RESEARCH ARTICLE

Unveiling an odd fate after death: The isolated Eneolithic cranium discovered in the Marcel Loubens Cave (Bologna, Northern Italy)

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Abstract

An isolated human cranium, dated to the early Eneolithic period, was discovered in 2015 at the top of a vertical shaft in the natural Marcel Loubens gypsum Cave (Bologna area, northern Italy). No other anthropological or archaeological remains were found inside the cave. In other caves of the same area anthropic and funerary use are attested from prehistory to more recent periods. We focused on investigating the circumstances surrounding the death of this individual, since the cranium shows signs of some lesions that appear to be the results of a perimortem manipulation probably carried out to remove soft tissues. Anthropological analyses revealed that the cranium belonged to a young woman. We analysed the taphonomic features and geological context to understand how and why the cranium ended up (accidentally or intentionally) in the cave. The analyses of both the sediments accumulated inside the cranium and the incrustations and pigmentation covering its outer surface suggested that it fell into the cave, drawn by a flow of water and mud, likely from the edges of a doline. The accidental nature of the event is also seemingly confirmed by some postmortem lesions on the cranium. The comparison with other Eneolithic archaeological sites in northern Italy made it possible to interpret the find as likely being from a funerary or ritual context, in which corpse dismemberment (in particular the displacement of crania) was practiced.

Introduction

An isolated human cranium (skull without mandible) was discovered in 2015 during the exploration of new branches of a natural gypsum cave near Bologna (Northern Italy). The

cave–named 'Marcel Loubens' after a French speleologist who died in 1952 at the age of 29 in an accident in Pierre Saint Martin Cave (France) during an exploration–is situated in the central area of the 'Dolina dell'Inferno' (Hell's sinkhole), the largest karst depression (900 x 600 m, 125 m deep) in the 'Parco Regionale dei Gessi Bolognesi e Calanchi dell'Abbadessa' (San Lazzaro di Savena, Bologna, Emilia Romagna, Italy) [1].

The cranium (hereafter referred to as the "MLC"–Marcel Loubens cranium) was found at the top of a shaft, which was reached by an artificial 12-metre technical climb from the lower lying 'Meandro della cattiveria' (Maze of Malice) (thus named because of the difficulties in moving through it). It was at a depth of 26 m below the ground level, in a cave that is mostly the result of a small temporary sinking creek, currently without any geomorphological evidence at the ground level (Fig 1A and 1B). The Marcel Loubens Cave is one of the sinking points likely connected with the nearby 'Coralupi-Pelagalli' karst system, whose waters are directed westward to the Zena River valley [2,3].

The cranium was vertically placed, exposing the basilar view: the cranial basis, palate, and occipital bone were visible and were embedded in a loamy matrix. Due to the difficulty in accessing the place where the cranium was found–with several passages that are not wide enough to allow more than one person to squeeze through–the recovery of the cranium was possible only on 7th June 2017 thanks to the team of speleologists of the GSB-USB Bologna Caving Club. No other anthropological or archaeological remains were found [4].

The MLC was brought to the Laboratory of Physical Anthropology of the University of Bologna to be subjected to an anthropological study. A tooth (LM^3) was used for the ^{14}C analysis at the CEDAD ('Centro di Datazione e Diagnostica dell'Università del Salento' [Dating and Diagnostic Centre of Salento University]). The Radiocarbon date (BP) is 4737 ± 45 [(δ^{13}C (‰): -15.5 ± 0.3]. The ^{14}C date was calibrated using the new calibration curve IntCal20 [5] range between 3,630 and 3,380 BC (with 68.2% probability) (Fig 1C), placing the MLC within

Fig 1. MLC on the top of the shaft and Lucia Castagna (a), the young archaeologist of GSB-USB that secured and recovered the cranium (Archive SABAP-BO/GSB-USB, ph. F. Grazioli; [The individual in this manuscript has given written informed consent (as outlined in PLOS consent form) to publish these case details]). Detail of MLC recovery (b) (Archive SABAP-BO/GSB-USB, ph. F. Grazioli). Calibrated conventional radiocarbon dates of LTL17161A sample (c) by CEDAD ('Centro di Datazione e Diagnostica dell'Università del Salento').

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the early Eneolithic phase in Northern Italy [6,7], even though for this area there is a general agreement in considering the 3600 BC as the beginning of the Eneolithic. In this area, a coeval anthropic frequentation was already documented in the Farneto Cave and the nearby deposit called 'Sottoroccia del Farneto' (Farneto rock shelter), just 600 metres away from the Marcel Loubens Cave. There, from 1924 to 1969, the explorer Luigi Fantini discovered some artefacts and multiple fragmented human remains, belonging to more than 25 individuals [8–10]. The site has been attributed to the Early Eneolithic period [11–13] and new, recently performed dating seems to confirm this chronology (data unpublished). The use of natural cavities for funerary purposes is known to have been common in the Emilia Romagna region for a long period, during the first half of the 3rd millennium BC–as the radiocarbon dates of the 'Tana della Mussina' Cave [14] and the analysis of grave goods of the 'Re Tiberio' Cave [15] have shown–up to the 2nd millennium BC, as suggested by Early Bronze Age finds [7,16].

The archaeological framework, the discovery of an isolated cranium, and the absence of any other archaeological and anthropological evidence in the Marcel Loubens cave give rise to many questions as to the interpretation of the context. Chronological data set the find within a broad funerary framework characterized by a focus on the crania [17–19]. Thus, the first aim of this study was to assess whether the cranium had undergone particular treatments. The next step was to determine if the cranium ended up in the cave accidentally or if it was placed there intentionally. Therefore, anthropological and taphonomical analyses were carried out taking the geological context into account.

Materials and methods

All necessary permits were obtained for the described study by 'Soprintendenza Archeologia, Belle Arti e Paesaggio per la città metropolitana di Bologna e le province di Modena, Ferrara e Reggio Emilia'. Access to the studied specimen (MLC-1) was granted by M.M., referent for the above-mentioned Institution, which complied with all relevant regulations and is the only beneficiary of concessions for excavation, study of materials, publication of results. Further study permits for this specimen can be evaluated upon request.

After the discovery and before removing the sediments filling the cranium, the MLC was subjected to a Computed Tomography (CT) scan in order to uncover any information regarding its original status at the time of its arrival at the Laboratory. The scan was performed using a tomographic system developed at the Department of Physics and Astronomy of the University of Bologna. The system is equipped with a 200 kVp X-ray tube and a CCD-based detector with an Apogee Alta U32 camera (2184 × 1472 pixels), optically coupled to a structured CsI (Tl) scintillator screen [20]. Acquisition parameters are listed in Table 1. The X-ray tube's

Table 1. Acquisition parameters of the two CT scans carried out on the MLC.

	Scan 1	Scan 2
Tube voltage	200 kV	130 kV
Tube current	3.7 mA	140 μA
Beam filtration	3 mm Fe	no
Exposure time/frame rate	6 s	5 fps
Frame average	1	4
Number of projections	900	900
Angular range	360°	360°
Detector pixel size	264 μm	127 μm
Magnification	1.295	1.24
Voxel size	204 μm	102.4 μm

integrated aluminium (Al) filter (1 mm thickness) was coupled to an additional iron (Fe) beam filter (3 mm thickness) in order to increase the average energy of the beam and reduce the beam-hardening artefacts in tomographic images [S1 Video]. The tomographic reconstruction was obtained using an in-house software application based on a standard Filtered Back-Projection algorithm [21], while VG Studio Max software was used for the 3D rendering of the CT data. Later, the sediments were removed and analysed to understand the type, place, and possibly time of their formation.

Two samples of sediment (~72.1 g and 67.8 g dry weight each) were randomly selected and soaked for 8 hours in a hydrogen peroxide solution (6% H_2O_2), filtered with a 63 μm-mesh sieve, and dried in an oven at 40˚C. Then the sample residue was weighed, qualitatively observed under a binocular microscope, and described.

Afterwards, the cranium was reconstructed by repositioning its various fragments using only a surgical adhesive tape and modelling clay, both easy to remove. This permitted a full reconstruction enabling morphological and metrical observations and making possible a new session of CT scans for a better observation of the overall and inner structures, and to create a virtual record of the specimen. A new tomographic analysis was then performed in the same Department of Physics and Astronomy of the University of Bologna using a different CT system equipped with a microfocus X-ray source, working at a lower power but capable of providing better image quality. The main system components were a Varian PaxScan 2520D flat-panel detector (25×20 cm^2, 1536×1920 pixels, 127 μm pixel size, 1–10 fps, 14 bits ADC) and a Kevex PXS-10 microfocus X-ray tube (130 kVp, 0.5 mA maximum current, 5 μm minimum focal spot size). The system was equipped with a two-axis translation stage for the detector, a vertical translation axis for the X-ray tube, and a micrometric rotary table for the object to be analysed [22]. Table 1 also shows the acquisition parameters for the second scan. It is worth noting that, in this case, the spatial resolution is higher (voxel size equal to half that of the first scan) [S2 and S3 Videos]. Moreover, four radiographic images were taken per angular step, and averaged in order to reduce noise and improve image quality.

To reconstruct the biological profile, we followed the customary anthropological standards [23]. In detail, the Acsádi and Nemeskéri index [24] was calculated for sex assessment. To achieve a better diagnosis, in the absence of the most dimorphic anatomical districts, a metric analysis was also conducted. A set of 20 measurements (S1 Table) according to Howells [25] were recorded and compared with those of a large sample (317: 164 males; 153 females) of modern European crania of known sex (Norway, Hungary, Austria; [25]) and 10 crania (5 males; 5 females) from modern identified human skeletons from the Certosa Cemetery of Bologna (Italy) (cf. [26]), as the latter are from the same geographical area as the MLC. A stepwise discriminant analysis was performed to determine the most dimorphic metric measurements across the known sample. Therefore, the stepwise selected measurements were analysed by leave-one-out cross-validation linear discriminant analysis (LDA), using final discriminant functions to predict the sex of the MLC. Finally, the MLC was projected into the Principal Component Analysis (PCA) previously computed on the known sample to explore its proximity with one sex or the other, as already done with other bones [27]. The cranial metric dataset was analysed in R v. 3.6.2 [28]. To estimate the age at death, the cranial suture closure method [29] was used. Occlusal dental wear [30,31] and the ossification of maxillary and palatine sutures [32] were also considered. Other biological features [non-metric traits (cf. [33]) and possible pathologies (cf. [34–41])] were recorded. Evidence of ante-, peri-, and postmortem injuries was studied, by examining possible bone modifications both macroscopically and under a stereomicroscope. To assess and distinguish the perimortem traumas (e.g. cut marks) due to intentional or accidental actions and natural events from postmortem ones, we used the criteria reported in the literature [42–48]. Bone fractures were also studied in order to

distinguish those produced on the fresh bone (a smooth surface forming an acute or obtuse angle with the bone surface), dry bone (some organic components still present; intermediate features between fresh and mineralized fractures), or mineralized bone (a largely rough surface, mostly perpendicular to the bone surface) ([49–52]).

To better understand the chemical features of a red coloured area of the right frontal ectocranial surface, ED-XRF analysis (a non-invasive technique) was performed, using a Bruker ARTAX 200 instrument, Mo tube at 50kV and 0.7 mA, in Helium flux, focusing on an area of approximately 1 mm^2. Raman microscopy, using a Labram from Jobin-Yvon with two lasers at 532 and 633 nm, was also performed. The instrument operated in backscattering with Edge filters. The dispersion was given by a monochromator coupled with a Charge Coupled Device detector having 256x 1024 pixels cooled to -70˚C by the Peltier effect. Two fluorite lenses, with 50x and 100x power, made it possible to focus on a small area, thus avoiding any contact with the sample surface. The spectral resolution was 1 cm^{-1} and the possible spatial resolution was 1 micrometre. Spectra were recorded for long acquisition times, according to their intrinsic intensity.

Results

State of conservation

Anatomical parts preserved. The cranium is in a rather good state of preservation (Fig 2). Its surface shows some radial and linear superficial cracks (affecting the frontal and parietal eminence). A full-thickness cross fracture affects the left parietal. Parietal and frontal bones are almost complete. The temporal bones lack a small portion of the squamous suture and the anterior portion of the zygomatic processes, while the left bone lacks the mastoid process. The occipital bone is only partially preserved. Most of the squama is present, while the *partes laterales* and *pars basilaris* are missing. The cranial base is not preserved and the large occipital fracture coinciding with the inferior nuchal line shows a curved, bevelled, almost regular profile. All edges and the preserved occipital surface are of the same colour and are irregularly covered by the same incrustations (Figs 2 and 3). A deformation is visible especially on the left side, making it impossible to join the occipital to the left parietal bone correctly (Figs 2E, 3A and 3B). The median area of the squama and the left part of the bone are partially covered by black-stained calcareous concretions and small black manganese oxide dots (Fig 3). The spheno-basilar synchondrosis is missing. The ethmoid bone is partially preserved. The splanchnocranium shows a great lacuna in the nasal region (nasal bones are absent). The zygomatic and maxillary bones are partially preserved. The palatine bones are broken; only small portions of their horizontal plates are preserved and joined to the maxillary bones. The alveolar processes and borders are not intact but all *alveoli* are visible (Fig 2). Some maxillary teeth are present (RC^1, RP^3, RP^4, and RM^1-M^3 and LP^3, LP^4, LM^1, LM3 –this last tooth was used for dating the specimen) and the others have been lost post-mortem.

Pigmentation and calcite crusts. The cranium is covered with a thin coating of a black material that does not react with H_2O_2, thus enabling us to rule out an organic staining (soot). These coatings consist of poorly crystalline manganese oxides and were formed by the flow of reduced water into the oxygenated cave environment. The reduced conditions are typical of water flowing through fine sediments and in the presence of large amounts of organic material (which became oxidized, thus consuming most of the O_2 present in the water).

Calcite speleothems are common chemical deposits in gypsum caves in temperate regions. This is due to the common-ion effect: gypsum ($CaSO_4.2H_2O$) is much more soluble than calcite, so infiltration waters will rapidly dissolve gypsum and come close to saturation with this mineral. In the presence of CO_2, this gas dissolves into the water and forms small amounts of
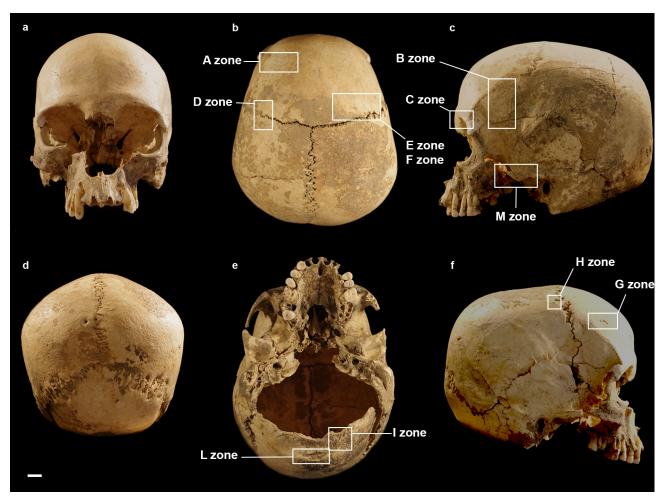
Fig 2. MLC in frontal (a), superior (b), left (c), posterior (d), inferior (e) and right (f) views. The boxes indicate the Zones (A-M) with the ectocranial lesions.

HCO_3^-, which in the presence of Ca^{2+} (coming from the dissolved gypsum) rapidly combines to form calcite; the latter precipitates as flowstones. Calcite flowstones in gypsum caves generally form during periods when CO_2 production in the soil is high, thus during warmer and wetter climates. Almost all carbonate speleothems found in the gypsum caves of the regions were formed during warm periods in the past [53,54].

In detail, irregularly thick calcite crusts partially cover the external and the internal surface of the cranium, where clay fills holes, cavities, and the imprint of the vascular net. In particular, incrustations (Fig 4) cover the cranial vault, especially the bregmatic area. The right cranial wall is free of calcite crusts (except for the mastoid, where there is a darker accumulation than that described for the cranial vault), whereas the left wall shows a fine black pigmentation in direct contact with the cranium surface, later partially covered (except for the temporal squama) by lighter incrustations. The occipital squama is free of manganese oxides and calcite crusts, whereas the left part, i.e. the external eminence, is diffusely stained with manganese deposits and then covered by thick calcite crusts mixed with black pigments. The left asteric region and the mastoid process are partially covered by crusts. The right lambdoid suture is partly filled by well-preserved accumulations of manganese minerals, especially in the right
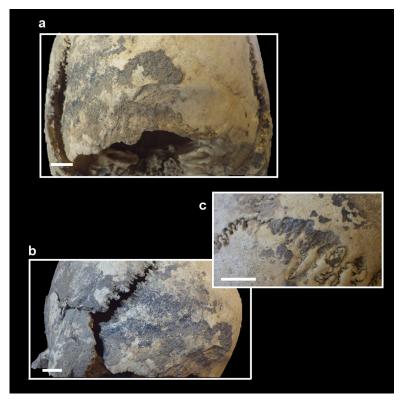
Fig 3. MLC—Detail of incrustations covering the occipital bone (a), left asteric region (b), and right lambdoid suture (c).

asteric region (Fig 3C). Due to a cranial deformation, the left branch of this suture is not completely joined. The margins of the suture and the surrounding parietal, temporal, and occipital left surfaces are covered with a fine black Mn pigmentation. In the basilar view, the general fine manganese deposit stains the preserved parts, with the exception of the orbital cavities. The glenoid temporal fossae are stained by manganese pigments and the right one is covered by thick calcite at the level of the articular tubercle.

The ED-XRF and Raman analyses of the right frontal ectocranial surface showing a red pigmentation, where an ante mortem lesion has been found (see the result section), have revealed an increased amount of Fe, together with Si and K, being the amount of Ca, Sr and P, coming from the bone, substantially constant (Fig 5A).

A greyish-black rough crust also covers the margin of the cranial base fracture and other fractured margins. Finally, manganese pigments have stained the preserved facial bones on their external surface, also involving the palate and exposed teeth roots. The nasal floor and the preserved maxillary sinuses lack pigmentation and incrustations (Fig 6). A thin layer of clay covers the incrustations.

The sediments filling the cranial cavity. As for the sediment filling the cranium, this appears homogenous (Fig 7). The texture of both samples was sandy pelite with the coarser fraction (>0.63 mm) representing approximately 24% and 33% of each sample's weight (16.1 g and 23.7 g, respectively). Worthy of note is the presence of sub-centimetre angular gravel-size particles, small fragments of gypsum, and several calcareous concretions (size <20 mm), along with the scattered presence of sub-millimetre-to-millimetre wood charcoal debris. Lastly, a few pulmonate and calciphile gastropods inhabiting elevations up to 2,600 m (*Vitrea* cf. *subrimata*
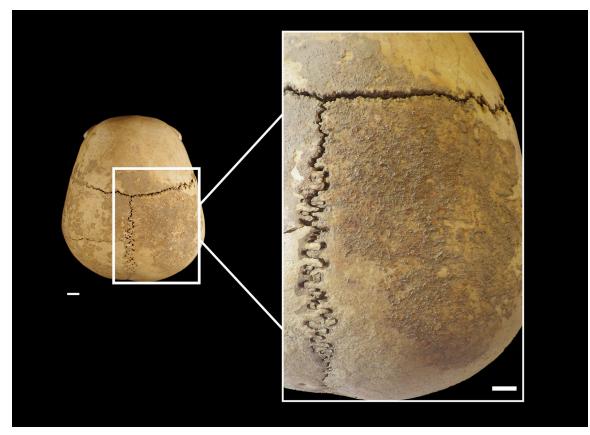
Fig 4. MLC—Detail of incrustations covering the right parietal bone and bregmatic area (superior view).

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and *Clausilia* sp.), along with other unidentifiable fragments of terrestrial mollusks, were found. No remains of micro- or meiofauna were seen in the residue.

Biological profile

The cranium falls within the young adult age bracket [23]. The external cranial suture obliteration indicated a wide age range (vault system: 18–45 yrs, lateral-anterior system: 25–49 yrs). The entire suture system is open on the outer and inner cranium surfaces. The age range was narrowed by observing the occlusal dental wear (24–35 yrs) and the maxillary-palatine suture ossification (26–35 yrs). The sexualization index (-0.55) indicates weak female traits. Stepwise discriminant analysis selected 15 out of 20 cranial linear measurements used in the analysis (S1 Table). Cross-validation LDA revealed that the 15 most dimorphic measurements (maximum cranial and nasion-occipital length, maximum frontal, biauricular, minimum cranial and biasterionic breadth, glabella projection, frontal chord, nasion-bregma subtense, parietal chord upper facial and nasal height, maxillo-alveolar breadth, mastoid height and breadth) separate males and females with 88.7% accuracy. The MLC ranks as female with a 99.6% posterior probability. Finally, the PCA plot (Fig 8) showed that the MLC falls within the area occupied by European females.

As regards some morphometric features, this cranium shows the vertical frontal bone and a flat posterior and lambdoid region. It shows a pentagon profile in the posterior view. The cranial index indicates brachycranic (81.8; length = 176 mm, breadth = 144 mm). Two lambdoid wormian bones, a weak trace of *os incae* due to the incomplete fusion of the transverse suture
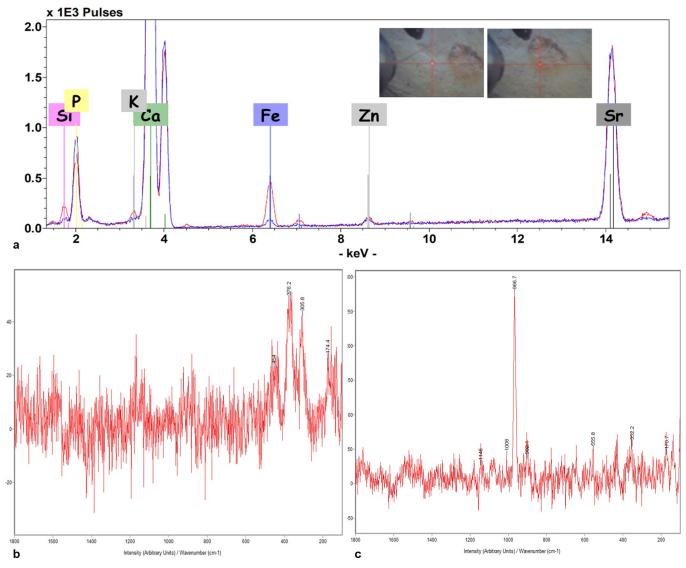
Fig 5. MLC—ED-XRF analysis on the G Zone: The blue and red lines refer to the area around (left picture) and inside (right picture) the lesion (a). Raman spectrum of the G Zone that shows the fluoro-apatite composition (b) and a yellow spot (Goethite) (c).

which separates the occipital squama (Fig 3), a double left parietal foramen (Fig 9C), and an accessory palatine suture on the right maxilla which delineates an anterior middle-palatine bone are detectable. Two small button osteomas (at the right frontal and left parietal) are present (Fig 9A and 9B). The external vault of the MLC shows a diffuse slight porosity (Fig 9D). Caries affects all molars (LM^1, RM^1, RM^2, RM^3, LM^3) and slight deposits of calculus are present on both P^3 and LM^1. A medium degree of dental wear (4-5th degree on the Smith's scale) [34–36] and a linear enamel hypoplasia (LEH) on both P^3 and RP^4 can be seen (Fig 9E).

Cranial lesions

Various lesions are visible (in the area free from incrustations) on the ectocranial surfaces of the frontal, right parietal, occipital, and left temporal bones. They are extensively described in Table 2 and Figs 10–15.

Fig 6. MLC–Cranium anterior view: Facial bones in the frontal (a) and superior (b) views.

Fig 7. MLC—CT scan with sediment filling the endocranial cavity.

Fig 8. PCA plot showing that MLC falls within the area occupied by the European females.

Discussion

The discussion will deal with the biological features of the specimen and the interpretation of the numerous lesions, in relation to their time of occurrence (peri-, post-, and antemortem)

Fig 9. Details of button osteomas on the frontal (a) and left parietal (b) bones (about 4mm of diameter), double left parietal foramina (c), diffuse porosity (d), linear enamel hypoplasia (LEH) on LP^3, RP^3 and RP^4 (e).

Table 2. Description of the cranial lesions in the frontal (A-G Zones), right parietal (H Zone), occipital (I-L Zones) and temporal (M Zone) bones.

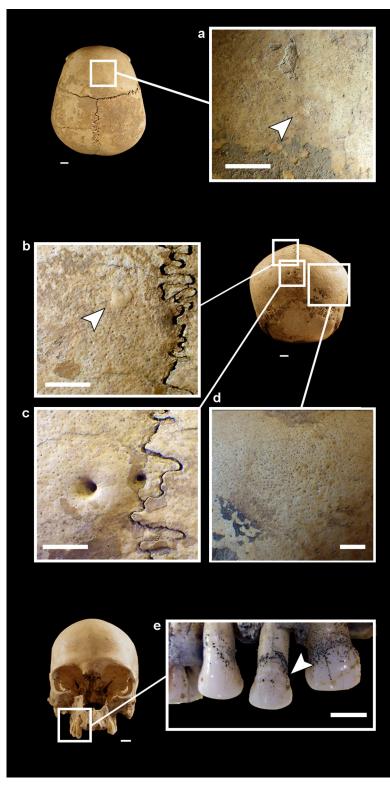| Bone	Position	Description	Interpretation	Note
		Frontal		
A Zone	Left frontal squama	Seven linear and narrow grooves. The longest one (24 mm) is oriented transversally to the mid-sagittal plane (28 mm far from the left temporal line, 50 mm from the coronal suture). Two other linear grooves are almost parallel to the first one, only 1 mm far from each other. The groove in the middle is 10 mm long, while the anterior one is 5 mm long. Four shorter (about 3 mm) linear grooves, parallel to each other, are perpendicular to the previous ones. The first three are only 1 mm far from each other, while the fourth one–i.e. the medial one– is 3.5 mm apart. The bottom of the marks shows microstriae inside and the same color of the bone surface. Only the longest track shows detachment of some very thin chips.	Perimortem human intervention during cleaning actions	Fig 10A and 10B
B Zone	Left portion of the frontal bone approximately at 2.5 cm from the temporal line	An oval-shaped, slightly bilobed, depressed area (7x5mm) (BA) is located immediately below the temporal line and is uniformly covered by compact tissue with fine parallel striae and by a diffuse, thin dark pigmentation. Immediately below, there is an irregularly shaped area (BB) (10x5mm), finely scraped and grooved by parallel striae. The bottom shows the same color as the rest of surface.	Perimortem human intervention during cleaning actions	Fig 10C
C Zone	Left superior orbital margin, at approximately half its length	Small, slightly depressed and detached area (5x3mm) covered by black pigmentation and crossed in half by a longitudinal mark (5 mm).	Perimortem human intervention during cleaning actions	Fig 10D
D Zone	Between the frontal and left parietal bones	The lesion is discontinuous, crossing the left coronal still open suture. Then, it shows two separated grooves (a longer and irregular one in the frontal bone and another shorter one in the parietal bone) that lied in the same direction.	Postmortem accidental events	Fig 11A
E Zone	Right frontal bone close to the coronal suture	A long (50mm) linear and superficial groove runs almost parallel to the coronal suture. The bottom is quite lighter-colored than the rest of the cranial surface. Only the most lateral part shows the same color as the surrounding cranial surface and irregular grooves.	Uncertain interpretation	Fig 11B
F Zone	Posteriorly placed to E Zone at about 4 mm from the coronal suture	Three marks shorter and larger than the 'E Zone' ones. Calcareous incrustations partially cover two of them.	Uncertain interpretation	Fig 11B
G Zone	Right frontal bone 10 mm above the temporal line	Two contiguous areas are detectable: the posterior better preserved than the anterior one. The posterior area about 30 mm from the coronal suture is ellipsoid (major axis about 12 mm) and relatively depressed. Its posterior border shows irregularity (a sort of bone 'amass') in continuity with the rest of the surrounding surface, being covered by compact bone. The bottom shows thin parallel microstriae. A sort of interruption separates this area from the more superficial anterior one. The layer of the compact bone of this area is erased, leaving an irregular, abraded, rough and lighter-in-color surface. Its margins are irregular and show the detachment of some superficial flakes. The red color stains almost the entire area of 'G Zone'.	Antemortem traumatic event (surgery?) with postmortem damage	Fig 12A and 12B

(Continued)

Table 2. (Continued)

Bone	Position	Description	Interpretation	Note
Right parietal				
H Zone	4 mm far from the coronal suture and approximately 10 mm above the temporal line	Zone characterized by various irregular pits affecting the compact layer. Two areas with smooth and rounded margins are detectable: the posterior larger (about 5 mm) that the anterior one. Some pits are filled with sediment.	Percussion pits due to perimortem human intervention	Fig 13
Occipital				
I Zone	Left border of the fracture in correspondence of the inferior nuchal line, at about 2 cm far from the mid-sagittal plane	Triangular-shaped (about 1 cm height) and peeled area with the same color as the rest of the surface. The central part of this area is stained with little dots of black pigments.	Post- or perimortem events. The black pigmentation is due to manganese oxide	Fig 14
L Zone	On the occipital external protuberance (inion)	A peeled oblong (20x10mm) irregular and rough surface area similar to 'I Zone'. The color is the same as the rest of the ectocranial surface. Little black dots of pigmentation affect this area and are abruptly interrupted along the left inferior margin of the surface. In the right part of the area, clay sediments fill the irregularities of the surface.		The whole border of the occipital fracture has a curved profile and a beveled irregular margin; its left side is rougher than the right one, with little and larger detached fragments of both sides.
Left Temporal				
M Zone	Lateral margin of the left zygomatic process	Superficial detachment of a thin bone flake, resulting in a flat area with a well-defined border (6x3mm) partially spared by sediments. On its superior and inferior margins, an interruption of the dark pigmentation is visible.	Perimortem human intervention (?) and postmortem damage	Fig 15

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and possible meanings. The analysis of the sediments and geological context will then be discussed to interpret the features of the deposit and the possible funerary context.

Biological features

The MLC may be attributed to a 24-to-35-year-old female. Even though only the cranium is preserved, we can provide some general information on the individual's state of health. As a matter of fact, the evident, generalized porosity in the cranial vault has been described in the literature as being related to an inflammatory bone response [37,38,40]. The traditional interpretation of porotic hyperostosis identifies chronic anaemia (iron or vitamin B_{12} deficiency), likely due to nutritional stress and/or pathogens [55–57]. In palaeopathological records, porotic hyperostosis significantly increased from the Neolithic onward as a result of both the diet, based on agricultural products, and new living conditions in more densely populated settlements, where hygienic conditions were poor and parasites and pathogens were common [58,59]. Two solitary and well-defined mounds of compact bone with a hard, dense, ivory-like appearance (osteomas), observed in the frontal and parietal bones (Fig 9A and 9B), are quite common and are considered benign tumours [37,38,60]. The linear enamel hypoplasia that affects the premolars indicates a disturbance in the normal process of enamel apposition [36]. Considering that P3 and P4 crown formation begins at 4–5 years of age and ends at around 6–7 years [61], it is possible to assume that the individual was affected by prolonged metabolic stress during her childhood. Among dental diseases, caries affected many molars on both sides (LM^1, LM^3, RM1, RM^2, RM^3), showing a rather high frequency (45%: 5/11), and in one case (RM^2) the crown was destroyed. Carious lesions began to increase mainly from the Neolithic onward, likely indicating an increased consumption of carbohydrates by farmers [62,63]. This may suggest a diet rich in carbohydrates for the individual examined. Other pathological and

physiological conditions, however, may cause this dental condition, such as endocrine disorders, occurring particularly during pregnancy in female individuals [64].

The interpretation of the cranium lesions

The interpretation of the injuries and the composition of the sediment covering and filling the skull made it possible for us to hypothesize some potential scenarios. The lesions observed in
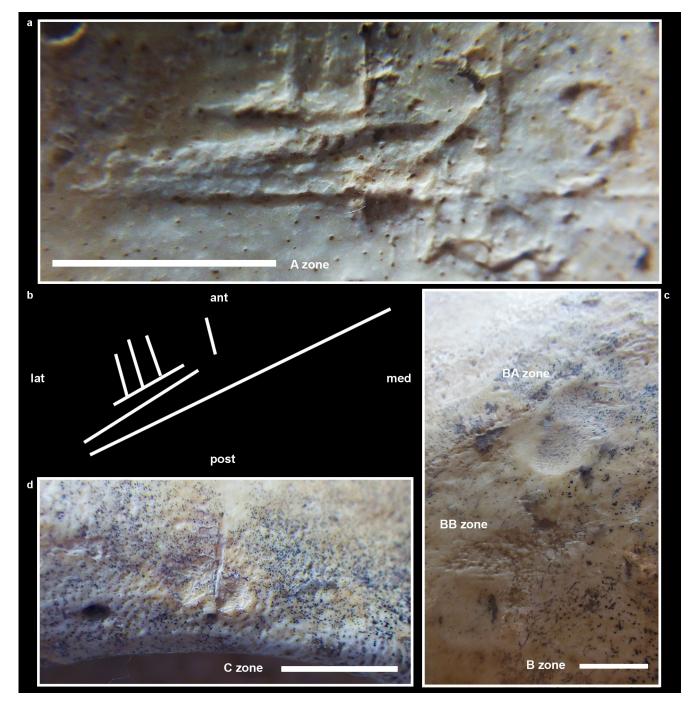

Fig 10. MLC- A Zone: detail of the grooves on left frontal squama (a) and drawing of the pattern (b); B Zone (c): Detail of the depressed and smooth (BA Zone) and scraped area (BB Zone) on the left portion of the frontal bone; C Zone (d): Detail of the detached area and groove on the left orbital margin.

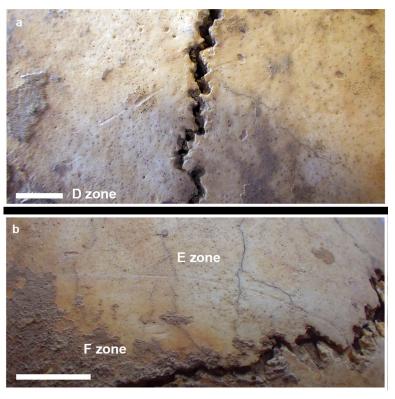https://doi.org/10.1371/journal.pone.0247306.g010

Fig 11. MLC—D Zone (a): Detail of the groove crossing the left coronal suture; E (linear groove) and F (three little marks) Zones on the right frontal squama (b).

the cranial vault may be due to intentional human intervention, before and around death, on the young female corpse (at least her head) and non-human taphonomic processes occurred after death. None of the lesions observed are attributable to animal actions involving teeth (gnawing), nails, and claws (trampling, scratching) ([44]). In the discussion below, the first comments concern the lesions interpreted as perimortem, with some uncertainty for some of them, followed by those on the postmortem and antemortem lesions.
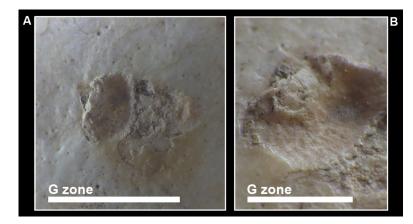

Fig 12. MLC- G Zone (a) on the right frontal squama. Note the red colour that stains the area; detail of the posterior part of the lesion: Microstriae in the bottom and bone remodelling in the posterior border are visible (b).
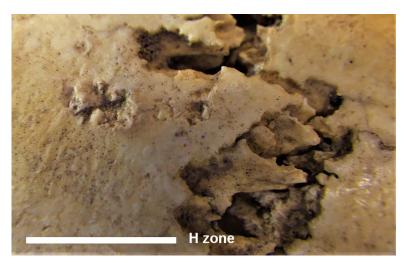
Fig 13. MLC—H Zone on the right parietal with detail of the areas with irregular pits.

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Perimortem and postmortem lesions. The shape, type, and absence of bone repair of the lesions on the left portion of the frontal squama (A Zone) (Figs 2, 10A and 10B) may indicate a perimortem intervention. The groove pattern, the presence of microstriae at the bottom of the grooves, and a colour that is the same as the remaining surface seem to indicate true cut marks (Fig 10A and 10B), likely produced in an attempt to remove soft tissues. This interpretation might be reinforced by the lesions in the B and C Zones situated on the left side of the skull (temporal and orbital margin, respectively) (Figs 2, 10C and 10D). The bone features and colour and the presence of manganese oxide inside both of them indicate old lesions.

Thus it is possible to think that all lesions situated in the left frontal bone may have been produced in an attempt to remove the soft tissues. The meaning of cut marks as a result of practices for the intentional removal of soft tissues from bones has been extensively described [43,65–68]. The cranial vault is covered by a large and dense superficial strip of connective tissue (*galea aponeurotica*) that connects the occipitofrontalis muscle and is attached anteriorly to the frontalis muscle, external occipital protuberance, and highest nuchal lines. The B Zone (Fig 10C) shows a smooth surface and the borders of a BA lesion, likely due to the detachment
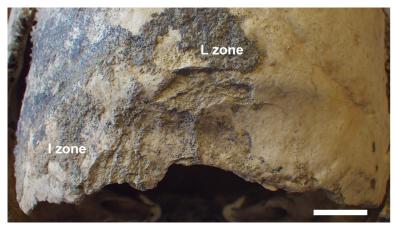

Fig 14. MLC—Occipital bone: Note the profile and margin of the fracture, the triangular-shaped and peeled area (I Zone) and the irregular and peeled surface on the inion (L Zone).

https://doi.org/10.1371/journal.pone.0247306.g014

Fig 15. MLC—M Zone on the lateral margin of the left zygomatic process with detail of the superficial detachment of a bone flake.

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of a thin bone chip (which likely floated away later due to the action of water), and scrape marks (BB area) could be the result of the detachment of the *galea aponeurotica* and temporal muscle. This muscle originates by a strong aponeurosis from the temporal lines and attaches to the coronoid process of the mandibular bone. The intervention and severing of those tissues may have also caused the disarticulation of the lower jaw, which–likely enlarging the cranial basis–facilitated the access to the brain, as already observed [69]. The lesion of the left orbital border (C Zone) (Fig 10D) could be related to these operations. Quite similar lesions have been observed in other prehistoric samples in a funerary context [70] and in modern samples from defleshing done to prepare a skeleton for teaching purposes (unpublished data).

The lesion on the left zygomatic process (M Zone) (Figs 2 and 15) could not be clearly interpreted. The feature might suggest postmortem damage (see the interruption of the dark pigmentation; Table 2). We could not, however, rule out its interpretation as being related to perimortem interventions, as a possible outcome of actions connected with the disarticulation of the mandible, in particular when excising the masseter muscle connecting the zygomatic process to the external mandibular angle.

The H Zone in the right parietal shows pits probably produced using a sort of tip perpendicularly to the cranial surface (percussion pits) (Figs 2 and 13) ([44]). These lesions seem to be produced perimortem using a tool as a hammerstone or during interventions on the cranial basis placing the skull with the cranial vault on a rough and irregular surface (e.g. stone or gravelly ground).

The long and short marks on the posterior part of the right frontal bone squama (E and F Zones) are of uncertain origin (Figs 2 and 11B). The most lateral part of the long mark (E Zone) shows signs of perimortem lesions, because it seems marked by many passages of a blade, as in a sawing motion. However, the lighter colour of the bottom of the medial part of the E Zone and of the F Zone might indicate that they were caused by accidental postmortem, but not recent, events, taking account that the F Zone is partly covered by calcareous incrustations. Also, the interruption of the black pigments in the D Zone (Fig 11A) indicates that the mark was caused by postmortem accidental events.

It is likely that the occipital bone lesions occurred postmortem. Calcareous deposits are interrupted quite abruptly along the margins, especially of the L Zone (Fig 14), possibly due to a strong impact that caused the removal of the protruding (the occipital external eminence) parts of the bone. The surface is rough but quite blunt, with well rounded edges, indicating

that the postmortem impact likely occurred when the bone was still fresh. The impact may be due to accidental events, although we could not rule out the possibility of intentional perimortem interventions. As regards the large cranial basis lacuna, its rather regular form and the blunt and detached border of the fracture strongly suggest an intentional enlargement of the base. The mandible disarticulation suggested by the lesion on the zygomatic process (M Zone) (Figs 2 and 15) could be related to that action, maybe in order to facilitate the access to the brain. The peeling on the I and L Zones (Fig 14) is similar to that described on animal and human ribs as the distinct result of butchering [43,71–73].

Antemortem lesions. The depressed area in the right frontal squama (G Zone) seems to be the result of an antemortem traumatic event. Remodelling processes are visible at the border of the lesion and the presence of thin, parallel grooves on its bottom may be the result of the use of some tools used with force and directed tangentially against the cranial vault for unknown reasons (surgery?) (Figs 2 and 12).

Intentional interventions, sometimes interpreted as therapeutic operations, such as cranial trephination, are well known in the Neolithic and later periods [74]. The non-decorative carbon tattoos of the 5,300-year-old Similaun Iceman (Ötzi), roughly coeval to the MLC, have been interpreted as "medicinal" tattoos to treat chronic or persistent pain [75]. The superficially erased anterior part seems damaged by a more recent postmortem event that left a rough surface, and interrupts the red-coloured area that has been chemically examined to clarify its nature and to test the hypothesis that it may be due to the use of ochre pigment. The chemical analyses confirmed this hypothesis. It is possible that ochre or similar inorganic material was applied around the injury for therapeutic reasons. The possible presence of ochre might be interesting, considering its functional use and numerous (healing, antiseptic) properties, already known from Palaeolithic times, while not ruling out its symbolic meanings, ethnographically documented and hypothesized in archaeological contexts [75–82]. The use of ochre is also attested in a cave ('Re Tiberio' Cave, Ravenna) not far from the Marcel Loubens Cave, where anthropic traces extended from the Eneolithic to Iron age [15].

Thanatocoenosis of the deposit

Regarding the black pigments and calcite crusts, the black Mn coating and the successive carbonate crusts confirm the thanatocoenosis of the deposit: the cranium was brought into the cave by a small creek at a time when the shaft below was not yet formed, and successively embedded in loamy sediments during a period when the sinkhole was becoming clogged and was then progressively abandoned. The by the active water flow. The Mn coating was formed inside the sediment by reduced Mn-rich waters that were slowly oxidized. Only later, when the sinkhole was reactivated again, new CO_2-rich infiltration waters dissolved the gypsum and caused the formation of new flowstones and carbonate crusts on the cranium. In this warmer and wetter period, the 12-m shaft was formed, and the cranium remained suspended high above the shaft's floor until its discovery.

In gypsum areas, and especially in large dolines, sinking points tend to be stable (and active) over short periods of time (typically less than a century), with the evolution of the doline surface forcing waters to find alternative sinking points upstream of the active ones. Once such a sinking point is abandoned, it fills up with debris and can stay closed for long periods, until favourable conditions can reactivate these passages once again.

The cranium was vertically situated, exposing its basilar view (cranial basis, palate, and occipital bone) and was embedded in a loamy matrix, representing a mudflow in a low-gradient environment (Fig 16A and 16B). These sediments, including the cranium, rested on an old flowstone formed while the sinkhole was still active, before the sediments were deposited in
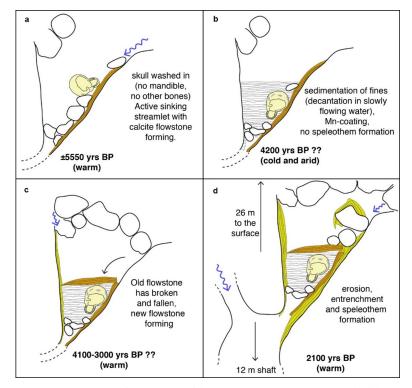
Fig 16. Reconstruction of the sequence of the taphonomic events: MLC enters the doline (a), initial deposition of sediments (b), flowstone is added to the deposition (c), and erosive and entrenchment processes occurred (d).

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the cave, probably due to the progressive occlusion (and abandonment) of the sinking point. After the sedimentation stopped, erosion again began to destabilize part of the old flowstone, a slab of which collapsed onto the sediment containing the cranium, thus protecting it from further erosion and transport (Fig 16C). These newly infiltrating waters, rich in CO_2, were able to deposit a new flowstone generation, partly eroding the sediment in contact with the walls. The reactivated cave passage started evolving downward, with the formation of a lateral sinking creek and carving out the maze lying below. This new reactivation was able to entrench approximately 12 metres of gypsum, connecting to the lowering base level (Fig 16D).

The high-frequency alternation of cave formation-sedimentation periods has been documented in many gypsum caves in the northern Apennines, and are often climate-driven [83]. The final entrenchment responsible for the 12-metre-deep shaft creation, likely developed in a warm and wet period (2100 yrs. BP?), caused the cranium and the sediment to remain suspended high above.

This reconstruction matches the observations on sediments in the cranial cavity. The type of material filling the cranium cavity, i.e. sandy pelite with mm-sized angular debris, micro wood charcoals, gypsum, and a few gastropod shells typical of calcareous substrata, suggest that the cranium was filled during transport toward its final resting place. The recovered sedimentary and fossiliferous features also indicate debris flow (or torrent flow) as a possible transport carrier. Indeed, such water-saturated processes are also common after intense wildfires, as combustion particles make the ground surface hydrophobic and facilitate the formation of a drainage network by rainwater across the burnt area, originating small debris flows that contribute to draining water-saturated masses of sediment to streams or sinkholes.

Thus it is possible to hypothesize that the body (or parts of it) was situated (likely exposed?) at the edge of a doline–probably at an advanced skeletonized stage, but still retaining some

fresh osseous tissue–and, due to movements of the terrain, moved from its original position, becoming disarticulated and dismembered. Meanwhile, the skull might have rolled away, generating the postmortem injuries to the occipital bone (which seem to have been produced on a fresh osseous tissue) and perhaps the large parietal fracture, as it was likely drawn by the water, debris, and mudflow. It is possible to suppose that if the skeleton was intact by the time of this sequence of events, other skeletal elements, different in shape and size, might have remained stuck elsewhere and dispersed during transportation. The cranium would have rolled more easily than other skeletal parts in a water stream and debris flow (cf. [84]), already in absence of the mandible (perhaps actively removed after death), since both glenoid fossae, especially on the left side, show the same dark pigmentation as the rest of the cranium, before arriving at the cave. During its decomposition and those dynamic phases, it would have been filled with sediment. Therefore, it would have reached the cave and come to a stop on the plateau where it was found.

The funerary context

The isolated MLC, even though it probably fell by accident into the cave where it was found, a place devoid of any archaeological finds, offers important insights into the peri- and/or postmortem practices of the Eneolithic populations of northern Italy. As far as we know, this is the first Italian Eneolithic cranium where evidence of intentional perimortem human intervention has been found. The findings and secondary deposition of crania in caves are well documented, but we were unable to find any reports of peri- or postmortem lesions.

In Eneolithic funerary contexts in Italy, scattered and commingled bones have been interpreted as the result of intentional disturbance and manipulation practices. For example, skeletal manipulation with a particular predilection for crania which are displaced within the same tomb chambers in niches or different tombs, are well known within the so-called Rinaldone Culture, widespread in the Tuscany, Northern Latium, and Marche regions [85–88].

In northern-central Italy, two main rituals have been recognized, corresponding to different geographical-ecological environments: simple pit graves in necropolis contexts in the central-eastern Po Valley, and collective burials in the Alpine region and Apennines, especially inside caves or under rock shelters. However, this distinction is not always so clear because, in some cases, the two above-mentioned funerary rituals coexist, as in Lombardy, Veneto and Emilia Romagna [19,89–93].

The use of caves, natural cavities, and rock shelters as places of collective burials is an Eneolithic period phenomenon that has been well known since the 19th century, thanks to the explorations of Father Gaetano Chierici, who discovered the presence of human remains belonging to male and female adults and subadults in the 'Tana della Mussina' Cave (Reggio Emilia, Emilia Romagna). Some of the skeletons there appeared disarticulated, others partially burnt, and they were considered part of a collective burial site that was frequented at various times [14,94]. These rituals have been interpreted as aimed at reinforcing social cohesion and collective memory throughout the cult of ancestors [15,17,18,86]. They have been observed in both the Apennine area and the Alpine and pre-Alpine region: Lombardy [91], Veneto [18,92], Trentino [95] Northern Tuscany [96], and Liguria [97]. In the Lombard pre-Alpine region, the funerary practices documented at 'Riparo Valtenesi di Manerba' (Brescia) [98] suggest the existence of distinct, specific areas, intended for different operations on human remains: a place where the decomposing bodies were kept for the subsequent manipulation of their remains and another place used as a proper ossuary, where bones were transferred for the performance of new rituals. This hypothesis has been confirmed in other caves and rock shelters of the pre-Alpine arc [91], and the custom may be considered part of a widespread

cultural phenomenon. In Liguria, in the 'Da Prima Ciappa' Cave in Val Frascarese (Genoa) [99], a calotte and a calvarium were found facing the entrance and resting on a mound of long bones.

In Emilia Romagna, numerous caves have been systematically explored by speleologists and archaeologists since the 19th century. Anthropic presence and funerary contexts are well documented in a period between the Eneolithic and the dawn of the Bronze Age [15,16]. In the province of Bologna (the same area where the Marcel Loubens Cave is located) human remains have been found in the 'Sottoroccia del Farneto' (only 600 m away from the Marcel Loubens Cave, Eneolithic [7,100]), in the Farneto Cave (Early Bronze Age 2; [13]), and in the 'Grotta di fianco alla chiesa della Gaibola' (Eneolithic, Early Bronze Age; [7]).

In the 'Sottoroccia del Farneto' many commingled and highly fragmented human remains were discovered in the 1960s [11,12] and, in part, studied to reconstruct their biological profiles [8–10]. However, the lack of archaeological documentation regarding the removal of human remains, typical for those years, means the context remains unclear. The anthropological re-examination performed to distinguish the non-human taphonomic vs the anthropogenic origin of the highly fragmented bones has revealed the presence of perimortem lesions related to an intentional treatment of the cadaver [101,102].

A few kilometres away from the Marcel Loubens cave, in the 1930s a human male calotte (now lost) [103] was discovered in a shaft near the entrance of the Gaibola Cave ('Grotta di fianco alla chiesa della Gaibola', Bologna) together with bear and wild boar teeth, flint flakes, and pottery fragments [104]. In the same cave, in a chamber named 'Sala dello Scheletro' (Skeleton Chamber), many other human bones were found in a layer containing pottery fragments, charcoal particles, stone tools, and red ochre. Under this layer, an incomplete male skeleton (lacking the cranium, while the mandible remained *in situ*) lying on its right side in a flexed position, surrounded by abundant clots of red ochre, was found together with some pierced animal teeth and shells. The lack of some bones has been attributed to the action of a small water stream that formed after the burial took place. Archaeological materials suggested that the first layer belonged to the final Eneolithic [7]. However, the presence of the skeleton with missing cranium could suggest the presence of burials inside caves from where crania were easily removed, accidentally (by water?) or even intentionally. Whether or not the cranium in the shaft belonged to the incomplete male skeleton is impossible to ascertain, but cannot be ruled out. This could suggest a scenario that can apply to the MLC find, also.

Human skeletal remains were also documented in caves in the area of 'Gessi Romagnoli' (Ravenna): 'Re Tiberio' Cave (Eneolithic and Early Bronze Age 1; [15,105]), 'Tanaccia di Brisighella' and 'Banditi' caves (Eneolithic/Early Bronze Age?; [16,105]). The 'Re Tiberio' Cave contained the remains of 16–17 individuals, apparently without a selection based on sex or age. Some skeletal parts were in primary deposition, but most of the bones were commingled and displaced. In some places inside the cave, long bones were arranged in an apparent order, indicating secondary interventions. The almost complete absence of crania leads to the same conclusion, especially considering that some maxillary teeth were found [15,105]. In the Tanaccia cave, two crania (one of an infant and one of an adolescent) were placed in a niche together with a vase and a pottery fragment, while in the 'Banditi cave' the mandible of a 6-year-old child was found in a hearth ([105]).

In Emilia Romagna, in addition to the above-mentioned funerary contexts in natural cavities, large necropolises with simple pit graves are well documented, such as the most famous ones in Spilamberto (Modena) [106–108] and 'Celletta dei Passeri' (Forlì-Cesena), where manipulation, removal and postmortem intervention on skeletal remains are documented [109]. The recent anthropological review of some previously studied Eneolithic skeletons of the open site of 'Fornace Cappuccini' (Ravenna)–where burials have been found in the

artificial trench around the residential area [110,111]–has provided some evidence of perimortem treatment on a cranium, in particular scrape marks located at the insertion of the temporal muscle on the right parietal bone [112].

Even in earlier times, peri- and postmortem treatments of human remains, especially skulls, in funerary contexts are largely documented. Here we just recall two Southern Italy Neolithic sites (Scaloria Cave and 'Passo di Corvo', both in Puglia) recently studied from an anthropological and taphonomic point of view that allowed to detect perimortem treatment of the corpses, offering new evidence regarding the funerary behaviour of those peoples [113–117]. In Emilia Romagna, during the Neolithic Culture VBQ, cranial manipulations are attested within some funerary contexts as postmortem activities [118]. We may suppose that the habit of manipulating the skulls might have been transmitted to the Eneolithic culture, where, as we have shown in the study of the specimen MLC, also the perimortem manipulation is clearly attested. Thus, to better understand the mortuary behaviour of Neolithic and Eneolithic peoples, an anthropological and taphonomic review of the previously studied human remains is in need.

Concluding remarks

The discovery of the cranium in the Marcel Loubens Cave dated to the early phase of the Eneolithic (between 3,600 and 3,300 B.C.) provides new insights for the interpretation of the anthropic presence in northern Italian areas and, more in general, throughout the Italian territory, adding new data about the perimortem treatment of corpses, possibly in a funerary context.

Our results suggest that the body of a young woman (or her head/cranium) was situated at the edge of a doline, most likely coming from an unknown burial place or other type of ritual context. Actually, the presence of cranial perimortem injuries and the comparison with some other archaeological contexts enable us to hypothesize that the body of this young woman was subject to treatment and manipulation within a funerary or other ritual context. Postmortem traumas indicate that the cranium (intentionally or accidentally removed from the body) rolled away and fell accidentally into the shaft of the Marcel Loubens Cave, where it was preserved and later found. Finally, the possible relationship between the antemortem cranial injury, likely treated with ochre, and the after death destiny of the woman remains completely unknown.

It is noteworthy that anthropological and taphonomic analyses, together with geological and speleological observations, made it possible for us to shed light on that context in the absence of any archaeological evidence. The presence of perimortem and postmortem injuries has contributed to the reconstruction of the manner and timing of the manipulation of the body and head, likely for the purpose of removing the soft tissues and lower jaw (likely to facilitate the access to the brain), up to the occurrence of the accidental natural events that brought the specimen to the shaft of the cave. We do not know if the context referred to a formal burial or other ritual context.

Supporting information

S1 Table. Cranial measurements taken from Howells (1989) and recorded from the modern identified human skeletal collection from Certosa cemetery of Bologna (Italy) are abbreviated as follows: GOL, maximum cranial length; NOL, nasio-occipital length; XCB, maximum cranial breadth; XFB, maximum frontal breadth; STB, bistephanic breadth; AUB, biauricular breadth; WCB, minimum cranial breadth; ASB, biasterionic breadth; NPH, upper facial height; NLH, nasal height; MAB, maxillo-alveolar breadth; MDH,

mastoid height; MDB, mastoid breadth; ZMB, bimaxillary breadth; WMH, cheek height; GLS, glabella projection; FRC, frontal chord; FRS, nasion-bregma subtense; FRF, nasion subtense fraction; PAC, parietal chord. *Stepwise selected measurements.
(XLSX)

S1 Video. MLC—Video of the sequence of the slices of the cranium (first CT scan).
(AVI)

S2 Video. MLC—Video of the of the slices of the cranium (second CT scan).
(AVI)

S3 Video. MLC—Video of the sequence of slices of the maxilla (CT scan).
(AVI)

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References

1. De Waele J, Piccini L, Columbu A, Madonia G, Vattano M, Calligaris C, et al. Evaporite karst in Italy: a review. International Journal of Speleology 2017; 46(2): 137–168.

2. Grandi L, Pisani L. I gessi del Farneto sotto una nuova luce: ricerche, esplorazioni e scoperte recenti nell'area carsica bolognese. Speleologia 2017; 77: 22–29.

3. Pisani L, Antonellini M, De Waele J. Structural control on epigenic gypsum caves: evidences from Messinian evaporites (Northern Apennines, Italy). Geomorphology 2019; 332: 170–186.

4. Cortelli R, Grazioli F, Castagna L. La fanciulla della Grotta Marcel Loubens. Sottoterra. Rivista di Speleologia del Gruppo Speleologico Bolognese e dell'Unione Speleologica Bolognese 2017; 145: 34–47.

5. Reimer PJ, Austin WEN, Bard E, Bayliss A, Blackwell PG, Bronk Ramsey C, et al. The IntCal20 Northern Hemisphere radiocarbon age calibration curve (0–55 kcal BP). Radiocarbon Journal 2020; Accepted.

6. Belcastro MG, Castagna L, Grazioli F, Preti N, Salvo P, Venturi M. Nota preliminare sul rinvenimento di un cranio umano nella Grotta Marcel Loubens (S. Lazzaro di Savena, BO). In: Boccuccia P, Gabusi R, Guarnieri C, Miari M, editors. Nel sotterraneo mondo: La frequentazione delle grotte in Emilia-Romagna tra archeologia, storia e speleologia, Atti del Convegno, Brisighella 6–7 ottobre 2017. DEA&MIBACT: Emilia-Romagna; 2018. pp. 85–86.

7. Boccuccia P. La frequentazione pre e protostorica nelle grotte tra Reggiano e Bolognese. In: Boccuccia P, Gabusi R, Guarnieri C, Miari M, editors. Nel sotterraneo mondo: La frequentazione delle grotte in Emilia-Romagna tra archeologia, storia e speleologia, Atti del Convegno, Brisighella 6–7 ottobre 2017. DEA&MIBACT: Emilia-Romagna; 2018. pp. 33–42.

8. Facchini F. Resti scheletrici umani rinvenuti presso la Grotta del Farneto (Bologna). Bologna: Arnaldo Forni Editore; 1962.

9. Facchini F. Nuovi rinvenimenti scheletrici umani nel deposito sottoroccia della Grotta del Farneto (Bologna). Firenze: Stamperia Editoriale Parenti; 1971.

10. Facchini F, Belcastro MG, Giusberti G, Mariotti V, Veschi S. Paleoantropologia e Preistoria. Il Museo di Antropologia dell'Università di Bologna. Bologna: Giorgio Barghigiani Editore; 1999.

11. Fantini L. Note di Preistoria bolognese. La grotta del Farneto. Il "Sottoroccia" nei pressi della grotta del Farneto. Strenna Storica Bolognese 1959; IX: 121–136.

12. Fantini L. Nuovi reperti archeologici dalla frana del sottoroccia del Farneto. Culta Bononia 1969; 2: 275–279.

13. Bonometti P. La frequentazione della Grotta del Farneto dal Bronzo Antico al Bronzo Recente. In: Boccuccia P, Gabusi R, Guarnieri C, Miari M, editors. Nel sotterraneo mondo: La frequentazione delle grotte in Emilia-Romagna tra archeologia, storia e speleologia, Atti del Convegno, Brisighella 6–7 ottobre 2017. Soprintendenze ABAP Emilia-Romagna, Bologna: DEA & MIBACT; 2018. pp. 77–84.

14. Tirabassi J., Valzolgher E. Tana della Mussina, 150 anni dopo: i recipienti ceramici rinvenuti nella grotta alla luce delle prime datazioni radiocarboniche. In: Boccuccia P, Gabusi R, Guarnieri C, Miari M, editors. Nel sotterraneo mondo: La frequentazione delle grotte in Emilia-Romagna tra archeologia, storia e speleologia, Atti del Convegno, Brisighella 6–7 ottobre 2017. Soprintendenze ABAP Emilia-Romagna, Bologna: DEA & MIBACT; 2018. pp. 45–58.

15. Miari M. Le sepolture secondarie e collettive in ripari sotto roccia e in grotte in Emilia e Romagna. In: De Marinis RC, editor. L'età del Rame. La pianura padana e le Alpi al tempo di Ötzi.(IIPP—Istituto Italiano di Preistoria e Protostoria), Brescia: Compagnia della Stampa Massetti Rodella editori; 2013. pp. 431–436. https://doi.org/10.1063/1.4811377 PMID: 23822364

16. Miari M. La frequentazione pre e protostorica nelle grotte della Romagna. In: Boccuccia P, Gabusi R, Guarnieri C, Miari M, editors. *Nel sotterraneo mondo: La frequentazione delle grotte in Emilia-Romagna tra archeologia, storia e speleologia, Atti del Convegno, Brisighella 6–7 ottobre 2017.* Soprintendenze ABAP Emilia-Romagna, Bologna: DEA & MIBACT; 2018. pp.109–118.

17. Cocchi Genick D. Preistoria. Verona: QuiEdit; 2009.

18. Cocchi Genick D. I rituali funerari dell'età del Rame nelle regioni settentrionali nell'ambito delle testimonianze italiane. In: De Marinis RC, editor. Le manifestazioni del sacro e l'età del Rame nella regione alpina e nella Pianura Padana. Firenze: Edizioni Euroteam; 2014. pp. 167–192.

19. Cardarelli A. Le età dei metalli nell'Italia settentrionale. In: Guidi A, Piperno M, editors. Italia preistorica. Roma-Bari: Editori Laterza, 1992; 366–419.

20. Morigi MP, Casali F. Radiography and Computed Tomography for Works of Art. In: Russo P. editor. Handbook of X-ray Imaging: Physics and Technology. Abingdon, CRC Press—Taylor & Francis Group; 2018; pp. 1181–1206.

21. Brancaccio R, Bettuzzi M, Casali F, Morigi M P, Levi G, Gallo A, et al. Real-Time reconstruction for 3-D CT Applied to Large Objects of Cultural Heritage. *IEEE* Transactions on Nuclear Science 2011; 58 (4): 1864–1871.

22. Brancaccio R, Bettuzzi M, Casali F, Morigi MP, Ragazzini L. Image Quality and Dose Assessment in Inner Ear Computed Tomography Imaging with a Flat Panel–Based System. *J.* Comput. Assist. Tomogr. 2015; 39(2): 232–239. https://doi.org/10.1097/RCT.0000000000000176 PMID: 25373472

23. Buikstra JE, Ubelaker DH. Standards for Data Collection from Human Skeletal Remains. Arkansas Archaeological Survey Research Series 44: Fayetteville; 1994. https://doi.org/10.1073/pnas.91.6.2091 PMID: 8134354

24. Acsàdi GY, Nemeskéri J. History of Human Life Span and Mortality. Budapest: Academia Kiado; 1970.

25. Howells WW. Cranium Shapes and the Map: Craniometric Analysis in the Dispersion of Modern Homo. Papers of the Peabody Museum of Archaeology and Ethnology (Volume 79), Cambridge (Massachusetts, US): Harvard University Press; 1989.

26. Belcastro MG, Bonfiglioli B, Pedrosi ME, Zuppello M, Tanganelli V, Mariotti V. The History and Composition of the Identified Human Skeletal Collection of the Certosa Cemetery (Bologna, Italy, 19th–20th Century). International Journal of Osteoarchaeology 2017; 27(5): 912–925.

27. Sorrentino R, Belcastro MG, Figus C, Stephens NB, Turley K, Harcourt-Smith W, et al. Exploring sexual dimorphism of the modern human talus through geometric morphometric methods. PloS One 2020; 15(2): e0229255. https://doi.org/10.1371/journal.pone.0229255 PMID: 32059040

28. R Core Team. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria; 2019: https://www.R-project.org/.

29. Meindl RS, Lovejoy CO. 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 1985; 68: 57–66. https://doi.org/10.1002/ajpa.1330680106 PMID: 4061602

30. Brothwell D. Digging Up Bones. British Museum (Natural History), London: Oxford University Press; 1981. https://doi.org/10.1002/ajpa.1330560425 PMID: 7032314

31. Lovejoy CO. Dental Wear in the Libbean population: its functional pattern and role in the determination of adult skeletal age at death. American Journal of Physical Anthropology 1985; 68(1): 47–56. https://doi.org/10.1002/ajpa.1330680105 PMID: 4061601

32. Mann RW, Jantz RL, Bass WM, Willey PS. Maxillary Suture Obliteration: A Visual Method for Estimating Skeletal Age. Journal of Forensic Sciences 1991; 36(3): 781–791. PMID: 1856646

33. Mann RW, Hunt DR, Lozanoff S. Photographic Regional Atlas of Non-Metric Traits and Anatomical Variants in the Human Skeleton. Springfield, Illinois, US: Charles C. Thomas Publisher LTD; 2016.

34. Smith BH. Patterns of molar wear in hunter–gatherers and agriculturalists. American Journal of Physical Anthropology 1984; 63(39): 39–56. https://doi.org/10.1002/ajpa.1330630107 PMID: 6422767

35. Hillson S. Dental Anthropology. Cambridge: Cambridge University Press; 1996. https://doi.org/10.1017/CBO9781139170697

36. Hillson S. Teeth (Cambridge Manuals in Archaeology). Cambridge: Cambridge University Press; 2005. https://doi.org/10.1017/CBO9780511614477

37. Ortner DJ, Putschar WGJ. Identification of Pathological Conditions in Human Skeletal Remains. Smithsonian Contributions to Anthropology (No. 28). Washington D. C, US: Smithsonian Institution Press; 1981.

38. Ortner DJ. Identification of pathological conditions in human skeletal remains. London: Academic Press; 2003.

39. Belcastro MG, Mariotti V, Facchini F, Bonfiglioli B. Proposal of a Data Collection Form to Record Dento-Alveolar Features–Application to Two Roman Skeletal Samples from Italy. Collegium Anthropologicum 2004; 28(1): 161–177. PMID: 15636073

40. Fornaciari G, Giuffra V. Lezioni di Paleopatologia. Genova: ECIG; 2009.

41. Irish JD, Scott GR. A Companion to Dental Anthropology. Hoboken, New Jersey (US): John Wiley & Sons, Inc; 2016.

42. Sauer NJ. The timing of injuries and manner of death: distinguishing antemortem, peri mortem and post mortem trauma. In: Reichs KJ, Editor. Forensic Osteology. Advances in the identification of human remains. 2nd edition, Springfield, Illinois, US: Charles C. Thomas, 1998; pp. 321–332.

43. White TD. Prehistoric Cannibalism at Mancos 5MTUMR-2346. Princeton: Princeton University Press; 1992.

44. White TD, Black MT, Folkens PA. Human Osteology, Third Edition. Burlington, US: Academic Press; 2011.

45. Domínguez-Rodrigo M, De Juana S, Galán AB, Rodríguez M. A new protocol to differentiate trampling marks from butchery cut marks. Journal of Archaeological Science 2009; 36: 2643–2654.

46. Andrews P, Fernández Jalvo Y. How to Approach Peri mortem Injury and Other Modifications. In: Bell LS, editor. Forensic Microscopy for Skeletal Tissues: Methods and Protocols. Methods in Molecular Biology, Vol. 915, Springer Science+Business Media, LLC; 2012. pp. 191–225.

47. Cappella A, Amadasi A, Castoldi E, Mazzarelli D, Gaudio D, Cattaneo C. The Difficult Task of Assessing Peri mortem and Post mortem Fractures on the Skeleton: A Blind Text on 210 Fractures of Known Origin. Journal of Forensic Sciences 2014; 59(6): 1598–1601. https://doi.org/10.1111/1556-4029.12539 PMID: 24990801

48. Galloway A, Zephro L, Wedel VL. Diagnostic Criteria for the Determination of Timing and Fracture Mechanism. In: Wedel VL, Galloway A, editors. Broken Bones. Anthropological Analysis of Blunt Force Trauma. 2nd edition. Springfield, Illinois, US: Charles C Thomas Publisher LTD; 2014. pp. 47–58.

49. Villa P, Mahieu E. Breakage patterns of human long bones. Journal of Human Evolution 1991; 21: 27–48.

50. Outram AK. A New Approach to Identifying Bone Marrow and Grease Exploitation: Why the "Indeterminate" Fragments should not be ignored. Journal of Archaeological Science 2001; 28: 401–410.

51. Outram AK. Bone Fracture and Within-bone Nutrients: an Experimentally Based Method for Investigating Levels of Marrow Extraction. In: Miracle P, Milner N, editors. Consuming Passions and Patterns of Consumption. Cambridge: McDonald Institute for Archaeological Research; 2002. pp. 51–64.

52. Outram AK, Knüsel CJ, Knight S, Harding A.F. Understanding complex fragmented assemblages of human and animal remains: a fully integrated approach. Journal of Archaeological Science 2005; 32: 1699–1710. http://doi.org/10.1016/j.jas.2005.05.008.

53. Columbu A, Chiarin V, De Waele J, Drysdale, Woodhead J, Hellstrom J, et al. Late quaternary speleogenesis and landscape evolution in the northern Apennine evaporite areas. Earth Surface Processes and Landforms 2017; 42(10): 1447–1459.

54. Columbu A, Drysdale R, Hellstrom J, Woodhead J, Cheng H, Hua Q, et al. U-Th and radiocarbon dating of calcite speleothems from gypsum caves (Emilia Romagna, North Italy). Quaternary Geochronology 2019; 52: 51–62.

55. Holland TD, O'Brien MJ. Parasites, Porotic Hyperostosis, and the Implications of Changing Perspectives. American Antiquity 1997; 62(2): 183–193.

56. Larsen CS. Bioarchaeology: Interpreting Behavior from the Human Skeleton. Cambridge: Cambridge University Press; 1997.

57. Walker PL, Bathurst RR, Richman R, Gjerdrum, Andrushko VA. The Causes of Porotic Hyperostosis and Cribra Orbitalia: A Reappraisal of the Iron-Deficiency-Anemia Hypothesis. American Journal of Physical Anthropology 2009; 139: 109–125. https://doi.org/10.1002/ajpa.21031 PMID: 19280675

58. Walker PL. Porotic hyperostosis in a marine-dependent California Indian population, American Journal of Physical Anthropology 1986; 69: 345–354. https://doi.org/10.1002/ajpa.1330690307 PMID: 3518481

59. Ubelaker DH. Porotic hyperostosis in Prehistoric Ecuador. In: Stuart-Macadam P, Kent S, editors. Diet, demography, and disease: changing perspectives on anemia, New York: De Gruyter; 1992. pp. 201–217.

60. Aufderheide AC, Rodríguez-Martin C. Human Paleopathology. Cambridge: Cambridge University Press; 1998.

61. Ubelaker DH. The Estimation of Age at Death from Immature Human Bone. In: Işcan MY, editor. Age Markers in the Human Skeleton. Springfield, US: Charles C. Thomas Publisher, 1989; 99–112.

62. Turner CG. Dental Anthropological Indications of Agriculture Among the Jomon People of Central Japan. American Journal of Physical Anthropology 1979; 51: 619–36.

63. Salvadei L, Spina A. Antropologia dentaria delle popolazioni padane del Neolitico medio. Dati patologici. In: Bernabò Brea M, Maggi R, Manfredini A, editors. Il pieno sviluppo del Neolitico in Italia. Atti del convegno Museo Archeologico del Finale, Finale Ligure Borgo, 8–10 giugno 2009. Rivista di Studi Liguri LXXVII-LXXIX, 2011–2013; 2014. pp. 399–402. https://doi.org/10.1002/ppul.22935 PMID: 24574431

64. Lukacs JR, Largaespada LL. Explaining sex differences in dental caries prevalence: saliva, hormones, and "life-history" etiologies. American Journal of Human Biology 2006; 18 (4): 540–55. https://doi.org/10.1002/ajhb.20530 PMID: 16788889

65. Olsen SL, Shipman P. Cutmarks and Peri mortem Treatment of Skeletal Remains of the Northern Plains. In: Owsley DN, Jantz R, editors. Skeletal Biology in the Great Plains: Migration, Warfare, Health and Subsistence. Washington: Smithsonian Institution; 1994. pp. 377–387.

66. Simmons T, Goring-Morris N, Horwitz L. What Ceremony Else? Taphonomy and the Ritual Treatment of the Dead in the Pre-Pottery Neolithic B Mortuary Complex at Kfar HaHoresh, Israel. In: Faerman M, Horwitz LK, Kahana T, Zilberman U, editors. Faces from the Past: Diachronic Patterns in the Biology of Human Populations from the Eastern Mediterranean. British Archaeological Reports International Series 1603. Oxford: Archaeopress; 2007. pp. 100–26.

67. Erdal Y.S. Bone or Flesh: Defleshing and PostDepositional Treatments at Körtik Tepe (Southeastern Anatolia, PPNA Period). European Journal of Archaeology 2011; 18 (1): 4–32.

68. Kanjou Y, Kuijt I, Erdal YS, Kondo O. Early Human Decapitation, 11,700–10,700 cal bp, within the Pre-Pottery Neolithic Village of Tell Qaramel, North Syria. Int. J. Osteoarchaeoly. 2015; 25: 743– 752. https://doi.org/10.1002/oa.2341

69. Belcastro MG, Condemi S, Mariotti V. Funerary practices of the Iberomaurusian population of Taforalt (Tafoughalt, Morocco, 11–12,000 BP): the case of Grave XII. Journal of Human Evolution 2010; 58: 522–532. https://doi.org/10.1016/j.jhevol.2010.03.011 PMID: 20471665

70. Germanà F, Fornaciari G. Trapanazioni, craniotomie e traumi cranici in Italia: dalla Preistoria all'Età moderna. Pisa: Giardini stampatori ed editori; 1992.

71. Blumenschine RJ. Blind Tests of Inter-analyst Correspondence and Accuracy in the Identification of Cut Marks, Percussion Marks, and Carnivore Tooth Marks on Bone Surfaces. Journal of Archeological Science 1996; 23: 493–507.

72. Pickering TR, Domínguez-Rodrigo M, Heaton JL, Yravedra J, Barba R, Bunn HT, et al. Taphonomy of ungulate ribs and the consumption of meat and bone by 1.2-million-year-old hominins at Olduvai Gorge, Tanzania. Journal of Archaeological Science 2013; 40: 1295–1309.

73. Saladié P, Rodríguez-Hidalgo A, Díez C, Martín-Rodríguez P, Carbonell E. Range of bone modifications by human chewing. Journal of Archaeological Science 2013; 40: 380–397.

74. Formicola V, Cammellini S, Caramella D, Del Lucchese A, Goude G, Saccone M, et al. An unusual surgical treatment of the skull following trauma during the Copper Age (IV millennium B.C.) in Italy. Journal of Anthropological Sciences. 2012; 90: 1–2. https://doi.org/10.4436/jass.90017 PMID: 23274750

75. Kean WF, Tocchio S, Kean M, Rainsford KD. The musculoskeletal abnormalities of the Similaun Iceman ("ÖTZI"): clues to chronic pain and possible treatments. Inflammopharmacology 2013; 21(1): 11–20. https://doi.org/10.1007/s10787-012-0153-5 PMID: 23096483

76. Formicola V, Pettitt PB, Maggi R, Hedges R. Tempo and mode of formation of the Late Epigravettian necropolis of Arene Candide cave (Italy): direct radiocarbon evidence. Journal of Archaeological Science. 2005; 32: 1598–1602.

77. Stafford MD, Frison GC, Stanford D, Zeimans G. Digging for the Color of Life: Paleoindian Red Ochre Mining at the Powars II Site, Platte County, Wyoming, U.S.A. Geoarchaeology: An International Journal 2003; 18(1): 71–90. https://doi.org/10.1002/gea.10051

78. Mariotti V, Bonfiglioli B, Facchini F, Condemi S, Belcastro MG. Funerary practices of the Iberomaurusian population of Taforalt (Tafoughalt) (Morocco, 11–12000 BP): new hypotheses based on a grave by grave skeletal inventory and evidence of deliberate human modification of the remains. Journal of Human Evolution 2009; 56: 340–354. https://doi.org/10.1016/j.jhevol.2009.01.001 PMID: 19362729

79. Mariotti V, Condemi S, Belcastro MG. The study of human remains in the reconstruction of funerary rituals: the Iberomaurusian necropolis of Taforalt (Morocco, 15000–12500 Cal BP). In: Nizzo V, editor. Archeologia e antropologia a confronto: archeologia e antropologia della morte, vol. 3. Costruzione e decostruzione del sociale, Atti del III incontro internazionale di studi, Roma, École Française-Stadio di Domiziano 20–22 maggio 2015, Roma; 2018. pp. 365–373.

80. Vercellotti G, Alciati G, Richards MP, Formicola V. The Late Upper Paleolithic skeleton Villabruna 1 (Italy): a source of data on biology and behavior of a 14.000 year-old hunter. Journal of Anthropological Sciences 2008; 86:143–163. PMID: 19934473

81. Dalmeri G, Mottes E, Nicolis F. The Mesolithic burial of Mezzocorona-Borgonuovo (Trento): some preliminary comments. Preistoria Alpina 2002; 34(1998): 129–138.

82. Cortell Nicolau A. El ocre en la Prehistoria: entre la funcionalidad y el simbolismo. Valencia: Archivio de Prehistoria Levantina Vol. XXXI 2016; 187–211.

83. Columbu A, De Waele J, Forti P, Montagna P, Picotti V, Pons-Branchu E, et al. Gypsum caves as indicators of climate-driven river incision and aggradation in a rapidly uplifting region. Geology 2015; 43 (6): 539–542.

84. Evans T. Fluvial taphonomy. In: Pokines JT, Symes SA, editors. Manual of Forensic Taphonomy. Boca Raton: CRC Press; 2013. pp. 115–141.

85. Cazzella A. Modelli e variabilità negli usi funerari di alcuni contesti eneolitici italiani. Rivista di scienze preistoriche 1998; 49: 431–445.

86. Conti AM, Persiani C, Petitti P. Analisi dei rituali: depositi archeologici e mito degli antenati. In: Negroni Catacchio N, editor. Preistoria e Protostoria in Etruria, Atti del settimo incontro di Studi, Pastori e Guerrieri nell'Etruria del IV e III millennio a.C., Milano: CSPP; 2006. pp. 455–459.

87. Petitti P, Conti AM, Persiani C. I rituali di deposizione nella cultura di Rinaldone alla luce della necropoli di Selvicciola. In: Negroni Catacchio N, editor. Preistoria e Protostoria in Etruria, Atti del settimo incontro di studi, Milano: CSPP; 2006. pp. 63–75.

88. Todaro SV, Girella L. Living through destructions. In: Driessen J, editor. Destruction: Archaeological, Philological and Historical Perspectives. UCL Presses Universitaires de Louvain; 2013. pp. 133–152.

89. Leonini V, Sarti L. Sepolture e rituali funerari nell'Eneolitico e al passaggio all'Età del Bronzo in Italia. In: Martini F, editor. La cultura del morire nelle società preistoriche e protostoriche italiane. Firenze: Origines; 2003. pp. 131–160.

90. De Marinis RC. La necropoli di Remedello Sotto e l'età del Rame nella pianura padana a nord del Po. In: De Marinis RC, editor. L'età del Rame: la pianura padana e le Alpi al tempo di Ötzi, Exhibition catalogue, Brescia: Compagnia della Stampa Massetti Rodella editori; 2013. pp. 301–352.

91. Baioni M, Poggiani Keller R. L'età del Rame in Lombardia: un breve quadro di sintesi. In: Cocchi Genick D, editor. Cronologia assoluta e relativa dell'età del Rame in Italia. Atti dell'Incontro di studi, Università di Verona, 25 giugno 2013. Verona: QuiEdit; 2013. pp. 27–49.

92. Cocchi Genick D. Le evidenze venete nel quadro dell'Eneolitico dell'Italia settentrionale. In: Leonardi G, Tinè V, editors. Preistoria e Protostoria del Veneto. Studi di Preistoria e Protostoria Vol. 2. Firenze: Istituto Italiano di Preistoria e Protostoria; 2015. pp. 147–146.

93. Steffé G, Miari M, Bernabò Brea M. L'Eneolitico dell'Emilia-Romagna In: Bernabò Brea M, editor. Preistoria e Protostoria dell'Emilia-Romagna I, Studi di Preistoria e Protostoria Vol. 3, Firenze: Istituto Italiano di Preistoria e Protostoria; 2017. pp. 139–158.

94. Tirabassi J. Tana della Mussina, una caverna sepolcrale dell'età del Rame a Borzano di Albinea (RE), In: De Marinis RC, editor. L'età del Rame: la pianura padana e le Alpi al tempo di Ötzi, Exhibition catalogue, Brescia: Compagnia della Stampa Massetti Rodella editori; 2013. pp. 423–429.

95. Mottes E, Nicolis F. Forme della ritualità funeraria tra età del Rame e antica età del Bronzo nel territorio della Valle dell'Adige (Trentino Alto Adige, Italia settentrionale). Nota di aggiornamento. In: Martini F, Salzani L, editors. Un lungo percorso di scienza. Scritti in onore di Leone Fasani. Memorie del Museo Civico di Storia Naturale di Verona. 2. Serie. Sezione Scienze dell'Uomo 13, Millenni. Studi di Archeologia Preistorica 22; 2019. pp. 191–219.

96. Cocchi Genick D, Grifoni Cremonesi R. L'età dei metalli nella Toscana nord-occidentale. Pisa: Pacini Editore; 1985.

97. Maggi R, Pearce M. Cronologia mineraria in Liguria. In: Cocchi Genick D, editor. Cronologia assoluta e relativa dell'età del Rame in Italia. Atti dell'Incontro di studi, Università di Verona, 25 giugno 2013. Verona: QuiEdit; 2013. pp. 5–15.

98. Barfield LH. Excavations in the Riparo Valtenesi, Manerba, 1976–1994. Firenze: Origines; 2007.

99. Maggi R, Formicola V. Una grotticella sepolcrale dell'inizio dell'Età del Bronzo in Val Frascarese, Preistoria Alpina 1978; 14: 87–113.

100. Busi C. Luigi Fantini e la scoperta del deposito osteologico del Sottoroccia del Farneto. In: Boccuccia P, Gabusi R, Guarnieri C, Miari M, editors. Nel sotterraneo mondo: La frequentazione delle grotte in Emilia-Romagna tra archeologia, storia e speleologia, Atti del Convegno, Brisighella 6–7 ottobre 2017. Soprintendenze ABAP Emilia-Romagna, Bologna: DEA & MIBACT; 2018. pp. 227–240.

101. Romagnoli E. Revisione e studio antropologico dei resti osteologici eneolitici del Sottoroccia del Farneto e della grotta di fianco alla chiesa di Gaibola, Unpublished master's degreethesis: University of Bologna; 2018.

102. Nicolosi T. Le potenzialità dello studio dei resti scheletrici frammentari, commisti o isolati. I reperti eneolitici dal Parco dei Gessi Bolognesi: il Sottoroccia del Farneto e la Grotta Marcel Loubens Unpublished Master thesis: University of Bologna; 2019.

103. Facchini F. Note antropologiche sui reperti scheletrici della grotta della Gaibola. Rassegna Speleologica Italiana 1972; IV (2): 140–145.

104. Benedetti B, Bertolani V, Rossi A. Studio archeologico-paletnologico della stazione in grotta. Rassegna Speleologica Italiana 1972; IV (2): 131–139.

105. Cavazzuti C. Resti umani e rituali nelle grotte emiliano-romagnole fra terzo e secondo millennio a.C. In: Boccuccia P, Gabusi R, Guarnieri C, Miari M, editors. Nel sotterraneo mondo: La frequentazione delle grotte in Emilia-Romagna tra archeologia, storia e speleologia, Atti del Convegno, Brisighella 6–7 ottobre 2017. Soprintendenze ABAP Emilia-Romagna, Bologna: DEA & MIBACT; 2018. pp. 129–140.

106. Bagolini B. Il Neolitico e l'Età del rame. Ricerca a Spilamberto e S. Cesario 1977–1980. Bologna: Cassa di Risparmio di Vignola; 1981.

107. Bagolini B. Archeologia a Spilamberto. Ricerche nel territorio (Spilamberto–S. Cesario). Bologna: Calderini; 1984.

108. Ferrari A, Steffé GS. Cesario sul Panaro. Eneolitico. In: Cardarelli A, Malnati L, editors. Atlante dei Beni Archeologici della Provincia di Modena, vol. III, 2. Collina e Alta Pianura, Modena. Firenze: All'Insegna del Giglio; 2009. pp. 90–206.

109. Miari M, Bestetti F, Rasia PA. La necropoli eneolitica di Celletta dei Passeri (Forlì): analisi delle sepolture e dei corredi funerari, Rivista di Scienze Preistoriche 2017; LXVII: 145–208.

110. Antoniazzi A, Bermond Montanari G, Giusberti G, Massi Pasi M, Mengoli D, Morico G, Prati L. Lo scavo preistorico a Fornace Cappuccini. In: AA.VV. Archeologia a Faenza. Ricerche e scavi dal Neolitico al Rinascimento. Exhibition catalogue. Bologna: Nuova alfa editoriale; 1990. PMID: 2135431

111. Giusberti G, Veschi S, Facchini F. Reperti scheletrici neolitici nel fossato di Fornace Cappuccini di Faenza (RA), Rivista di Antropologia 1997; 75: 63–97.

112. Amitrano A. Il sito neolitico di Fornace Cappuccini (Ravenna), ipotesi interpretativa. Unpublished Master Thesis, University of Bologna; 2018.

113. Robb J, Elster ES, Isetti E, Knüsel CJ, Tafuri MA, Traverso A. Cleaning the dead: Neolithic ritual processing of human bone at Scaloria Cave, Italy. Antiquity 2015; 89: 39–54.

114. Knüsel C, Robb J, Tafuri MA. The Human Skeletal Remains from Scaloria Cave. In: Elster EE, Isetti E, Traverso A, Robb J, editors. The Archaeology of Grotta Scaloria. Ritual Neolithic Southeast Italy. Monumenta Archaeologica, Los Angeles, US: Cotsen Institute of Archaeology Press; 2016. pp. 117–191.

115. Tiné S. Passo di Corvo e la civiltà neolitica del Tavoliere. Genova: SAGEP Editrice; 1983.

116. Mariotti M, Muntoni IM, Belcastro MG. New insights into the funerary rituals of the Neolithic site of Passo di Corvo (Apulia, Italy): The study of the human remains. Journal of Archaeological Science: Reports. 2020; 34: 102643.

117. Venturini M, Belcastro MG, Mariotti V. Lo studio dei resti umani nella ricostruzione dei rituali funerari: le sepolture del sito neolitico di Passo di Corvo (Foggia); 2015. Poster presented at 3rd Meeting "Antropologia e Archeologia a confronto" (Rome,20–22 May 2015)—Archeologia e antropologia della morte.

118. Bernabò Brea M, Maffi M, Mazzieri P, Salvadei L. Contesti funerari VBQ dell'Emilia occidentale: le sepolture anomale. In: Bernabò Brea M, editor. Preistoria e Protostoria dell'Emilia-Romagna I, Studi di Preistoria e Protostoria Vol. 3, Firenze: Istituto Italiano di Preistoria e Protostoria; 2017. pp. 211–218.