Identification of dermestid beetle modification on Neolithic Maltese human bone: Implications for funerary practices at the Xemxija Tombs

Jess E. Thompson[a*], Daniel Martín-Vega[b,c], Laura T. Buck[d,e] Ronika K. Power[a,f], Simon Stoddart[a], Caroline Malone[g]

[a] Department of Archaeology, University of Cambridge, UK
[b] Departamento de Ciencias de la Vida, Universidad de Alcalá, Spain
[c] Department of Life Sciences, Natural History Museum, UK
[d] Human Origins Research Group, Department of Earth Sciences, Natural History Museum, UK
[e] Department of Anthropology, University of California Davis, USA
[f] Department of Ancient History, Macquarie University, Australia
[g] School of Natural and Built Environment, Queen's University Belfast, Northern Ireland
*Corresponding author contact details: Department of Archaeology, Downing Street, Cambridge, CB2 3DZ; jet71@cam.ac.uk

E-mail addresses: l.buck@nhm.ac.uk (L. Buck); c.malone@qub.ac.uk (C. Malone); daniel.martinve@uah.es (D. Martín-Vega); ss16@cam.ac.uk (S. Stoddart); ronika.power@mq.edu.au (R. K. Power)

Abstract

Taphonomic modifications to Neolithic human skeletal remains from six rock-cut tombs in Malta has provided key information about funerary practices and the local environment. Application of microscopic analysis, computed tomography (CT) scanning, and 3D imaging of the modifications has allowed their comparison with similar examples in modern and archaeological skeletal material. The modifications are interpreted as pupal chambers and feeding damage by dermestid beetles. Based on observation of the behaviour and ecology of dermestid beetles, we suggest several scenarios for funerary practices at the Xemxija tombs which nuance our current understanding of collective burial during the late Neolithic in Malta.

Keywords: Archaeoentomology; dermestid beetles; funerary practices; human bones; Neolithic; taphonomy; Malta.

1. Introduction

Modifications to human skeletal remains from archaeological contexts provide a wealth of information regarding individual health, cultural interactions with the remains of the dead, and the effects of the burial environment (White 1992, Haglund 1997a, 1997b, Andrews and Fernandez-Jalvo 2003, Ortner 2003a, Smith 2006, Duday 2009, Robb et al. 2015). The latter two categories of taphonomic markers – cultural and natural modifiers to human remains following death and deposition – are sometimes juxtaposed, and there is debate as to whether natural modifications to skeletal remains can reveal cultural practices (cf. Knüsel and Robb 2016, 656). As the emerging field of funerary archaeoentomology is beginning to show, however, insect modifications to human skeletal remains allow us not only to reconstruct

palaeoenvironments, but also advance our understanding of funerary practices (Huchet and Greenberg 2010, Huchet et al. 2013, Huchet 2014a, 2014b, Matu et al. 2017).

Among the non-anthropogenic modifiers of bone, rodents and carnivores have particularly been noted for their ability to disturb archaeological assemblages through feeding practices (Haglund 1997a, 1997b). Much less studied, however, are modifications to bone which result from insect activity such as feeding and the excavation of pupation chambers. Within the forensic sciences, insects provide crucial information to estimate the postmortem interval as they occupy specific ecological niches (Rodriguez and Bass 1983, Haskell et al. 1989, Wells and LaMotte 2001). Only four orders of insects have been recognised as agents of bone modification, particularly on fossil dinosaur (Paik 2000, Roberts et al. 2007, Britt et al. 2008, Bader et al. 2009, Xing et al. 2013) and faunal remains (Martin and West 1995, Kaiser 2000, Holden et al. 2013). These include Coleoptera (dermestid beetles), Diptera (specifically the larvae of certain sarco-saprophagous flies), Hymenoptera (wasps and burrowing bees) and Isoptera (termites) (Huchet 2014b). Insect modification to archaeological human remains can aid the interpretation of funerary practices, as each insect species has specific ecological niches and feeding practices and leaves morphologically distinct marks in bone. For example, dermestid beetles only colonise exposed cadavers and thrive best in warm, dry environments with restricted light; thus, they can provide information regarding both the environmental and cultural circumstances of funerary practices (Huchet et al. 2013).

This study presents the first analysis of entomological modification to human skeletal remains in the central Mediterranean from a series of six rock-cut tombs in northern Malta dating to the Neolithic (Fig 1). Radiocarbon dates recently obtained from tooth dentine from five left mandibular second molars show that the tombs were used for deposition for an extended period, from at least 3500-2450 cal BC (McLaughlin et al. forthcoming). The skeletal assemblage from the Xemxija rock-cut tombs contains a small number of fragmented bones which exhibit circular and ovate borings. Analysis of these modifications through microscopy and 3D imaging has implications for understanding Neolithic funerary practices in Malta. Until now, the lack of excavation records and aggregated human bone assemblage has impeded an interpretation of the process of collective burial in the Xemxija rock-cut tombs. The results of this study show that taphonomic modifications to a small sample of the human bones are most consistent with an assemblage formed by successive deposition of primary interments, rather than by the secondary interment of already-exposed remains.
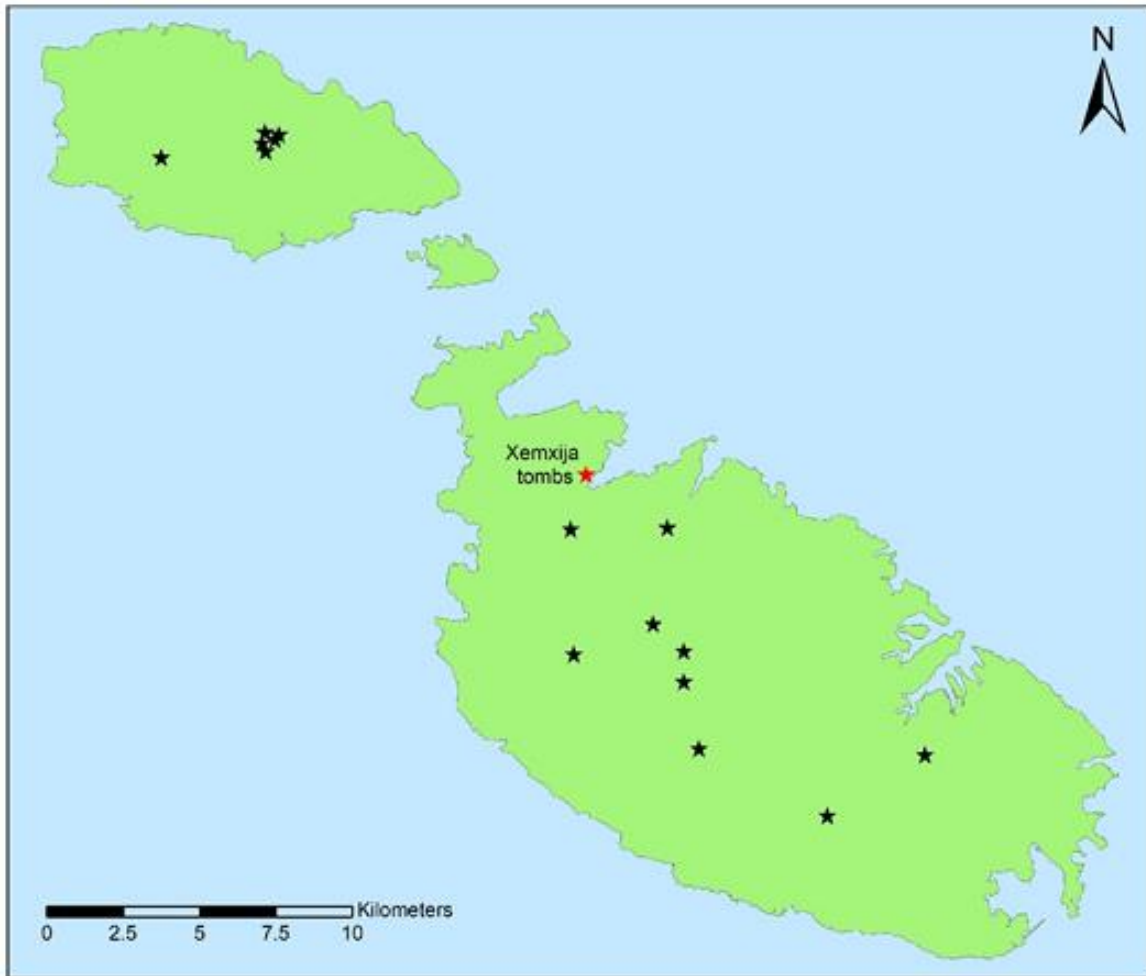
Figure 1: Location of Xemxija tombs and other known Neolithic burial sites on the Maltese islands.

2. Archaeological context

Human bones were excavated from six rock-cut tombs in the Xemxija limestone plateau in northeast Malta (Fig 2). Excavations were carried out in 1955 by John Evans and a team of local workmen, although details of the excavation methods have unfortunately not survived (Evans 1971). Stratigraphically, most tombs were observed to have two fills: an upper brown clay layer and a lower deposit of white lime coloured with red ochre containing the burial deposit (Evans 1971, 113). Each tomb is reached through a small entrance hole in the limestone plateau, which opens into a burial chamber with a domed roof. The internal layout of each tomb differs, from one kidney-shaped burial chamber to three or five small lobed chambers radiating from the central entrance. Although each tomb is relatively small, and does not provide adequate standing room, some tombs contained more internal distinctions in the burial space. Following excavation, most human remains from the tombs were originally divided according to tomb number, but these distinctions have now been lost and the remains from all tombs are aggregated. The absence of detailed excavation records, and the aggregation of all human remains, poses significant difficulties for the reconstruction of funerary practices at this site.

Neolithic funerary practices in Malta are characterised by collective burial in rock-cut tombs, caves, and hypogea (Malone et al. 2009, Tagliaferro 1911, Zammit 1925). The process of collective burial resulted in commingled assemblages of human remains in various states of preservation, from articulated skeletons, to disarticulated and fragmented bones, alongside faunal remains and material culture. These commingled assemblages could have been formed through a variety of different practices, including successive deposition of primary inhumations, exposures of corpses followed by secondary deposition of selected body parts, cultural curation or removal of specific bones, or a combination of these. As funerary practices are intricately linked to social understandings of death and the process of dying (cf. Kellehear 2007, Robb 2013), these different models have compelling implications for our interpretation of this period. The resulting lack of contextual information for the human remains from the Xemxija tombs significantly compounds the problem of equifinality, as multiple possible scenarios could explain the assemblage's formation. Osteological analysis is typically unable to distinguish between different methods of deposition, and even attempts to model funerary practices based upon skeletal part representation curves will be limited due to the aggregation of the assemblage (cf. Robb 2016). To establish the funerary practices carried out in these tombs detailed taphonomic analysis of surface modifications to the bones is necessary.
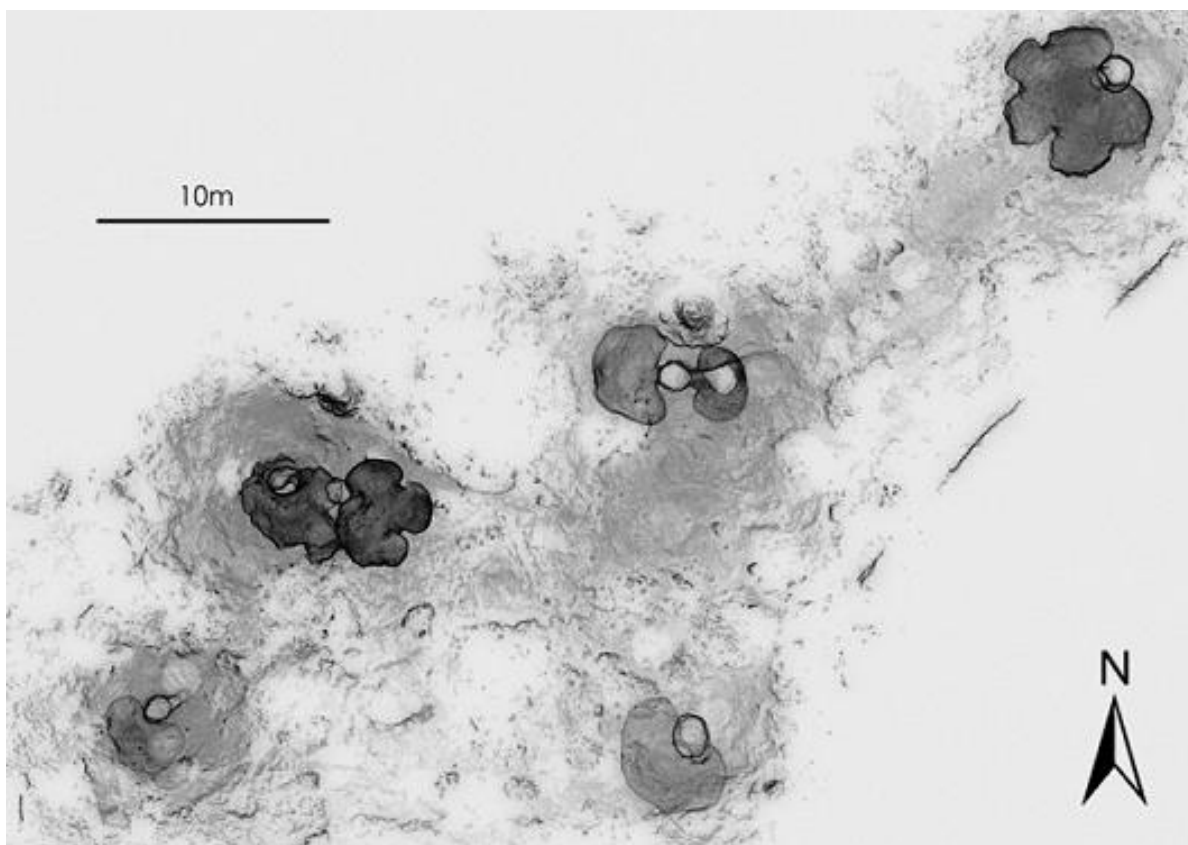.

Figure 2: Plan of the Xemxija tombs (generated from laser scan data using surface normals by John Meneely).

3. Insects as taphonomic modifiers

Necrophagous insects associated with human remains are of critical importance in forensic contexts to refine the estimation of the postmortem interval (PMI). Cadavers are colonised by the larvae of necrophagous insects that consume dead tissues to complete their development. Thus, estimation of the age of the immature insects collected on a cadaver can provide a minimum PMI (Wells and LaMotte 2001). Typically, flies colonise a cadaver first and will be succeeded by beetles, although factors such as the environment, season of death, and the condition and location of the body may change the pattern of succession (Campobasso *et al.* 2001; Vanin and Huchet 2017, 173). A positive correlation has been noted between temperature and developmental rate in insects, which can lead to a strong seasonality in the presence of some species (Martín-Vega et al. 2017; Vanin and Huchet 2017).

Archaeologically, evidence of this process of insect colonisation has particularly been detected in cases of mummified individuals. Analysis of insect larvae can refine the season of death (Vanin and Huchet 2017). In the case of one Chachapoya mummy, remains of several insect species were present within the mummy wrappings and preserved brain tissue (Nystrom et al. 2005). The succession phases of the species present, alongside palaeopathological analysis, suggested that the individual had died 10-12 days after suffering cranial trauma and trepanation, during which time the open wounds attracted Diptera and parasitoid Hymenoptera and an osseous response to the trauma was initiated. The evidence suggested that the individual was wrapped soon after death. Hence, insect species identification has the potential to reconstruct funerary rites and, in exceptional cases, the final stages of an individual's life.

When only skeletonised remains are present, as in this study, analysis of insect activity relies upon traces left on bones. These traces typically take the form of bores, burrows and gnaw marks and according to present knowledge are attributed to four orders of insects which are known to modify human bone (Vanin and Huchet 2017). These comprise Isoptera (subterranean termites) which tunnel and consume both buried and exposed bone, Coleoptera (beetles) which preferentially feed on exposed dried tissues, Hymenoptera (wasps and burrowing bees) which may construct nesting galleries in bones, and Diptera (sarco-saprophagous fly larvae) which can erode bone through their acidic digestive juices (Pittoni 2009, Backwell et al. 2012, Huchet 2014b, Vanin and Huchet 2017).

4. Material and methods

Almost 15,000 fragments of human bone have been identified in the assemblage from the Xemxija tombs. From this assemblage, a minimum number (MNI) of 112 individuals was determined, although due to the aggregation of the human remains, this is likely to significantly under-estimate the original burial population. All remains were highly fragmented and many displayed a variety of cortical surface modifications. A small number of fragments (n=45) were observed to present circular or ovate borings ranging from c.0.6-4mm in diameter. These modifications were not noted in the original analysis of the human

remains by Pike (1971a). All 45 fragments from the Xemxija tombs displaying circular or ovate borings represent less than 50% of the original skeletal element, indicating their high fragmentation. They are present on long bone (n=40) and cranial bone (n=5) fragments ranging in size from 30-130mm (to the nearest 10mm). These skeletal elements comprise thick cortical bone which was likely preferentially selected for boring (Fig. 3). Only one of these fragments retains more than 50% of the original cortical surface, demonstrating that taphonomic effects such as erosion, abrasion and weathering may have altered and truncated some surface modifications. Of this total, fifteen fragments were retained for analysis, presented below.[1] These fragments were selected on the basis that they were representative of the total sample: they derived from crania, upper and lower limb bones, and exhibited usually more than one well-defined bore hole.

Figure 3: From left to right, XEM11081 (ectocranial aspect), XEM6626 (endocranial aspect), XEM10048, XEM477, XEM8720 (photos J. Thompson) (scale bar = 50mm).

4.1 Microscopic analysis and 3D imaging

The use of Computed Tomography (CT) and 3D imaging has greatly increased recently within the field of archaeology, and particularly within palaeoanthropology (Weber and

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[1] The human bones from the Xemxija tombs were curated at University College London, UK at the time of analysis, but were repatriated to Malta in 2017. Permission was granted by the Superintendence of Cultural Heritage Malta for 15 fragments of human bone to be retained for analysis in the UK.

Bookstein 2011, Uldin 2017). CT imaging is an excellent tool for non-destructive analysis, providing the means to view and manipulate fragile remains in digital space, aiding their conservation through the creation of a digital record which also allows for the reconstruction of fragmented remains (Lautenschlager 2016, Mahfouz et al. 2017). Further advantages include the ability to take accurate measurements and view surfaces which are usually obscured, such as the internal aspect of bones.

All fifteen fragments isolated from the Xemxija tombs assemblage were analysed using a Leica® M165 stereo microscope and selected measurements were taken using Leica Application Suite EZ software (Leica Microsystems GmbH, Germany). Thirteen[2] of these fragments were selected for microCT-scanning with a Nikon Metrology XT H 225 ST at the Cambridge Biotomography Centre (UK). MicroCT-scans of these fragments have voxel sizes ranging from 0.06 to $0.12\mu m^3$ (to two decimal places).[3] The specimen exhibiting the most well-defined pupal chambers was processed, with pupal chambers segmented and 3D visualisation generated, using Avizo 9.0 software (Visualization Sciences Group, Bordeaux, France) at the Natural History Museum. While the interpretation of these modifications draws on the total fifteen analysed fragments, due to time constraints it was only possible to render a 3D model of one specimen.

5. Description of the modifications

The assemblage was carefully searched for any remains of the potential burrowing insects, but no evidence was found. As a result, identification of the species which produced these modifications proceeded through categorisation of the marks, their morphology, and comparative analysis with modifications made by known insect species (Huchet 2014a). The modifications bear similarities to those described on fossil vertebrates and attributed to dermestid beetles due to the shape, size and well-defined edges of the marks (Martin and West 1995, Britt et al. 2008, Bader et al. 2009, Holden et al. 2013). Moreover, the size and morphology of pupal chambers was found to be consistent with modern examples bored by dermestids in bone, Styrofoam, wood and paper (Huchet et al. 2013, 3796). Archaeological evidence of dermestid modification to human bone is limited, although the recent re-analysis of remains from the tombs of Jericho and Munhata reveals similar circular borings on a large number of human bone fragments (Huchet et al. 2013, 3796).

The borings are pseudopathological and could be mistaken for diseases involving focal osteoclastic activity, such as multiple myeloma or secondary carcinoma (Ortner 2003, 376). However, the borings exhibit regular well-defined edges, and are observed to occur in groups of borings of a similar size (typically 1-4mm in diameter). These characteristics are consistent with excavation by insect mandibles, unlike the scalloped edges and irregular size of lytic lesions typically associated with myeloma.

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[2] Two of the 15 fragments could not be CT-scanned due to time constraints.

[3] Specimen 477 has an isotropic voxel size of 0.12mm. Specimens 5273, 6626, 11074 and 11081 have isometric voxel sizes of 0.075mm. Specimens 5369, 5567, 8701 and 10048 have isometric voxel sizes of 0.07mm. Specimens 8720, 8895 and 10051 have isometric voxel sizes of 0.06mm. The voxel size of a CT scan depends on the distance from the specimen to the gun (x-ray source). Each specimen was placed as to optimise the resolution of the scan (i.e., it was placed as close as possible to the gun), but this distance depends on the size of the specimens and thus varies between specimens.

Following Britt et al. (2008), modifications on each of the fifteen fragments retained from the Xemxija tombs have been categorised into three types according to the morphology of marks: pits, bores and furrows (Table 1). Britt et al. (2008) also record grooves, which are shallow paired scratches made by mandibles as a result of gnawing. These are not visible on most of the specimens from the Xemxija tombs due to the poor preservation of bone cortices, and so this category has been eliminated from this study. Pits are defined as hemispherical excavations that do not have parallel sides (Fig. 4a) and are distinguished from shallow pits which are less than 0.5mm in depth. Shallow pits are sometimes referred to as incipient pits, and have been linked to practices of feeding on bone (Zanetti et al. 2014). Bores have parallel sides and represent internal mining of the bone for pupation chambers (Fig. 4b,c); they are divided into shallow (<5mm) and deep (5<mm) varieties. Furrows are the result of external mining and resemble meandering channels on the surface of the bone (Fig. 4d).

Specimen Number	Element	QBI	Pit	Bore	Furrow
XEM477	Femur	1	-	X (E)	X (E)
XEM5273	Parietal	1	-	X (E)	-
XEM5368	Long bone	3	X (I)	X (I & E)	-
XEM5369	Femur	1	X (E)	X (E)	-
XEM5567	Femur	0	X (E)	X (E)	-
XEM6626	Cranial fragment	1	X (I & E)	X (I & E)	-
XEM8701	Femur (L)	0	X (E)	-	-
XEM8720	Femur	0	X (E)	X (E)	-
XEM8892	Long bone	1	X (E)	X (I & E)	-
XEM8893	Long bone	0	-	X (E)	-
XEM8895	Long bone	0	X (I & E)	X (E)	-
XEM10048	Long bone	0	X (E)	X (E)	X (E)
XEM10051	Humerus (R)	0	X (E)	X (E)	-
XEM11074	Cranial fragment	2	-	X (I)	-
XEM11081	Cranial fragment	0	-	X (E)	-

Table 1: Modifications observed as a result of beetle activity (X = present; -= absent; E=external/ectocranial; I= internal/endocranial).
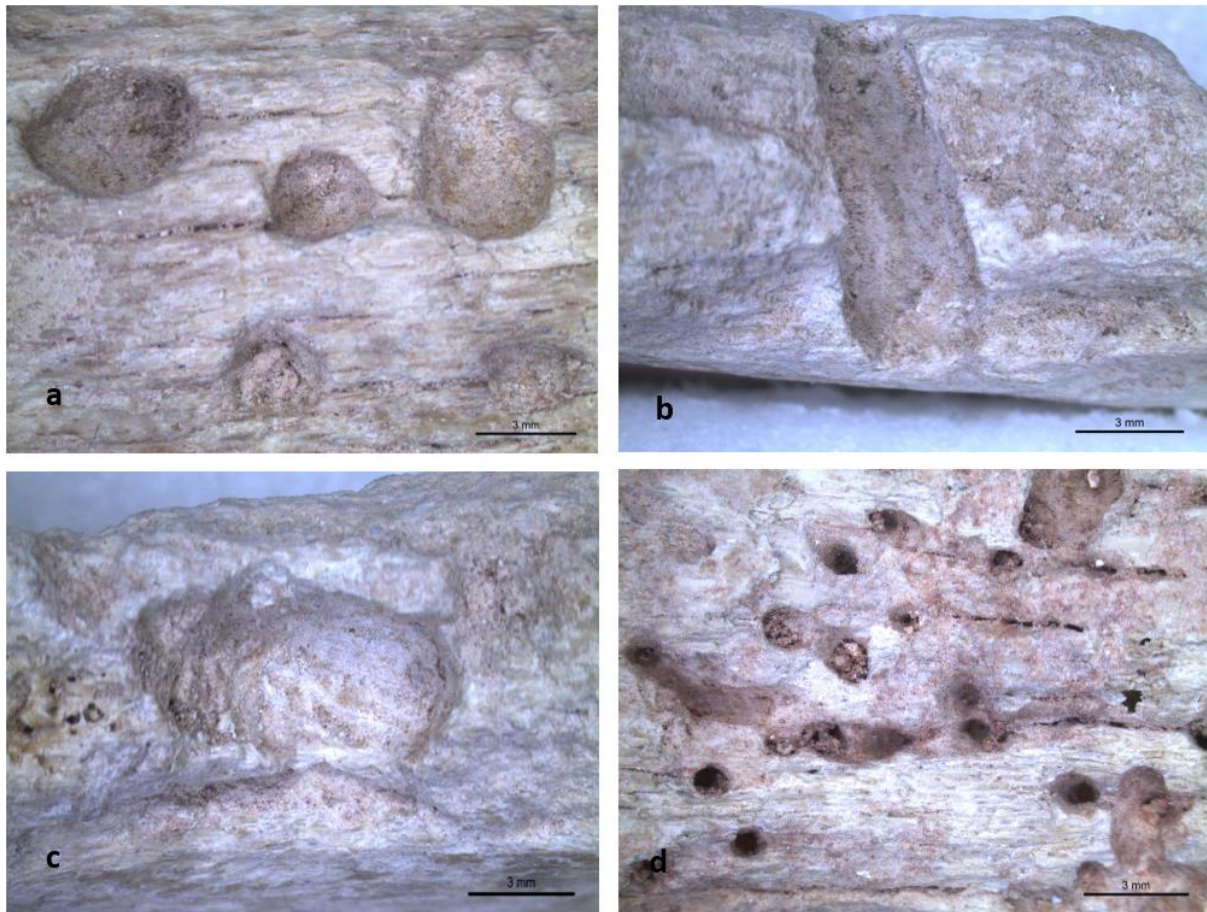
Figure 4: Types of beetle modifications observed on Xemxija human remains; a: circular hemispherical pits (XEM8720); b: deep bore truncated by fragmentation (XEM8895); c: deep bore excavated into fragmentation margin (XEM8895); d: furrows between incipient bores (XEM477).

The cortical preservation of each element has been scored on a scale from 0-5 using the Qualitative Bone Index (QBI), where 0=0%, 1=1-24%, 2=25-49%, 3=50-74%, 4=75-99%, 5=100% (Bello 2005). All specimens display poor preservation of cortical surfaces which affects the visibility of taphonomic modifications. Although it is possible that some cortical degradation is a result of beetle activity such as incipient boring, it is not possible to assess this because of the high level of erosion across the assemblage. Furrows were observed on only two of the fifteen analysed fragments and, as discussed, their preservation may have been compromised as a result of cortical erosion and abrasion. Modifications on the internal aspects of bones are rare but are often observed alongside external modifications. Only in one case (XEM11074) is a single bore observed, in this case on the internal aspect; however, since we are unable to observe the complete element it is possible that more, and external, modifications were originally present. In all other cases, multiple marks are observed on each fragment.

Measurements were taken of the maximum diameters of pits and bores across three fragments (Table 2). The mean diameter of the modifications is slightly below that noted for dermestid pupal chambers on human bone from archaeological and modern samples, as reported by Huchet et al. (2013, 3796), although falls within the range observed by Martin

and West (1995) on Pleistocene and Miocene bison. Given the morphology and size of the pits and bores, we therefore believe that dermestid beetles are the most likely agent of the modifications. The smaller average size of pupal chambers on skeletal remains from the Xemxija tombs may be explained with reference to dermestid feeding patterns, with incipient pits resulting from feeding on bone (cf. Zanetti et al. 2014, 999), or simply as initial attempts to excavate bores (cf. Huchet et al. 2013, 3800). These small pits are also evident on the internal aspects of some fragments. Dermestid beetles have never been observed to penetrate the internal aspect of bones on decomposing remains. The few specimens presenting internal modifications strongly suggests that dermestid beetles were able to colonise already-fragmented bones.

Specimen number	Diameter 1 (mm)	Diameter 2 (mm)	Depth (mm)	Type
XEM477	0.627	0.842		Pit
XEM477	0.667	0.822		Pit
XEM477	1.135	1.139		Pit
XEM8720	2.567	2.269		Pit
XEM8720	2.889	2.928		Pit
XEM8720	2.572	2.885		Pit
XEM8720	3.972	3.655		Pit
XEM8895	3.314	3.771	9.445	Bore
XEM8895	3.07	4.086	9.128	Bore
XEM8895	3.899	-		Pit
Mean	2.471	2.488		

Table 2: Measurements across maximum diameter of pits, and diameter and depth of bores, from three specimens.

The specimen exhibiting the most well-defined pupal chambers (XEM8720) was reconstructed in 3D with a majority of the chambers segmented in order to more clearly define their morphology (Fig 5a-d). The pupal chambers isolated on this specimen are mostly ovate borings of irregular depth (Fig 5e). It is possible that many of the shallow borings, which have been classified as pits, in fact represent the base of the pupal chamber if it was originally excavated in dried tissue (see discussion below).
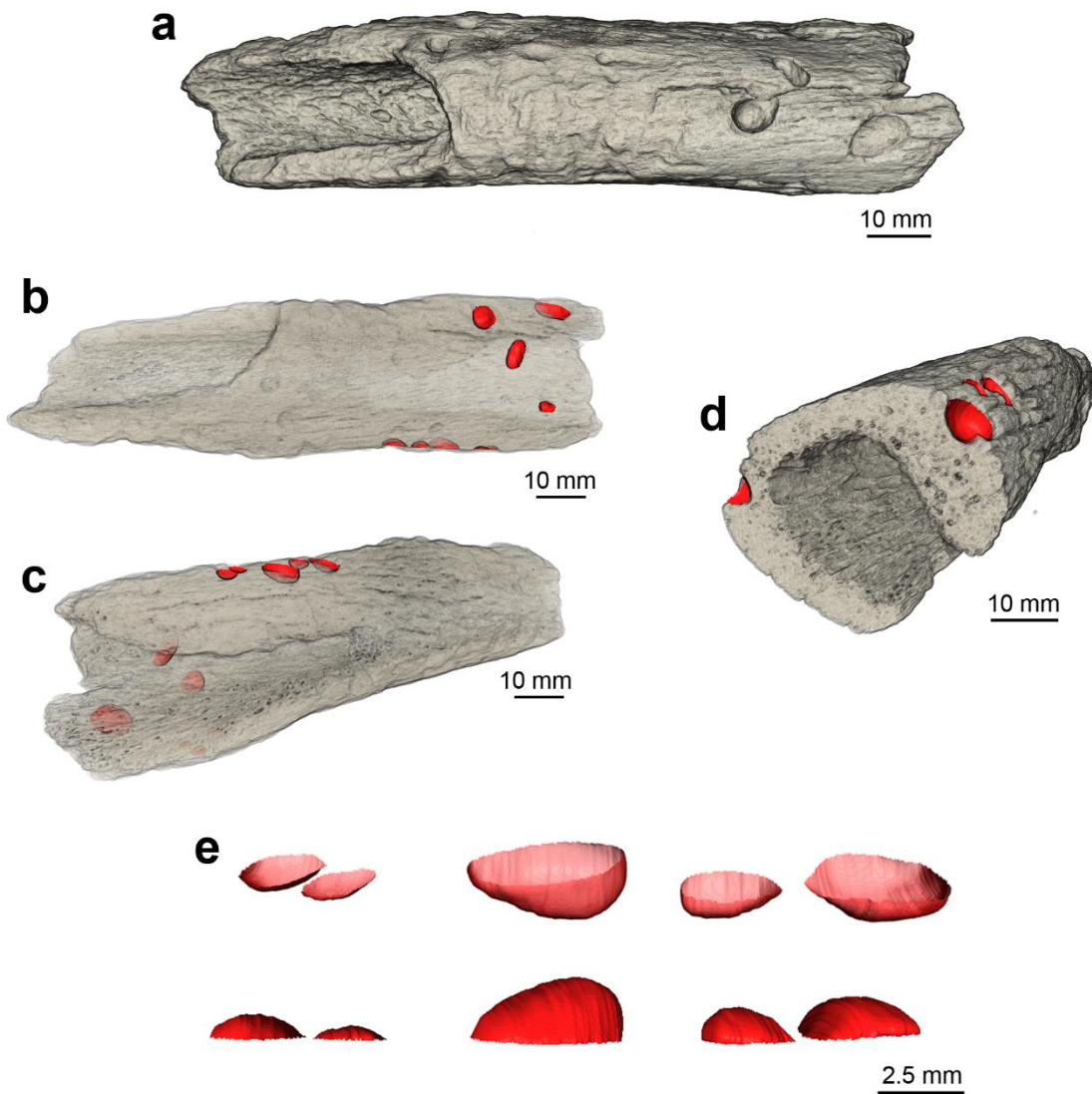
Figure 5: 3D reconstructions of a human femur from Xemxija tombs (XEM8720); a: lateral view; b: pupal chambers on the proximal aspect of the element segmented and modelled in red; c: pupal chambers on the distal aspect of the element; d: virtual transverse section; e: lateral and laterodorsal views of segmented pupal chambers showing ovate morphology with varying size and depth.

6. Dermestid beetles

With over 1200 species distributed among 45 genera (Háva 2003), beetles of the family Dermestidae have a major negative impact as a pest of stored animal products (Fontenot et al. 2015). Most species within the genus *Dermestes* Linnaeus, 1758 are scavengers during both the adult and larval stages (Zhantiev 2009). Dermestid beetles are frequently collected in association with sub-aerially exposed cadavers in advanced stages of decomposition, feeding on dry skin and desiccated tissues. Dermestids are therefore potentially useful indicators in both forensic and archaeological investigations concerning skeletonised or mummified remains (Huchet et al. 2013, Charabidze et al. 2014, Vanin and Huchet 2017). Only nineteen species of dermestids have been recorded on the Maltese islands

(Háva 2003, Háva and Mifsud 2006). These include three of the most common outdoor species in the Mediterranean region: *Dermestes maculatus* De Geer, *Dermestes frischii* Kugelan and *Dermestes undulatus* Brahm (Háva 2006, Martín-Vega and Baz 2012). These species are also among the small number which have been directly observed on human remains (Charabidze et al. 2014). Usually, only one species of dermestid is observed on a single corpse, but *D. undulatus* and *D. frischii* are occasionally found together (ibid.).

Dermestid larvae thrive in warm and dry environments, actively avoiding both excessive light and humidity (Charabidze et al. 2014). Studies have shown that dermestid larvae survival is highest when temperatures are between 20-30°C and their period of activity is restricted to the warmest months of the year (Amos 1968, Raspi and Antonelli 1996, Zanetti et al. 2016a, 2016b, Martín-Vega and Baz 2012, Martín-Vega et al. 2017). Thus, their presence can indicate seasonality. Temperature can also significantly affect the duration of the larval stage, which can vary from 26.8 to 78.8 days, with a colder temperature requiring a longer period of pupation (Martín-Vega et al. 2017, 1143). Under optimal, warm and dry conditions, dermestid adults and larvae can appear in large numbers, greatly accelerating the skeletonisation process of a cadaver (Schroeder et al. 2002, Charabidze et al. 2014).

During the pupal stage, the insect undergoes metamorphosis and becomes quiescent, thus being highly vulnerable to cannibalisation by surrounding larvae (Archer and Elgar 1998, Fontenot et al. 2015). Because of this, when a mature larva ceases feeding, it actively searches for a safe place to pupate, usually excavating a protective pupation chamber into the most appropriate nearby material (Archer and Elgar 1998, Fontenot et al. 2015). Although pupal chambers are frequently bored away from food sources, dermestid larvae can bore into meat or carrion substrate, sometimes perforating the underlying bone (Martin and West 1995, Archer and Elgar 1998). In this case, because the desiccated tissue decays later, pupal chambers are usually found as partial casts of different depths in the bone, rather than complete burrows (Martin and West 1995, Huchet et al. 2013). Dermestid pupal chambers have been found in both archaeological and palaeontological contexts on bones from a range of vertebrates, including humans (Martin and West 1995, Britt et al. 2008, Huchet et al. 2013). In the case of human cadavers, the preferential feeding areas for dermestids are said to be the face, hands and feet but the excavation of pupation chambers is opportunistic and will not necessarily follow this pattern (Charabidze et al. 2014).

Consequently, the excavation of pupal chambers provides information not only on the local ecology and environment, but also on funerary practices. As dermestids exclusively colonise exposed remains, evidence of dermestid modification to human bones indicates that corpses were not initially covered with earth. Dermestid pupal chambers usually occur in clusters and, when they appear on bones, may indicate a situation of stress with limited availability of food and alternative pupation substrates (Roberts et al. 2003). As discussed, the morphology of pupation chambers is suggested to be linked to whether remains are fleshed or skeletonised at the time of their excavation. Huchet et al. (2013, 3800) have argued that pupation chambers excavated in fleshed remains will only leave a trace of the base of the chamber, in the form of shallow and narrow pit in the bone. Thus, when skeletonised remains are burrowed, the bore hole is likely to be both larger and deeper. Moreover, when little dry tissue is available on skeletonised remains, dermestid beetles start to eat the bones themselves, leaving pits and mandible marks on the bone surface (Zanetti et al. 2014). In

summary, dermestid modifications reveal crucial information regarding the state of the cadaver; the depth of pupation chambers, and the presence of other marks on the bone surface, can indicate whether remains were fleshed, desiccated or skeletonised at the time of their exposure to dermestid larvae.

7. Reconstructing funerary practices at the Xemxija tombs

A small number of human remains from the Xemxija tombs present pits and bores of varying size and depth on both the external and internal aspects of bones which we have attributed to dermestid beetles. As evidence for funerary practices, these insights suggest a number of hypotheses. We present three scenarios for funerary practices at the Xemxija tombs which resulted, in a small number of cases, in osseous modifications arising from dermestid colonisation. These scenarios are not mutually exclusive:

1. A restricted period of exposure for some individuals prior to their secondary deposition.
2. Primary, successive interment of corpses on the ground surface of chambers.
3. Redistribution of the remains of previous interments, including the movement of some bones outside of the chamber, before their re-deposition.

The first scenario suggests that dermestids were only able to access a small number of corpses, implying that funerary practices may have differed perhaps according to the time or circumstances of death, or in relation to facets of an individual's identity. The second scenario assumes that dermestid beetles were able to access tomb chambers in order to colonise the fleshed remains of recent interments as well as the skeletonised remains of earlier inhumations. The final scenario presents a model of movement of some remains outside of the chamber, during which time dermestids could colonise the skeletal material. The temperature and condition within the tombs is amenable to dermestid habitation, although the tombs would likely only reach the optimal temperature for the dermestid larval cycle during the hottest part of summer.

The first model, of exposure and excarnation of a small number of individuals, is the interpretation reached by Huchet et al. (2013) to explain dermestid modifications on the Jericho and Munhata remains. Larger and more consistently-sized pupal chambers were observed in those cases than on the remains from the Xemxija tombs. Furthermore, exposed corpses invite a range of other scavengers which can leave traces on skeletal remains (cf. Haglund 1997a, 1997b). No evidence of carnivore or rodent gnawing has been identified on the Xemxija tombs assemblage, nor on the skeletal remains from the Xagħra Circle, the only other contemporary burial site to have been recently analysed (Stoddart et al. 2009). The evidence at the Xemxija tombs for mining on the internal surface of bones, and on fragmented bones, further discounts this model.

The second model, of successive inhumation of fleshed remains overlying previous interments, would have provided the opportunity for dermestid beetles to colonise desiccated tissues and bones for both subsistence and pupation substrate. The small number of fragments displaying dermestid modifications may seem to challenge the hypothesis that dermestids were present within the tombs, although it is possible that other surface modifications were present on more fragments than have been identified. As dermestid beetles rarely excavate

pupation chambers in bone, it can be suggested that on other occasions a more suitable pupation substrate may have been available. There are at least two means by which dermestid beetles may have gained access to the tombs. It is possible that corpses were wrapped or carried into the tombs in organic materials such as animal hide, which provide a suitable environment for dermestid beetle habitation (Fontenot et al. 2015; Nicki Whitehouse pers. comm.). The use of hide wrappings has been suggested at the contemporaneous burial site, the Xagħra Circle, due to the presence of animal feet bones in association with the human remains (Stoddart et al. 2009: 335). The animal bones from the Xemxija tombs may support the same hypothesis, as a high number of metapodials and phalanges have been identified (Pike 1971b)

The third model, of redistribution of decomposing remains between tombs, could have facilitated the colonisation of exposed remains by dermestid beetles. This model cannot be conclusively proven with taphonomic evidence, however. The high level of fragmentation may support this hypothesis but can also be explained by successive interment in the model above. However, this model finds support in the evidence for redistribution of skeletal remains at contemporaneous burial sites. In particular, the highly commingled and disarticulated skeletal assemblage at the Xagħra Circle hypogeum suggests there may be precedence for the movement of remains outside of spatially discrete areas (Malone et al. 2009).

We suggest that the most parsimonious model is that individuals were interred in the Xemxija tombs soon after death and bodies were not covered with sediment. Dermestids were most likely transported into the tombs only occasionally, through animal hide used to wrap corpses, or perhaps through the redistribution of decomposing remains. They were therefore able to colonise the fleshed remains of recently interred individuals and the decomposing or skeletonised remains of prior interments. In exceptional cases, when other pupation substrates were unavailable and during optimal temperature conditions, pupation chambers were excavated within both fleshed remains and surrounding fragmented human bones. When the environment was particularly nutrient-poor, dermestids fed on the bones themselves, leaving evidence in the form of incipient pits.

7. Conclusion

Modifications arising from insect activity are likely to be much more common on archaeological human remains than is typically recognised. These modifications are significant for understanding both past environments and funerary behaviour. As funerary archaeoentomology remains in its infancy, however, there is a limited pool of case studies to draw on for comparative analysis. Only in circumstances of excellent archaeological preservation will direct evidence of insects be recovered, for example through their surviving pupal cases (e.g. Huchet and Greenberg 2010). Despite this, traces of pupal chambers may be left in osseous material even where preservation conditions are not optimal. As we have shown, their identification has significant implications for understanding funerary practices.

Until now, there has been a dearth of taphonomic research on Neolithic collective burials from the Maltese islands. This paper presents the first results for dermestid modification to human remains in the central Mediterranean. Modifications on a small

number of human bone fragments from the Xemxija tombs is consistent with current interpretations of late Neolithic funerary practices in Malta. Collective burials during this period were characterised by their long duration; centuries of successive depositions facilitated extensive rearrangement, fragmentation and commingling of human remains. In the context of the rock-cut tombs at Xemxija, the practice of successive deposition provided the opportunity for dermestid beetles to exploit both fleshed and skeletonised remains. This research thus provides strong justification for the importance of revisiting osseous assemblages and the need for a robust understanding of taphonomic processes and modifications when working with fragmented, commingled human remains.

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