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ORIGINAL ARTICLE

Palaeopathological Study of the Mompaderno Cranium (Croatian Istria) Reveals Interpersonal Violence during Early Bronze Age

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Abstract

The Mompaderno cranium was found in 1883 at Baderna/Mompaderno in Croatian Istria. It was suspected to date from the Mesolithic or Neolithic period, but radiocarbon analyses, performed by accelerator mass spectrometry (AMS) on collagen extracted from two teeth, have provided an age range of 2,202–1928 cal. BC, which corresponds to the Early Bronze Age in the investigated region. Macroscopic observations and X-ray micro-tomography (micro-CT) of the cranium have shown antemortem sharp force trauma on the frontal bones, probably caused by a bronze axe, and a related osteomyelitis likely caused by an infection of the wound. The study has also revealed a previous depressed fracture and an osteolytic area interpreted as intradiploic meningioma. Results provide rare and earliest evidence of interpersonal violence in the northern Adriatic region.

KEYWORDS

Croatian Istria, Early Bronze Age, Mompaderno cranium, sharp force trauma; interpersonal violence, X-ray micro-tomography

INTRODUCTION

The long and troubled history of the Mompaderno cranium starts in 1883 when it was discovered by Carlo Marchesetti in a cave located around Baderna/Mompaderno in Croatian Istria (Figure 1a–b). Though the investigation of the surrounding area reached a depth of one meter, the influent archaeologist claimed to have found no other remains than the cranium (Battaglia, 1944).

The presence of the cranium alone could be attributed to taphonomic processes and the possibility that this was once part of a burial as has been attested elsewhere in Istria (Bernardini et al., 2014; Komšo, 2008) and cannot be excluded. Older comparative morphological studies (Battaglia, 1944) relatively dated the remains to the Mesolithic or Neolithic period but such chronology was not verified by absolute dating in recent times. After almost 140 years from its discovery, accelerator mass spectrometry (AMS) radiocarbon dating, macroscopic observations, and X-ray micro-tomography (micro-CT) have been applied in order to define its chronology and the possible manner of death of the individual.

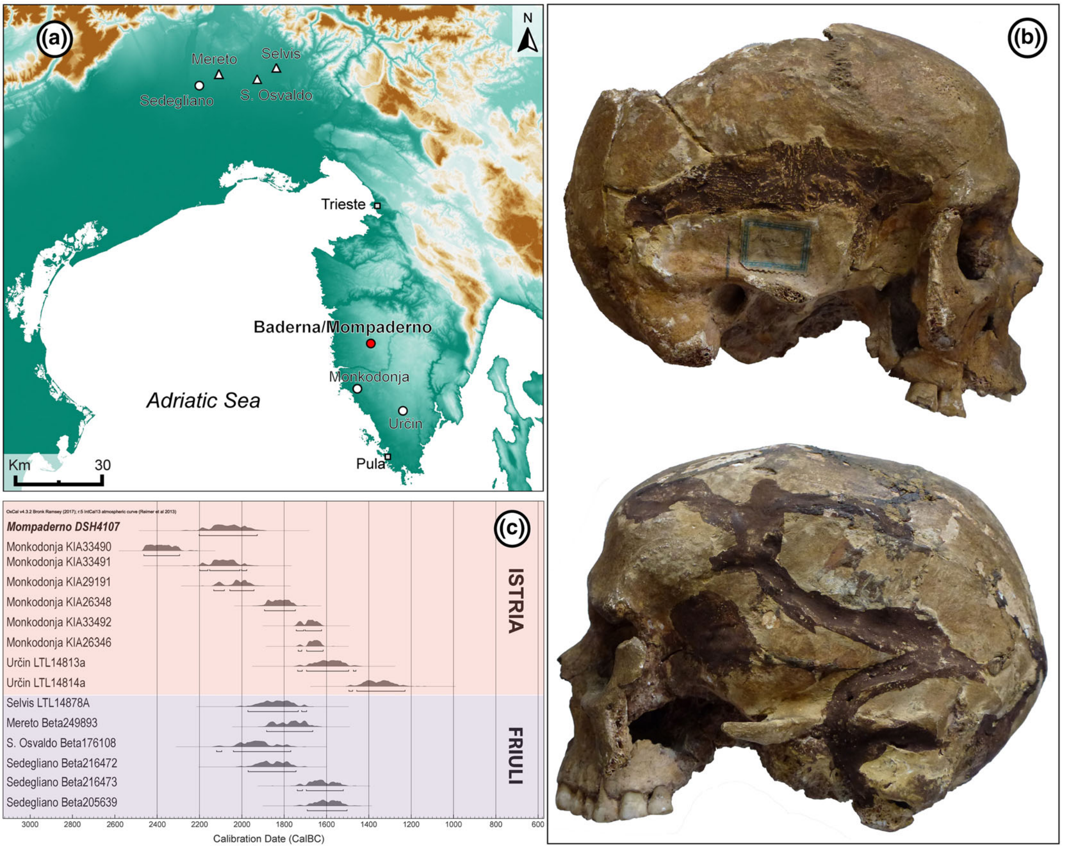

FIGURE 1 (a) Baderna/Mompaderno (Croatia) and other localities of the north-eastern Adriatic regions mentioned in the text where Early-Middle Bronze Age human remains have been discovered; (1b) right side (top) and left side view (below) of the cranium; (1c) calibrated radiocarbon dates of main Early-Middle Bronze human remains from north-eastern Adriatic regions, calculated with OxCal version 4.3.2 (Bronk Ramsey, 2017) using IntCal13 atmospheric curve (Reimer et al., 2013)

MATERIALS AND METHODS

The Mompaderno cranium is broken in the superior aspect of the vault (affecting both temporal and parietal bones along the sagittal suture) and shows a number of post-mortem fractures suggesting that the specimen was originally found in several pieces or was broken during excavation. It was then re-assembled and the few small missing parts filled with plaster (Figure 1b).

Radiocarbon analysis was performed on collagen extracted from the roots of the left lateral incisor and canine. Collagen extraction and combustion were carried out using standard procedures (Marzaioli et al., 2008; Passariello et al., 2007). The CO_2 produced by the combustion was purified into a steel cryogenic line through H_2O and CO_2 spiral traps. It was then transferred to a sealed pre-cleaned pyrex® tube with Zn and TiH_2 powder, where the graphitization took place at 565°C for 8 hr (Marzaioli et al., 2008). Finally, the resulting graphite was pressed into an aluminum cathode and measured by means of the CIRCE AMS system (Terrasi et al., 2008).

The cranium was visualized by X-ray micro tomography (micro-CT) at the at the Multidisciplinary Laboratory of the Abdus Salam International Centre for Theoretical Physics, Italy, using a system (Tuniz et al., 2013) specifically designed for the study of archaeological and paleoanthropological samples (e.g. Bernardini et al., 2019, 2018, 2012, 2015; Di Vincenzo et al., 2017; Tuniz et al., 2012; Zanolli et al., 2018). It was scanned in three partially overlapping parts, just changing the vertical spatial coordinate. The micro-CT acquisitions were carried out with a source voltage of 140 kV, a current of 200 μA, a 1 mm aluminium filter, an exposure time of 1 s and recording 4,800 projections of the sample over 360°. The resulting micro-CT slices, reconstructed using the software DigiXCT with a pixel size of 42 μm, were merged in order to obtain a single 3D image of the specimen. A virtual endocast of the Mompaderno cranium (Figure 2) was produced using Amira v.5.3 software. Meshlab software was used for surface measurements.

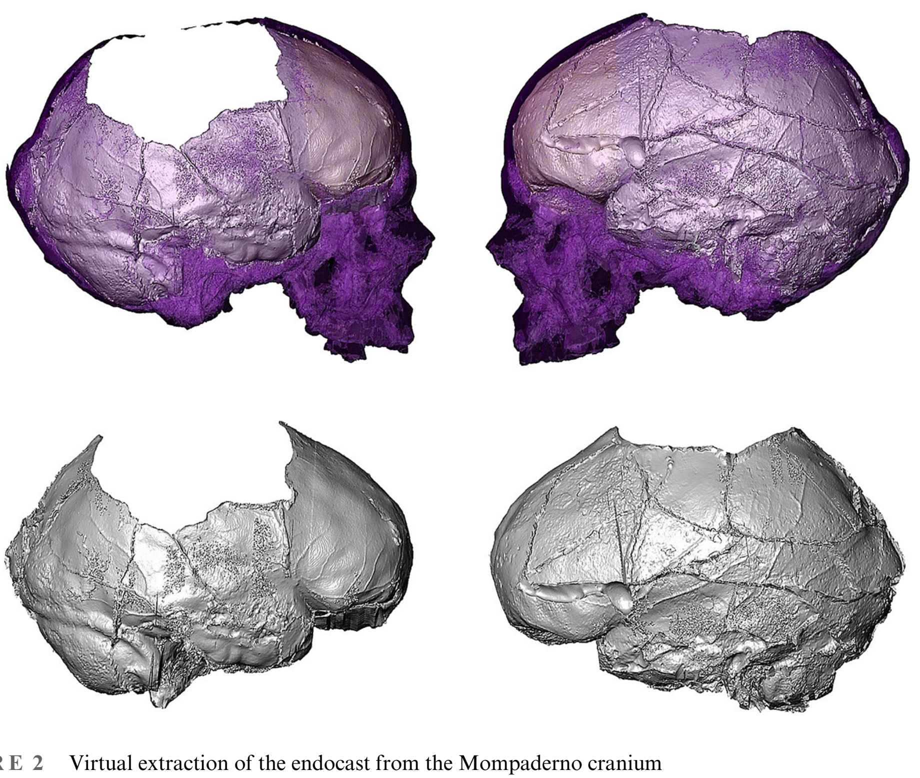

FIGURE 2 Virtual extraction of the endocast from the Mompaderno cranium

To establish the sex of the individual, the characteristics proposed by Acsadi and Nemeskeri (1970) were considered. Age determination was carried out using cranial suture closure as well as dental wear (Molnar, 1971).

RESULTS

Absolute dating and archaeological background

The radiocarbon age obtained (3,679 ± 51 BP) was calibrated using the OxCal v 4.3.2 program (Bronk Ramsey, 2017), considering the IntCal13 calibration curve (Reimer et al., 2013), provided a range spanning 2,202–1928 cal. BC (2σ) (Figure 1c, sample DSH4107). This result revealed that the individual lived during the Early Bronze Age of Istria. In the north Adriatic region, the last centuries of the Copper Age and the beginning of the Bronze Age (around 2,500–1800 BCE) mark a period of progressive stabilization of settlement forms, which resulted in the foundation of the first long-lasting fortified settlements, approximately between 1800 and 1,600 BC (Borgna et al., 2018, 68 with refs.; Borgna & Càssola Guida, 2009). This time span corresponds to the Early Bronze Age II in the Italian relative chronological system (Cardarelli, 2009) and to the BZ A2 in the Central European Reinecke system (Hänsel, 2009).

These villages, generally located on strategic hilltops, were settled for many centuries, sometimes until the late Iron Age (Mihovilić, 2013). As reported above, the Mompaderno cranium dates back to the Early Bronze Age and, in particular, to a period just before the rise of the first permanent protohistoric settlements (Borgna et al., 2018). Traces of earlier ephemeral occupation (i.e., Late Copper Age and Early Bronze Age) of the hilltops later occupied by fortified settlements have been recognized at several sites and mainly consist of pottery fragments and stone artefacts. At the settlement of Monkodonja, near Rovinj, some pottery finds ascribed to Cetina types (Hellmuth Kramberger, 2017) and a few polished stone shaft-hole axes (Bernardini, 2018; Zupančič et al., 2012) indicate an ephemeral occupation of the hill during the Late Copper Age. Similar episodes of early occupations are, for example, documented in other hillforts in Istria (Mihovilić, 1997, 2001; Sakara Sučević, 2008), Karst (Guštin, 1979; Maselli Scotti, 1988; Montagnari Kokelj, 1989), and Friuli (Gerdol & Stacul, 1978; Visentini et al., 2014). Moreover, pottery finds of Cetina and Wieselburg-Gata types were found at several caves in Friuli (Simeoni, 2009; Simeoni & Corazza, 2011; Simeoni & Tasca, 2008), Trieste Karst (Montagnari Kokelj, 1994, 1996), and Istria (Forenbaher, 2018), demonstrating the existence in this period of contacts with Dalmatia and Central Europe.

Human remains contemporary with the period of the Mompaderno cranium are rare in Istria, whereas their number increases during the following centuries (Figure 1c). The radiocarbon dating of some of the human remains coming from the cist tombs of Monkodonja (Figure 1a and c, samples KIA33490, KIA33491 and KIA29191; Hänsel et al., 2015), located close to one of its main entrances, provided an age considerably older then the supposed occupation of the protohistoric hill fort. This has been related to the so-called reservoir effect (Hänsel et al., 2015). Other dates on bones from the same graves cover approximately the period between the 1900 and 1,600 BC (Figure 1c, samples KIA2648, KIA33492 and KIA26346; Hänsel et al., 2015).

Considering the human remains from a similar context, new dates obtained from two individuals buried in a monumental cemetery found next to the main fortified entrance at Určin indicate a longer span of time approximately between 1700 and 1200 BC (Figure 1a and c, samples LTL14813a, 14814a; Cupitò et al., 2018).

Other evidence for this period comes from the settlement of Sedegliano in Friuli and consists of five inhumation graves inserted into a low earth work and later covered under the following reinforced ramparts. Three of these graves were dated to a period spanning from around 1950 to 1550 BC (Figure 1a and c, samples Beta216472, Beta205639, Beta216473 and Beta205639; Canci et al., 2005; Canci, 2006) corresponding to the initial phases of occupation of the area.

A final group of human remains pointing to approximately the same period are featured by burials under tumuli. These funerary monuments are widespread in the whole north Adriatic region between the upper plain of Friuli, Istria, and Dalmatia (Borgna & Müller-Celka, 2011).

Available dates are thus only known for the area of the Friuli plain, where three individuals found at Selvis (Figure 1a and c, sample LTL14878A; Canci et al., 2018), Mereto (Figure 1a and c, sample Beta-249,893, Borgna et al., 2013), and S. Osvaldo (Figure 1a and c, sample Beta176108; Canci, 2006), respectively, span from around 2050 to 1650 BC. This chronological span seems to be confirmed by rare materials collected in a few similar structures found in Istria, suggesting to place the beginning of this phenomenon in the first centuries of the second millennium BC in both Friuli and Istria regions (Buršic-Matijašic & Žeric, 2013; Codacci-Terlević, 2011).

Overall, small cemeteries close or within the hillfort fortifications and tumuli represent the main funerary contexts attested in Istria for the Early Bronze Age period, whereas the funerary use of caves is quite rare and so far limited to later Bronze Age phases. So far, the available documentation consists of few small cemeteries found at the Laganiši cave in Croatian Istria (Komšo, 2008) and at Ladrica cave in the Slovenian Karst (Bernardini et al., 2014). Other fragmented skeletal remains of two individuals have been recovered from mixed stratigraphic layers at Romuald's cave, again located in Croatian Istria (Janković et al., 2015). For the Early Bronze Age of this area, the Baderna/Mompaderno cranium represents therefore the earliest certain evidence of this type.

Find conditions, sex and age determinations

The cranium (Figures 1b and 2) is incomplete, missing portions of the upper right and left parietals, it lacks the zygomatic processes and the mastoid processes are damaged in their apical part. At the time of discovery, a portion of the left side of the cranium was covered by calcite concretion.

Cranial features including glabella, supra-orbital margin, and frontal inclination (1.1 following the method proposed by Acsadi and Nemeskeri (1970)) suggest a male attribution. Moreover, the partial obliteration of the cranial sutures and severe dental wear (grade 3 recorded in the first left molar, following the method by Molnar, 1971) indicate an adult probably aged over 35 years.

Antemortem loss of the right I2, P3, and P4 and, in particular, of I2 most likely occurred just before death due to incomplete resorption of the alveoli.

Antemortem trauma

Two wounds were detected on the cranium: one on the frontal and one on the right parietal bone. Both traumatic lesions are visible to the naked eye. The micro-CT analysis revealed the presence of osteolytic areas that affected the diploë both of the frontal and right parietal.

Frontal injury

The lesion is located in the right frontal region, close to the coronal suture (Figure 3a–b). The lesion, preserved up to a length of 29.05 mm, ends at the incomplete postmortem fractures.

The lesion does not feature a perfectly rectilinear course and runs from the posterior-medial to the antero-lateral featuring a transversal V-shaped cross section (Figure 3a–b). Near the anterior part of the lesion, the removal of a thin portion of external bone can be observed: this removal is wider in the antero-lateral part, measuring 13.56 mm, reduces in size to ca. 5.16 mm in the central region, ends at the edge of the fractured bone with a width of 2.95 mm and deepens toward the posterior (Figure 3a–b). The total area of the removed region corresponds

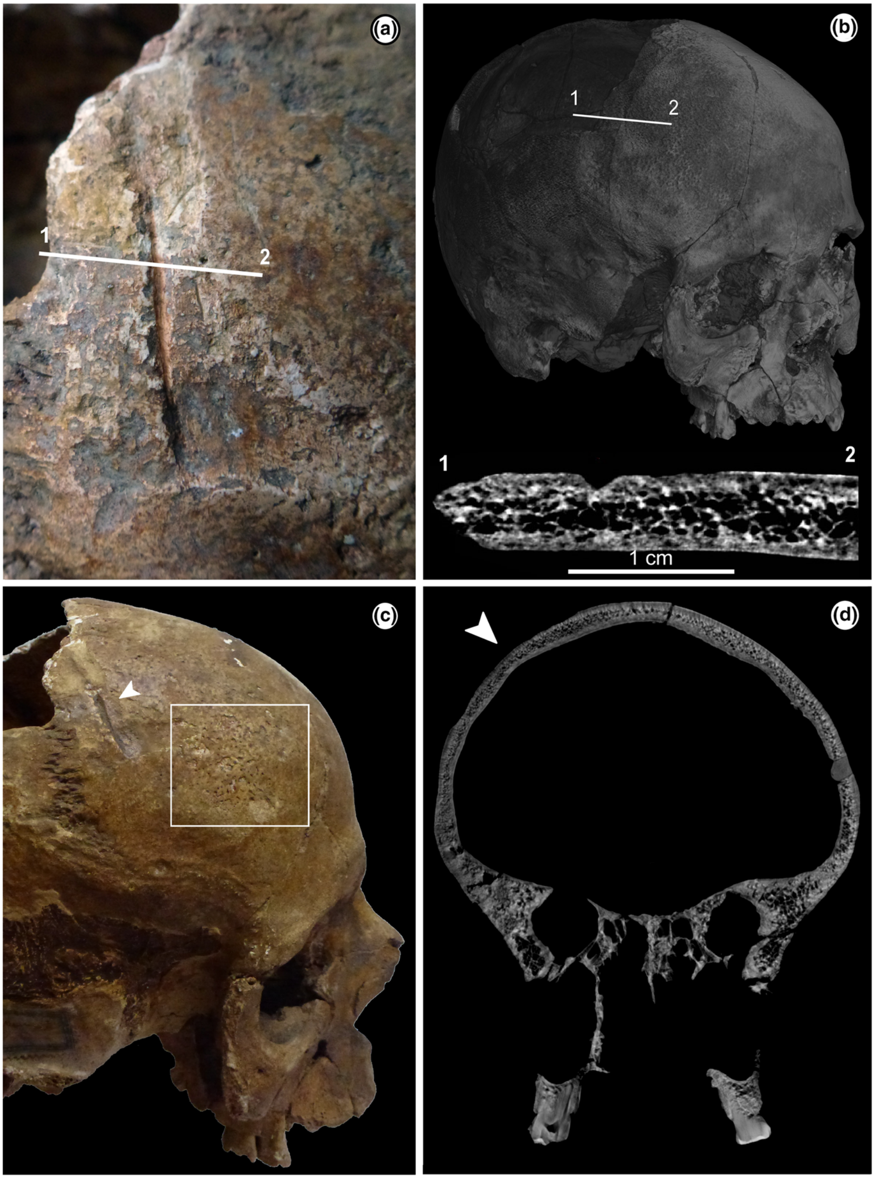

FIGURE 3 (a) Top view of the frontal injury identified on the Mompaderno cranium; (b) micro-CT virtual rendering of the cranium and transversal cross-section through the injury (for the position see the white line), showing a V-shaped morphology. The length of the of the injury corresponds to about 3 cm; (c) top view of the Mompaderno cranium showing a related polished area (white square) and the frontal injury (white arrow); (d) micro-CT virtual transversal section of the Mompaderno cranium showing the area with rarefaction of the diploic pattern (indicated by a white arrow) to 246.03 mm^2. The cut were not deep enough to damage the diploë. On the posterior edge of the cut small concavities are present.

On the wound and the adjacent frontal area a sclerotic area of the cortical surface is present, occasionally interrupted by small cavities of sub-circular and dendritic shape (Figure 3c).

Radiologically, a focal interruption of the external cortex associated with the rarefaction of the trabecular diploic structure is present in the area of the wound that differs from the opposite side of the left frontal bone (Figure 3d).

Parietal injury

The trauma on the right parietal bone is situated at the same level as the parietal foramen: the distance from the sagittal suture is 44.16 mm and 22.77 mm from the lambdoid suture. The lesion consists of a circular depression with a diameter of ca. 10 mm (Figures 4–5a) and covers a surface of 81.44 mm^2. Moreover, the micro-CT image demonstrates that the lesion on the outer table caused a discontinuity in the diploë without altering the profile of the inner table (Figures 4–5a).

Parietal osteolytic area

In the right parietal diploë, between the lambdoid and parietomastoid suture, an osteolytic formation is present, causing a swelling on the internal table area (Figure 5b–f). The gap is 10,02 mm from the lamdoid suture (24.09 mm from the intersection between the lambdoid and parietomastoid suture) and 31.73 mm from the parietal trauma. The 3D segmentation of the osteolytic gap (Figure 5c–f) allows to establish a surface of 35.65 mm^2 and a volume of

FIGURE 4 Depressed fracture on the right parietal bone of the Mompaderno cranium (area within the white box)
Note: The diameter of the lesion is about 10 mm

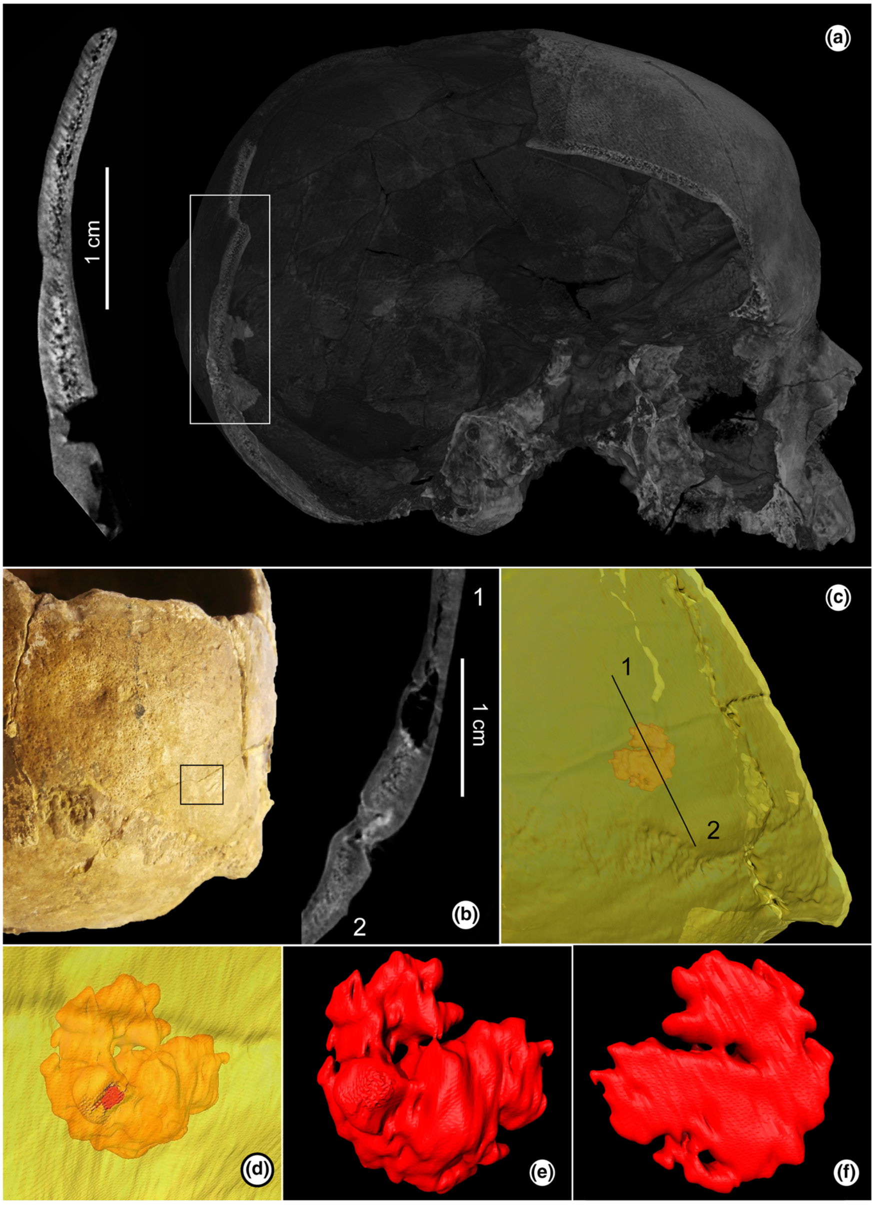

FIGURE 5 (a) Micro-CT section of the depressed fracture identified on the right parietal bone of the Mompaderno cranium (for the position of the section see the white box); (b) top view of the osteolytic area indentified in the right parietal bone and micro-CT cross-section through it (for the position of the section see Figure 5c); (c–d) micro-CT renderings showing the cranium in transparency and the lacuna left by the osteolytic area in red; (e–f) virtual extraction of the lacuna left by the osteolytic area seen from the external and the internal tables of the cranial vault. The osteolytic area is about 1.2 cm in size

256.24 mm^3. Last, this formation extends into the internal table and is connected with the meninges through an opening, probably a bone break at the point of greatest fragility just below the sulcus of the inferior meningeal artery (though a vascular origin is also possible; Figure 5d).

DISCUSSION

Frontal injury

The trauma detected on the frontal bone (Figure 3a–c) is compatible with the unidirectional impact (in an anteroposterior direction) of a blade on the ectocranial surface that caused the removal of the external table, leaving a 29,05 mm groove on the bone (Figure 3a–b). The presence of small concavities along the defect edge was caused by the formation of splinters at the terminus of the lesion (Figure 3a–c). The surface polishing that formed anterior to the lesion appears in micro-CT as a bright white plaque present on the external table (Figure 6a–c). The rarefaction of the diploic structure can be attributed to the lesion in this area (Figure 5a). These are symptomatic of an infective process. Based on the literature (Barbian & Sledzik, 2008), bone reactions on the cranium are visible from the second week, and, within the sixth week, all the cranial lesions observed featured some form of osteoblastic and osteoclast activity. Healing is generally linked to factors such as the position of the injury, soft tissue damage, the degree of bone loss, the alteration or loss of blood, and intrinsic factors, especially biological ones, such as age, sex, and previous pathologies (Cruess, 1984). A wound causing an increase in the vascularization and temporary immunosuppression may be subject to infections and predisposes an individual to bone lesions (Suchanda et al., 2012) and the immunological response aimed at eliminating a pathogen (Marcove & Arlen, 1992). In some cases, it is possible to mistake the effects of infection with bone remodelling because an infection can cause new bone formation (Barbian & Sledzik, 2008). Currently, the organism that causes the infection in 90% of cases is *Staphylococcus aureus*, and the second in frequency is *Streptococcus*, whereas all others constitute the remaining infective pathogens (Olson & Bingaman, 1999; Ortner, 2003a), although not knowing the sanitary conditions in which people in the past lived, this type of consideration can be excessively restrictive, as demonstrated by case studies from the world's poorer regions (Sundar et al., 2013).

The dynamics of the trauma would have caused the raising of the scalp, thus favouring the attack of external pathogens. In this case, the involvement of the diploic bone implies that it was an osteomyelitis: this is an inflammatory process accompanied by bone destruction and caused by an infective microorganism (Kim, 2012; Ortner, 2003a).

The vast majority of chronic cases of osteomyelitis can be traced back to trauma, and the infection is spread from adjacent sites (Osei-Yeboah et al., 2007): in the present case the infectious agent conveyor is the cut present on the external table. In cases of cranial osteomyelitis, the infection tends to remain localized (Ortner, 2003a), as in this case. The initial bone changes following the inoculation of the bacteria are basically alterations of the pH and the capillary permeability that contribute to regional edema, the release of cytokine, tissue breakdown, the recruitment of leukocytes, reduction in oxygen tension, increased local pressure, thrombosis of the small vessels, and bone deterioration (Prasad et al., 2007; Tsukayama, 1999). When the infection spreads to the medullary cavity, the increase in pressure causes its extension to the cortex from the Haversian and Volkmann channels with a successive diffusion to the subperiosteal area and finally to the periosteum and adjacent soft tissues (Pincus et al., 2009; Pineda et al., 2009; Strumas et al., 2003).

There are several osteomyelitis classification systems: this study followed that of Cierny et al. (2003). This system takes into consideration the anatomical area of bone involvement and the physiological condition of the subject. In stage I, medullary osteomyelitis, the infection affects only the medullary cavity of a bone segment. In stage II, superficial osteomyelitis, septic bone necrosis affects a fraction of the cortical bone and does not reach the medullary cavity. In stage III, localized osteomyelitis, osteomyelitis spreads across the full width of the medullary and cortical space. Stage IV, diffuse osteomyelitis, is similar to III but more extensive.

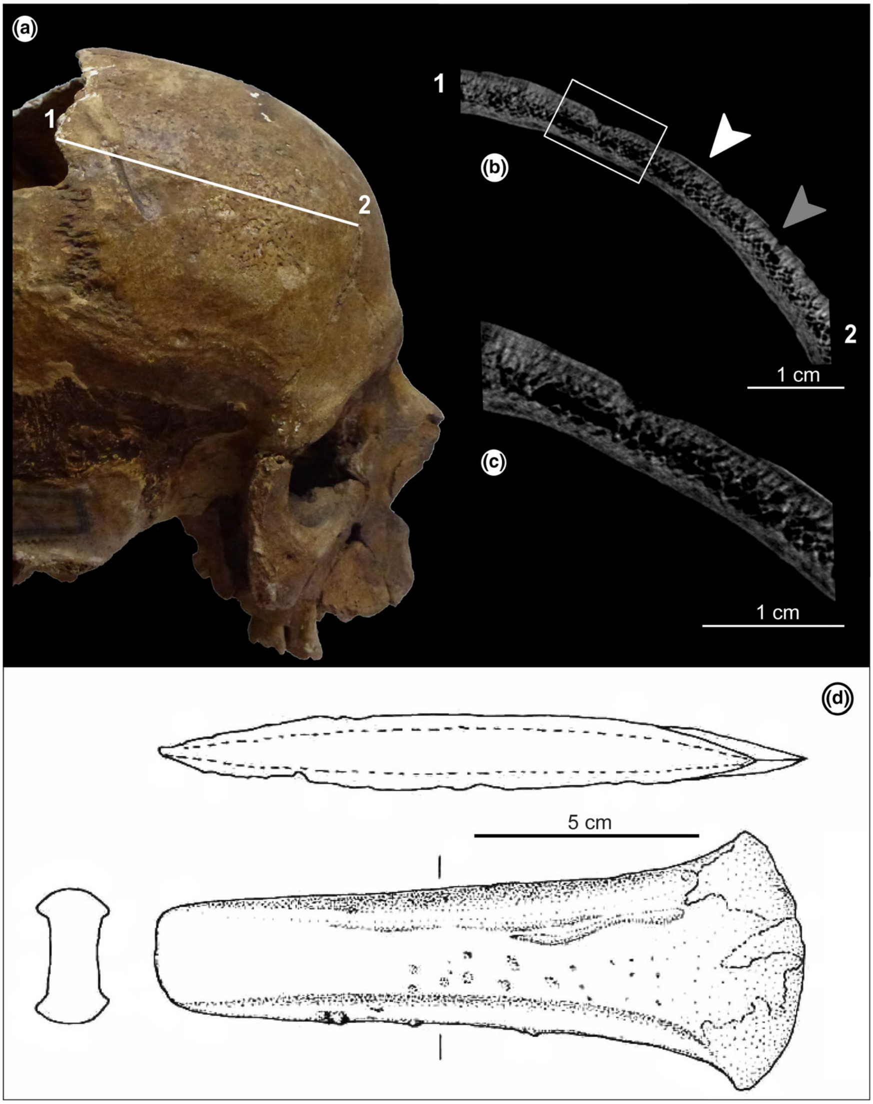

FIGURE 6 (a) Lateral view of the Mompaderno cranium with the position of the micro-CT virtual section of Figure 6b; (b–c) micro-CT virtual section through the area affected by trauma due to a metal-edged weapon: the white box shows the lesion and the related osteolytic area, the white arrow the newly formed bone polished surface, the grey arrow the openings that occurred in the new bone formation; (d) drawing of a winged bronze axe from Talmassons (Torsa, Friuli), compatible with the wound on the frontal bone of the Mompaderno cranium (from Tasca, 2011)

In the Mompaderno cranium, rarefaction in the diploic structure might have been caused by a medullary osteomyelitis. In this case the infections of the diploë tend to remain circumscribed and to assume a chronic course with a considerable peripheral sclerosis (Ortner, 2003a). Moreover, on the frontal cortical surface, new bone formation indicates a superficial osteomyelitis. Superficial osteomyelitis is a lesion adjacent to the focus and the affected area may be on a prominent callus of a healed open fracture. Medullary and superficial osteomyelitis share a pathophysiological component: the compression of soft tissue (Cierny et al., 2003). This analysis suggests a case of localized osteomyelitis (stage III in the classification by Cierny et al. (2003) that often has the combined characteristics of medullary and superficial osteomyelitis and that can often result as a sequela of one of these two entities (Cierny et al., 2003). Similar cases of osteomyelitis are reported from South America (Gerszten et al., 1998).

In the present study, from the wound on the cranium case it can be inferred that the traumatic lesion runs in an anterior to posterior direction and that the injury was caused from sharp force trauma. In trauma caused by bladed weapons, the extent of the damage is determined by the weight of the weapon, the force applied, the impact surface, and the presence of soft tissues or other protective elements (Lewis, 2008). This type of lesion excludes the possibility of trauma caused by an accidental event and indicates that it was the result of an act of interpersonal violence. From the structure of the wound (Figure 3a–b), it can be inferred that it was produced by a slightly curved blade, compatible with a metal axe.

According to the axe types attested in the north Adriatic region in the Early Bronze Age and in consideration of the probable length of the blade, a flanged axe with small wings is the weapon most compatible with the identified wound (Figure 6a–c). This type is so far not attested in Istria but is represented by items from Friuli (Tasca, 2011; Tasca & Vicenzutto, 2018; Figure 6d). All these items have a blade length of around 5–6 cm. On the basis of the typology of Italian hoards and Central European comparisons this type has been attributed to the second period of hoards (Carancini & Peroni, 1999), approximately corresponding to around the 20th–19th century BC.

The presence of bone neo-formation and infections following the trauma are most probably related to antemortem trauma. Cases of survival to cranial trauma are documented in two coeval individuals from the hypogeum of Serra Crabiles (Germanà, 1978) and from Grotta Lu Maccioni (Maxia, 1963), both located in Sardinia (Italy).

Parietal injury

The traumatic lesion on the right parietal bone is situated at the same level as the parietal foramen: the lesion consists of a slight circular depression with a diameter of ca. 10 mm (Figures 4–5a).

A bone subjected to mechanical stress goes through two phases: an elastic one, in which the bone has the capacity to bend and return to its original shape, and a plastic one, in which the bone remains permanently deformed or fractures (Harkess et al., 1984). A fracture represents an abrupt interruption of a segment caused by pressure applied to the bone (Kimmerle & Baraybar, 2008; Ortner, 2003b). Depending on the direction and strength of the impact, different types of fracture may occur. On the cranial vault the bone responds in one of four different ways, from endocranial fracture to the complete displacement of a portion of the cranial bone (Moritz, 1954).

Under compression from cranial trauma trabeculae of the diploë are first to fail, followed by the junction area between the external compact bone and the diploë; finally, the external compact bone breaks (Zhi-Jin & Jia-Zhen, 1991). A concentric fracture occurs around the impact area that starts at the external table and spreads to the inner table. As the fractures gradually passes from the external to the internal table, it encounters forces that deflects the angle in the direction of the fracture (Moritz, 1954). Internally, the concentric fracture associated with a blunt force trauma tends to be bevelled.

The shape and extent of the fracture depends on a number of intrinsic (e.g. bone elasticity, plasticity, and density) and extrinsic factors (the violence of the blow, impact velocity, weapon weight), and their interaction in the production of bone fractures is complex (Berryman & Haun, 1996).

In the case of Mompaderno, the lesion appears as a remodelled sunken fracture that affects an area of 81,44 mm^2. From the micro-CT (Figures 4–5a), it is possible to observe that the fracture involved only the external table and diploë, whereas the internal table does not appear to have been affected. This implies that the impact must have not been particularly violent. The remodelling of the wound suggests that the trauma occurred long before death.

Osteolytic parietal area: possible causes

Osteolytic lesions of the cranium constitute ca. 1% of all cranial tumours and may be congenital, traumatic, inflammatory, and neoplastic (Anwar et al., 2014). In children and young adults they are often caused by eosinophilic granuloma, encephalocele, epidermoid and dermoid cysts, osteoblastomas, haemangiomas, and aneurysmal bone cysts. In adults osteolytic lesions are often caused by metastases and multiple myeloma. Pathologies documented in all ages may be attributable to osteomyelitis, fibrous dysplasia, lymphoma, intraosseous meningioma, sarcoma, intracranial tumours, and histiocytosis X (Anwar et al., 2014; Sandeep et al., 2017). A detailed description of possible causes of osteolytic lesions of the *cranium* is reported in the online resources (see Supplementary Material).

In the case of Mompaderno, the osteolytic area is situated in the diploë and noticeably modifies the profile of the internal table. On the basis of the available information, based on the adult at death, the lack of associated pathologies, the clinical consequences, the incidence of the previously described pathologies and the close vicinity of a trauma tic lesion to a cranial suture (Figures 4–5), it is possible to hypothesise that the osteolytic lesion was caused by an intradiploic meningioma. The prevalence of meningiomas is probably higher than that generally mentioned in the literature because only those sufficiently large are detected. Studies conducted on skeletal remains suggest a greater prevalence: Campillo (1991) found five cases out of 3,000 crania with a prevalence of 0.17% (95% CI 0.05–0.38%), with one adult male showing an osteolytic lesion; Waldron (1998, 2009) found three cases out of 167 burials with a prevalence of 1.60% (95% CI 0.55–4.61%) with all three individuals showing osteolytic lesions and Jónsdóttir et al. (2003) found a osteolytic lesion in an adult male. Further cases of hyperostotic meningiomas are also reported (Danforth et al., 2019) as well as intra-osseous, benign intracranial tumour in the left anterior parieto-temporal region, documented in the skeleton of the "Gristhorpe Man", a male adult found in northern England and recently dated to the Early Bronze Age (Melton et al., 2010; Melton et al., 2013).

CONCLUSIONS

All the data presented in this study indicate that the Mompaderno cranium belongs to an adult individual, most likely a male who lived during the beginning of the Early Bronze Age, around 2200–1900 BC. Macroscopic observations and micro-CT data permitted the identification of sharp force antemortem trauma on the right side of the frontal bone, a depressed fracture on the right parietal and an osteolytic area close to it.

The sharp force trauma on the frontal bone, probably caused by a bronze axe, produced a localized osteomyelitis that led to a rarefaction of the diploë and the formation of a sclerotic area around the wound. The consequences of the infection triggered by the sharp force trauma can be considered the manner of death. A small depressed fracture identified on the right parietal bone probably had no particular consequences. Near this fracture an osteolytic area was recognized. Based on the information in this contribution, it has been interpreted as a meningioma. None of the aforementioned trauma on the parietal bone can be considered a possible cause of death.

The radiocarbon age of the Mompaderno cranium partly overlaps the period marked by the formation and spread of fortified settlements in the north Adriatic region, possibly related to an increase in violence among groups. The trauma identified on the cranium could represent tangible evidence of such a context. The occurrence of victims in the surroundings of defended settlements has been noted elsewhere in similar Bronze Age contexts (Thorpe, 2013, with refs; Jimenez-Brobeil et al., 2011; Harding et al., 2007). At a European scale, however, violent episodes attested by osteological lesions are rather rare in this period, albeit with relevant documented exceptions (Hårde, 2005, 2006; Louwe Kooijmans, 1993), and quite numerous only since the second half of the second millennium BC (Kristiansen, 2018; Peter-Röcher, 2007; Thorpe, 2013). Few protohistoric examples of intergroup violence come from the neighbouring Adriatic regions, such as the necropolis of Olmo di Nogara in north-eastern Italy (Canci et al., 2009) and Roca Vecchia in Apulia (Fabbri, 2002; Vincenti, 2014), both dated to the Middle Bronze Age. Other possible cases of interpersonal violence are documented elsewhere in the eastern Adriatic (southern Croatia) at the Early/Middle Neolithic site of Smilčić-Barica and at three Bronze Age sites located in the Split-Dalmatia county (Crip, Matkovii, and Veliki Vanik). Of these, the evidence of a penetrating trauma in the left femur of the individual buried at Smilčić is not sufficient to exclude the possibility of a hunting accident (Janković et al., 2020), whereas parry fractures of the ulna and frontal trauma documented in samples from the Split area sites strongly suggest deliberate interpersonal violence among the members of a community or between different groups (Novak et al., 2011). Some of these latter documented cases, dated to the Early Bronze Age, constitute relevant comparisons for the Mompaderno cranium, which provides a rare and earliest protohistoric evidence of interpersonal violence in the adjacent northern Adriatic region.

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AUTHOR CONTRIBUTIONS

F.B. designed, initiated, and led the study; Giorgia V., P.F.F. performed palaeopathological research; F.B., G.V. performed archaeological research; F.B., Giorgia V. carried out microCT analysis and data elaboration; F.M., I.P. performed radiocarbon dating; Giorgia V., G.V., P.F.F., F.B. wrote the manuscript with contributions from all authors; all authors contributed to final interpretation of data.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of this article.

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