Chapter 8
Beneath the Surface Imaging Techniques and the Jericho Skull

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The Jericho skull in the British Museum collection (BM 127414) is one of seven Neolithic plastered human skulls found by Kathleen Kenyon at Jericho in 1953 (Kenyon 1953, 83–7, pls XXXVI–XXXVII). The site of ancient Jericho, a mound which lies about 2km to the north-west of the modern town in the State of Palestine, was excavated by Kathleen Kenyon on behalf of the British School of Archaeology in Jerusalem from 1952 to 1958. Her work at the site was pivotal to the study of the Neolithic and Bronze Age in the Middle East. The skull occupies a position of relative isolation within the Middle Eastern department at the British Museum, being much older in date than most of the collection. It has also been separated from the other skulls it was placed in the cache with, which were subsequently distributed among other institutions (see **Table 1** for the present location of the other skulls). It is nevertheless important as archaeologists have long considered 'Skull Cult' (a range of mortuary rituals involving removal, decoration and caching of skulls) to be a key component in understanding the mortuary and social practices of the Neolithic period (Kuijt 1995; Goring-Morris 2000, 124–5; Croucher 2012, 97–8). Artificial cranial modification (the permanent alteration of a skull's shape by intentionally moulding growth in early childhood) has also been linked to cultic activities. Identifying and investigating such practices through modified human remains is challenging, as often the decoration obscures areas of the skull that would otherwise be observed and the whole cannot be split into constituent parts (plaster, human remains and shell) simply to make the analytical process more convenient. Non-invasive radiographic imaging techniques are therefore vital for capturing the internal structure of rare and valuable cultural artefacts such as the Jericho Skull (Abel *et al.* 2011). The most relevant of these techniques are micro-CT scanners and associated software which can be used to create 3D computer models for virtual dissection of tissues and/or anatomical features (see Abel *et al.* 2012).

Archaeological and cultural context of the Jericho skull

The Jericho skull was deposited in a cache during the Middle Pre-pottery Neolithic B (*c.* 10100–9250 calibrated ^{14}C years BP) (Kenyon 1953, 84). The skulls appear to have been deposited in no particular order and this was interpreted as a careless form of disposal, as other skull caches recovered at Jericho showed deliberate arrangement in lines or circles (Kurth and Röhrer-Ertl 1981, 436; Kenyon 1956, 75, pl. XIII.). It was originally suggested that the cache represents the disposal of cultic equipment at the end of its useful life (Kenyon and Holland 1981, 77), as has been suggested for other Pre-pottery Neolithic B (PPNB) ritual objects, such as plaster statues (Garfinkel 1994; Simmons *et al.* 1990, 109). There is little evidence, however, that the burial of plastered skulls at Jericho was entirely associated with the disposal of waste. The skulls within the cache were in remarkably good condition and arguably, like other more structured burials, the cache formed a symbolic expression of a community's beliefs and values (Kuijt 2000b, 148).

The PPNB period saw significant changes in the lifestyles of the inhabitants of the Levant (modern Syria, Lebanon and Jordan) with a marked population increase and

Excavation number (Kenyon and Holland 1981)	Location	Accession number
D110	Jordan Archaeological Museum, Amman	J5756
D111	Ashmolean Museum, Oxford	AN1955.565
D112	Jordan Archaeological Museum, Amman	J5758
D113	British Museum, London	BM 127414
D114	Jordan Archaeological Museum, Amman	J5757
D115	Royal Ontario Museum, Toronto	1955.165.1
D116	Birmingham Museum and Art Gallery, Birmingham	1964A27
D117	University of Sydney, Sydney	57.03
D118	University of Cambridge, Museum of Archaeology and Anthropology, Cambridge	1957.159
E22	Rockefeller Museum, Jerusalem	JPE 121.32

Table 1 Locations of other plastered skulls from Jericho

movement to inhabit drier regions (Bar-Yosef and Alon 1988, 28; Bar Yosef 1986, 159–62; Rosenberg and Redding 2000, 39–40; Rollefson *et al.* 1992, 444). Ritual practices were focused on skull modification, removal and caching, alongside the creation of clay figurines, stone masks and plaster anthropomorphic statues (Bar-Yosef and Belfer-Cohen 1989, 61–8; Cauvin 2000, 75–116; Garfinkel 1994, 182; Rollefson 1990; Bar-Yosef and Belfer-Cohen 1991, 192–3; Kuijt and Goring-Morris 2002, 387–98, 399–404; Kuijt 2000b, 142; Cauvin 1972, 43–66; Verhoeven 2002, 236–47). Following skull removal, further treatments include the application of bitumen on the upper skull (Rollefson 2000, 171) and the modelling of facial features in plaster. Cranial removal was also expressed through wall paintings and the decapitation of figurines (Kuijt 2000b, 149). Recent work at Çatalhöyük and Köşk Höyük now attests that plaster remodelling of skulls was also practised in central Anatolia in later periods (9th and 8th millennia calibrated ^{14}C years BP) (Hodder 2004, 10; Lichter 2007, 250–1; Yakar 1991, 192; Silistreli 1988, 62, 65, pl. 7). In most examples, plaster covers the face, sides and base of the head, but not the cranial vault, which has led to suggestions that some skulls originally also had a wig or other form of head covering (Griffin *et al.* 1998, 66; Goring-Morris 2000, 124–5; Arensburg and Hershkovitz 1988, 53–4; Arensburg and Hershkovitz 1989, 117–23; Yakar and Hershkovitz 1988, 60–2).

Imaging techniques and museum collections

The British Museum Jericho skull (BM 127414) consists of a human cranium, with the lower jaw removed and facial features remodelled in plaster (**Pl. 1**). These modifications and additions presented several challenges for its analysis. It is axiomatic within a museum context that non-destructive and non-invasive techniques should be used to unravel the details of an artefact's construction wherever possible (see Chapter Three, this volume, for a commentary on this subject). To achieve this, it is often necessary to attempt to look beneath the surface of an artefact in a way that does not cause damage. This is particularly important for human remains that have been modified, as in the case of the plastered skull discussed here, or are held in a complex relationship with other objects and materials, such as Egyptian mummies. In these instances, while it is important to know how those human remains have been treated and what lies beneath their outer surface, a direct internal investigation would cause irreversible alteration and might even mean their permanent disassembly. The public mummy unwrapping displays of the Victorian era (see for example Tapp 1979) have been left behind. Not only might a researcher wish to know how a modification has been made or what lies within a funerary shroud, but they may also seek more fundamental biological data such as the age, sex and state of health of an individual to help understand the social context. A number of techniques have been used to resolve these problems, but two imaging methods – conventional radiography and computerized tomography (CT) – stand out as being regularly employed within museums.

Radiography is one of the earliest and most frequently used techniques available for the internal investigation of museum collection material (Lang and Middleton 2005). It facilitates the non-invasive examination of a range of materials without physical damage. Radiographic images have been available for over 100 years (Spiegel 1995) and the technique has been used by the British Museum to research artefacts since 1949. The methods used in museums are very similar to those used in a medical context, although the quantity of radiation used is adapted to the density of the specimens and can sometimes exceed the levels which are safe for living organisms.

Radiography involves firing a stream of radiation, usually in the form of X-rays, at the subject under examination. Some of this radiation will pass through, some will be absorbed and some will be scattered. The amount which passes through depends on a number of factors, but mostly on the composition and thickness of the subject being examined. Radiographic images were traditionally captured on film or, less frequently, on fluorescent screens, but digital formats are now generally the first choice for image collection or examination (for discussions of the reasons for this, see Lang and Middleton 2005).

Despite the availability of radiographic equipment, when the skull first arrived at the Museum in 1954 no attempt was made to undertake a radiographic study. This was because plaster and bone have similar radio-opacities which makes it

Plate 1 Front view of the Jericho skull, 10100–9250 calibrated ^{14}C years BP. British Museum, London (BM 127414)

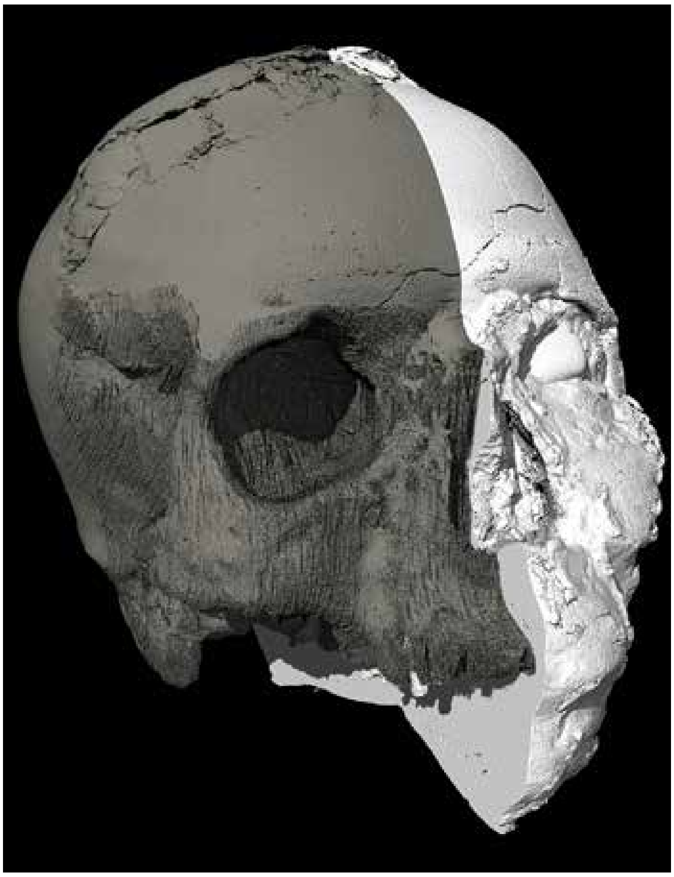

Plate 2 Computer assisted 3D reconstruction of the Jericho skull showing the structure of the cranium below the plaster face

difficult to distinguish between them by using this technique. The soil fill of the cranium posed further problems; the sheer density of this material was certain to make it difficult to penetrate the skull, while the scatter generated by the fill would be likely to fog the image and complicate its interpretation. However, success in using digitized X-radiographs to examine skeletal material from the Royal Cemetery at Ur encouraged us in 2005 to experiment by examining the British Museum Jericho skull through the use of this technique (Irving and Ambers 2002; Molleson and Hodgson 2003, 108–12). A number of radiographs of the skull were therefore produced under different voltage and exposure conditions allowing the interior to be examined at different depths and levels of contrast. These provided much information about the skull, particularly with regard to pre-mortem modification, but could not answer all questions for a number of reasons; the geometry of the skull and the equipment limited the angles at which the skull could be examined and the detail that could be achieved; the similarities in the radio-opacity of bone and plaster remained a problem despite digital adjustment of the images produced; and images of the central parts of the skull were largely obscured by the superposition of different elements and the soil packing. However, the information gained from the radiographic images allowed us to make a strong case that the skull should be the subject of a computerized tomography (CT) study.

X-ray computed tomography (CT) has been available since the 1970s and uses X-rays in conjunction with computing algorithms to create sub-surface images. Digital geometry processing is used to generate a cross-sectional image (tomogram) of the interior of an object from hundreds of two-dimensional X-ray images taken around a single axis of rotation. Computer-assisted reconstruction can also be used to generate a 3D representation of the scanned subject (**Pl. 2**).

CT scans have several advantages over traditional radiography. As it operates in the form of a series of slices, CT permits the differentiation and isolation of specific areas and substances, eliminating the problem of superposition within the subject being studied. In addition, the inherently high-contrast resolution of CT means that slight differences in the density of materials (less than 1%) can be distinguished, while the ability to reconfigure the data from a single CT scanning procedure means that images of the object can be viewed as through three different planes: axial (horizontal), coronal (vertical, front to back) or sagittal (vertical, left to right) (see **Pl. 3**). In the case of the British Museum Jericho skull, this allowed us to examine areas that could not otherwise be seen in detail such as the inner and outer surfaces of the cranial bones, the teeth, the soil packing and the plaster.

Methods

Other plastered skulls have been the subject of sub-surface investigations which have offered opportunities for comparison with the British Museum Jericho skull (Hershkovitz *et al.* 1995; Hershkovitz *et al.* 1996; Bonogofsky 2002; Goring-Morris 2000, 126; Goring-Morris *et al.* 1994–5,

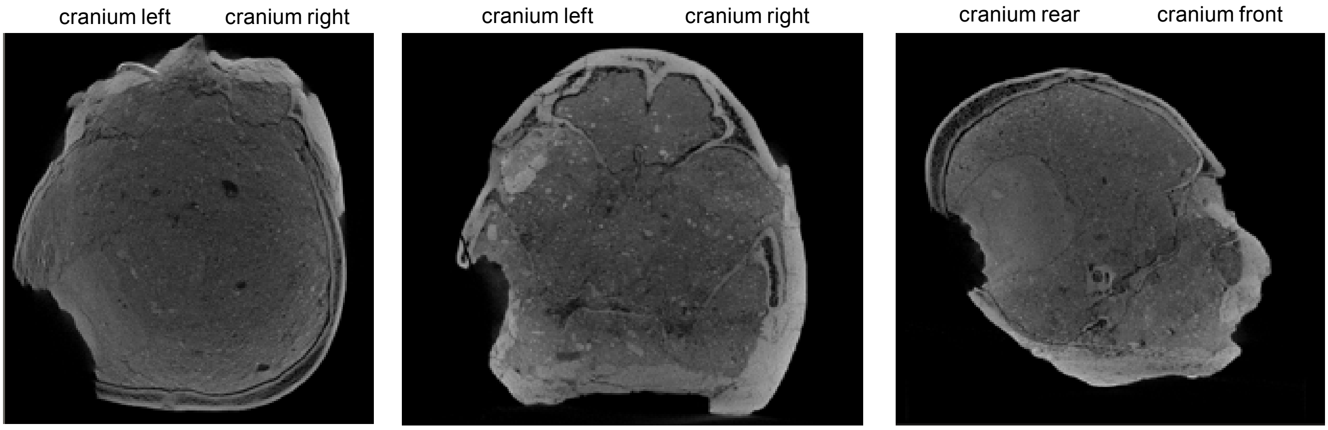

Plate 3 Axial (left), coronal (middle) and sagittal (right) views of the Jericho skull created by CT scan

112). A detailed physical and anthropological study was therefore carried out (Fletcher *et. al.* 2008) using surface investigations and sub-surface examinations conducted by radiography and CT scanning. The CT scan images were assembled to show a single point in three views (axial, coronal and sagittal; **Pl. 3**). The skull was scanned sitting on its plaster base. This combined with its inherent asymmetry owing to cranial modification (see below) means that the axial, coronal and sagittal slices are not placed at right angles with the skull. This makes their interpretation more challenging and means that sometimes several images need to be compared to obtain all the information about a specific area. A list of skull treatments was compiled from published examples, with which the British Museum Jericho skull was compared and the presence or absence of specific features noted. Sex was evaluated through traditional methods; examination of the supraorbital margins, mastoid process, occipital crest, zygomatic arches and the presence of a temporal line (Workshop of European Anthropologists 1980). Age was estimated following cranial suture observation (Meindl and Lovejoy 1985). Epigenetic traits (skeletal variations between individuals thought to result from genetic inheritance or environmental factors) were also recorded (Berry and Berry 1967).

Micro-CT scanning was performed using an HMXST 225 CT system (Nikon Metrology, Tring, UK). Due to the density and size of the Jericho skull, the X-ray penetration was very low. Accordingly the X-ray energy had to be set to a high level (45,000W). X-rays were generated from a tungsten target using a voltage and current of 225kV and 200μA respectively. A total of 6,284 angular projections were collected at 0.057° intervals in a single 360° rotation. The radial projections were reconstructed into a three-dimensional matrix of 2000 × 2000 × 1000 (length × width × height) 250μm cubic voxels using the software package CT-Pro (Version 2.0, Metris X-Tek, Tring, UK). Due to the high density of the skull and plaster (>2.6 g/cm3), the reconstructed scan data contained beam hardening artefacts, evident as a ring of increased brightness (representing false density enhancement) on the margins of an object and decreased brightness at the centre, giving the shape commonly referred to as a 'cupping' artefact. Beam hardening artefacts are caused by the process of selective removal of low energy X-rays from the polychromatic X-ray beam. As X-rays pass through an object, lower energy X-rays are removed so that the beam becomes progressively harder, or more penetrating. In order to reduce beam hardening artefacts, a copper filter was used to remove low energy X-rays, and the scan data was post-processed using CT-Pro 2.0 to remove cupping by normalizing the grey values at the edge and centre of the reconstructed scan (following Ronan *et al.* 2010; 2011).

The data was exported as a stack of TIF files for visualization and segmentation using VG Studio Max (Volume Graphics, Heidelberg, Germany). Reconstruction, thresholding, segmentation and rendering were carried out following the ten-step process recommended and described in detail by Abel *et al.* (2012)

Results: surface examination

The skull does not appear to have been significantly compressed after it was buried as all the sutures and facial features remain intact. This suggested that any modification to skull shape discovered during examination occurred in life and not due to factors such as distortion caused by the weight of soil above the burial cache. There was some damage observed above the left eye and at the top of the head (near craniometric point bregma), where impact damage was suggested by splintering of the bone with radiating fractures, indicative of the breaking of fresh bone. This may not have been related to the individual's death and could have occurred during peri-mortem (i.e. around death) treatments, handling or burial. There is a large area on the left side towards the back of the skull, which initially appeared to have been sliced off during excavation (**Pl. 4**). The evidence from the CT scans contradicted this theory (see **Pls 11, 12**), as will be discussed below, illustrating why it is advisable to apply different imaging techniques to a single specimen in order to achieve a more accurate data set.

Plaster had been applied to the area of the face finishing at the eye sockets and temples. All the edges of the plastered zone are rough and broken, indicating that when complete, it extended over a greater area than is now preserved. Although other examples from Jericho showed partial plastering with the crown of the skull left bare (Kenyon and Holland 1981, pls 51–9), the practice of full cranial plastering is attested elsewhere (Lechevallier 1978, 151, fig. 2) and therefore cannot be ruled out. The broken plastered margins surrounding the nasal cavity suggest that this example did once boast a modelled nose. The remaining ear is stylized,

Plate 4 Left lateral view of the British Museum Jericho skull showing the sub-circular opening cut into the left parietal bone

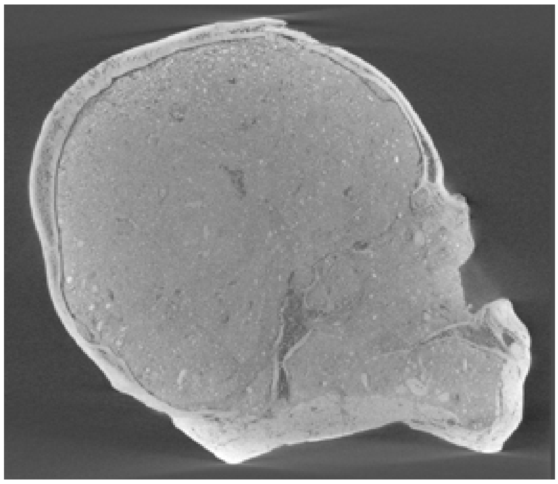

Plate 5 Sagittal CT scan on the mid-line showing that the sagittal and coronal sutures are fused which indicates a mature age adult. The image also shows the profile of the hard palate

as are the lips. The eyes are represented by shells that appear to be from a small marine bi-valve (*Donax* sp.) (Fletcher *et al.* 2008). The modelling of the eyelids covers the edges of the shells, obscuring diagnostic features and making identification of the species difficult. On the left side, one intact shell is in place while another portion is missing, suggesting another shell had originally been placed alongside it. On the right side there is a single shell that had been broken into two pieces.

Removal of the lower jaw means the face is foreshortened, a characteristic seen in other examples (Lechevallier 1978, 151, fig. 2; Goren *et al.* 2001, 674, table 1; de Contenson 1967, pl. 1 A–B). Plaster covers the full extent of the skull's base and the modelling of the plaster chin means that the skull sits upright without support as do other examples from Jericho (Strouhal 1973, 236, 238, 240). The British Museum Jericho skull shows no visible evidence for painted decoration or facial features in contrast to some other skulls (Strouhal 1973, 235–6; Goren and Segal 1995, 157–8; Goren *et al.* 2001, 673, 680; Kingery *et al.* 1988, 232; Hodder 2004, 10; Butler 1989, 143, fig. 2).

Biological characteristics and results: sub-surface examinations

Age was estimated by examining how far the cranial sutures had closed. The points where the sagittal and coronal sutures at the top (bregma) and the lambdoid and sagittal sutures at the back (lambda) of the skull meet are no longer complex and are nearing obliteration. The fused sagittal and coronal sutures can be further observed through the CT scans (**Pls 5, 15**) as can the unfused squamous suture around the top of the temporal bone (**Pl. 15**). These observations are consistent with a mature adult. The majority of plastered skulls appear to be adult, but age estimations vary (compare Strouhal 1973, 244 and Kurth and Röhrer-Ertl 1981, 437) and cranial suture ageing can only provide an approximate age at death. During the visual examination a slight linear depression was observed running approximately from ear to ear (perpendicular to the sagittal suture at the bregma). This suspected artificial cranial modification was later confirmed by radiography and CT scan (see below). It is possible that the alteration may have contributed towards atypical suture closure and as such, the age of other individuals may have been over or underestimated; the possibility of skull modification may not have been considered where it was not immediately apparent. During previous examinations of the British Museum Jericho skull for example, it was not noted or recognized by other researchers (Kurth and Röhrer-Ertl 1981, 436–9). Extra ossicles were identified in the lambdoid suture, with cranial modification being one possible cause of the formation of accessory bones in the cranium (Hanihara and Ishida 2001). Extra ossicles were also seen in the Nahal Hemar Homo 9 specimen, but were not a feature of all skulls at this site (Arensburg and Hershkovitz 1989).

The skull was originally classed as female (Kurth and Röhrer-Ertl 1981, 437), but the sex of this individual is ambiguous with both male and female characteristics present. Indicators that the sex is possibly male are the rounded margin and shallow roof of the orbit (eye socket) (**Pl. 6**), thick orbit ridge, large mastoid (**Pl. 6**), deep palate (**Pl. 5**) and large cheek bones indicative of a robust individual. In contrast, the generally gracile form of the cranium and lack of nuchal crest or temporal line are female traits. It is possible that the skull was deliberately selected because it had no distinctively male or female attributes visible and it is perhaps significant that the plaster face has little indication of gender either. The lips are barely defined and there is no indication of features such as facial hair. The smoothing of the plaster also means the face does not reflect the age of the individual at death. Either deliberately or coincidentally, owing to the nature of the plaster that has been used, the skull has what appears to be an ungendered, young face reproduced upon it.

Sub-surface investigation allowed observation of the object's construction and further illuminated the cranial morphology. The radiographic investigation was particularly useful in looking at the linear depression thought to relate to artificial cranial modification. This had not been noted for this skull previously, although it had been identified in skulls within the same burial group (Kurth and Röhrer-Ertl 1981, 438–9). In an individual without a

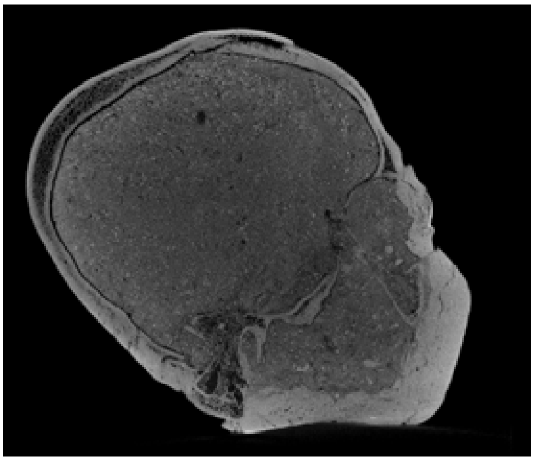

Plate 6 Sagittal CT scan off the mid-line showing variation in thickness of diploë on the vertex and frontal regions where the outer table was deflected towards the inner table. The image also shows the rounded margin and shallow roof of the orbit (eye socket) and a large well-pneumatized mastoid

modified skull, the middle layer of the cranial bone (the diploë) is a constant thickness, thinning only towards the sutures. Pressure exerted on the bone during artificial cranial modification causes deflection of the outer cranial table imposing variations in the thickness of the diploë (Merkle *et al.* 1998), which can only be observed non-destructively through radiography or CT scanning (Molleson and Campbell 1995). Both imaging techniques revealed variations in the thickness of the diploë of this individual (**Pl. 6**) in the same location as the linear depression observed by eye, confirming that this individual had experienced cranial modification. Since human skulls cannot be modified in adulthood, this must have happened at an early age. Further asymmetry in the shape of the cranium (**Pl. 15**) probably resulted from this modification.

Some clues as to the method used to artificially modify skulls at Jericho may be gained by another skull from the same cache (Strouhal 1973, 237, pl. 2). This has painted stripes running across the parietal bones from ear to ear, which could be interpreted as a representation of how the head was bound to change the shape of the skull (compare with Özbek 1974, 473, fig. 2; Meiklejohn *et al.* 1992, fig. 2). Changes identified in other skulls from Jericho have been ascribed to post-mortem agents (Strouhal 1973, 232–4), but the variation in diploë thickness in this example is a strong indicator of pre-mortem artificial modification. Radiography of other Jericho specimens to examine diploë thickness could reveal the extent of this practice.

The radiographic investigation also revealed that there is an upper jaw and some teeth present within the soil/plaster matrix surrounding the lower portion of the face. It was not clear from the radiographs whether the teeth were in anatomical position. The CT scans, however, were able to illustrate the position and condition of the teeth in more detail. Some teeth are still in position, albeit broken and two abscesses were identified; one on the cranium's right side (first molar) and one on the left side (first premolar) (**Pls 7–8**). Dental caries (tooth decay) can be visualized in the crown of the left side first premolar. Both the first molar on the right and the left of the upper jaw were broken. The overall evidence from this example suggests that the teeth were in poor condition and that the individual had suffered from worn and damaged teeth, caries, abscesses and tooth loss during their lifetime. This fits well with the age of a mature adult. The tooth sockets for the first incisors were plugged with plaster (**Pl. 9**). The practice of destruction and remodelling of dentition has previously been noted for examples from Jericho (Strouhal 1973, 243), Beisamoun (Lechevalier 1978, 180), Kfar HaHoresh (Goren *et al.* 2001, 674), Ain Ghazal (Butler 1989, 145) and Tell Ramad (Ferembach 1969, 66–7), but their deliberate removal (avulsion) in order to mimic toothless (thereby elderly) ancestral males is doubtful (Bonogofsky 2002) and can be ruled out as an in-life practice in this case as the alveolus (tooth socket) would have healed and closed. The second and third molars were completely absent (**Pl. 10**), having never

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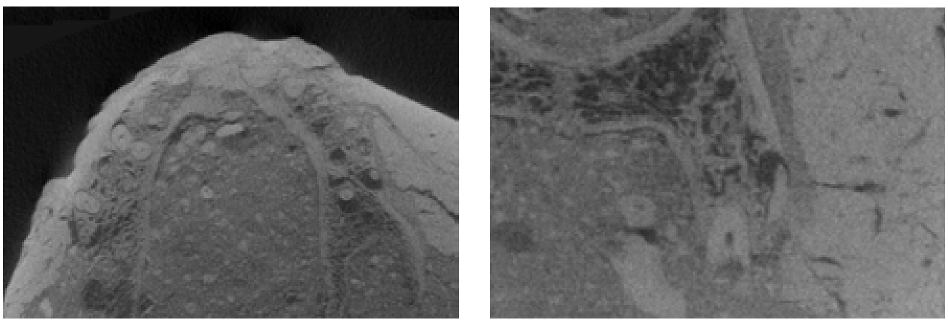

Plate 7 Axial (a) and enlarged coronal (b) CT scans showing the first molar on the right side of the cranium which is broken at the crown and has an abscess on the mesiobuccal root

a b

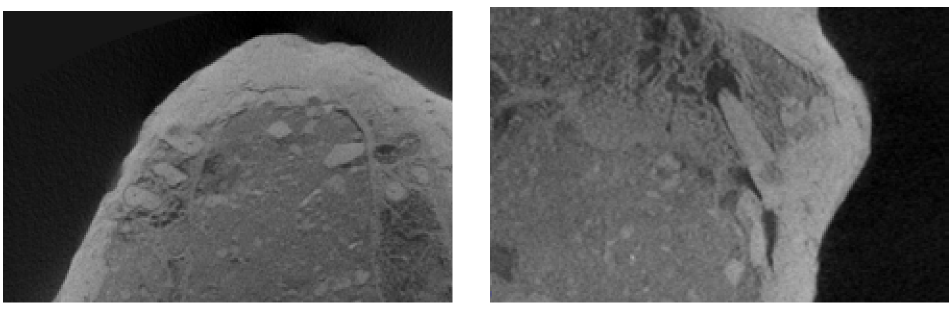

Plate 8 Axial (a) and enlarged sagittal (b) CT scans showing the first premolar on the left side of the cranium with an abscess on the palatal root and dental caries in the crown

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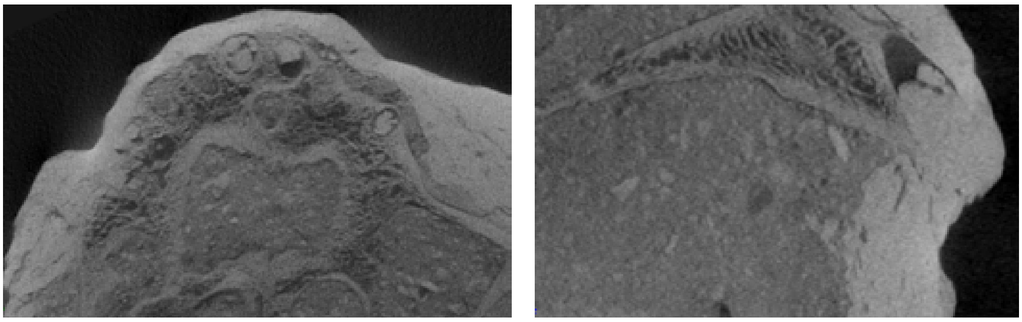


Plate 9 Axial (a) and enlarged sagittal (b) CT scans showing left incisor cavity plugged with plaster

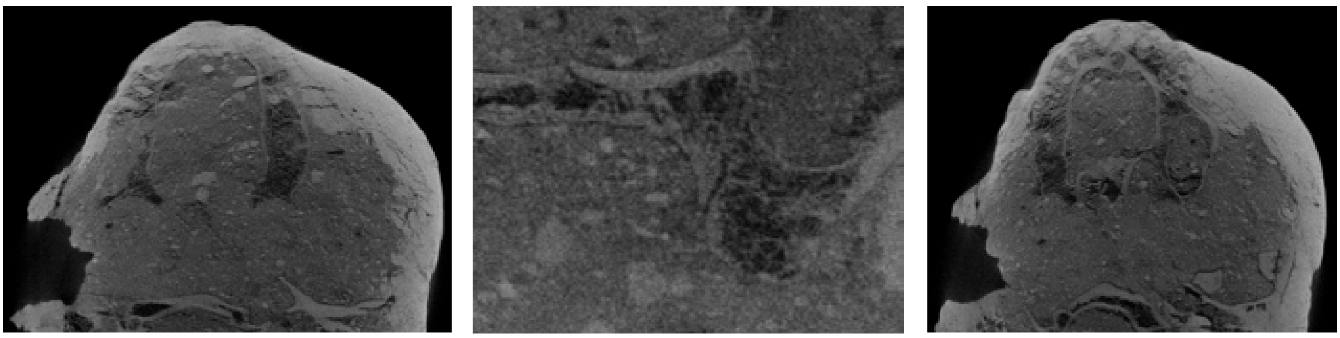
developed. The second incisor on the right side is missing with no alveolus (tooth socket) present. The canine appears to have moved to close the gap. This additional example of a tooth failing to develop (hypodontia) supports the possibility that the missing second and third molars may be inherited (see Alt *et al.* 2013). It is difficult to assess the significance of the failure of these teeth to develop without a comparative population, although their identification in other examples could further the discussion surrounding plastered skulls, inherited social status and ancestor cult (Bonogofsky 2002; 2003, 1–2; 2004, 118; 2005, 133–4).

Damage to the plastered nose and the left parietal of the skull revealed that the cranium contains a brown soil matrix. Since all potential paths for soil to penetrate the skull had been closed over during plastering, it appears that soil was deliberately used to fill the skull, rather than accumulating as part of post-depositional processes. The radiographic images were unable to help further elucidate this, but CT scanning confirmed this theory as the images clearly showed different phases of filling for the interior (**Pl. 11**). The concentric alignment of the grit inclusions within the soil matrix suggested that the hole at the rear of the skull on the left side had been cut in antiquity and subsequently was used as the access point to fill the skull's interior. A final ball of soil of slightly finer and therefore firmer texture appears to have been used to pack down the filling as shown by the patterns of concentric cracking around it. The inclusion alignments and the patterns of cracking suggest the filling was moistened before being applied and there may have been a gap in deposition between the two phases. The first layer of filling also appears to have pulled away from the interior surface of the skull, again probably whilst drying (**Pl. 12**). The pattern of bone breakage at the edge of the access hole suggest the bone was relatively fresh when it was cut (**Pl. 12**) and it is possible that the roundel of bone was originally replaced after the cranium had been filled. Although it was subsequently lost, its presence during the use-life of the skull may explain why the friable (easily broken up) soil filling has survived so well. The soil filling would have given support to the outer surface of the cranium as the plaster modelling was being added. Other skulls from Jericho reportedly have a plaster fill (Strouhal 1973, 232, 235, 240), suggesting there may have been variation in practices of cranial filling. As there has been no systematic study of this phenomenon across the Jericho examples, it is difficult to draw firm conclusions about the significance of these differences, if any.

Soil was also used to fill the eye sockets before the plaster used to create the face was applied (**Pl. 13**). No layering can be distinguished by eye in the plaster of the British Museum Jericho skull, in contrast to others from the same cache (Strouhal 1973, 232, 235, 240). Sub-surface studies of a plastered skull from Kfar HaHoresh, northern Israel, also showed that it was constructed in several stages with four different plaster mixtures applied to the skull (Goring-Morris 2000, 126; Goring-Morris *et al.* 1994–5, 112; Hershkovitz *et al.* 1995, 783–7). Goren *et al.* (2001, 679–85) have identified differences in the technical properties of plaster layers used on skulls from Jericho and Kfar HaHoresh. Such variation in plaster type is not discernible in the CT scans of the British Museum's Jericho skull, although the use of soil to fill the interior may reflect efforts to conserve the resources associated with obtaining or recycling materials to make plaster. The plaster for the British Museum's Jericho skull does appear to have been applied in sequence (**Pl. 14**). Cracks between plaster layers suggest that the base was plastered first, followed by the sides of the skull. An initial plug of plaster also appears to have been applied to the foramen magnum (the hole in the skull through which the spinal cord connects to the brain) (**Pl.**

Plate 10 Axial and enlarged coronal CT scans demonstrating the absence of second and third molars at the back of the right dental arcade (a–b), axial CT scan demonstrating the absence of second and third molars at the back of the left dental arcade (c)

a b c



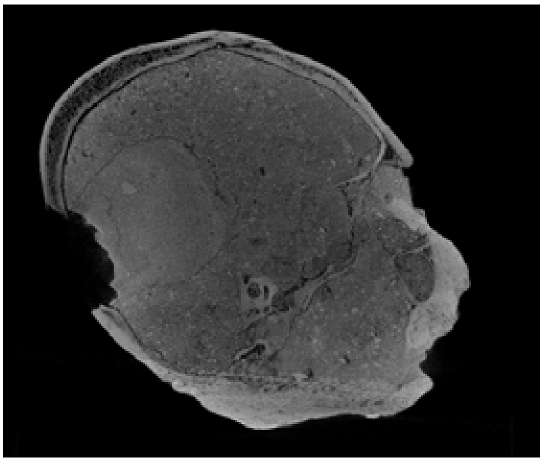


Plate 11 Sagittal CT scan of lateral left side showing layers of clay packing within the British Museum Jericho skull

15). The plaster was applied directly to the bone and the burnished finish on the surface of the face of the British Museum example was probably achieved by polishing the plaster with a smoothing tool (see Strouhal 1973, 232, 238).

The interpretation of the skull cult and social relationships in Pre-pottery Neolithic B society

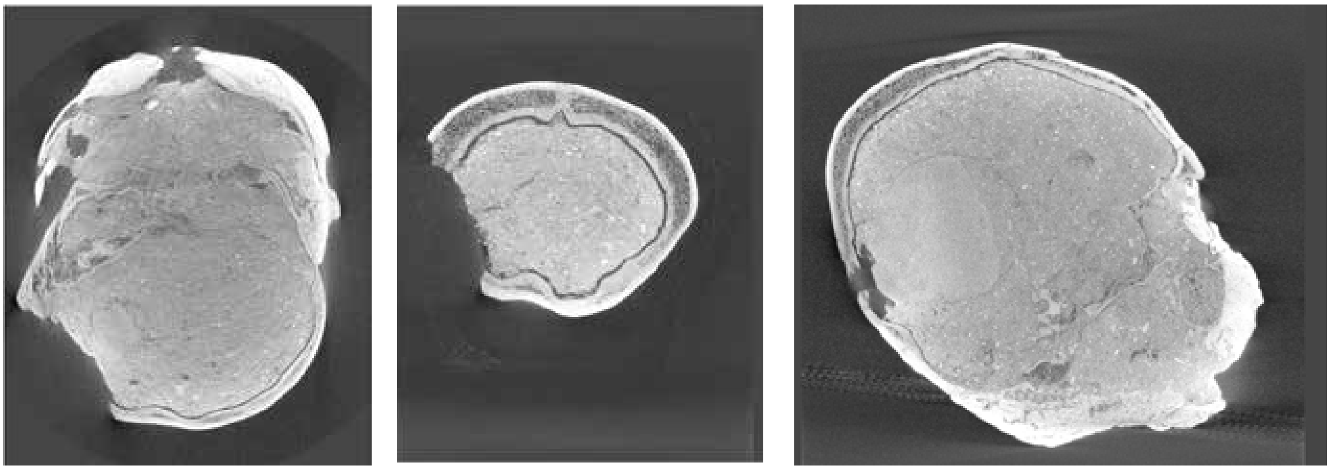
The selection of skulls for plastering

There is considerable debate surrounding what factors may have influenced the choice of skulls for plastering. A number of authors have been keen to attribute this to biological sex (see Strouhal 1973; Kurth and Röhrer-Ertl 1981; Arensburg and Hershkovitz 1989), but no patterning can be seen in the current sex assignments and some are still debated (Strouhal 1973, 231–41, 244; Kurth and Röhrer-Ertl 1981, 437). Artificial cranial modification identified for some examples (Arensburg and Hershkovitz 1989, 127–8; Strouhal 1973, 241, 244; Özbek 1974) may account for difficulties encountered in determining the sex of remodelled crania. Indicators of sex and age on the skull can also be obscured by the plastering itself and post-depositional site-formation processes such as compression, which also means that sexing and population typing of such skulls should be treated with caution, especially as the pelvis is a more accurate indicator of biological sex. This is significant because studies linking plastered skulls with an ancestor cult based on the veneration of elder males would therefore appear to be based on insubstantial evidence (see Bonogofsky 2003, 2 for examples).

Other studies have suggested that skulls were selected post-mortem for plastering according to their shape. Crania with a low wide face and broad vault, similar to the elongated shape seen in modified skulls, tended to be chosen (Garfinkel 1994, 166–70; Strouhal 1973, 243; Arensburg and Hershkovitz 1988, 55–7; Meiklejohn *et al.* 1992, 95; Arensburg and Hershkovitz 1989, 127; Verhoeven 2002, 249). The repetition of elongated head shapes on some figurines may also indicate that these were viewed as aesthetically pleasing (Meiklejohn *et al.* 1992, 95; Cauvin 2000, 147, 149, fig. 48; de Contenson 1969, 33, figs 13–14; 1971, 285; Daems and Croucher 2007, 7–13). Plaster faces were frequently modelled with little regard for the underlying bone structure and are often stylized, undermining the importance of morphological characteristics within the selection process (Garfinkel 1994, 165; Strouhal 1973, 241–4; Ferembach and Lechevallier 1973, 224–6; Lechevallier 1978, 150; Ferembach 1978, 179–80; Arensburg and Hershkovitz 1988, 55–7; Arensburg and Hershkovitz 1989, 127–9; Bienert 1991, 15, 19; Griffin *et al.* 1998, 62, 66; Goring-Morris *et al.* 1995, 47–8). As regards to the British Museum Jericho skull, it is not immediately obvious to the naked eye whether the individual underwent cranial modification or not. It is therefore unlikely that this would have been a significant factor in the selection process without prior knowledge that the individual had experienced modification through processes such as head binding in childhood. If cranial modification was an important factor in choosing skulls for plastering, the British Museum example suggests that the knowledge of an individual having undergone this process was more important than its physical result.

The occurrence of skull removal, caching and plastering within archaeological contexts is rare in relation to other burial types. This has been interpreted as indicating that

Plate 12 Axial (left), coronal (middle) and sagittal (right) CT scans. The thin dark line between the soil matrix and inner surface of the cranium shows that the clay filling contracted as it dried and pulled away from the bone. The bevelled edge of the broken bone in the coronal and sagittal views suggests the cutting/chipping of relatively fresh bone to gain access to the cranial vault rather than the accidental breakage of dry bone at a much later date



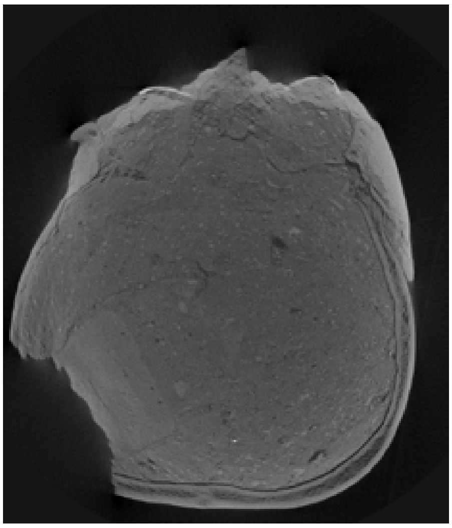


Plate 13 Axial CT scan showing soil packing within the eye sockets and overlying shell

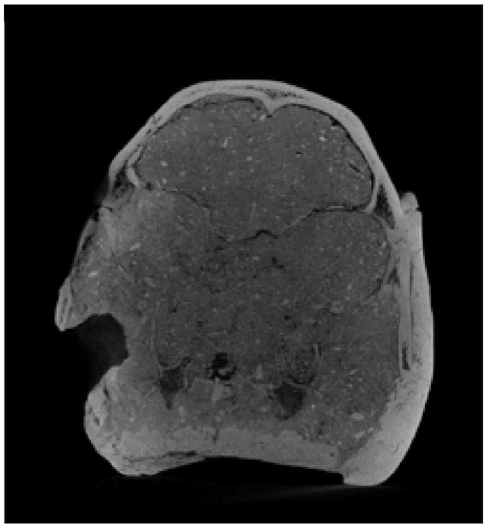


Plate 14 Coronal CT scan at the mid-point of the eye sockets (orbits) showing that a layer of plaster was applied to the base of the cranium before the sides

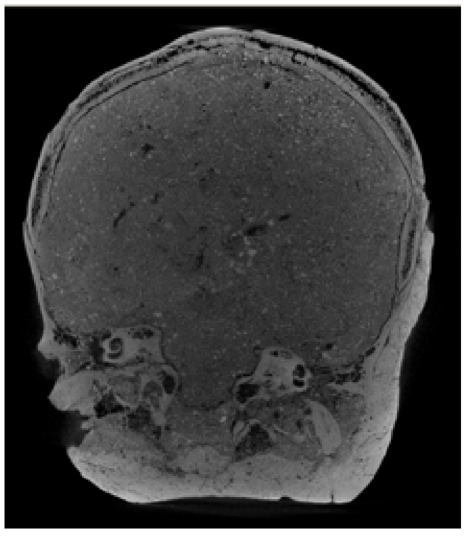
removal and treatment of the skull may have related to inherited or achieved status as only a small segment of the population was selected (Goring-Morris 2000, 130; Rollefson 2000, 184; Kuijt 2001, 94). The stylized rendition of facial features suggests that the skulls were not intended to look like realistic representations of the deceased (Goren *et al.* 2001, 686), which undermines arguments (Kenyon 1960, 51–4; Simmons *et al.* 1990, 109) that the skulls could be portraits of revered members of the community. It seems that the use of plastered skulls as ritual objects was more complex than simply acknowledging an individual's status (Verhoeven 2002, 251) and a general consensus of opinion has emerged that relates skull removal and associated practices to ancestor worship or ancestor cult (Cauvin 1972, 62–4; 2000, 93, 114; Bienert 1991, 20; Hershkovitz and Gopher 1990, 19–23; de Contenson 1971, 281; 1985, 22; Bar-Yosef and Alon 1988, 14, 20–8; Bar Yosef and Belfer-Cohen 1991, 193; Arensburg and Hershkovitz 1988, 55–7; Simmons *et al.* 1990, 109; Strouhal 1973, 244; Lechevallier 1978, 150; Bonogofsky 2003).

Ancestor-cult and cranial modification

Like the term 'skull cult', ancestor cult is broadly defined owing to the many different ways of practising ancestor worship identified in anthropological studies (Hardacre 1987). The representation of the dead among the living is regarded as important by archaeologists, although opinions differ regarding the exact relationship between material culture and a community's ancestral past (compare Parker-Pearson 1999, 158–61; Kuijt 2001, 82; Arensberg and Herschkovitz 1989, 129). It appears that modern scholarship has created a false impression that the plastered skulls represent venerated elderly males (Bonogofsky 2002; 2003, 1–2; 2004, 118; 2005, 133–4). Examples of post-mortem cranial removal from child skeletons in PPNA (Pre-pottery Neolithic A) and Middle PPNB contexts at Jericho (Kurth and Röhrer-Ertl 1981, 444–5, pl. VIIc; Kenyon and Holland 1981, 9, 49–50, 74, 287, 300; Kenyon 1956, 75; Cornwall 1956, 116–23, pls XX 4a–b, XXI 5b; 1981, 399–400; Naveh 2003, 86, 90) and at 'Ain Ghazal (Rollefson *et al.* 1992, 461–3; Rollefson 2000, 169–71) point to the existence of forms of veneration that were more varied than the worship of adults alone.

Ritual activities based around skulls in the Middle PPNB encouraged the development of belief systems that cut across household and kin groups, which may reflect attempts to cope with the social and economic stresses associated with Middle PPNB population growth (Kenyon 1960, 54–6; Naveh 2003, 94). At Jericho, many of the skull caches were buried in publicly accessible locations, facilitating community participation (Kuijt 2000b, 148). Participation in such practices for the wider community would have been more easily accepted through reference to a generalized group of ancestors and standardized social rules, hence children as well as adults could have assumed a significant role in linking living communities with their past (Kuijt 1996, 315–32; Kuijt 2000b, 138–56; Kuijt 2001, 80–95; Kuijt

Plate 15 Coronal CT scan in the region of the petrous (ear) bones and foramen magnum. Layers of plaster applied to the base of the British Museum Jericho skull can be seen as can the plaster plug placed within the foramen magnum The sagittal suture is fused; the squamous suture around the temporal bone is not fused. Asymmetry caused by the modification of the cranium can also be seen



and Goring-Morris 2002, 419; Croucher 2006, 34, 36). Thus, the post-mortem treatment of skulls promoted the idea of a community's shared history and restricted the creation of inherited social status (Kuijt 2000b, 157–9; 2000c, 95–9; Byrd 1994, 656–61; Banning and Byrd 1987, 321–3; Kuijt and Goring-Morris 2002, 420–3).

The link between skull modification and status is both significant and complex (Verhoeven 2002, 249; Goring-Morris 2000, 130; Rollefson 2000, 184; Simmons *et al.* 1990, 109; Kenyon 1960, 51–4; Kuijt 2001, 94). The selection of modified skulls for plastering creates a link between physical alteration and social position. It is particularly important that modification must be done whilst the skull is still growing, suggesting that the affected person was probably too young to have a choice regarding whether their skull was reshaped or not (Croucher 2006, 33). The debate cannot progress because there is currently no accurate data regarding the frequency of cranial modification within Middle PPNB populations. The analysis of the Jericho skull shows that cranial modification is not always easily discernible by eye, yet attempts to quantify the proportion of modified crania present in a population have not used sub-surface examination to quantify the presence of this practice (e.g. Daems and Croucher 2007, 5–8, table 1; Croucher 2006, 32). Therefore, it is possible that deformation is present in more skulls, both plastered and not, than currently recognized, which makes a discussion of the social significance of this practice premature for the time being. In the case of the British Museum Jericho skull, the subtlety of its alteration suggests that the decision to plaster this skull was associated with a collective knowledge of the experiences an individual had undergone during their life. Future work must therefore utilize imaging techniques such as radiography and CT scanning to assess whether modified skulls are disproportionately represented in plastered skulls when compared with undecorated skulls from contemporary burials.

Conclusions

This research highlights the significance of non-destructive imaging techniques and the importance of sub-surface examination for revealing new data concerning existing collections and suggesting further avenues of research for related collections elsewhere. The work has significantly advanced our knowledge concerning how the skull was modified both during life and after death. The previously anonymous individual is now known to be a mature male who most likely suffered from poor dental health. This research has prompted a re-evaluation of the ways in which skulls were selected for plastering, with implications for the interpretation of mortuary practices within the Neolithic period of the Middle East. It is clear that the study of cranial deformation has a crucial role to play in the understanding of skull cults, ancestor worship and their role in social cohesion; perhaps plastered skulls should be viewed as primarily representing life practices, rather than death rituals. Sub-surface imaging has shown that artificial cranial modification can be identified in skulls that were not previously considered as having undergone such treatment and knowledge of this change appears to have influenced the choice of this skull for special treatment after death. This suggests that physical and social alteration may have been linked, but conflicting social messages were also expressed by plastered skulls as they also signified aspects of community-wide ancestor worship.

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