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Paleopathological evidence of the cranial remains from the Sima de los Huesos Middle Pleistocene site (Sierra de Atapuerca, Spain). Description and preliminary inferences

The large Sima de los Huesos sample provides for the first time the opportunity of performing a paleopathological study of a Middle Pleistocene population. A high frequency of bilateral temporomandibular arthropathy has been observed. We found an ear hyperostosis in Cranium 4, that probably caused deafness that we consider to be of infectious origin. Three osteomata were found in the cranial collection. One severe trauma was evident on the left supraorbital torus of an immature individual. Many cranial vault erosions, mostly restricted to the external table, are found in the sample. Cranium 5 displays thirteen of these. Cranium 5 also shows an extensive maxillary osteitis associated with a dental apical abscess, as well as another dental apical abscess in its mandible. Most of the adult frontal bones show a worm-like pattern of vascular channelling in the orbital roof, also found in modern populations.

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Introduction, material and methods

The Sima de los Huesos (SH) site is situated in the Sierra de Atapuerca near Burgos in Northern Spain. This site is currently assigned to the second half of the Middle Pleistocene based on biostratigraphical studies (Cuenca-Bescós *et al.*, 1997; García *et al.*, 1997). Moreover, a minimum age of about 200 ka and a probable age of more than 300 ka for the human fossils have been obtained by radiometric analyses (Bischoff *et al.*, 1997).

Since 1976 this site has yielded more than 1600 human fossils belonging to at least 33 individuals. Sima de los Huesos represents the largest sample from one Middle Pleistocene site (Arsuaga *et al.*, 1991, 1993, 1997*a*,*b*; Martínez & Arsuaga, 1997; Carretero *et al.*, 1997), providing for the first time the opportunity of performing a paleopathological study of a Middle Pleistocene sample belonging to one single biological population. In previous papers (Pérez & Martínez, 1990; Pérez, 1991), the paleopathology of the SH cranial sample found up to the 1991 field season was analyzed. Signs of degenerative temporomandibular arthropathy and several minor cranial pathologies were found.

The new fossil material found since the 1992 field season includes eight more or less complete skulls and many cranial fragments with evidence of pathology, providing the opportunity to extend knowledge of the diseases suffered by a Middle Pleistocene population (Tables 1 and 2). In this paper we focus on the description, frequency and preliminary interpretation of the pathologies found in the SH cranial sample. We found several fossils in the sample with some atypical features of problematic interpretation. In these cases, we describe them in order to record their presence in the sample. Of course, although we only describe those specimens that display pathological alterations or atypical images, the complete sample has been considered in order to calculate the prevalence of each pathology.

Microscope inspection of all fossils was undertaken and CT Scan and conventional radiography applied to Crania 4 and 5.

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Table 1 Crania from SH site with pathological evidences

Fossil	Age	Description	Pathology
Cranium 1	Adult	Partial vault comprising an almost complete occipital plus a large portion of the right parietal bone plus part of the right temporal bone.	One cranial depression.
Cranium 2	Adult	Partial cranial vault including a frontal fragment, an almost complete left parietal, two sagittal fragments of the right parietal, a lambdatic wormian bone and eight occipital fragments.	One cranial depression.
Cranium 3	Immature	A fragmentary cranial vault including both orbital fragments.	One cranial depression.
Cranium 4	Adult	Complete neurocranium.	Two cranial lesions. Worm-like pattern on both orbital roofs. Hyperostosis in both auditory canals. Temporomandibular arthropathy.
Cranium 5	Adult	Complete skull.	Thirteen cranial depressions Worm-like pattern on the left orbital roof. Maxillary osteitis. Two apical abscesses. Temporomandibular arthropathy.
Cranium 6	Immature	Skull lacking fragments of the cranial vault and facial skeleton.	One cranial depression. Temporomandibular arthropathy.
Cranium 7	Immature	An almost complete right parietal bone, a lambdatic wormian bone connected to a small fragment of the left parietal, large portion of the occipital bone and the almost complete left temporal bone.	One cranial depression. Temporomandibular arthropathy.
Cranium 8	Adult	A complete left parietal, fragments of frontal bone, fragments of right parietal, lambdoidal ossicles and part of the left temporal.	One cranial depression.

Results and discussion

Degenerative temporomandibular arthropathy

In previous studies we found an unusually high frequency of temporomandibular arthropathy in the Sima de los Huesos sample (Pérez & Martínez, 1990; Pérez, 1991). Prior to 1992, there were only isolated temporal bones and it was not possible to determine whether this joint disease had bilateral occurrence in the Atapuerca SH sample. Crania 4 [Figure 1(a)], 5 [Figure 1(b)] and 6 [Figure 1(e)] display bilateral temporomandibular arthropathy. Signs of this pathology were also identified on six isolated fragments which belong to five different individuals [Table 2; Figures 1(c), (d), (f) and (g)] and in the left temporal bone of Cranium 7. There are another three temporal bones, corresponding to three different individuals, without this temporomandibular disease. The frequency of this joint disease in the SH sample (70% of individuals) is well above that currently found in historic populations. For instance, in the archaeological site of Abusir, Egypt (VIIth to IVth Centuries B.P), Strouhal (1982) reports that this temporomandibular disease had a prevalence of 15·4 and 19·3% in adult men and women, respectively. Surprisingly only one mandibular condyle, among eight individuals from SH sample, shows signs of arthropathy.

Table 2 Isolated cranial fragments with pathological / attypical patterns

Fossil	Age	Description	Pathology
AT-84 + AT-1163	Adult	Complete left temporal bone plus a small portion of the left parietal.	Temporomandibular arthropathy.
AT-121 + AT-1545	Adult	Left lateral region of the frontal torus plus the left zygomatic bone.	Worm-like pattern on the orbital roof.
AT-124	Adult	Left temporal. Glenoid fossa region.	Temporomandibular arthropathy.
AT-200	Adult	Includes the glabellar segment and part of the right supraorbital region of the frontal torus.	Worm-like pattern on the orbital roof.
AT-237 + AT-499 + AT-1155 + AT-1156	Adult	Includes the glabellar segment, the right supraorbital region of the frontal torus and part of the frontal squama.	Worm-like pattern on the orbital roof.
AT-365	Immature	Right temporal. Includes part of the mastoid and the complete glenoid fossa.	Temporomandibular arthropathy.
AT-401	Immature	Part of the right supraorbital region of the frontal torus.	Worm-like pattern on the orbital roof.
AT-421	Immature	Left temporal. The glenoid fossa and part of the petrosal and mastoid regions are preserved.	Temporomandibular arthropathy.
AT-465 + AT-624 + AT-764 + AT-765 + AT-766 + AT-1159	Immature	An almost complete face, lacking the left maxilla and nasal and alveolar borders of the right maxilla.	Traumatic healed depression on the left supraorbital margin.
AT-630 + AT-777 + AT-1168 + AT-1550	Adult	A complete right supraorbital torus with the glabellar region plus part of the adjacent squama plus the right greater wing of the sphenoid. AT-1550 represents the left part of the supraorbital torus and squama.	Worm-like pattern on the orbital roofs. Two osteomata on the right orbital roof.
AT-643*	Immature	Left temporal. Almost complete, it lacks most of the temporal squama.	Temporomandibular arthropathy.
AT-644*	Immature	An almost complete right temporal.	Temporomandibular arthropathy.

*AT-643 and AT-644 are compatible in size, morphology and developmental stage.

Several hypotheses have been proposed to explain the origin of this temporomandibular disease. Pérez & Martínez (1990) related this pathology to occlusal disequilibrium due to extensive wear of the anterior dentition. This hypothesis has been weakened by the presence of the disease in immature individuals (Cranium 6, for instance). On the other hand, Rosas & Pérez (1995) associate this temporomandibular joint arthropathy with morphogenetic processes related to evolutive modifications in the basicranium.

Hyperostosis in the external auditory meatus

Cranium 4 exhibits symmetrical hyperostosis in both auditory canals. There is an extensive growth of the bone from the tympanomastoid and tympanosquamosal sutures and the tympanic plate appears to curl into the external auditory canal, narrowing it [Figures 1(h), (i), (j)].

The literature on ear hyperostosis is large and sometimes confused and contradictory. Kennedy (1986) made an exhaustive study of this issue, pointing out the lack of consensus

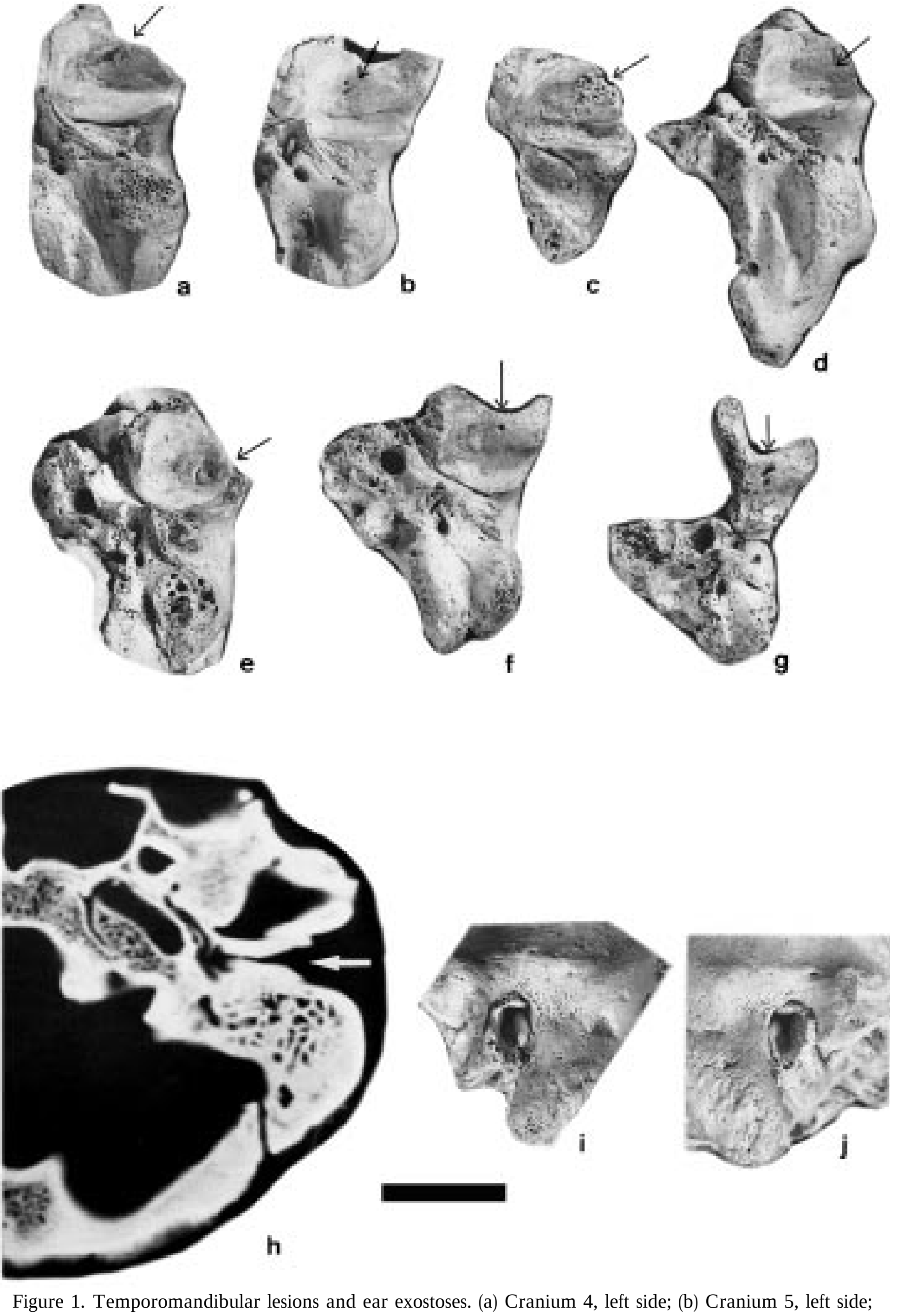


Figure 1. Temporomandibular lesions and ear exostoses. (a) Cranium 4, left side; (b) Cranium 5, left side; (c) AT-124; (d) AT-84; (e) Cranium 6; (f) AT-643; (g) AT-421; (h) TAC transverse section of Cranium 4, showing the stenosis of the left auditory canal; (i) left auditory meatus of Cranium 4; (j) right auditory meatus of Cranium 4. Scale bar = 1 cm.

in the literature. There is much disagreement on the definition of the two main types of auditory hyperostoses: exostoses and osteomata. To Sheehy (1958) ear exostoses are bilateral and symmetrical and present an extensive base, whereas auditory osteomata have small and narrow bases, only affecting the tympanomastoid and tympanosquamosal sutures and generally do not occur bilaterally. Following these criteria we include the hyperostosis of Cranium 4 among the ear exostoses (*sensu* Sheehy, 1958).

The etiology of ear hyperostosis has been related to external factors such as a continued cold water exposure (Kennedy, 1986; Manzi *et al.*, 1991) or infections (Kennedy, 1986). On the other hand, some authors (Hrdlička, 1935; Roche, 1964; Steinbock, 1976; Benítez & Linn, 1980; Mann, 1986; Gregg & Gregg, 1987) related this pathology to genetic factors, using it as a non-metrical trait to establish genetic distances. The authors are in agreement with Hrdlička (1935) and believe that auditory hyperostoses, and those of Cranium 4 in particular, are the result of an external factor that stimulates a genetic predisposition. None of the other six individuals from SH that preserve the auditory canal have any signs of ear hyperostosis, suggesting a singular external stimulus for the condition in Cranium 4. So, although a cold water hypothesis would have very interesting implications for Middle Pleistocene hominids, the only source of cold water in the Sierra de Atapuerca is the Arlanzón River, and it is difficult to imagine what kind of activities required a frequent head immersion of this particular individual in the cold river waters. On the basis of the available evidence, we prefer to suggest an infectious process as the most probable origin.

Visual inspection of the auditory canals [Figures 1(i) and (j)] and of the tomographic image of the canals [Figure 1(h)] show that the hyperostoses almost closed them in Cranium 4. As a result of this extreme stenosis, the hearing of this individual might have been severely affected, and perhaps the stenosis caused deafness. Finally, the disease occurred after the tympanic plate had completed its normal growth.

Osteomata

In the orbital roof of the frontal fragment AT-777 there are two small protuberances that we identify as osteomata [Figure 2(a)]. The most lateral one projects only slightly (less than 1 mm), it is oval shaped (7·5 mm × 5·3 mm) and its surface is made of irregular fine cancellous bone. The medial one is more protruding (1 mm), subcircular (5 mm in diameter) and of compact ‘‘ivory’’ type bone. This last osteoma is located on the border of an elongated depression (16 mm × 6·7 mm) and is associated with an atypical vascularization [Figure 2(a), (c)], both on the internal and external surfaces of the bone.

On the left parietal of Cranium 4 there is a small osteoma, located in the posterior part of the bone, just above the superior temporal line [Figure 2(b)]. It is subcircular in shape (6 mm diameter) and slightly protruding (less than 1 mm). There are no differences between the surface of the osteoma and that of the surrounding bone.

Maxillary osteitis

There is a large osteitis, rising as a conspicuous mound of bone with a rough and porous surface, on the alveolar process of the left maxilla of Cranium 5, stretching from above the lateral incisor to the distal alveolar septum of the first molar. This osteitis (mentioned in Arsuaga *et al.*, 1993) extends upwards and medially, affecting and deforming the infero-lateral border of the piriform aperture and the frontal maxillary process [Figure 3(a), (b)]. An apical dental abscess on the left P^3 is also seen in Cranium 5, and a drainage canal crosses the irregular and thick build-up of new bone.

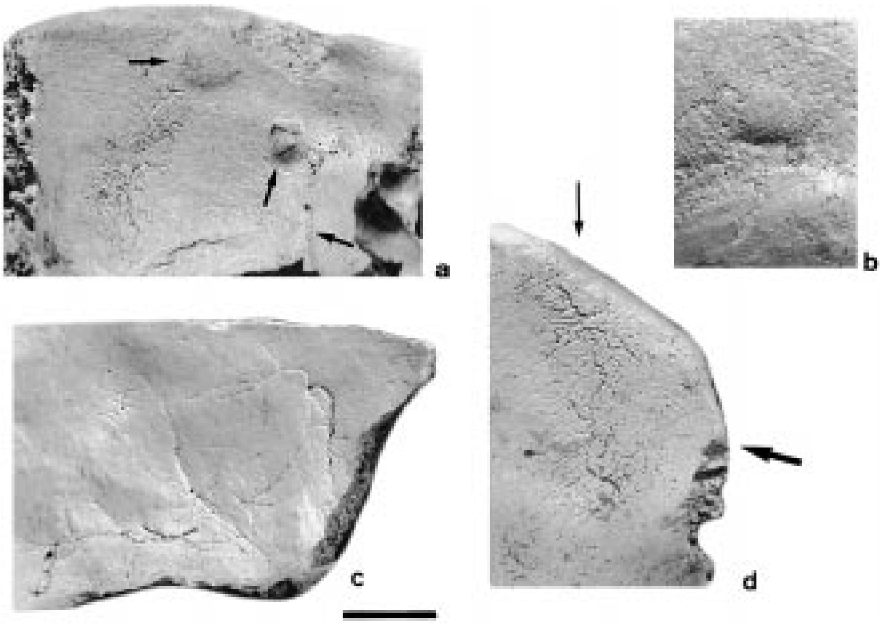


Figure 2. Osteomata and worm-like atypical pattern. (a) AT-777 right orbital roof, showing two osteomata, atypical vascularization, a depressed area and the worm-like pattern. Black arrows point to the osteomata and hypervascularization on the orbital roof; (b) benign osteoma on the left parietal bone of Cranium 4; (c) hypervascularization on the endocranial surface of the frontal fragment AT-777; (d) AT-1550. Big arrow points to the frontomalare orbital point, small arrow points to the anterior orbital border. Scale bar = 1 cm.

This maxillary osteitis could resemble a late lesion of a nonvenereal treponematosis, as claimed for the ER-1808 early *Homo* skeleton (Rothschild *et al.*, 1995). However, none of the other Sima de los Huesos fossils which represent different skeletal elements and more than 33 individuals show any bone lesions that could resemble those described as characteristic of these kind of diseases (Brothwell, 1981; Steinbock, 1976).

In our opinion, the Cranium 5 maxillary osteitis was most likely related to the apical dental abscess in the left P^3.

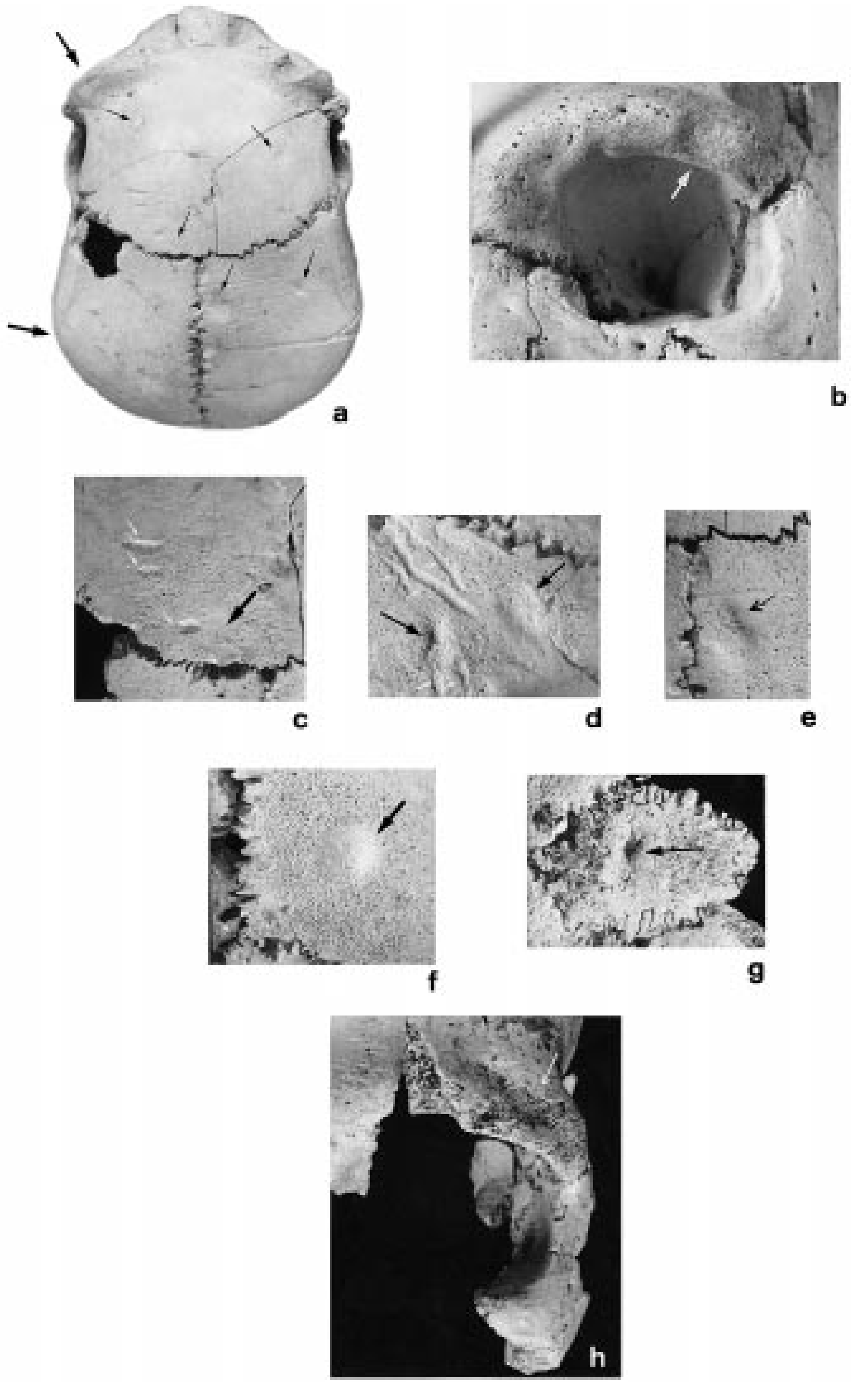
The mandible AT-888, belonging to the same individual as Cranium 5, shows a big dental abscess cavity developed at the level left of the I_2 apex [Figure 3(a)]. This abscess cavity is surrounded by a periostitic surface that affected the mandibular body from the left I_2 to the right I_2. It is likely that the left I_2 was lost before death and, probably also the left I_1.

In addition to these features, there is also a generalized periodontal infection in Cranium 5. All the evidence suggests that the individual represented by Cranium 5 suffered from a severe gingivitis that later developed into a periodontitis. This individual shows a strong deposition of dental calculi (category 4; Dobney & Brothwell, 1987) on both maxillary and mandibular teeth, except for the right upper central incisor (the only non-molar tooth preserved). Resorption of alveolar bone is also present in this individual, scored as a medium degree of resorption (following Brothwell, 1981). Cranium 5 displays anomalous tooth–neck wear on the molars, already described in other specimens from the Atapuerca SH sample (Pérez *et al.*, 1982; Bermúdez de Castro & Arsuaga, 1983*a*,*b*). This wear consists of a groove across the neck, that can be observed on the mesial and distal surfaces. Bermúdez de Castro & Arsuaga

Figure 3. Maxillary osteitis. (a) Cranium 5 and AT-888 mandible, showing periodontal disease; (b) Cranium 5, maxillary osteitis. Scale bar = 1 cm.

(1983*a*,*b*) have reported a close relationship of these wear grooves to periodontal bone resorption in modern and fossil populations. These grooves are attributed to the repeated use of hard objects as ''tooth picks'' for the elimination of food fragments lodged in the interdental spaces during mastication (Pérez *et al.*, 1982; Bermúdez de Castro & Arsuaga, 1983*a*,*b*). No caries are observed in this individual nor in any tooth of the Atapuerca SH sample.

The degree attained by the infectious process in this individual must have been very serious. Due to the proximity of the maxillary osteitis to the infraorbital foramen, the infection may have developed into a generalized septicemia, causing the death of the individual.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Cranial erosions

The SH cranial sample displays several cranial erosions (Figure 4). Table 3 shows the location and gives a description of these injuries. In 13 cases the lesions are oval or of subcircular shape and there are six grooves. Seven of these erosions are located on the frontal bone (five on the left side, one on the right side and one on the midline), 11 on parietal bones (six on left parietal bones and five on right ones) and four on occipital bones (two on the right side and two on the midline). All of these lesions are situated on the cranial vault above the occipital torus and the superior temporal line. There is a marked difference between the number of lesions in Cranium 4 and Cranium 5, the only two specimens which preserve the complete vault. Cranium 4 displays three injuries and Cranium 5 displays 13. All these cranial vault injuries seem to be a reaction to an inflammatory process that affected the scalp and, consequently, the cortical cranial bone. Whether the inflammation was the result of blows, or local or systemic infections, cannot be determined.

Although some times similar cranial erosions have been described in other fossil hominids (e.g., Keith, 1931, reported two in the Zuttiyeh specimen and Weidenreich, 1943, found another in the Skull XII from Zhoukoudian) the high incidence of these features in Cranium 5 is remarkable [Table 3, Figures 4(a)–(e)].

Traumatic lesions

There are no fractures nor clear traumatic lesions among 1200 postcranial elements (J. M. Carretero & C. Lorenzo, personal communication).

The frontal bone fragment AT-764, that belongs to an immature individual, shows a severe traumatic lesion, on the left browridge [Figure 4(h)]. The rounded edges show that bone healing took place. It is not possible to determine to what degree it affected soft tissues, but visual capabilities may have been diminished.

Anomalous pattern on the orbital roof

There are 20 orbital roofs that can be examined on the Atapuerca SH sample (Tables 1 and 2). Two out of three frontal bones with both orbits represented, show a worm-like pattern of vascular channelling in the orbital roof (bilaterally in both individuals), with an anatomical distribution similar to that generally found for cribra orbitalia [Figures 2(a), (d)]. The other five adult orbits in the SH sample display the same pattern (corresponding to Cranium 5, where only in one side the presence or absence of this trait can be recorded, and four fragmentary frontal bones preserving only one orbit). On the other hand, in the eight Atapuerca immature orbits (corresponding to three individuals preserving both sides and two isolated frontal fragments) there are no signs neither of the worm-like pattern nor of cribra orbitalia.

As far as we know, this worm-like pattern on the orbital roof has been described in the literature only by Webb (1982, 1989), and this is the first time this feature is observed in non-modern human fossils. Webb (1982, 1989) found this pattern only in adult specimens, and suggests that it corresponds to a recovery stage of cribra orbitalia (grade 4 or scar category). He

Figure 4. Cranial trauma. (a) Superior view of Cranium 5, showing some of the slight cranial depressions; (b) depression on the left brow ridge of Cranium 5; (c) oval depression and surrounding periostitic area on the frontal bone of Cranium 5; (d) linear and oval depressions on the occipital bone of Cranium 5; (e) oval depression on the right parietal bone of Cranium 5; (f) rounded depression on the right parietal bone of Cranium 3; (g) scar on a lambdatic wormian bone of Cranium 7; (h) severe traumatic lesion on the left brow ridge of the frontal bone (AT-764) of an immature individual.

Table 3 Cranial depressions in SH sample

Specimen	Situation	Description*
Cranium 1	Centre of the occipital squama.	Slight subcircular depression (9 mm in diameter)†.
Cranium 2	Bregmatic quadrant of the left parietal bone.	Slight subcircular depression (9·8 mm in diameter)†.
Cranium 3	Lambdatic quadrant of the right parietal bone.	Moderate subcircular depression (12 mm in diameter)†.
Cranium 4	Midpoint of frontal squama.	Narrow and slight depression† (13 mm in diameter).
	Asterionic quadrant of the left parietal bone, just above the superior temporal line.	Elongated groove moderately depressed (15·7 mm in length)†.
	Just above the occipital torus at its right side.	Circular slight depression (14·4 mm in maximum length)†.
Cranium 5	Left browridge.	Subcircular slight depression (12·7 mm × 7·5 mm)†.
	Left side of frontal squama.	Oval slight depression (7·1 mm × 3·7 mm)†.
	Right side of frontal squama.	Oval slight depression (7·3 mm × 6·2 mm)†.
	Left side of frontal squama, close to bregma.	Oval slight depression (15·5 mm × 7·5 mm).
	Lambdatic quadrant of the left parietal bone.	Inverted ‘‘V’’ shaped groove slight depressed (12·7 mm of maximum breadth)†.
	Lambdatic quadrant of the left parietal bone.	Subcircular slight depression (6·6 mm in diameter)†.
	Asterionic quadrant of the left parietal bone, just above the superior temporal line.	Subcircular slight depression (14·2 mm in length)†.
	Lambdatic quadrant of the right parietal bone.	Linear slight depression (10·7 mm of maximum length)†.
	Bregmatic quadrant of the right parietal bone.	Linear slight depression (8·8 mm of maximum length)†.
	Lambdatic quadrant of the right parietal bone.	Circular slight depression (4 mm in diameter)†.
	Bregmatic quadrant of the right parietal bone.	Oval moderate depression (12·3 mm × 7 mm)†.
	Midline of the occipital squama.	Moderate groove (8 mm in length)†.
	Right side of the occipital squama.	Oval slight depression (13·4 mm × 8·6 mm)†.
Cranium 6	Left part of the supratoral sulcus of the frontal bone.	Circular slight depression (8·2 mm in diameter)†.
Cranium 7	Centre of the lambdatic wormian bone.	Oval hole, that affects the diploic bone (8·8 mm × 4·4 mm), at the floor of an oval slight depression (12·8 mm × 4·4 mm)†.
Cranium 8	Lambdatic quadrant of the left parietal bone.	Oval slight depression (8 mm × 3 mm)†.
AT-624 + AT-764 + AT-765 + AT-766 + AT-1159	Almost the complete left browridge.	Strong subrectangular depression (22 mm × 7·8 mm)†.

*The depressions have been categorized into three classes: Slight: the depression only affects the external table and is less than or equal to 1 mm in depth; Moderate: the depression is more than 1 mm deep and only affects the external table; Strong: the depression affects the diploic space. †Healed lesion.

observed the worm-like vascular channelling in seven modern Australian samples, its frequency ranging between 8·5 and 13·7% (calculated on data from Webb, 1989). We have also found this unusual pattern (in seven out of 20 cases, or 35%) in a small sample (from the

Duckworth collection in the University of Cambridge) of recent New Guinea aborigines, a population biologically related to Australian aborigines, and also in a larger modern adult European sample (from the Museum of Anthropology of the University of Coimbra), where we scored this worm-like pattern, also bilaterally, in 25 out of 82 individuals (30·5%). Thus, this unusual condition on the orbital roofs is not restricted to modern Australasian populations.

With regard to the hominid fossil record, we have studied some original Middle Pleistocene specimens and Neandertals. We have not found this pattern in the adult specimens of Broken Hill, Petralona, Arago 21 (in this case observation on cast), Tabun 1 and Gibraltar 1, nor in the immature Neandertals Le Moustier, Gibraltar 2 and La Carihuela.

Whether the etiology of this anomalous worm-like vascular pattern is related to cribra orbitalia or not is difficult to ascertain. What can be said is that the evidence suggests that it is restricted to adult individuals both in modern samples and in the Sima de los Huesos fossil hominids.

Summary and conclusions

The Sima de los Huesos sample provides for the first time the opportunity of studying the paleopathology of a Middle Pleistocene population. Temporomandibular arthropathy has been observed bilaterally in Crania 4, 5 and 6, as well as on five isolated temporal bones, which belong to four different individuals. The prevalence of this disease in the sample is remarkable (70% of the individuals).

We include as an ear exostosis (*sensu* Sheehy, 1958) the ear hyperostosis of Cranium 4 and we propose an infectious process as the most plausible external factor that stimulated this pathology. This individual possibly became deaf.

Three osteomata were found in the cranial collection. One severe trauma affected the left supraorbital torus of an immature individual. Many cranial vault erosions, mostly restricted to the external table, are found in the sample. Cranium 5 displays a striking number of them (13).

Cranium 5 shows an extensive maxillary osteitis associated to a dental apical abscess, as well as another dental apical abscess in its associated mandible AT-888.

Most of the adult frontal bones show a worm-like pattern of vascular channelling in the orbital roof. To Webb (1982, 1989), they could represent scars (i.e., a recovery stage) of cribra orbitalia. The absence of conventional cribra orbitalia and the worm-like pattern in all the immature specimens makes Webb's explanation unlikely for the SH sample, except if it is accepted that all the adult individuals that show the worm-like pattern belong to the same generation, that grew under the same environmental conditions and developed cribra orbitalia, or that the juvenile specimens of the sample represent a different generation that did not developed cribra orbitalia. Considering the small size of the Atapuerca SH collection, sampling error is another possible explanation for the absence of cribra orbitalia in the SH juveniles.

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