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VIRTUAL ASSESSMENT OF A POSSIBLE MENINGIOMA IN A ROMAN-PERIOD CRANIUM

ESTUDIO VIRTUAL DE UN PROBABLE MENINGIOMA EN UN CRÁNEO DE ÉPOCA ROMANA

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Highlights:

- Meningiomas are rare in the archaeological record which complicates tracing them in ancient human populations.
- The use of computerized microtomography (MicroCT) and virtual 3D models makes it possible to identify tumours in those internal cranial regions where the lesions are not visible.
- Paleopathological analysis of a Roman cranium has revealed, in addition to cranial trauma, a new possible case of meningioma.

Abstract:

Diseases have accompanied human populations since prehistoric times. Knowing the paleopathologies and their consequences derived from them can help us to understand their impact and how have been decisive in our ancestors' ways of life. Taphonomic and paleopathological studies are key to understanding how injuries occurred; they can provide information on causes of death, analyzed populations behaviour, such as the existence of interpersonal conflicts or how they took the care of the sick. Those studies also confirm the existence of certain diseases, mentioned in the archaeological record. This paper explains the analysis of four lesions found in a Roman-era cranium from *Sima de Marcenejas*, located in Northern Spain. An anthropological analysis of this cranium has revealed that it corresponds to an adult male individual. This work focuses on the differential diagnosis of the lesions, to be able to discern the most likely aetiologies. The following techniques have been implemented: classical morphological analysis, forensic taphonomic analysis and virtual analysis. MicroCT and 3D microscopy have been used as essential tools for the virtual analysis of the cranium and its lesions. The results obtained revealed the existence of a tumour and three exocranial traumas, all of them antemortem. The location of the tumour, as well as its morphology together with other aspects, support the meningioma as the most probable tumour type. This possible ancient meningioma represents the first case for these chronologies on the Iberian Peninsula, where there are few documented cases. The three traumatic lesions reveal the existence of injuries produced by both, blunt and sharp objects, related to events of interpersonal violence. By applying virtual 3D analyses, the researchers have demonstrated that it is viable to identify tumours in those internal cranial regions, where the lesion is not visible, thus providing new comparative data for the paleopathological record of past populations.

Keywords: neoplasm; tumour; blunt force trauma; sharp force trauma; interpersonal violence; computerized microtomography (MicroCT)

Resumen:

Las enfermedades han acompañado a las poblaciones humanas desde la prehistoria. Conocer las paleopatologías y sus consecuencias puede ayudar a entender cómo han influido en las formas de vida de las poblaciones del pasado. Los estudios tafonómicos y paleopatológicos son claves para entender el origen de las lesiones; también pueden aportar información sobre las causas de muerte, el comportamiento de las poblaciones analizadas, así como la existencia de conflictos interpersonales o el cuidado de los enfermos. De esta manera se pueden obtener datos sobre la existencia de determinadas enfermedades en el registro arqueológico. Aquí presentamos el análisis de cuatro lesiones encontradas en un cráneo romano de la cueva de Marcenejas, situada en el norte de España. El análisis antropológico de este

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cráneo ha revelado que corresponde a un individuo masculino adulto. Este trabajo se centra en el diagnóstico diferencial de las lesiones para discernir las etiologías más probables. Se han aplicado las siguientes técnicas: análisis morfológico clásico, análisis tafonómico forense y análisis virtual. La microtomografía computarizada (MicroTC) y la microscopía 3D se han empleado como herramientas esenciales para el análisis virtual del cráneo y sus lesiones. Los resultados obtenidos han revelado la existencia de un tumor y tres traumatismos exocraneales, todos ellos *ante mortem*. La localización del tumor, así como su morfología junto con otros aspectos apoyan el meningioma como tipo de tumor más probable. Este meningioma representa el primer caso para estas cronologías en la Península Ibérica, donde hay pocos casos documentados. Las tres lesiones traumáticas revelan la existencia de lesiones producidas tanto por objetos contundentes como cortantes, relacionadas con eventos de violencia interpersonal. La aplicación del análisis 3D virtual ha demostrado que es factible identificar tumores en aquellas regiones craneales internas donde la lesión no es visible, aportando nuevos datos comparativos para el registro paleopatológico de poblaciones del pasado.

Palabras clave: neoplasia; tumor; traumatismo con objeto contundente; traumatismo con objeto cortante; violencia interpersonal; microtomografía computerizada (MicroTC)

1. Introduction

Identification of disease and injuries in the archaeological record is not an easy feat: the bony lesions are limited most of the time, and their features are not always diagnostic (Brothwell & Brothwell, 2016; Cook & Danforth, 2022). Paleopathological and taphonomic-forensic analyses provide insight into how bone injuries were produced and how they affected the lives of these individuals, thus helping to determine their causes of death (Kimmerle & Baraybar, 2008). This approach can provide information about past populations, their behaviour, and their diseases.

It is important to study existing trauma in the human archaeological record in order to identify incidents of interpersonal violence and to understand the capabilities of populations to survive severe traumatic injuries (Wu, Schepartz, Liu, & Trinkaus, 2011). Patterns of injury prevalence and distribution may also reflect the risks to which these societies were exposed in their daily activities or during periods of social upheaval (Erfan et al., 2009). Specifically, blunt force trauma has been documented in human populations since the Palaeolithic, and its characterization is crucial since it sometimes allows inferences to be made about the way of life or interpersonal violence (Berger & Trinkaus, 1995; Sala et al., 2015; Sala, Pantoja-Pérez, Arsuaga, Pablos, & Martínez, 2016; Wu et al., 2011).

In addition to trauma, infectious or metabolic diseases, another pathology that can affect and modify the bone structure are tumours (Ortner & Putschar, 1981). The challenge faced when making a differential diagnosis of tumours in the archaeological record is that, at the bone level, different neoplasms may leave similar traces on the bone. The differential diagnosis of tumours remains one of the most challenging aspects of paleopathology. The most frequent primary tumours of the central nervous system today are meningiomas (Watts et al., 2014). It is also likely these types of tumours were regular in past populations and that a portion of these meningiomas left skeletal evidence. However, reports of this condition in ancient populations are not common. This may be because they are not primary bone tumours, or there is not even a well-accepted set of characteristics associated with their diagnosis in dry bone (Brothwell & Brothwell, 2016; Cook & Danforth, 2022).

However, advances in imaging have revolutionized paleopathology, and these techniques are helping to diagnose these types of lesions. CT scanning and 3D virtual imaging provide an opportunity to identify new tumours that do not affect the outer cranium table, and whose characteristics are not currently seen too (Gomez, Schiffman, & Bhatt, 2018; Gracia-Téllez et al., 2013; Martín-Francés, Martinón-Torres, Gracia-Téllez, & Bermúdez de Castro, 2015; Martín-Francés, Martinón-Torres, Gracia-Téllez, & Bermúdez de Castro, 2016; Sala et al., 2015, 2016).

We present the virtual diagnosis of a probable meningioma and three traumas that are located in the Sima de Marcenejas (Valle del Losa - Burgos) (Fig. 1). This cranium dates from between the 3rd and 5th century AD (258 - 409 cal AD; OxA-40362) (Figure S1).

The discovery and description of the markers related to a meningioma provide new evidence and comparative data about a pathology scarcely recorded (Brothwell & Brothwell, 2016; Campillo, 1993). Applying mCT allows identifying the bone changes related to this type of lesion.

2. Material and methods

In February 2019, a team of speleologists, including members of Gaem (Madrid), Takomano (Burgos), Geoda (Madrid), Flash (Madrid) and A.E.Get (Madrid) reported the discovery of a cranium located in the Sima de Marcenejas (Fig. 2). After receiving the news and examining the photographs of the finding, it was decided to send a second exploration team to locate and recover the cranium. The cranium was found submerged in a nearby pool. It displayed various types of damage, which prompted the speleological team to urgently extract the remains from the cavity, later storing them at the National Centre for Research on Human Evolution (CENIEH), where they were restored and studied (Fig. S2).

The sex of the individual was determined using two methods. On the one hand, a discriminant function analysis was performed based on the study of 23 cranial variables (Table S1). On the other hand, discrete characters, which displayed a certain degree of sexual dimorphism, were considered (Table S2) (Garvin, Sholts, & Mosca, 2014; Walker, 2008).

In order to estimate the age of the individual, we studied the lateral-anterior ectocranial suture system (Meindl & Lovejoy, 1985). The dental wear patterns were also studied following different models (Brotwell, 1965; Lovejoy, 1985; Miles, 1963; Zoubov, 1968). It should be noted that these methods are population-dependent and that all of them do not belong to the same population as the individual Marcenejas. In addition, these methods have a large margin of error.

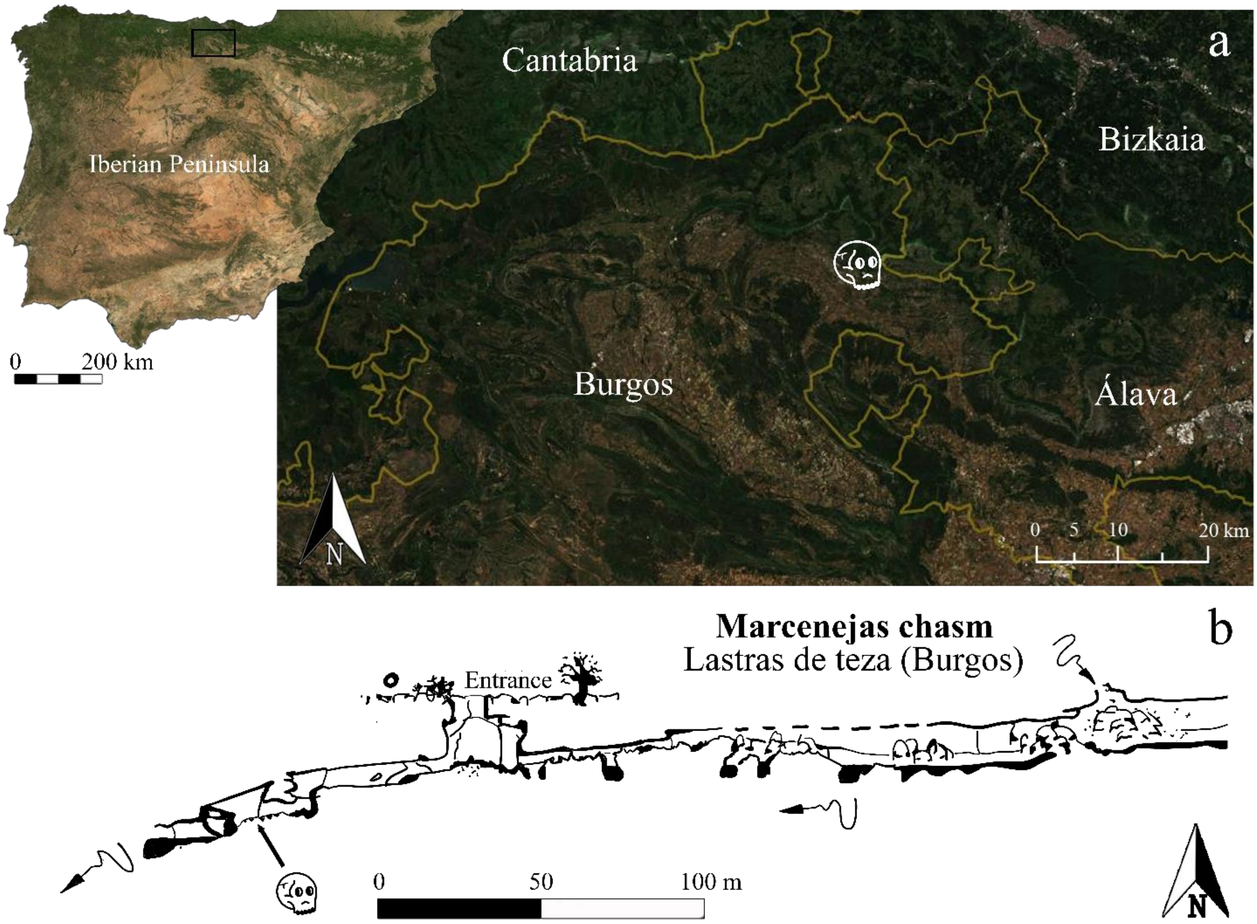

Figure 1: a) Location of the Marcenejas chasm and orthoimage of the chasm showing the original site where the skull was found in Marcenejas, Burgos (Spain); b) The sketch belongs to and was made by the Alavés and Edelweiss speleological groups.

Figure 2: Sima de Marcenejas' cranium from different views: a) anterior, superior and inferior views; b) right lateral, left lateral and posterior views.

The taphonomic and paleopathological analyses were performed by examining the bone surface at both macroscopic and microscopic levels. For this purpose, the cranium was scanned using a microCT (model V|Tome|X s 240 de GE Sensing & Inspections Technologies) belonging to CENIEH, which took computed tomography (CT) images with a voxel size of 0.1227 mm. The CT images allowed us to describe the internal bone changes in the cranium. A virtual 3D model of the skull was then generated from the resulting slices using Mimics 21.0 (Materialize N.V.). In addition, in order to visualize and study the lesion in the endocranial region (L1), it was necessary to segment virtually the sediment adhered to the cranium. The segmentation was implemented using the mask editor in Mimics v. 10.0 and it was performed semi-automatically due to the similar values of the Hounsfield units of the cranial bone and part of the sediment. After removing the sediment, the new 3D model was created from this edited mask and the dimensions of the internal trauma surface were taken. Microscopic analysis was also performed using a 3D reflected light microscope (Olympus DSX1000) for the most severe exocranial injury (L2), generating two 3D microtopographies. Two images were taken with the Olympus microscope to generate the microtopographies. The first image was taken of the area exhibiting bone remodelling, with a number of images equalling 10 with a range of 11.369 mm between them. The second image was taken at the edge of the bone lesion and illustrates, the contrast between the remodelled bone and the healthy bone. This image is composed of a total of 13 images with a range of 14.976 mm between them.

In order to discriminate between possible accidental falls from blunt head injuries, we used the location with respect to the "hat brim line" (HBL). HBL is defined as the area located between two lines parallel to a line inspired by the Frankfort horizontal plane, the superior margin passing through the glabella and the inferior margin passing through the centre of the external auditory meatus. According to the HBL rule, a blow would generally produce a wound above this line (Guyomarc'H, Campagna-Vaillancourt, Kremer, & Sauvageau, 2010).

3. Results

3.1. Sex and age estimation

The discriminant function and principal component analysis (PCA) shows that the cranium from Marcenejas corresponds to a male individual with a confidence index of 90.4%. The analysis of the discrete characters is also consistent with these results. The nuchal crest, orbital margin, supraorbital arches, and glabella reveal a degree of expression indicating robustness. The mastoid process, though lacking a pronounced projection below the external auditory meatus, shows a large volume (Figs. S3 and S4).

Visual analyses of all sutures, except for the Midcoronal suture, have a degree of synostosis of 3, which would correspond to an age range of 34 to 68 years (Fig. S5). On the other hand, the wear analyses of the preserved molars are correlated with different ages depending on the method applied, between 20 and 40 years old (Fig. S6).

Taking all these data into account, we establish that the most likely age of death for this individual is between 30 and 40 years old. However, this result should be taken with caution as both methods have a large margin of error and were established in populations that differ from that of the Marcenejas cranium.

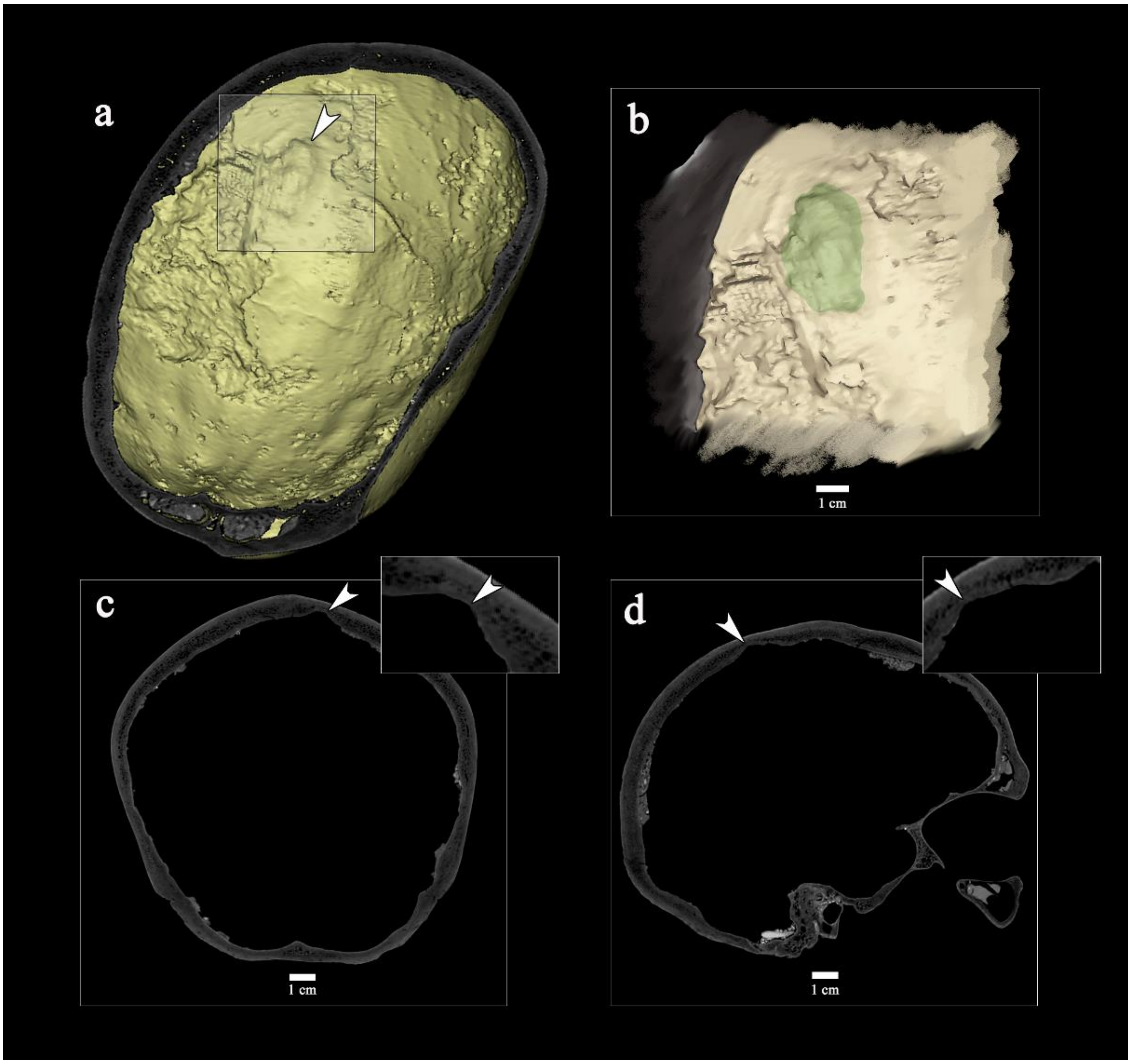

Figure 3: MicroCT visualisation of the endocranial lesion: a) 3D model of the endocranial region; b) in green: detail of the endocranial area affected by the lesion; c) coronal CT images showing the area depressed by the lesion, as well as adherent sediment; d) sagittal CT images showing the area depressed by the lesion.

3.2. Analysis of cranial injuries

We recognized four antemortem injuries: one in the endocranium (L1); and three in the exocranium (L2, L3 and L4).

The pathological condition is represented by bone destruction endocranially and remodelling of the inner table, which can be observed in the MicroCT (Figure 3). This endocranial injury (L1) is located in the anteromedial region of the left parietal. It is oval-shaped and has a maximum length of 23.30 mm and maximum breadth of 14.12 mm. It is characterized by a depressed area affecting both the inner table and the diploë. In addition, it can be observed sediment attached to the lesion.

The first exocranial lesion (L2) is located in the anterior part of the right parietal near the mid-sagittal plane (Figure 4). It is an abnormal lesion composed of porous compact bone (sensu Ortner & Putschar, 1981) with a subcircular shape and measures 18.02 mm long by 15.18 mm wide, with an area of 214.84 mm^2. This injury also has a depressed area whit a porous texture. The lesion's borders are well-demarcated. Upon analyzing the images obtained from the MicroTC, we observed that the lesion affected both the external table and superior region of the parietal diploë, while the internal table remained undamaged (Figure 5A). In addition, small pores can be observed penetrating the cortex, like a bone with modified bone tissue.

The second exocranial injury (L3) is found in the left frontal area, near the temporal lines (Fig. 6). It is a non-penetrating incised lesion with an angulated morphology (85º) composed of compact bone. It has a semi-V-shaped linear groove of limited depth and a single-bevelled but rounded edge. It measures 13.62 mm long by 6.72 mm wide and 2.18 mm deep. There is evidence of healing processes in the tiny pores penetrating the cortex. MicroCT images show that the lesion affects the external table but not the diploë (Fig. 5B).

The third exocranial lesion (L4) is found in the frontal bone, located medially near the coronal suture (Fig. 7). It measures 7.56 mm long by 1.11 mm wide, which gives it an oval morphology and is composed of compact bone. This lesion also has tiny pores penetrating the cortex. MicroCT evidence shows that the lesion affects the external table, but not the diploë (Fig. 5C).

In addition, the Marcenejas' skull also shows some postmortem fractures and defects. These fractures are found in the splanchnocranium, in the posterior region of the foramen magnum, in the squamous portion of the temporal bones, and in the mastoid processes (Fig. S7). The loss of some teeth, which occurred postmortem because there is no alveolar resorption, can also be observed. Some additional postmortem defects include signs of exfoliation of the external table in the posterior region of the cranium. Trampling has also been documented on the right parietal.

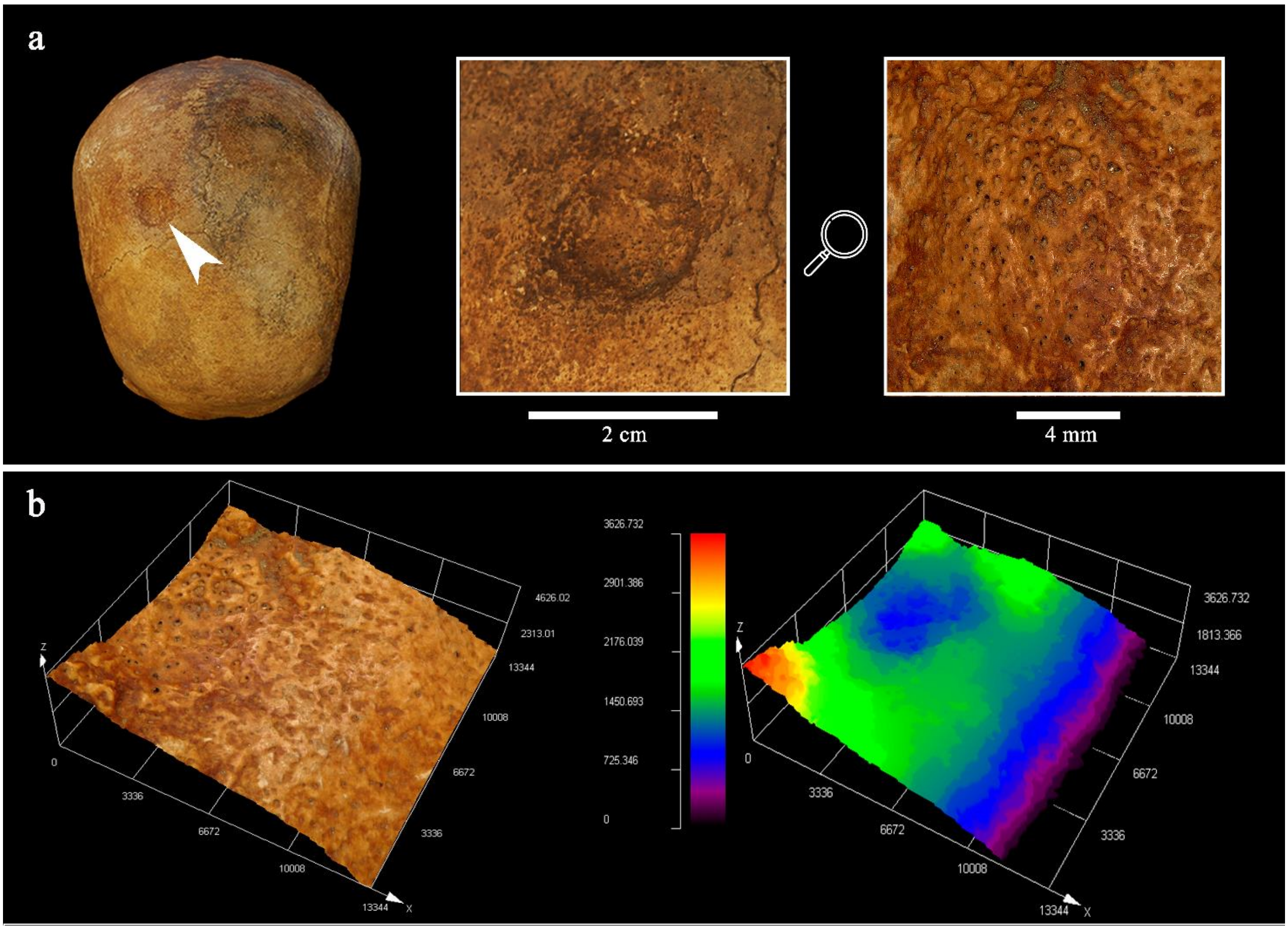

Figure 4: Exocranial lesion (L2): a) Skull in top view with a white arrow indicating its location and morphological details of the lesion; b) Microtopography images showing the porous appearance of the lesion and its depth.

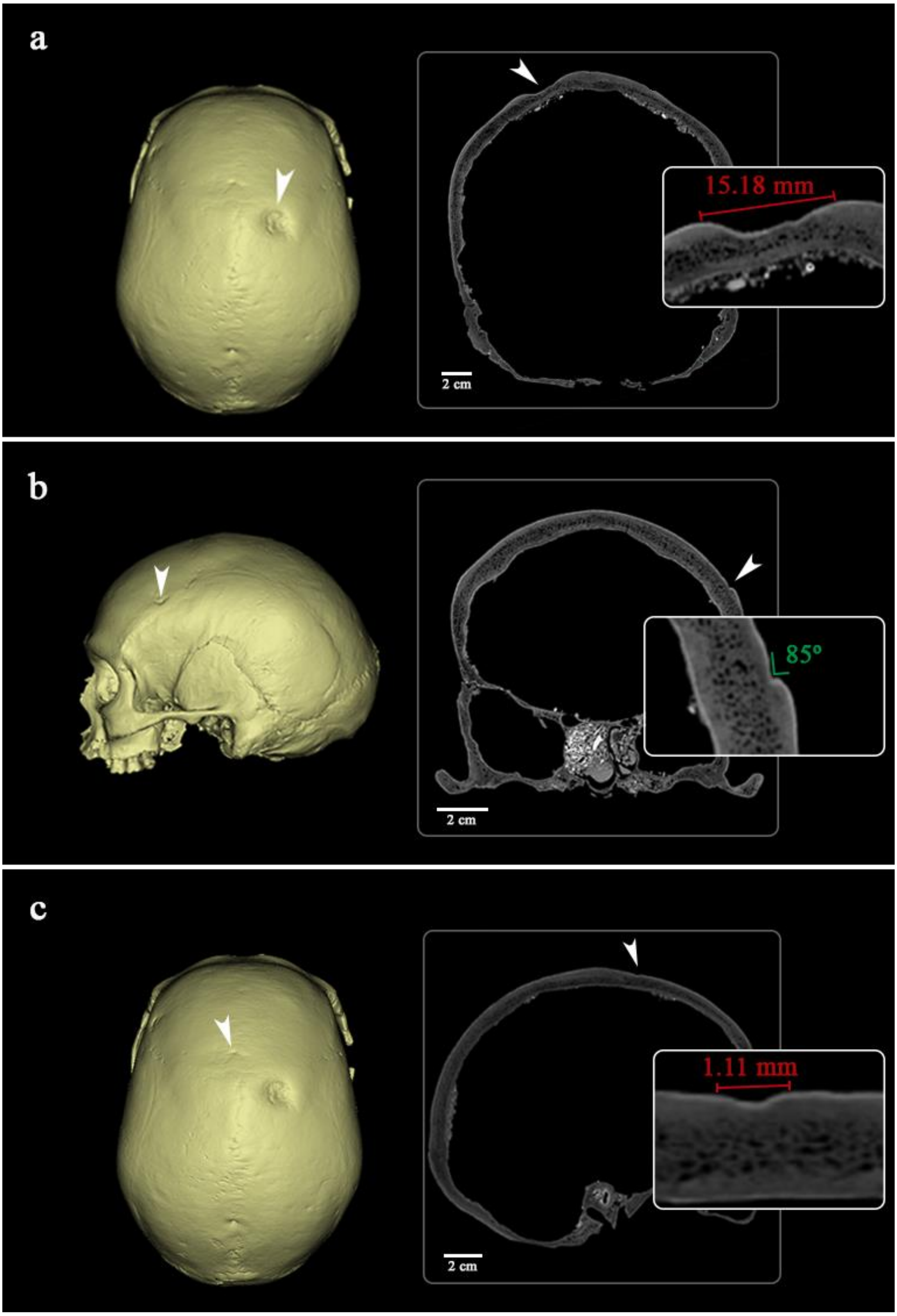

Figure 5: Exocranial lesions present in the skull from sima de Marcenejas. 3D model and microCT images of L2 (a), L3 (b) and L4 (c). The white arrows indicate the location of the lesion.

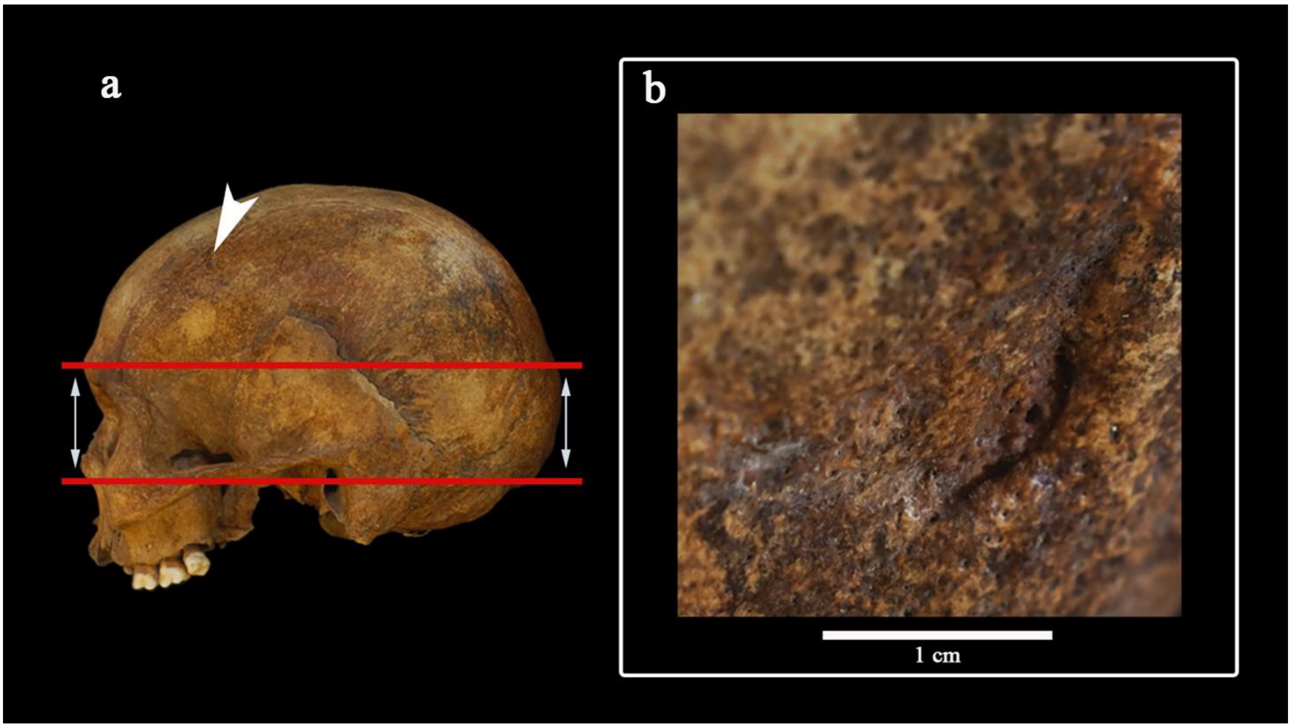

Figure 6: Exocranial lesion (L3): a) Marcenejas skull in left lateral view. The white arrow indicates the location of the lesion. The distance between red lines indicates "hat brim line"; b) detailed image of the lesion.

4. Discussion

4.1. Endocranial injury (L1)

The bone anomalies detected in the inner table of the cranium do not appear to be the result of postmortem processes, because we can observe the remodelling of the inner table in the MicroCT (Fig. 3). This lesion also does not appear to be related to any kind of metabolic disease, because there is no thickening of the diploë or porosity in the cortex (Walker, Bathurst, Richman, Gjerdrum, & Andrushko, 2009; Wu et al., 2011). We also rule out infectious diseases, as these occur very rarely within the skull, and can involve both tables and generate a small lesion which perforates the skull or multiple lesions that cause widespread destruction (Kang, Park, Kwon, & Hong, 2010; Spekker et al., 2022). However, the possible existence of a neoplasm cannot be ruled out. The most common neoplastic diseases that can produce lesions in the calotte are metastases and tumours (Arbizu et al., 2011; Gomez et al., 2018). The most common options are as follows:

(1) Fibrous dysplasia is characterized by a progressive replacement of cancellous bone by fibrous tissue, thus altering the intradiploic density resulting in a bulging of the outer table (Gomez et al., 2018).

(2) Eosinophilic granuloma presents as a lytic lesion with well-defined non-sclerotic borders affecting all three calotte tables (Stubenvoll & Hunsaker, 1987).

(3) Erdheim-Chester disease manifests itself in the calotte causing osteosclerosis and its thickening.

(4) Paget's disease and Paget's sarcoma are chronic, genetically based pathology characterized by bone destruction, abnormal and excessive bone remodelling, osteoporosis, and cortical and trabecular thickening resulting in a loss of bone table definition.

(5) Multiple myeloma is a malignant neoplasm that usually spreads multifocally, generating purely osteolytic, rounded, uniformly sized lesions with well-defined margins (Del Cura Allende et al., 2018). None of these neoplasms is compatible with the lesion observed. There is neither evidence of alterations in the outer table or intradiploic density, nor there is evidence of osteosclerosis, osteoporosis, multiple or purely lytic lesions.

Metastases are the most frequent of cranial neoplasms, predominant over primary tumours (Hernández Varela et al., 2006). This pathology is usually characterized by the development of poorly defined margins, with multiple osteolytic lesions, involving both the inner and outer tables (Casas Parera et al., 2016; Del Cura Allende et al., 2018; Merczi et al., 2014). The lesion's distinct morphology, as well as the absence of multiple osteolytic lesions, does not support this diagnosis.

On the other hand, primary tumours tend to have unique characteristics. They can be classified as intra-axial, located directly in the brain parenchyma itself, and extra-axial, located in the coverings of the brain (Arbizu et al., 2011). The location of the intra-axial tumours allows us to rule out this group as the possible cause of the lesion as they do not maintain direct contact with the calotte. In the absence of overlapping findings, the following types of extra-axial tumours can be ruled out:

(1) Aneurysmal bone cysts are benign expansive tumours that rarely affect the skull (Del Cura Allende et al., 2018; Navas-García, Pulido-Rivas, Pascual-Garvi, Manzanares-Soler, & Sola, 2011).

(2) Haemangiomas are benign vascular bone tumours, with a higher incidence in middle-aged women. They have an oval or rounded shape and tend to develop an intradiploic osteolytic lesion that tends to expand the outer table, causing a bulging (Politi, Romeike, & Reith, 2005).

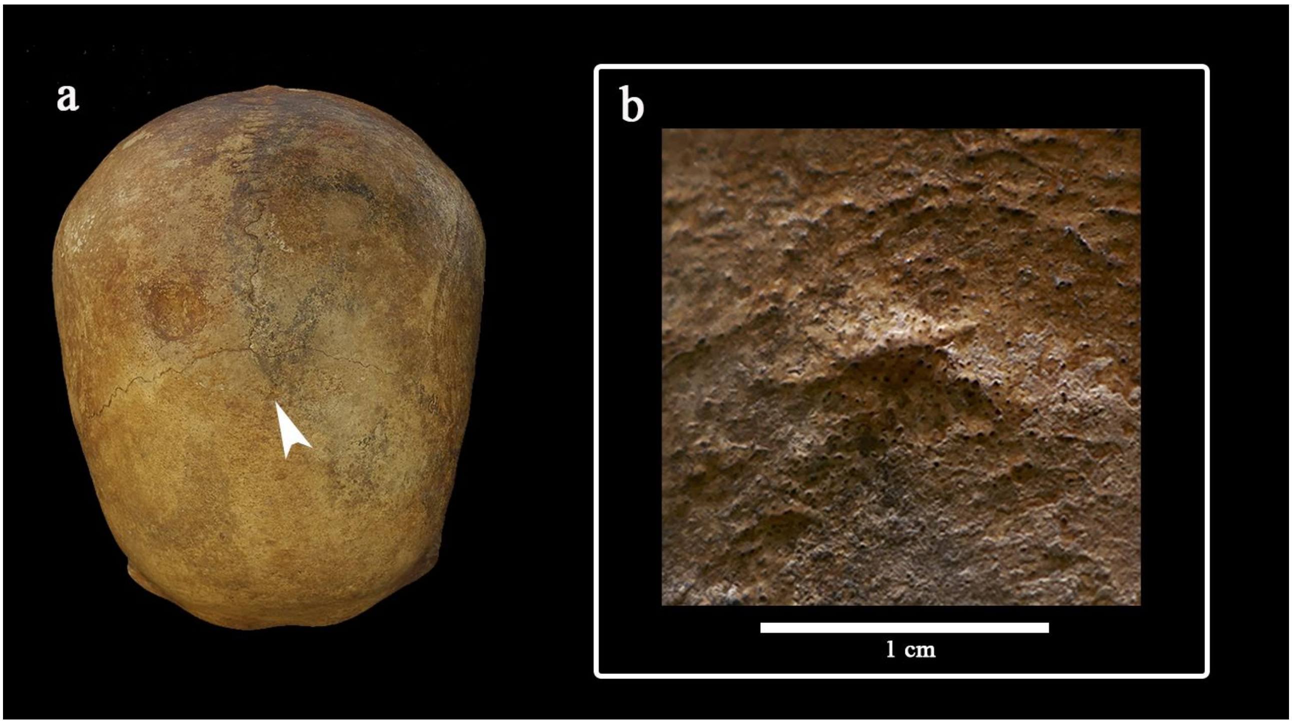

Figure 7: Exocranial lesion (L4): a) Marcenejas skull in top view. The white arrow indicates the location of the lesion; b) Detailed image of the lesion showing its porous surface.

(3) Haemangioendotheliomas are another very rare malignant cranial lesion. Radiologically, they are characterised by multipleosteolytic lesions (Bourekas et al., 1996).

(4) Osteosarcoma is a malignant tumour that usually occurs in adolescents and adults. It is characterized by lytic and/or osteoblastic lesions and is very aggressive through the formation of immature bone (Kanazawa, Yoshida, Takahashi, Matsumoto, & Teramoto, 2003).

We cannot rule out a hemangiopericytoma due to its location, typically parasagittal or frontal (Del Cura Allende et al., 2018; Mena, Ribas, Pezeshkpour, Cowan, & Parisi, 1991). However, even though bone erosion is presented, its border is not characterized by irregular edges as is common in this type of tumour. Moreover, considering that this type of tumour is scarce because it only constitutes approximately 2% to 3% of tumours linked to the meninges (Rutkowski et al., 2010), it is unlikely that the lesion is related to a hemangiopericytoma.

In contrast, meningiomas are the most common type of extra-axial tumour. Generally, these tumours are benign, and represent approximately 15% of all intracranial neoplasm. Their most frequent location is towards the parietal convexity of the skull (Cook & Danforth, 2022; Leyva-Pérez, Guerrero-Avendaño, & Ramón Hernández-Paz, 2013; Watts et al., 2014). The occurrence of meningiomas increases with age and most of them are diagnosed in adult individuals. However, these neoplasms have a greater tendency to develop in females (Campillo, 1991, 1993; Casas Parera et al., 2016; Leyva-Pérez et al., 2013). Meningiomas are characterized by a broad base of dural implantation, with smooth margins and a mushroom-shaped or slightly lobulated morphology. Many of these tumours cause bone alterations and can cause osteolytic or osteoblastic reactions, or both. The most common manifestation of these processes is evidenced by the appearance of hyperostosis or depression in the calotte in the area of tumour implantation (Campillo, 1991, 1993; Del Cura Allende et al., 2018; Leyva-Pérez et al., 2013).

In order to evaluate these features with an actual case, we compared the endocranial lesion of Marcenejas with the report on a meningioma reported in (Ichimura, Takahara, & Fujii, 2019). This report shows how the tumour is localized in the parietal region, invading the bone. In addition, the tumour shows margin equal to or less than 1 cm with lobulated morphology. These features are coincident with the lesion present in Marcenejas.

Consequently, the existence of an extra-axial meningioma seems the most likely cause of the lesion. The location and morphology of the neoplasm, the age of the individual, the appearance of osteolytic lesion and osteoblastic reaction, and the existence of depression in the area of the tumour implantation support this diagnosis.

4.2. Exocranial injuries (L2), (L3) and (L4)

The Marcenejas cranium has three exocranial injuries with signs of healing. Such head injuries can be caused by different circumstances, however, non-traumatic pathologies were ruled out based on:

(1) The absence of porotic hyperostosis and the different morphology compared to trauma rule out anaemia as a possible pathology (Walker et al., 2009; Wu et al., 2011).

(2) Infectious diseases, such as syphilis or tuberculosis, often produce bone destruction and may affect the diploë (Ortner & Putschar, 1981). Since there are no multifocal lesion patterns or signs of osteolysis in the bone, we can rule out the possibility that the injury was caused by this type of disease.

(3) Certain bone tumours may occur in different exocranial regions, although this is a rare phenomenon as most tumours occurring in the head usually develop in the endocranium or adjacent membranes (Arbizu et al., 2011).

Benign bone tumours with an exocranial presence include some osteoblastic tumours (osteoma and osteoblastoma) and fibrous dysplasia, which are characterized as a genetic disorder resulting in the replacement of cancellous bone with abnormal fibrous tissue containing immature bone (De Salvo et al., 2022; Gomez et al., 2018). Malignant tumours can also occur in the cranial vault, the most common being chordomas and chondrosarcomas. Benign tumours usually begin in other regions of the skull, such as paranasal regions, while chordomas and chondrosarcomas have their highest incidence rates at the base of the skull (De Salvo et al., 2022; Lin, Commins, Fedenko, & Pinsky, 2005). The presence of tumours does not appear to be the cause of these exocranial lesions, not only because of the low frequency of their occurrence but, above all, because they would include an extensive repertoire of bone lesions, such as a characteristic bulge bone formations and aggressive bone destruction, none of which are present in this individual (Del Cura Allende et al., 2018; Kakkar et al., 2016).

On the other hand, the analysis of the internal bone structure in the areas where the injuries occur seems to indicate that the individual must have suffered at least two strong impacts, which he survived. All these lesions are located above HBL and in the parietal (L2) and frontal bone (L3 and L4). Falls are usually associated with generalized cranial trauma. However, falls also tend to produce large linear fractures, especially at the level of the HBL. This allows us to rule out falls.

The first trauma (L2) is the most severe trauma observed in the calotte (Fig. 4). Analysis of this trauma reveals a pattern of injury resulting from a compressive force. This type of trauma is often associated with blunt force trauma (Erfan et al., 2009; Fenton, deJong, & Haut, 2003). And although cranial depression fractures can be a consequence of accidents, they are more likely to be the result of an event of interpersonal violence (Guyomarc'H et al., 2010).

As for the second trauma (L3) and third trauma (L4), both are located above HBL, supporting the hypothesis that were produced during an episode of interpersonal violence. Moreover, for the second trauma (L3), if the breadth-depth correlation is taken into account (6.72 mm x 2.18 mm), it is clear that it might have been made by a sharp object (Fig. 6). Sharp force injuries often result in trauma related to episodes of interpersonal violence (Moreno-Ibáñez, Saladié, Morales, Cebrià, & Fullola, 2021). On the other hand, the third trauma (L4) is characterized by a small plastic deformation towards the interior of the cranial vault (Fig. 7). This injury could have been caused by blunt or sharp force trauma. However, the characteristics of the injury do not provide sufficient data to confirm or rule out such possibilities because it seems to be that advanced scarring could be masking the cause of the original injury.

5. Conclusion

The *Sima de Marcenejas*' cranium corresponds to a male individual with an age at death of between 30 and 40 years old, dated between 258 and 409 AD. This cranium was found inside a cavity lacking any archaeological context.

Paleopathological and taphonomic analyses of the cranium show the existence of a neoplasm in the parietal convexity, which appears to be a meningioma. The meningioma was identified using a microCT and a 3D model generated from the slices. Considering these results, we hope that the identification of this possible meningioma will contribute to the diagnosis of more tumours using microCT and to the creation of a wider comparative framework. On the other hand, the analysis of the external structure of the cranium led to the identification of three injuries of traumatic origin linked to events of interpersonal violence.

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Supplementary files

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References

Arbizu, J., Domínguez, P. D., Diez-Valle, R., Vigil, C., García-Eulate, R., Zubieta, J. L., & Richter, J. A. (2011). Neuroimagen de los tumores cerebrales. *Revista Española de Medicina Nuclear*, *30*(1), 47–65. https://doi.org/10.1016/j.remn.2010.11.001

Berger, T. D., & Trinkaus, E. (1995). Patterns of trauma among the Neandertals. *Journal of Archaeological Science*, *22*, 841–852. https://doi.org/10.1016/0305-4403(95)90013-6.

Bourekas, E. C., Cohen, M. L., Kamen, C. S., Tarr, R. W., Lanzieri, C. F., & Lewin, J. S. (1996). Malignant Hemangioendothelioma (Angiosarcoma) of the Skull: Plain Film, CT, and MR Appearance. *American Journal of Neuroradiology*, *17*, 1946–1948.

Brothwell, M., & Brothwell, D. (2016). Evidence for ancient meningiomas and a probable case from Medieval Tarbat, Scotland. *International Journal of Paleopathology*, *13*, 65–69. https://doi.org/10.1016/j.ijpp.2016.01.004

Brotwell, D. (1965). *Digging up Bones. The Excavation, Treatment and Study of Human Skeletal Remains.* New York: Cornelll University Press.

Campillo, D. (1991). The possibility of diagnosing meningiomas in palaeopathology. *International Journal of Osteoarchaeology*, *1*(3–4), 225–230. https://doi.org/10.1002/oa.1390010315

Campillo, D. (1993). *Paleopatología. Los primeros vestigios de la enfermedad*. Barcelona: Fundación Uriach.

Casas Parera, I., Báez, A., Banfi, N., Blumenkrantz, Y., Halfon, M. J., Barros, M., … Lozano, C. (2016). Meningiomas en neurooncología. *Neurologia Argentina*, *8*(3), 210–226. https://doi.org/10.1073/pnas.117113108

Cook, D. C., & Danforth, M. E. (2022). Meningiomas in ancient human populations. *Cancers*, *14*(4). https://doi.org/10.3390/cancers14041058

De Salvo, S., Pavone, V., Coco, S., Dell'agli, E., Blatti, C., & Testa, G. (2022). Benign bone tumors: An overview of what we know today. *Journal of Clinical Medicine*, *11*(3). https://doi.org/10.3390/jcm11030699

Del Cura Allende, G., Bermejo Espinosa, N., Loizaga Ingunza, E., Angulo Gorriño, M., Arechaga Vidales, L., & Olabarria Vicente, I. (2018). Lesiones de calota en adultos: Diagnóstico por imagen. *33 Congreso Nacional Sociedad Española de Radiografía Médica (SERAM)* (pp. 1-21). Bilbao, España.

Erfan, M., El-Sawaf, A., Al-Tohamy Soliman, M., Sarry El-Din, A., Kandeel, W. A., Abd El-Shafy El-Banna, R., & Azab, A. (2009). Cranial trauma in ancient Egyptians from the Bahriyah oasis, Greco-Roman period. *Research Journal of Medicine and Medical Sciences*, *4*(1), 78–84.

Fenton, W. T., deJong, L. J., & Haut, C. R. (2003). Punched with a fist: the etiology of a fatal depressed cranial fracture. *Journal Forensic Science*, *48*(2), 1–5.

Garvin, H. M., Sholts, S. B., & Mosca, L. A. (2014). Sexual dimorphism in human cranial trait scores: Effects of population, age, and body size. *American Journal of Physical Anthropology*, *154*(2), 259–269. https://doi.org/10.1002/ajpa.22502

Gomez, C. K., Schiffman, S. R., & Bhatt, A. A. (2018). Radiological review of skull lesions. *Insights into Imaging*, *9*(5), 857–882. https://doi.org/10.1007/s13244-018-0643-0

Gracia-Téllez, A., Arsuaga, J. L., Martínez, I., Martín-Francés, L., Martinón-Torres, M., Bermúdez de Castro, J. M., … Lira, J. (2013). Orofacial pathology in *Homo heidelbergensis*: The case of Skull 5 from the Sima de los Huesos site (Atapuerca, Spain). *Quaternary International*, *295*, 83–93. https://doi.org/10.1016/j.quaint.2012.02.005

Guyomarc'H, P., Campagna-Vaillancourt, M., Kremer, C., & Sauvageau, A. (2010). Discrimination of falls and blows in blunt head trauma: A multi-criteria approach. *Journal of Forensic Sciences*, *55*(2), 423–427. https://doi.org/10.1111/j.1556-4029.2009.01310.x

Hernández Varela, A., Basulto Vega, S., Nápoles Domínguez, M., Betancourt Mosquera, G., Roura León, H., Da Conceiçao Almeida, F., & Cardoso Núñez, O. (2006). Metástasis craneales sobre los senos durales de la convexidad. Informe de nueve casos. *Revista Mexicana de Neurocirugía*, *7*(3), 240–245.

Ichimura, S., Takahara, K., & Fujii, K. (2019). Fibrous meningioma with skull invasion. *Journal of Neurosciences in Rural Practice*, *10*(4), 707–710. https://doi.org/10.1055/s-0039-3399600

Kakkar, A., Nambirajan, A., Suri, V., Sarkar, C., Kale, S. S., Singh, M., & Sharma, M. C. (2016). Primary bone tumors of the skull: Spectrum of 125 cases, with review of literature. *Journal of Neurological Surgery, Part B: Skull Base*, *77*(4), 319–325. https://doi.org/10.1055/s-0035-1570347

Kanazawa, R., Yoshida, D., Takahashi, H., Matsumoto, K., & Teramoto, A. (2003). Osteosarcoma arising from the skull-case report. *Neurologia Medico Chirug (Tokyo)*, *43*, 88–91. https://doi.org/10.2176/nmc.43.88

Kang, S. H., Park, S. W., Kwon, K. Y., & Hong, W. J. (2010). A solitary skull lesion of syphilitic osteomyelitis. *Journal of Korean Neurosurgical Society*, *48*(1), 85–87. https://doi.org/10.3340/jkns.2010.48.1.85

Kimmerle, E. H., & Baraybar, J. P. (2008). *Skeletal Trauma. Identification of Injuries Resulting from Human Rights Abuse and Armed Conflict.* Boca Raton: CRC Press.

Leyva-Pérez, I., Guerrero-Avendaño, G., & Ramón Hernández-Paz, J. (2013). Meningiomas: apariencia por tomografía y por resonancia magnética. Localizaciones más frecuentes. *Anales de Radiología México*, *1*, 36–44.

Lin, Y. C., Commins, D. L., Fedenko, A. N., & Pinsky, G. S. (2005). A rare case of periosteal osteoblastoma located in the frontal cranial bone. *Archives of Pathology & Laboratory Medicine*, *129*(6), 787–789. https://doi.org/10.5858/2005-129-787-ARCOPO

Lovejoy, C. O. (1985). Dental wear in the libben population: Its functional pattern and role in the determination of adult skeletal. Age at death. *American Journal of Physical Anthropology*, *68*, 47–56. https://doi.org/10.1002/ajpa.1330680105

Martín-Francés, L., Martinon-Torres, M., Gracia-Téllez, A., & Bermúdez de Castro, J. M. (2015). Evidence of stress fracture in a *Homo antecessor* metatarsal from Gran Dolina Site (Atapuerca, Spain). *International Journal of Osteoarchaeology*, *25*(4), 564–573. https://doi.org/10.1002/oa.2310

Martín-Francés, L., Martinón-Torres, M., Gracia-Téllez, A., & Bermúdez de Castro, J. M. (2016). Evidence of trauma in a ca. 1-million-year-old patella of Homo antecessor, Gran Dolina-Atapuerca (Spain). *Comptes Rendus - Palevol*, *15*(8), 1011–1016. https://doi.org/10.1016/j.crpv.2016.04.014

Meindl, R. S., & Lovejoy, C. O. (1985). Ectocranial Suture Closure: A revised method for the determination of skeletal age at death based on the lateral-anterior sutures. *American Journal of Physical Anthropology*, *68*, 57–66. https://doi.org/10.1002/ajpa.1330680106

Mena, H., L. Ribas, J., H. Pezeshkpour, G., N. Cowan, D., & E. Parisi, J. (1991). Hemangiopericytoma of the central nervous system: A review of 94 cases. *Human Pathology*, *22*(1), 84–91. https://doi.org/10.1016/0046-8177(91)90067-Y

Merczi, M., Marcsik, A., Bernert, Z., Józsa, L., Buczkó, K., Lassányi, G., … Molnár, E. (2014). Skeletal metastatic carcinomas from the Roman period (1st to 5th Century AD) in Hungary. *Pathobiology*, *81*(2), 100–111. https://doi.org/10.1159/000357435

Miles, A.-E.-W. (1963). Dentition in the estimating of age. *Journal of Dental Research*, *42*, 255–263. https://doi.org/10.1177/00220345630420012701

Moreno-Ibáñez, M. Á., Saladié, P., Morales, J. I., Cebrià, A., & Fullola, J. M. (2021). Was it an axe or an adze? A cranial trauma case study from the Late Neolithic – Chalcolithic site of Cova Foradada (Calafell, Spain). *International Journal of Paleopathology*, *32*, 23–30. https://doi.org/10.1016/j.ijpp.2020.11.002

Navas-García, M., Pulido-Rivas, P., Pascual-Garvi, J. M., Manzanares-Soler, R., & Sola, R. G. (2011). Quiste óseo aneurismático frontal. Caso clínico y revisión de la bibliografía. *Revista de Neurología*, *52*(6), 349–354.

Ortner, D. J., & Putschar, W. G. J. (1981). *Identification of Pathological Conditions in Human Skeletal.* Washington: Smithsonian Institution Press.

Politi, M., Romeike, B., & Reith, W. (2005). Intraosseous hemangioma of the skull with dural tail sign: radiologic features with pathologic correlation. *American Journal of Neuroradiology*, *26*(8), 2049–2052.

Rutkowski, M. J., Sughrue, M. E., Kane, A. J., Aranda, D., Mills, S. A., Barani, I. J., & Parsa, A. T. (2010). Predictors of mortality following treatment of intracranial hemangiopericytoma. *Journal of Neurosurgery*, *113*(2), 333–339. https://doi.org/10.3171/2010.3.JNS091882

Sala, N., Arsuaga, J. L., Pantoja-Pérez, A., Pablos, A., Martínez, I., Quam, R. M., … Carbonell, E. (2015). Lethal interpersonal violence in the Middle Pleistocene. *PLoS ONE*, *10*(5). https://doi.org/10.1371/journal.pone.0126589

Sala, N., Pantoja-Pérez, A., Arsuaga, J. L., Pablos, A., & Martínez, I. (2016). The Sima de los Huesos Crania: Analysis of the cranial breakage patterns. *Journal of Archaeological Science*, *72*, 25–43. https://doi.org/10.1016/j.jas.2016.06.001

Spekker, O., Váradi, O. A., Szekeres, A., Jäger, H. Y., Zink, A., Berner, M., … Tihanyi, B. (2022). A rare case of calvarial tuberculosis from the Avar Age (8th century CE) cemetery of Kaba–Bitózug (Hajdú-Bihar County, Hungary) – Pathogenesis and differential diagnostic aspects. *Tuberculosis*, *135*. https://doi.org/10.1016/j.tube.2022.102226

Stubenvoll, R. W., & Hunsaker, D. H. (1987). Eosinophilic granuloma of frontal bone. *Military Medicine*, *152*(6), 327–329.

Walker, P. L. (2008). Sexing skulls using discriminant function analysis of visually assessed traits. *American Journal of Physical Anthropology*, *136*(1), 39–50. https://doi.org/10.1002/ajpa.20776

Walker, P. L., Bathurst, R. R., Richman, R., Gjerdrum, T., & Andrushko, V. A. (2009). The causes of porotic hyperostosis and cribra orbitalia: A reappraisal of the iron-deficiency-anemia hypothesis. *American Journal of Physical Anthropology*, *139*(2), 109–125. https://doi.org/10.1002/ajpa.21031

Watts, J., Box, G., Galvin, A., Brotchie, P., Trost, N., & Sutherland, T. (2014). Magnetic resonance imaging of meningiomas: A pictorial review. *Insights into Imaging*, *5*(1), 113–122. https://doi.org/10.1007/s13244-013-0302-4

Wu, X. J., Schepartz, L. A., Liu, W., & Trinkaus, E. (2011). Antemortem trauma and survival in the late Middle Pleistocene human cranium from Maba, South China. *Proceedings of the National Academy of Sciences of the United States of America*, *108*(49), 19558–19562. https://doi.org/10.1073/pnas.1117113108

Zoubov, A. (1968). *Otonlogía. Metódica de las investigaciones antropológicas.* Moscú: Nauka.