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Title: Transforming the ancestors: early evidence of fire-induced manipulation on human bones in the Near East from the Pre-Pottery Neolithic B of Kharaysin (Jordan).

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ABSTRACT

Cremation is an unusual burial practice in the Neolithic of the Near East. At Kharaysin, a Pre-Pottery Neolithic site in Jordan, we found a secondary burial with evidence of burnt human bones. This paper assesses 1) the intentionality of fire-induced alterations on human bones, 2) the pre-burning condition of the human remains and, 3) their significance within the burial customs of the Pre-Pottery Neolithic in the Near East. Burial SU-815 was a secondary multiple burial with burnt and unburnt human remains from at least three adult individuals. Directly dated at 8010 ± 30 BP (7058-6825 cal BC), it corresponds to the Late Pre-Potttery Neolithic B (LPPNB). Macroscopic changes in human remains were analysed to investigate the circumstances of burning. Some bones were selected for mineralogical and compositional analysis through X-ray diffraction (XRD) and Fourier Transform Infrared Spectroscopy (FTIR). Colour changes, fractures, cracking, and chemical changes on bones were identified as resulting from fire-induced alterations. Our results show that bones were intentionally burnt when they were already skeletonised or almost dry. This intentional manipulation using fire happened after other burial practices took place. After burning, bones were collected and transported to this burial during a final episode. Fire-induced manipulation or cremation was not a significant development of the habitual burial practice, but evidence from Kharaysin shows an innovation in handling the human remains. Therefore, this case provides new insight into the complexity and variability of burial customs within the Late Pre-Pottery Neolithic B in southern Levant.

Keywords: Cremation, ~~Heat-induced alterations~~, Human taphonomy, Burial practice, Pre-Pottery Neolithic, Jordan

INTRODUCTION

Cremation, a widespread funerary practice, aims to burning and/or fragment the body transforming the appearance of the human remains. This is a burial practice that accelerates the decay process through a wide sequence of gestures and actions aimed at commemorating the dead on an individual and collective scale (Jones 2003; Williams 2005; Cerezo-Román 2014; Nilsson-Stutz and Kuijt 2014). Cremation includes several scenarios and stages such as the locations where mortuary acts take place, cremation itself, collection of bones from pyre, manipulation of cremated remains, storage, bury and the rituals associated with the different stages (Appleby 2013; Cerezo-Román and Williams 2014). The process of burning a human corpse also offers a very different visual, auditory and olfactory set of sensory experiences (Williams 2004; Flohr Sørensen and Bille 2008), which are remarkable different from those experienced in an inhumation.

Intentional combustion of human remains has been documented since the Late Pleistocene Lake Mungo site in Australia (circa 40,000 BC) (Bowler et al. 1970; Bowler et al. 2003). Cremation, as specific burial practice aims to destroy fresh corpses, has been reported in a Palaeo-Indian site in Alaska (circa 11,500 BC) (Potter et al. 2011). There were also early Holocene cremations on the southern coast of California (circa 10,000 BC) (Walthall 1999), the Philippines (circa 8,500 BC) (Lara et al. 2015), China (circa 8,000 BC) (Fengming 2005), the Midwestern United States (circa 6,000 BC) (Goldstein and Meyers 2014), and southern Scandinavia (circa 5,200 BC) (Larsson and Nilsson-Stutz 2014). Cremation in Eurasia started to be more frequent in the Late Neolithic and Chalcolithic, including the Fertile Crescent, the Mediterranean basin, and Europe (Gatto 2007; Duffy and MacGregor 2008; Cataroche and Gowlan 2015; de Becdelievre et al. 2015; Silva et al. 2015).

In the Near East, the earliest cremation known so far come from the Kebara cave (Fig 1). Here, burnt human remains were found during Turville-Petre's excavation in 1932. Direct radiocarbon date on one charred bone yielded a dated of 12,470 ± 180 BP (OxA-2798, uncalibrated). Therefore, these burned remains were allocated to the Early Natufian period (Bar-Yosef and Sillen 1993; Bocquentin 2003). Recent observations suggest that burnt remains belong to a secondary deposit of a minimum number of 31 individuals. The bone representation indicates a cultural selection of the skeletal regions. Lack of burning traits also suggests these remains were previously cremated at other location when bones were already skeletonised (Bocquentin 2003). There is not clear evidence of cremation in another Natufian assemblage (ca 12,300-9800 cal BC). Indeed, this is an exceptional example of cremation so far until the Pre-Pottery Neolithic C (PPNC) of southern Levant (ca 7000–6500/6400 cal BC).

At the PPNC levels of Beisamoun in Israel (Fig 1), archaeologists have found three cremations there: two secondary deposits of selected human remains and a combustion-burial structure with a few cremated human bones (Bocquentin et al. 2014). The combustion-burial structure was reported in a pit where human remains were cremated and then buried. The pit showed entirely burnt walls and was full of ashy sediment and burnt human bones. Bones displayed all types of colour changes including chalky-white hues and did not show a high level of fragmentation, with some burnt elements remaining almost complete. Secondary contexts with burnt human bones included secondary cremations and burning of fresh corpses. Interestingly, one deposit consists of some burnt bones and ashy sediments in a semi-circular pattern conforming a wall effect, suggesting they were disposed of inside a perishable container. The archaeologists interpreted that this container was used to move some selected cremated remains from the burning site to the burial (Bocquentin et al. 2014:38).

The following cremations at three Pottery Neolithic sites were reported in the northern Levant: Yarim Tepe II (6th millennium BC) (Merpert and Munchaev 1993), Yümüktepe (6th millennium BC) (Garstand, 1953 in Akkermans, 1989), and Tell 'Ain el-Kerkh (6474–6266 and 6415–6252 cal BC) (Tsuneki 2011) (Fig 1). At 'Ain el-Kerkh, four collective cremation burials were found with at least 37 cremated individuals. Three were *in situ* cremation pits and many different burning temperatures were detected on bones based on colour changes. Human remains appeared disarticulated and in secondary position. Therefore, excavators suggest human remains proceeded from primary burials and they were cremated when bones were already skeletonised. This burial practice was associated with primary and secondary inhumations in the earlier stages of the Pottery Neolithic, but cremations declined later (Tsuneki 2011). At Yarim Tepe II and Yümüktepe, secondary and primary cremations were reported in Halaf culture contexts. At Yümüktepe (Mersin), a single cremation of a child and a mass cremation burial of an unknown number of adults was found at level XIX. Interestingly, the mortuary practice of cremation is attested after the introduction of Halaf culture in Yümüktepe (Akkermans 1989).

Seven cremation burials have been found in levels 7-8 of Yarim Tepe II (c. 5800-5400 BC). One burial consisted of an *in situ* cremation of a single child in a rectangular oven. This individual was interred with a necklace, some pendants and three stone and two pottery vessels deliberately broken (Akkermans 1989). Burial N53 was an oval pit containing the cremated remains of a child. The pit displayed slight traits of burning at the sides and bottom suggesting it may be other *in situ* cremation. The burial N54 seems to be other *in situ* cremation. Three burials were secondary deposits in pits where cremations took place at other locations. Burial N43 was an open-air space with an accumulation of ashes and charcoal remains where a child of about ten years old was cremated. The human remains were stored into a lugged jar and buried next to the fireplace. In Yarim Tepe II, some bodies were cremated soon after death based on heat-induced deformation of bones (Merpert and Munchaev 1993; Akkermans 1989). Interestingly, there were other deposits with cremation pits where animal bones were burnt and stone vessels were broken, including zoomorphic and anthropomorphic vessels (Merpert and Munchaev 1987;1993).

Cremation seems to be an innovation in the mortuary practice in Levant since PPNC but especially in Pottery Neolithic. Previously, the mortuary practice in the PPNB of Southern Levant consists of a broad spectrum of behaviours including both primary and secondary burials, secondary handling, bone retrieval, body manipulations and plastered skulls (Eshed et al. 2008; Kuijt, 2008; Croucher 2012; Goring-Morris and Belfer-Cohen 2014; Santana et al. 2015; Bocquentin et al. 2016). This complexity and diversity in burial practices also introduces great intra e inter-site variability that make difficult to establish a normative mortuary practice. Even so, the primary burial lies in the majority of individuals interred in a flexed articulated position underneath the floors, courtyards or in cemetery areas inside the settlements. Primary burials were frequently reopened over time and body parts were removed. Skull and long bones were preferentially collected from graves and they were curated, manipulated and reburied in secondary deposits. In the Middle and Late Pre-Pottery Neolithic B (8200-7200 cal. BC), a sophisticated secondary treatment of skulls included modelling of facial features using lime plaster in southern Levant (Bonogofsky 2006). Anthropogenic manipulation of the body before burial is sporadic and most of evidence for body manipulation occurred at a later stage when bodies were putrefied or already skeletonized. Variability in burial customs in the LPPNB has also been observed (late 8th millennium BC) in southern Levant. At 'Ain Ghazal and Tell Labwe (Fig 1), there were multiple primary burials, which were rare in previous periods, and also non-normative primary burials where the corpses were not carefully handled, suggesting a certain disaffection towards these individuals (Rollefson et al. 1992; Ibáñez et al. 2018). Furthermore, significant changes occurred in the burial customs from the PPNC to Pottery Neolithic in the southern Levant, including the decrease and later disappearance of cranial retrieval, plastered skulls, burials underneath plastered floors, and secondary multiple burials (Rollefson et al. 1992; Rollefson and Köhler-Rollefson 1993; Galili et al. 2005; Eshed and Nadel 2015). Therefore, changes in the temporality of the mortuary practices suggest fundamental shifts in the relationship of the dead, social memory and the livings in the late 8th millenium BC onwards.

This paper considers burial SU-815, a secondary multiple burial with burnt and unburnt human remains from Kharaysin, a Pre-Pottery Neolithic site in north Jordan (Fig 1). We attest the use of cremation at the beginning of the 7th millennium cal BC in southern Levant as part of the shifts in the funerary customs that took place at the end of the PPN. We discuss 1) the intentionality of the fire-induced bone alterations; 2) the pre-burning condition of the human remains; and 3) their significance in the burial customs of the Pre-Pottery Neolithic in the Near East.

2 MATERIAL AND METHODS

Material

Kharaysin (Quneya, Zarqa) is a large site of around 25 ha that was discovered in 1984 by Hanbury-Tenison and colleagues during the Jerash Region Survey (Edwards and Thorpe 1986). We excavated this site from 2015 to 2018, identifying four occupation levels in four excavation zones (Fig 2): 1) a Late PPNA phase dated at the beginning of the 9th millennium BC (Zones A and B); 2) an Early PPNB phase at the second half of the 9th millennium (Zone B); 3) a Middle PPNB phase at the beginning of the 8th millennium BC (Zones A and C); and 4) a Late PPNB phase from the end of the 8th millennium to the beginning of the 7th millennium BC (Zone D) (Ibáñez et al. 2016; 2019; Moník et al. 2018).

Fig 1 Location of Kharaysin, Late PPNB settlements and sites cited in the text

Fig 2 Plan of Kharaysin archaeological site excavation zones and location of the burial SU-815 in Zone D

Burial SU-815 was found in a fill (SU812) within square BE190 in the north-eastern area of Kharaysin (Zone D; Fig 3). In this area, the test excavation of a trench of 6x4m was carried out. This stone wall may likely be near the limits of the Neolithic village because it is located at a slope that goes to a small wadi where the bedrock emerges. The stone wall goes straight from north to south and there is no evidence of occupation floors at the western (SU814) or the eastern sides (SU812). Geophysical survey with electrical resistivity tomography (ERT) was carried out in a square area of 19.5 m × 15.5 (ERT11) m at the west and northwest of the excavated square (BE190) and another one of 15.5 m × 7.5 m (ERT10) at the south of BE190 (Moník et al. 2018). High resistivity spots (around 200 Ω m.) indicate the presence of important buildings in this area. Probable walls detected by ERT are disposed parallel or perpendicularly with respect to the wall documented in BE190, suggesting that this wall is part of an extended ensemble of buildings.

The grave is in an oval-shaped pit made in a fill at the bottom of a straight stone wall (SU803). Oriented north by south, the grave measured 1.25 m long by 0.70 m wide and about 0.25 m deep. There were not clear, well-defined pit limits and grave extension was defined by distribution of bones. The grave was covered with the same sediment from the fill where it was opened. The burial contained an assemblage of comingled fragmented and completely disarticulated human remains.

They were distributed mainly along the stone wall where long bones were intentionally arranged and oriented north by south. Cranial and shorter bones were mainly placed on the edge of the grave. One bovid phalanx was found inside the grave alongside human remains. There were several overlapping and interweaving bones into the burial suggesting the simultaneous deposition of human remains. In this assemblage, there is an infra-representation of axial, short and flat bones such as scapulae, coxal and hand/feet bones. Epiphyses are also poorly represented, and it may be consequence of fragmentation occurred prior buried in Burial SU-815. Long bone diaphyses had suffered transversal fragmentation because of crushing and compression by the weight of the blocks and sediment overburden. Moreover, some bones display clear traits of fire-induced alteration, comprising various colour changes and heat-induced fractures. Intentional clustered of long bones, lack of anatomical connections and infra-representation of several skeletal regions suggest a secondary burial profile. There are not traits of any fire episode such as reddish or dark sediment, wood charcoal remains or fire-induced alterations on stones inside or next to the grave. Absence of charcoal remains is noteworthy since systematic flotation and dry-sieved of the whole sediment of the grave was performed.

Fig 3 Burial SU-815 in square BE190 (Zone D)

Methods

The excavation of Kharaysin site is organized following the Harris Matrix method of identification of Stratigraphic Units (SU) (Harris 1979). The geometric definition of the Stratigraphic Units has been carried out using two major strategies: Point-to-point documentation, through total stations (Leica TCRM 1205 and TCRM 1105 plus) and point cloud documentation, using photogrammetric techniques (processing photographic software Photomodeler Scanner). All coordinates are integrated into a local system oriented towards the maximum slope. For other purposes, this system has been moved to the general WGS84 coordinate system in its UTM projection. In the case of SU-815, all bones were individualized as point entities and line entities (long bones) by total station, as they were removed from their original context. The surface of the SU and its bottom were defined as polygon entities. With photogrammetric techniques, three successive 3D models of ‘bone packs’ were generated, from which various orthophotos and contour maps were deduced (Fig 4). With these 2D documents, the final SU ortho-image was composed.

Fig 4 Successive orthophotos based on 3D models of burial SU-815

The bones were cleaned using distilled water and brushes. Since many of the remains were covered in concretions, wooden sticks were also used to carefully remove these adhered deposits. Unfortunately, some bones still had dense concretions that were not possible to remove, so these remains were not analysed (categorised as unidentified specimens). Human bone fragments were identified and recorded according to skeletal element and portion. We quantified the ‘number of identified specimens’ (NISP) as an observational unit (Lyman 1994) and calculated the ‘minimum number of elements’ (MNE) and ‘minimum number of individuals’ (MNI), according to the ‘minimum number of expected elements’ (MNEe). The skeletal survival rate (%survivorship) was also calculated to establish the proportion between the expected and recovered elements (Lyman 1994). This percentage expresses the frequency of the MNE observed and the number of elements expected (MNEe) according to the minimum number of individuals (MNI): %survivorship= MNE x 100/MNEe. Sex was estimated by the morphological appearance of the cranial and hip bones (Buikstra and Ubelaker 1994; Bruzek 2002). Osteometric methods such as Gonçalves et al. 2013 or Cavazzuti et al. 2019 were not used since bones were mostly charred and not completely calcined. Osteometric methods can be indeed applied only to high-temperature cremations (>700°C), resulting in the typical calcined/chalky appearance of the bones (Cavazzuti et al. 2019). Age was estimated in two individuals according to published standards (Buikstra and Ubelaker 1994; Coqueugniot and Weaver 2007; Cardoso 2008a, b).

Macroscopic changes in bones

Fire-induced alterations observed on bones were analysed and described regarding colour changes, heat-induced fractures and warping (Shipman et al. 1984; Buikstra and Swegle 1989; Nicholson 1993; Mayne Correia 1997; Duday et al. 2000; Whyte 2001; Gatto 2007; Depierre 2014; Gonçalves and Pires 2016). These variables were considered together at the same time to infer the main circumstances that caused these alterations: fire intensity, oxygen availability and their pre-burning state.

Colour changes were used to tentatively infer the intensity of burning to which bones were exposed, rather than a specific or precise temperature reached by the fire (Shipman et al. 1984). Experimental studies have demonstrated that colour changes are based on differences in oxygen availability and duration of exposure to heat (Shipman et al. 1984; Mayne Correia 1997; Walker et al. 2008). Experimental evidence also highlights that fleshed, defleshed and dry bones display a variety of hues ranging from brown to grey-blue, black, grey, grey-white, and chalky-white, with increasing temperature (Shipman et al. 1984; Buikstra and Swegle 1989; Stiner et al. 1995; Mayne Correia 1997; Depierre 2014). In general terms, it is widely accepted that yellowish colour ranges through temperatures from 0 to 200/300 °C, dark brown and black from 200/300 °C to 550 °C, greyish from 300 to 700 °C, and whitish from 600 to 1000 °C (Shipman et al. 1984; Nicholson 1993; Stiner et al. 1995; Thompson 2005; Walker et al. 2008).

Colour change was assessed per specimen in a dry condition under a bi-directional incandescent light. Temperature exposure was estimated from colour changes according to de Becdelievre et al. (2015), scoring the following colours: “yellowish” (usual colour of unburnt bones), “brown-grey”, “dark-black”, “blue-grey”, and “chalky-white”. This colour range is based on the observations of several researchers (Bonucci and Graziani 1975; Shipman et al. 1984; Stiner et al. 1995; Thompson 2005; Walker et al. 2008).

We also evaluated the uniformity of colour on each specimen to establish whether the heat source/s modified the burnt remains in a regular way. In addition, we investigated colour changes in the internal and external surface of bones to infer if they might have been burnt after fragmentation. Colour changes associated to higher temperatures in the internal surface than on the external surface of long bones might be considered as consequence of pre-burning fragmentation of skeletonised remains (Godinho et al. 2019).

Heat-induced fractures were analysed to identify fractures that might have occurred when bones were burnt (Buikstra and Swegle 1989). Here we considered cracking as a reliable indicator of burning because this type of fractures is usually observed on burnt bones (Buikstra and Swegle 1989; Stiner et al. 1995; Depierre 2014; Gonçalves et al. 2015). Furthermore, this type of fractures is common on freshly burnt bones although may also occur in dry bones (Gonçalves et al. 2011; Gonçalves and Pires 2016). Cracks were analysed according to their orientation relative to the longer axis (transverse and various other orientations), as well as their pattern (curved or straight) (Buikstra and Swegle1989; Stiner et al. 1995; de Becdelievre et al. 2015). Warping and twisting were also searched for, but we did not find any in this assemblage. In addition, we analysed the fragmentation pattern to investigate the skeletisation stage of human remains during fragmentation (green-bone breakage and dry-stick breakage) (Villa and Mahieu 1991; Sauer 1998; Knüsel and Outram 2006; Sala et al. 2015). Green-bone breakage usually displays a longitudinal and oblique/curved outline, oblique and mixed angles, and smooth edges and surfaces (Wieberg and Wescott 2008). Dry or mineralised bone breakage includes transverse fractures to the long axis, right fracture angles, and jagged edges (Villa and Mahieu 1991; Sala et al. 2015). This condition is important to analyse the post-depositional fragmentation and their relationship with human remains manipulation.

Mineralogical and spectroscopic analysis of bones

In order to confirm the burning of bone remains, 2 dark-black bone samples (N1 and N2) and other chalky-white bone samples (B1 and B2) were selected for mineralogical and compositional analysis through X-ray diffraction (XRD) and Fourier Transform Infrared Spectroscopy (FTIR). They were carefully dry-cleaned and ground to powder in an agate mortar. Subsequently, a mineralogical analysis of the samples was carried out by semi-quantitative X-ray diffraction (XRD), using a Bruker D8 Advance diffractometer equipped with a Cu tube (voltage 40kV and intensity 30 mA) and a LynxEye XE detector. The DIFFRACplus basic EVA software package was used for diffractogram interpretation and mineral identification. Two different scan settings were used; the first a general scan from 10° to 70° 2θ angles with a step-size of 0.05° and a measuring time per step of 2 s. A second scan, focused on phosphate identification, was conducted between 32° to 40° 2θ angles, with 0.02 step-size and a 5 s measuring time. Fourier Transform Infrared Spectroscopy (FTIR) analyses were performed in the medium infrared region (4000-400 cm^{-1}) with an A JASCO FT-IR 4200 spectrophotometer, equipped with an ATR PRO ONE single reflection device for attenuated total reflectance (ATR) measurements. Each recorded spectrum was the result of 128 scans at 4 cm^{-1} resolution.

Radiocarbon dating

Different approaches were applied to directly date bone remains based on the minimum number of individuals. Standard radiocarbon dating was not successful due to the lack of organic material in bones. Bone collagen is poorly preserved in prehistoric sites in the Near East due to the arid environment and the geological features (Weiner & Bar-Yosef 1990). We therefore selected totally cremated chalky-white bone samples for dating, after bone carbonate extraction (acid wash prior to acidification). Unfortunately, skeletal representation of chalky-white specimens only allowed for selecting one individual for radiocarbon analysis using this approach. When bones are heated above 600°C, the osteocalcin (apatite) in the bone is converted to structural carbonate, which can be dated. It is very resistant to change and not easily contaminated once cremation has occurred and has therefore been shown to be a good substance for reliable AMS dating. This second approach was successful and one dating was obtained. The AMS method in Beta Analytic Laboratories was used, calibrated using Oxcal software and the Intcal'13 calibration curve (Ramsey 2009; Reimer et al. 2013).

RESULTS

The assemblage contained 324 human bone specimens, 239 identified (73%) including 30 cranial (26 from cranium, 3 from mandible, and one isolated tooth) and 213 postcranial specimens (Table 1). We established a minimum number of 62 elements (6 cranial and 56 postcranial). Human bones belonged to three individuals as MNI, based on the representation of cranium, femur, ulna and tibia. This assemblage consisted of one male, one female, and one indeterminate, comprising one young adult based on epiphysis fusion of postcranial bones (17-25 years old), and one adult according to the appearance of the pubic symphysis (30-39 years old).

The percentage of survivorship (%survivorship) reveals an infra-representation of most skeletal regions, including fragile and persistent bones (Table 1). It suggests that some anatomical regions such as sternum, sacrum and patella were likely affected by natural taphonomic factors, since these skeletal regions are very fragile (Galloway et al. 1997; Willey et al. 1997; Bello and Andrews 2006). However, poor preservation of some long bones (i.e. clavicle, humerus, and radius) points to a cultural selection of remains, as they are considerably harder than other regions preserved in this assemblage. This constitutes a %survivorship profile typical of a secondary burial.

We identified 139 specimens (59% of total NISP) displaying traces of burning such as colour changes and heat-induced fractures (Table 1). These remains belong to a minimum number of two individuals. They were not manipulated to deflesh and disarticulate the corpses prior to fire exposure. Furthermore, there were 100 specimens (41% of total NISP) without evidence of fire-induced alteration or human-induced manipulation, suggesting that when they were moved to the burial, they were likely still skeletonised. Unburnt and burnt specimens were randomly distributed in the pit (Fig 5). This pattern is compatible with heterogeneous heat diffusion affecting the bones and suggests fire was not occurred at the pit.

Fig 5 Distribution of burnt and unburnt bone remains according to colour hues from various views. Long bones were plotted as segments and other bone as dots.

[Table 1 here]

Colour changes

Colour changes show heterogeneous combustion, implying that bones were exposed to various fire intensities and oxygen availability (duration, temperature, and location). Burnt bones comprise brown-grey, dark-black, chalky-white, and blue-grey hues (Table 2; Fig 6).

Fig 6 Burnt human remains from the burial SU-815; a) and b) Dark-black colour; c) and d) Chalky-white colour; c) Heat-induced fractures (cracking) in a chalky-white specimen

The predominant colour change was dark-black with 86 identified burnt specimens (62% of 139 specimens) for all skeleton categories (Table 2; Fig 7). It suggests that most remains were exposed to low intensity temperatures (200°C to 550 °C) for some time. Brown-grey colour changes were also observed in 26 specimens (19% of 139 specimens). This pattern of colouration is related to lower heating intensity (200–550 °C), and when bones are burnt when already or almost skeletonised (Buikstra and Swegle 1989; Costamagno et al. 1999; Baker Bontrager and Nawrocki 2008). Chalky-white colour changes were noticed in 19% of burnt specimens (NISP=26 of 139 specimens), comprising all the skeletal categories except mandible. This hue is usually observed when bones are exposed to high intensity temperatures (> 600º/800º) for some time. Whitish hues are considered as indicators of combustion of fresh corpses or bones surrounded by muscles and fat (Baker Bontrager and Nawrocki 2008; Symes et al. 2008; Walker et al. 2008). However, the burning of fresh corpses also produces other macroscopic traits such as warping and twisting that are not observed in this assemblage. Ultimately, one specimen (0.7% of burnt specimens) displays blue-grey colour traits compatible with low-medium intensity of combustion at temperatures from 300 to 700 °C (Shultz et al. 2008; Depierre 2014).

[Table 2 here]

The pattern of colour distribution indicates that all the skeletal regions were exposed to heat (Fig 7). Flat bones and long bone diaphyses were more calcined than other regions, indicating differential combustion due to their thinner cortical tissues. This distribution also indicates that all the skeletal regions were accessible to the heat source/s. It suggests that most soft tissues were removed at the time of this fire alteration (Keough et al. 2015).

Various colour changes were reported on both upper and lower surfaces of 56 specimens (40% of burnt specimens), according to their spatial distribution in the pit.
Uniform colour changes were noticed in 83 specimens (60% of burnt specimens), suggesting spatially Uniform colour changes
were noticed in 83 specimens (60% of burnt specimens), suggesting spatially regular exposure of these bones at the time of fire and/or a reducing atmosphere (Blaizot 2005). We did not detect heat lines, heat borders or delineation, which are typically detected in the early stages of decomposition when a body is still fully or partly fleshed (Thompson 2005). Moreover, we observed chalky-white and grey colour changes in the internal surface of several long bones that display dark-black hues in the external surface (NISP=12 of 139 total burnt specimens); 12 of 42 diaphysis specimens). It suggests that these bones were exposed to higher temperatures in the internal surface than on the external surface.

Fig 7 Percentage of colour changes on burnt and unburnt specimens according to skeletal regions

Heat-induced fractures and breakage

Heat-induced fractures were detected in 13 chalky-white specimens (50% of 26 specimens). Most specimens display a straight pattern of cracking (NISP=9), but only four show a curved pattern, which might be consequence of fresh bone burning (Gonçalves et al. 2011). Cracking orientation is principally transverse to the main axis of specimens (NISP=12), and only one case shows various orientations (Table 3, Fig 6.d.). The four specimens with curved cracking also display no mineralised breakage (diaphysis of long bones). This pattern may result from burning when bones retained some organic component, but examination of chalky-white specimens does not reveal fire-induced alterations to fresh bones, such as warping, suggesting that bones were fractured dry (Gonçalves et al. 2011; 2015).

The assemblage includes large-sized specimens such as several long bones that were almost complete in the burial pit. This condition is also suggesting dry bones burning since fresh bones always display a higher level of fragmentation (Théry-Parisot and Costamagno 2005). In these cases, most epiphyses have disappeared, which might be influenced by thermal destruction of long bones in proportion to the duration and intensity of the fire (Symes et al. 2008). However, most specimens show post-depositional fracturing through ploughing and crushing due to the weight of superimposed soil and stones. In addition, dry fractures on long bone ends and lack of epiphyses fragments suggest that these skeletal regions may have disappeared before final burying due to mineralisation fractures at previous locations (i.e. primary burials). Low preservation of epiphyses is also influenced by bone density of these element portions (Willey et al. 1997) and /or handling of skeletonised and/or cremated remains from previous locations may have influenced in their increased fragmentation and eventual destruction (McKinley 1994; 1997).

We reported 37 specimens that display longitudinal splintering, and oblique fractures (15.5% of the 239 identified specimens) (Table 3). This breakage is not associated with the mechanisms that cause predictable fractures of skeletonised bones, suggesting it may be influenced by the heat exposure and/or handling of bones before skeletonisation (Mayne Correia 1997; Keough et al. 2015). Chalky-white specimens were most burnt remains affected by breakage (NISP=11, 42% of 26 specimens). Seven chalky-white specimens from long bone diaphyses display oblique and longitudinal fracture outlines with acute/obtuse angles and smooth edges, while four specimens from cranium (NISP=3) and scapula (NISP=1) exhibit transverse fracture outlines with mixed angles and smooth edges. Dark-black (NISP=7; 8% of 86) and brown-grey (NISP=5; 18.5% of 26 specimens) specimens exhibit various fracture outlines, acute/obtuse angles and smooth edges. Indeed, some fractures highlight the direct relationship between breakage fire temperature since chalky-white specimens display more clear traits. Lack of warping suggests that breakage occurred when bones were skeletonised or mostly skeletonised. In addition, we documented breakage of 10 unburnt specimens (10% of unburnt specimens) similar to that of green-bone (non-mineralised): seven specimens from long bone diaphyses displaying longitudinal fracture outlines, of which one specimen had a right angle and six mixed angles, and all specimens showing jogged edges. This non-mineralised pattern is probably result of that remaining collagen still rendered the bone elastic to some extent when fractured.

One burnt left parietal specimen (dark-black hues) was subjected to intentional breakage by percussion (Fig 8). This displays an irregular fracture edge with contiguous semi-circular notches at the posterior region, next to the occipital and sagittal suture. These impacts are reflected in intense flaking on the internal face of the cranium, indicating that the percussion was from the outside toward the inside.

[Table 3 here]

Fig 8 Cranium fragment intentionally fragmented by percussion. Percussion impacts and semi-circular notches on both external sides of the cranium fragment

Mineralogical and spectroscopical analysis of bones

XRD analysis confirms that all bone samples have hydroxyapatite (HAp) as a main mineralogical component, but calcite is also present in dark-black and chalky-white samples (Fig 9A). Unburnt reference medieval bone is composed of HAp (100% wt.) but dark-black bone samples show variable but relatively high (19.7-10.6% wt.) calcite content. The calcite content is drastically reduced in chalky-white samples (3.5-2% wt.) (Fig 9A). The only significant difference concerns the HAp peak intensity variations calculated in different samples following Person et al. (1995), which reflect crystallinity changes, and the variable presence of amorphous components (Piga et al. 2008) (Fig 9A). Crystallinity index varies significantly among the bone samples, decreasing from typical values of 0.59 in unburnt medieval sample F1 (Person et al. 1995), to 0.19 (N1) and 0.12 (N2) in dark-black samples. It increases notably in white-chalky samples, reaching the highest values 1.24 (B1) and 1.26 (B2).

The infrared spectra of four bone samples (N1, N2, B1 and B2) are provided in Fig 9B as well as additional non-burnt medieval human bone for reference. The spectra of the chalky-white samples B1 and B2 are essentially the same. Comparison with the spectrum of unburnt bone reveals strong similarities, but the white-chalky bones have a greater carbonate content (see bands around 1455, 1412 and 873 cm^{-1}) (Fig 9B). B2 also shows the presence of water (weak bands at 3402 and 1633 cm^{-1}), which is negligible for B1. In addition, a weak band at 713 cm^{-1} was also observed in B1 and

B2. Bands around 700 cm^{-1} in burnt bones have previously been reported (Reidsma et al. 2016), attributed in some cases to cyanamide (N=C=N−) arising from the presence of ammonia, which can come from the thermal treatment of protein-containing biological materials (collagen, skin, etc.) (Snoeck and Schulting 2014). However, in these studies, the band at 700 cm^{-1} is concomitant with another more intense one at 2010 cm^{-1}, which is absent in our spectra (Fig 9B). Together with the high temperature of the thermal treatment necessary to calcine the bone samples, this finding allows us to propose this band as a result of ν_4 (CO_3^{2-}) modes (Callens et al. 1998; Almança Lopes et al. 2018; Scorrano et al. 2017). No shoulders around 1123 cm^{-1} nor distortions in the bands around 560 cm^{-1} were detected, which suggests there were no appreciable amounts of whitlockite, β-$Ca_3(PO_4)_2$ (Piga et al. 2018).

Fig 9 Mineralogical and geochemical composition of bones from burial SU-815. A) Ternary diagram of the main mineral phases in analysed bones. Light blue bubbles represent the relative Crystallinity Index of Hap samples. B) Infrared spectra of dark-black (N1 black, N2 pink) and chalky-white bone samples (B1 in red, B2 blue) and a medieval unburnt bone reference sample (F1, green). Selected bands numbered in increasing energy. The proposed assignments are: (1) $\nu_2(PO_4^{3-})$; (2) $\nu_4(PO_4^{3-})$; (3) $\nu_{libration}(OH)_{HAp}$; (4) $\nu_4(CO_3^{2-})$; (5) $\nu_2(CO_3^{2-})$; (6) $\nu_1(PO_4^{3-})$; (7) $\nu_3(PO_4^{3-})$; (8) $\nu_3(CO_3^{2-})$; (9) Amide II / $\nu_3(CO_3^{2-})$; (10) δ(HOH) / Amide I; (11) $\nu(OH)_{water}$ / ν(NH); (12) $\nu(OH)_{HAp}$.

On the other hand, the spectra of N1 and N2 are almost identical, with a certain resemblance to those previously mentioned (Fig 9B). Absence of hydroxide stretching and libration bands was detected around 3570 and 630 cm^{-1} respectively, together with the presence of larger amounts of water and organic matter (broad bands around 3365−3345 cm^{-1} and a plateau in the 1530−1630 cm^{-1} region). There was a band shift at 1455 to 1445 cm^{-1} and a decreased intensity of this band with respect to that at 1411 cm^{-1}, along with an almost negligible absorption at 713 cm^{-1}.

DISCUSSION

The burial SU-815 is a multiple secondary burial with evidence of burnt and unburnt human remains in the Late Pre-Pottery Neolithic B levels of Kharaysin. Burnt remains support that two individuals were intentionally manipulated using fire.

Other hypotheses such as natural or
accidental fires would be more controversial, due to the intensity of burning. Burning buildings may reach temperatures high enough to extensively burn bone above the ground, but it only affects <10 cm below ground. When this happens, whitish colour changes, cracking and other features rarely appear (Cain 2005; Pérez et al. 2017The possibility that these individuals were accidentally burnt while still alive, during the destruction and combustion of a building, is also unlikely. In this burial, most of the fire-induced effects were produced when bones were skeletonised or almost skeletonised. Moreover, archaeological examples of victims excavated from burnt buildings do not show excessive burning such as the types differentiated here in SU-815 (Owsley et al. 1977; Hurlbut 2000; Fairgrieve 2008). Therefore, we should rule out that burnt bones were the result of burials disturbed by fire or accidental burning and eventually buried in a pit.

Burnt and unburnt specimens were randomly distributed throughout the assemblage, whether in regard to colour changes, cracks or “non-mineralised breakage”. For instance, chalky-white and unburnt specimens were equally represented at the top and bottom of the pit (Fig 5). The whole sediment of the grave was systematically flotated and dry-sieved but there was no evidence of pyre debris or charcoal remains that might indicate that burning took place at this location. Although lack of charcoal remains may be result of taphonomic factors, as mentioned for other archaeological sites in the Near East (Arranz-Otaegui 2017), this kind of evidence appears in all the stratigraphic levels of Kharaysin. In addition, there was not reddish or dark sediment or fire-induce alterations on stones inside the grave.

Fire-induced alterations on bones

Colour changes show heterogeneous combustion of bones, suggesting they were exposed to various fire intensities (duration, temperature and location). The predominance of dark-black hues (62%) and uniform distribution of fire-induced changes (60%) indicate that burning was characterised by low heat intensity, and/or reducing conditions of combustion. According to most scholars, dark-black hues regularly appear when bones are burnt from c. 200°C to 550 °C (Shipman et al. 1984; Stiner et al., 1995; Walker et al. 2008), although this hue may also be attributed to duration of fire exposure and/or presence of oxygen (Bennett 1999; DeHaan 2008; Walker et al. 2008). Brown-grey colour changes (19%) also indicate lower heating intensity (200–550 °C). This pattern also denotes a low efficiency of combustion that may be due to a range of factors like insufficient fuel curtailing the process, wet weather, or a cut-off in oxygen supply (Gatto 2007). Moreover, the prevalence of dark-black and brown-grey hues is also noticed on burning dry bones (Buikstra and Swegle 1989; Costamagno et al. 1999; Ellingham et al. 2015).

Dark-black colour is frequently attained when bones are burnt in a reducing atmosphere, even though the temperature of the fire reaches 900 °C (Stiner et al. 1995; Walker et al. 2008). Uniform distribution of colour changes is expected when defleshed, green and dry bones are burnt through direct and indirect heat in a reducing atmosphere (Buikstra and Swegle 1989; Bennett 1999; Valentin and Clark 2013). However, chalky-white specimens (19%) indicate that the fire technology was sufficiently developed to achieve high intensity temperatures (> 600º/800º) for some time (Shipman et al. 1984; Stiner et al. 1995; Walker et al. 2008). It means that people managed to provide enough fuel, time, temperature and a circulation of oxygen to facilitate combustion.

The mineralogical (XRD) composition of bones shows that the main mineralogical phase in all the samples is HAp and its crystallinity increases from unburnt to white-chalky samples, indicating an increasing combustion temperature. No phosphate mineral neoformation e.g. whitlockite was detected, indicating that the burning temperature in samples did not reach >750 ºC for long (Piga et al. 2013; Monge et al. 2014). The most notable mineral change was the formation of calcite in the HAp due to thermoalteration (Fleet 2009); in dark-black samples (N1 and N2) this comprised 19-10 % wt., which decreased sharply in chalky-white samples to 2-3 % wt. (B1 and B2), due to the calcination of carbonate (decarbonatation) that normally starts above 775 ºC (Piga et al. 2008). The FTIR spectra of N1 and N2 suggest, on the whole, that they were formed via incomplete pyrolytic processes, where water and notable amounts of organic materials remain. The absence of the bands attributed to OH^{-} groups in HAp for N1 and N2, together with the FTIR spectrum profile as a whole, suggests carbonisation temperatures below 500 ºC for both samples. By contrast, the thermal treatments applied to B1 and B2, with the presence of a sharp peak at 3572 cm^{-1} and a clear band at 631 cm^{-1}, could have been in the 700−800 ºC range.

The combustion of fresh corpses usually produces chalky-white bones, because of the additional fuel originating from the fat of spongy bones, soft tissues and body fluids. Corpses burnt while fresh also display warping, cracks and breakage (Buikstra and Swegle 1989; Baker Bontrager and Nawrocki

2008; Depierre 2014). There is no warping in this assemblage, cracks are not generalised in all the chalky-white bones (NISP=13 of 26 specimens), and non-mineralised breakage was only observed in half of these remains (NISP=11 of 26 specimens). In addition, most cracks displayed a straight orientation along the diaphysis (NISP=9 of 13 specimens, which is typical when bones are burnt when almost or already skeletonised (Thurman and Willmore 1982; Buikstra and Swegle 1989; Depierre 2014; Gonçalves et al. 2011; 2015). However, there is controversy concerning the estimation of the pre-combustion state of bones based on scoring cracks (Mayne Correa 1998; Symes et al. 2008; Gonçalves et al. 2011; 2015). Therefore, we should consider that chalky-white bones could be the result of an intense temperature or a more oxygenated atmosphere, instead of being from freshly burnt corpses.

Evidence suggests that most bones were skeletonised or almost skeletonised when they were burnt. Most specimens display fire-induced alterations compatible with a reducing atmosphere of combustion, while some others show more oxygenated alterations attributable to an open-air fire. Additionally, the bones belonging to two individuals displayed similar patterns of burning, suggesting these remains were exposed to fire under the same circumstances. During the decay process, dark-black colour prevalence and uniform patterns of charring/calcination increase because there is less fleshed material to burn. Furthermore, whenever soft tissues disappear, then more skeletal regions are exposed to fire. For instance, the trunk takes longer to decay than the skull and lower limbs, because of its greater tissue mass (Keough et al. 2015). The bone assemblage of SU-815 contains specimens from the trunk region that were also affected by fire and display dark-black hues, so these regions may have already been skeletonised. Moreover, there is no evidence of the linear burn progression or patches of fire-induced alteration usual in fresh bones (Symes et al. 2008). In addition, there are not significant differences in the percentage of colour changes on burnt specimens according to skeletal regions (Fig 7). Only flat bones display a higher percentage of chalky-white hues due to their thinner cortical tissue. Similar percentages between long bone diaphyses and epiphyses indicate a comparable fire exposure for both skeletal regions. This suggests that complete bodies or skeletonised remains in primary burials were not likely cremated. However, non-uniform colour distribution (NISP= 85 of 139 specimens)is compatible with heterogeneous heat diffusion rather than uneven tissue protection during burning, since there is no evidence of warping or twisting. Therefore, this pattern may be due to asymmetries at the time of fire and/or heat exposure (Blaizot 2005).

Large-sized specimens and dark-black colour prevalence indicate that applying fire was not intended to reduce the remains to very small fragments. This is unusual in cremations, which are characterised by a large proportion of smaller pieces of bones (Mayne Correia 1997; Blaizot 2005; Valentin and Clark 2013). Fire-induced alterations under 700°C produce black hues on bones and little fragmentation except that of long bone epiphyses (Bohnert et al. 1997; Pope and Smith 2004). We documented evidence of higher temperatures in the internal surface of 12 specimens belonged to long bone diaphyses that may be related to burning after fragmentation. This condition is most likely in skeletonised remains since the outer surface of bones is exposed sooner to heat than the internal surface during cremation (Bohnert et al. 1998; Symes et al. 2008; Godinho et al. 2019). However, this order may be modified if shaft is compromised with fractures due to fire (Symes et al. 2008). Unburnt specimens were also fractured, indicating that other taphonomic factors could have affected

Special consideration must be given to the burnt cranium intentionally fragmented by direct percussion. This manipulation reduced its size and eliminated the head volume. We could not discern if the cranium was broken before or after the fire-induced alteration, since all the fragments display a uniform dark-black colour, which obscures possible bone colour changes at the fracture line.

Moreover, it is no possible to establish if this skull breakage had a ritual or a practical purpose. There are ethnographical examples that describe cranium fracturing of fresh corpses to prevent the head exploding during heating (Grévien 2004).

If we consider this particular cranium was deliberately broken for a ritual purpose, it would be highly
If we consider this particular cranium was deliberately broken for a ritual purpose, it would be highly
If we consider this particular cranium was deliberately broken for a ritual purpose, it would be highly noteworthy because crania were frequently selected for special deposits, where they often played a leading role (Kuijt 2008; Santana et al. 2012; Bocquentin et al. 2016).

CONCLUSIONS

This contribution offers a comprehensive analysis of burial SU-815, a example of intentional manipulation using fire in the PPNB, providing new insight into the complexity and variability of the funerary customs of this period. This is an instance of a multiple secondary burial with unburnt and burnt remains from at least three adult individuals. The funerary sequence included an intermediary period, after which the bones of the deceased were removed from their primary burials or storage sites. Two individuals were then submitted to fire when most bones were already or almost skeletonised. Evidence suggest that the earlier stages of the mortuary practice associated with unburnt bodies could have remained unchanged for the two cremated individuals, i.e. primary burial. Bones were afterwards collected and transported during a final episode to a new location, the final burial site. The percentage of survivorship (%survivorship) reveals an infra-representation of some skeletal regions including both fragile and hard bones. Modern crematorium experiments and archaeological *in situ* cremation burials have shown that the bones tend to be recognizable after cremation, so low representation of skeletal regions in cremation burials may be consequence of intentional collection of body parts rather than accidental non-retrieval (McKinley 1994; 1997; Marshall 2011; Appleby 2013). Therefore, infra-representation of some skeletal regions may indicate a cultural selection of remains in burial SU-815. Unfortunately, there is no evidence to establish the length of the interval between death, primary burial, cremation and final burial for the cremated remains.

Intentional manipulation using fire may have been transmitted to northern Levant, given that it appeared later in various archaeological sites of the Early Pottery Neolithic, including cremations. We should also consider that the identification of burnt remains with a low degree of transformation is challenging, since bone remains are usually covered by dense concretions that impede recognition of fire alterations. This means that some cremations may go unnoticed. Were these individuals cremated because of a social or ritual distinction, or a consequence of special circumstances of death? At Kharaysin, Late PPNB levels are still little understood because archaeological work has focused on earlier occupational episodes at Zones A, B and C (from PPNA to Middle PPNB). Therefore, there is little evidence to support any variation related to special distinction of individuals or circumstances of death. At Yarim Tepe II, some cremated individuals were buried with grave goods that are scarce in inhumations, suggesting special privilege (Merpert and Munchaev 1993). However, evidence from burial SU-815 indicates that individuals were skeletonised or almost skeletonised when burning took place. This behaviour suggests it would be a complementary rather than a contrasting secondary burial practice, where fire may have been used to transform the nature of the deceased.

Similar evidence from the nearby site of Beisamoun suggests that different communities from the Late PPNB and PPNC could have shared this funerary behaviour in southern Levant. Cremation introduced a new mortuary practice that involved fundamental shifts from previous assumptions based on both primary and secondary inhumation burials. The bone remains of the unburnt individuals were easily recognized and treated as particular bodies in PPNB burials. Several authors have suggested that human bones were usually considered as relics in ancentralisation practices aimed to reinforce the social relations within the community (i.e. plastered skulls in MPPNB). These social relations could have been renewed and renegotiated through a series of mortuary practices such as primary burials, body manipulation and secondary deposits (Kuijt 2008). This study shows that bone manipulation using fire was an innovation that radically differed from the burial customs of the PPNB. Although these were characterised by a highly diverse and complex multi-stage practice, cremation implied a radical new approach after LPPNB, transforming the remains of the deceased and facilitating their destruction through the technology of fire. This practice also introduced new sensory experiences not previously experienced in inhumations.

During the LPPNB, some changes are reported in the funerary behaviour, such as more frequent multiple primary burials and non-canonical primary burials denoting disaffection (Rollefson et al., 1992; Ibáñez et al. 2018). It happened alongside other social changes that lead to fundamental shifts in Neolithic settlements in southern Levant. At this time, Late PPNB villages along the Jordanian Highlands experienced a significant demographic development toward mega-sites (Goring-Morris and Belfer-Cohen, 1998; Kuijt, 2000; Kuijt and Goring-Morris, 2002; Gebel, 2004). In the subsequent PPNC, the population density drops dramatically alongside changes in subsistence practices and environmental degradation (Rollefson and Kohler-Rollefson, 1989; Goring-Morris and Belfer-Cohen, 1998; Zielhofer et al., 2012). Ultimately, these transformations implied decentralisation and social fragmentation toward smaller Pottery Neolithic hamlets in southern Levant (Goring-Morris and Belfer-Cohen, 2010). The mortuary practice of cremation, therefore, may reflect a reinterpretation of the meaning of burial as a practice and a shift in the relationship of the dead, social memory and social relationships during the social changes occurred at the LPPNB onwards.

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