos de Orce y Cueva Victoria. En (Gibert *et al.*, edit.): *Presencia humana en el Pleistoceno inferior de Granada y Murcia*. Museo de Prehistoria y Paleontología de Orce.
- Gibert, J., Campillo, D., Martínez, B., Ribot, F. Caporicci, R., Ferrández, C. (1993). Nuevos restos humanos en el Pleistoceno inferior de Orce y Cueva Victoria. *El Cuaternario en España y Portugal*. Instituto Tecnológico y Geominero de España, 441-443.
- Gibert, J., Palmqvist, P., Martínez, B. (1994a). Los primeros Europeos. *Investigación y Ciencia*.
- Gibert, J., Sánchez, F., Malgosa, A., Martínez, B. (1994b). Nouvelles découvertes de restes humains dans les gisements d'Orce (Grana, Espagne). *C.R. Acad. Sci. Paris*, 319: 963-968.
- Gibert, J. and Palmqvist, P. (1995). Fractal analysis of the Orce skull sutures. *J. Hum. Evol.*, 28: 561-575.
- Gibert, J., Campillo D., Arquès, J. M., García-Olivares, E., Borja, C. and Lowenstein, G. (1998a). Hominid status of the Orce cranial fragment reasserted. *J. Hum. Evol.*, 34: 203-217.
- Gibert, J., Gibert, L. and Iglesias, A. (1998b). Two "Oldowan" assemblages in the Plio-Pleistocene deposits of the Orce region, southeast Spain. *Antiquity*, 72: 17-25.
- Gibert, J., Malgosa, A., Sánchez, F., Ribot, F. and Walker, M. (1999a). Humeral fragments attributable to *Homo* sp. from Lower Pleistocene sites at Venta Micena (Orce, Granada, Spain). En (J. Gibert *et al.* Ed.): *The hominids and their environment in the middle and lower Pleistocene of Europe and Asia*. Museo de Prehistoria y Paleontología "J. Gibert" (Orce, Granada), 87-112.
- Gibert, J., Albaladejo, S., Gibert, LL., Sánchez, F., Ribot, F. and Gibert, P. (1999b). The oldest human remains of the Orce region. *Hum. Evol.*, 14: 3-19.
- Gibert, J., Gibert, L., Albaladejo, S., Ribot, F., Sánchez, F. (1999c). Molar Tooth Fragment BL-0: the Oldest Human Remains Found in the Plio-Pleistocene Orce Region (Granade, Spain). *Hum. Evol.*, 13: 000-000.
- Gibert, J., Campillo, D., García-Olivares, E., Walker, M., Ferrández, C., Borja, C., Malgosa, A., Sánchez, F., Ribot, F., Gibert, L., Albaladejo, S., Iglesias, A., Gibert, P. (1999d). Contribution à l'étude des premiers peuplements de l'Europe occidentale: L'apport des recherches sur le Plio-Pléistocène d'Orce et de Cueva

- Victoria (Espagne). *Jahr. Römisch-German. Zentralmus. Mainz.*, 46. Jahrgang 1999.
- Gibert, J., Gibert, L., Ferrández, C., Iglesias, A., González, F. (2001). Venta Micena, Barranco León 5 and Fuentenueva 3: tree archaeological sites in the early Pleistocene of Orce, South-East Spain. En (Ed. S. Miliken): *A Very Remote Period Indeed*. Oxbow Books.
- Gibert, J., Sánchez, F., Ribot, F., Gibert, L., Ferrández, C., Iglesias, A., Gibert, P., González, F. (2002). Restes humans dans les sédiments du Pléistocène inférieur de la région d'Orce et de Cueva Victoria (sud-est de l'Espagne). *L'Anthropologie*, 106: 669-683.
- Gibert, J., Ribot, F., Ferrández, C., Sánchez, F., Gibert, P., Gibert, L. (2003). Early Pleistocene Human Remains From Orce (SE Spain). *Antropología y Biodiversidad*. (Edit. Aluja, Malgosa y Nogués). Editorial Bellaterra (Barcelona).
- Lowenstein, J. M. (1995). Immunological reactions on fossil bones from Orce. *Int. Conf. Hum. Palaeontol.* (Orce, Granada), 27.
- Lowenstein, J. M., Borja, C. and García-Olivares, E. (1999). Species-specific albumin in fossil bones from Orce, Granada, Spain. *Hum. Evol.*, 14: 21-28.
- Martínez Navarro, B. (1992). Revision sistemática de la fauna de macromamíferos del yacimiento de Venta Micena (Orce, Granada, España). *Presencia humana en el Pleistoceno inferior de Granada y Murcia*. Museo de Prehistoria y Paleontología de Orce.
- Martínez-Navarro, B. (2002). The skull of Orce: parietal bones or frontal bones? *J. Hum. Evol.*, 43: 265-270.
- Moyà, S. and Agustí, J. (1989). Una reinterpretación del fragmento craneal de Orce: *Equus stenorhis* COCHI. In (J. Gibert, D. Campillo and E. García-Olivares, Edit.): *Los restos humanos de Orce y Cueva Victoria*. Sabadell: Inst. Pal. "Dr. M. Crusafont". Diputación de Barcelona.
- Moyà, S. and Köhler, M. (1997). Anatomy of a mistake. *J. hum. Evol.*, 33: 91-97.
- Torres, J. M., Borja, C., García Olivares, E. (2002). Inmunoglobulin G in 1.6 Million-year-old Fossil Bones from Venta Micena (Granada, Spain). *Journal of Archaeological Science*, 29: 165-175.
- Shapiro, R., Janzen, A. (1960). Normal Skull. *Ed. Harper & Brothers*. Nueva York.

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