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Journal Name	**Forensic Science, Medicine and Pathology**	
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Schedule
Received
Revised
Accepted 5 November 2018

Abstract

In this paper we present the study of a skull belonging to a young male from the Italian Bronze Age showing three perimortem injuries on the frontal and parietal bones; the peculiarity of the frontal injury is represented by its singular shape, which may be indicative of the weapon that caused the lesion. The aim of the present study is to examine the traumatic evidence in relation to possible etiological factors, in order to attempt to establish if the lesion occurred peri or post-mortem, and to evaluate if these traumatic injuries could be interpreted as an evidence of interpersonal violence, by combining anthropological, taphonomic and ESEM investigations. The combination of multidisciplinary methods of study can provide important new insights into inter-personal violence.

Keywords (separated by '-')
Skeletal remains - Cranial injury - Interpersonal violence - Taphonomic analysis - Forensic anthropology

Foot note information

Forensic Science, Medicine and Pathology
https://doi.org/10.1007/s12024-018-0054-z

LESSONS FROM THE MUSEUM

Violence in the Early Bronze Age. Diagnosis on skull lesions using anthropological, taphonomic and scanning electron microscopy techniques

Alba Pasini[1] · Emanuela Gualdi-Russo[1] · Filippo Scianò[1] · Ursula Thun Hohenstein[2]

Accepted: 5 November 2018

Abstract
In this paper we present the study of a skull belonging to a young male from the Italian Bronze Age showing three perimortem injuries on the frontal and parietal bones; the peculiarity of the frontal injury is represented by its singular shape, which may be indicative of the weapon that caused the lesion. The aim of the present study is to examine the traumatic evidence in relation to possible etiological factors, in order to attempt to establish if the lesion occurred peri or post-mortem, and to evaluate if these traumatic injuries could be interpreted as an evidence of interpersonal violence, by combining anthropological, taphonomic and ESEM investigations. The combination of multidisciplinary methods of study can provide important new insights into inter-personal violence.

Keywords Skeletal remains · Cranial injury · Interpersonal violence · Taphonomic analysis · Forensic anthropology

Introduction

The collection of the Department of Biomedical Sciences and Surgical Specialties at University of Ferrara includes human skeletal remains of prehistoric and historical epochs.

In the present study, we examined the case of a skull with a frontal injury from the Italian Early Bronze Age (EBA). Since the interpretation of trauma is an essential task for forensic anthropologists, the primary focus of our study is to establish the possible cause of death of the individual and to evaluate if the traumatic injury could be interpreted as an evidence of interpersonal violence.

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Materials and methods

Among the commingled remains of 27 individuals from Ballabio (Lecco, Italy) [1, 2], a skull (devoid of a mandible) presenting a peculiar injury on the frontal bone was found (Fig. 1).

The skull was analyzed by traditional anthropological methods to determine the sex of the decedent [3–5] and to estimate their age at death [3, 4, 6–9]. Osteometric traits of the skull were measured directly, when possible.

Description and interpretation of traumas were performed according to documented methods commonly applied in forensic anthropology to assess their nature (peri or post-mortem, accidental or intentional) [10–16].

Taphonomic analysis included macroscopic and microscopic observations through Environmental Scanning Electronic Microscope (ESEM). Replicas of the marks [17, 18] were made to perform ESEM analyses on small areas of the surfaces to evaluate possible traumatic marks, avoiding metallization of the original specimen and assuring a high degree of definition/reproduction of traces below 1 μm [19, 20]. Silicone elastomer for casts and epoxy resin were used for positive copies.

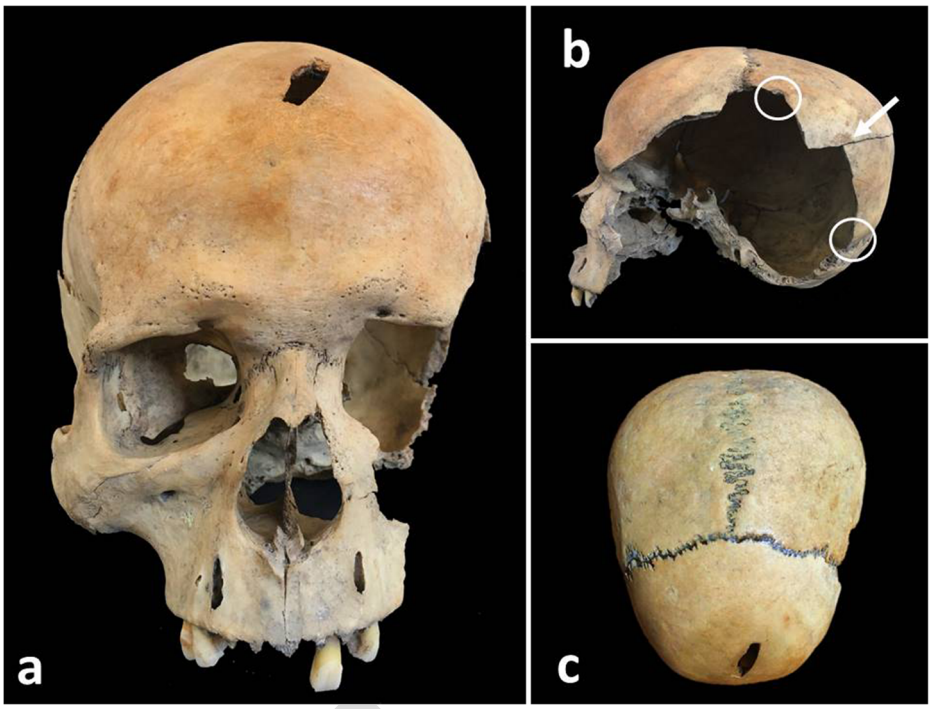


Fig. 1 Male skull from Ballabio: (**a**) frontal view; (**b**) lateral view (circles show location of the parietal injuries, arrow indicates the radiating fracture); (**c**) superior view

Craniofacial restoration, reconstruction and modelling were performed by computer graphics according to methodological indications [21–25]. A 3-D model of the skull was generated by NextEngine Desktop Scanner. A mandible from the same necropolis and consistent with the biological profile of the individual was scanned and adapted to the skull for reconstruction purposes. A generic head model (FaceGen) was imported and molded on the skull tagged with markers oriented orthogonal to cranial surfaces.

Results

The skull was found to be in a good state of preservation. According to our assessment, the subject was a young adult male (25–35 years old), brachycranial, with a middle upper face and mesorhinous (Table 1). No pathological evidences were observed.

Virtual restoration of the missing portions of the skull was carried out digitally before reconstruction, and a standard head of a male Caucasoid of the same age was molded on the soft tissue thickness indicators (Fig. 2). Some characteristics of the face (lip thickness, pigmentation, hairiness) were freely chosen from those possible in Caucasoid persons.

A sub-rectangular penetrating injury measuring 2.7 × 0.9 cm was observed on the frontal bone (Fig. 3a). The right edge of the injury presented a sub-circular widening, while the other

Table 1 Measurements and indices of the Ballabio skull (measures collected on the virtual skull are in italics)

Traits	
-Maximum cranial length (mm)	181
-Maximum cranial breadth (mm)	*147*
Cranial Index	81.2
-Upper facial height (mm)	67
-Bizygomatic breadth(mm)	*133*
Upper facial index	50.4
-Nasal height (mm)	50
-Nasal breadth (mm)	25
Nasal index	50

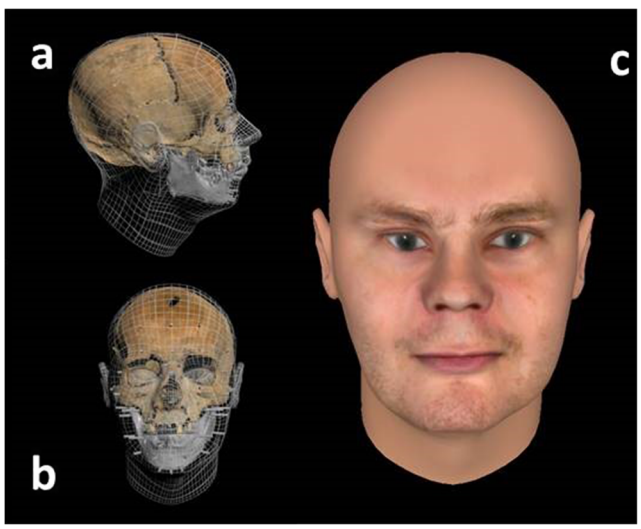


Fig. 2 Left pictures show profile (**a**) and frontal (**b**) views of the textured skull after adaptation of a generic head. The right picture (**c**) represents the final facial reconstruction of the man from Ballabio

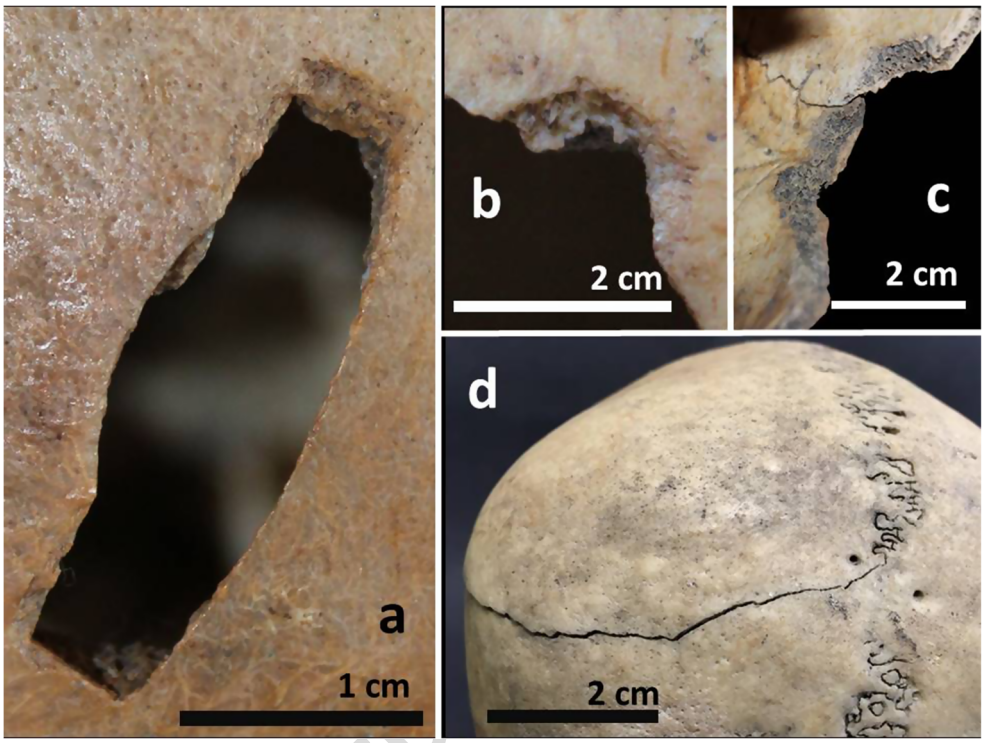
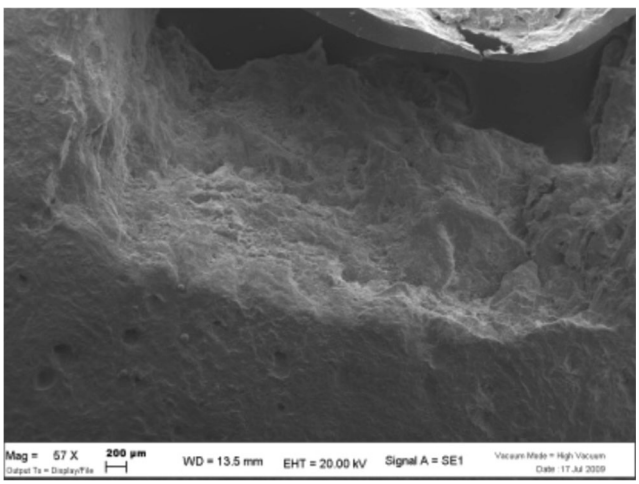


Fig. 3 Injuries on the frontal bone (**a**), parietal bone (**b**, **c**) and radiating fracture on the parietal bone (**d**)

margins appeared regularly straight and sharp. The inner wall of the right margin is slanting to the cranial vault, while the left one is perpendicular to the cranial vault. Micro-fractures on the inner and outer surface were observed. The endocranial surface showed marked bevelling and partial exposition of the diploe. No radiating or additional fractures were observed for this injury. The absence of healing processes pointed to this trauma as occurring peri-mortem [10–16, 26, 27].

The presence of a traumatic breakthrough, attested by the stepped morphology of the edges and the presence of micro-fracturing, was observed by ESEM (Fig. 4). The impact point was located on the left side, given the presence of a sharper edge and a sub-circular operculum.



Q2 **Fig. 4** Picture from the ESEM analysis of the frontal injury

Two further wounds were observed on the left parietal bone, presenting features similar to the frontal injury (regular margins, bevelling of the endocranial diploe) (Fig. 3b-c), along with a clearly distinguishable fracture, crossing the parietal bone to the coronal suture (Fig. 3d).

Discussion

The biological profile of this case suggests the man died at a young age and there is evidence of him suffering a violent death. His relatively large skull and the intermediate values of the facial and nasal indices are consistent with the characteristics of the Alpine populations.

The primary focus of our analysis was to assess whether the lesions were inflicted intentionally or accidentally. As pointed out by several researchers [28–31], injuries located on cranial bones are usually related to violence, indicating the action was intentional. The presence of multiple traumas provides further confirmation of an interpersonal violence case [15].

The singularity of the frontal trauma led us to assess the typology of the weapon involved in the traumatic evidence. Features of the Ballabio skull injuries are not consistent with a sharp force trauma provided by dirks, since their typical marks (a narrow V-shaped groove with a distinct apex at the bottom or a broader U-shaped groove with a flat bottom) [10, 15, 32, 33] were not observed in the present case.

Chopping or slashing wounds can be caused both by sharp and blunt forces (axes or heavy swords) [13, 15, 32]; evidence

of this weapon type being used are similar to sharp-force injury marks; a fractured appearance of the injury edges and impression fractures, often with loose fragments [15].

Light and short swords such as were usually used in the EBA generate slashing traumas with incision marks including V-shaped kerfs, a narrow cross-section and minimal wastage [34].

Typical EBA axes were excluded as being the weapon used in this case since they create damage through a combination of incision and percussion [32, 34]; despite their small dimensions, these axe types can cause typical hacking wounds, characterized by significant wastage, breakage and fracturing, with concentric and depressed fractures characterizing cranial injuries [15, 34]; moreover, this weapon class does not create square-shaped or cleft-shaped defects [15, 34].

Typical projectile injuries present penetrating or grazing defects with complete, linear, radiating, and multi-fragmented fractures; the lesion shape is usually influenced by the shape of the projectile itself [2, 3, 10, 15, 33]. When there is a combined action of pointed and sharp forces (i.e. penetrating tools with one or more sharp edges, such as metallic arrowheads), a mold fenestration with at least one sharp edge, due to the divaricating action of the blade, is present [13].

Considering the morphology of the lesion in this case we hypothesize that they were inflicted by a perforating weapon or weapon-like object with a sharp edge, leaving typical geometrical and square shaped lesions of the same size as the tool involved [35]. Moreover, the presence of a sub-circular edge on the left margin of the frontal lesion led us to assume that extraction of the weapon caused the detachment of an operculum due to the application of a leverage action [13].

Although ESEM did not provide sufficient diagnostic elements on the composition (stone, metal, antler or bone) of the weapon, stone tools were excluded due to the absence of typical multiple striae and micro-fragments [36–38].

The two partially-conserved parietal wounds present features similar to the frontal lesion showing endocranial bevelling and a clear external margin. The fracture crossing the parietal bone shows typical traits of radiating fractures, such as elastic deformation, sharp edges, and theabsence of discoloration [27, 39]; this traumatic evidence was generated by a high-energy impact propagating from the impact site along path of least resistance up to the coronal suture [27, 39].

We assessed that all fractures were caused by the same weapon class. The absence of healing processes led us to conclude that all of the injuries were inflicted peri-mortem, probably during the same traumatic event. We cannot determine the exact sequence of the different impacts, although this individual was probably attacked first from his upper-left side, as shown by the frontal wound, and then laterally.

In conclusion, since bone lesions are frequently found in homicide victims [40], the reported case could be of interest in the forensic context when potential signs of violence are detected on skeletal remains. Depending on the degree of skeletonization, anthropological and taphonomic analyses may be usefully applied to investigate and interpret injuries on skeletal remains.

Acknowledgments The authors acknowledge Rita Bovolenta, Valentina Russo and Simonetta Zonari for technical support. Thanks also to Vanessa Manzon and Letizia Fazzari for collaboration in preliminary studies.

Compliance with ethical standards

Ethical approval Not required.

Conflict of interest The authors declare that they have no conflicts of interest.

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