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MODERN VISUALIZATION BY DIGITALLY MODELING NEOLITHIC CRAFTED HUMAN SKULLS

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ABSTRACT:

Our digital modeling in 3D aims to visualize Neolithic crafted skulls found in the Near East for their preservation and study taking into account both the possibilities of skull deformation *in vivo* as well as crafting them postmortem. Decapitation and burying or caching human skulls is met already in Palaeolithic contexts. Postmortem cranial crafting by drilling and carving, or modelling with plaster and asphalt using human skulls as basis was practiced in the Near East during the Pre-Pottery Neolithic and Late Neolithic period. The first examples of plastered human skulls were discovered at Jericho in the 1950s, then belonging to Jordan, after which to Israel and now to the Palestinian territories. Similar skulls were later found in various sites in the Near East. The examples digitally reconstructed here include skulls from Göbekli Tepe and Köşk Höyük found in Turkey, from the cave at Nahal Hemar at the Dead Sea in the Judean mountains of Israel and skulls from Jericho in the Palestinian territories. Both drawings and photographs were used in digitally reconstructing the skulls in 3D. The Blender software allowed us to sculpt the complex shape of the skull from a base mesh. Graphic Processing Unit (GPU) rendering sped up rendering thanks to Nvidia graphics cards. UV mapping was carried out for importing the texture. The visualization enabled us to make further anthropological observations. Beside the generally acknowledged Neolithic "skull cult" we also wish briefly to discuss other reasons for the phenomena and practices.

1. INTRODUCTION

1.1 Burying Detached and Crafted Skulls

In the present study we intend to digitally model and reconstruct some Neolithic crafted human skulls found in the Near East through computer-aided digital 3D imaging and modelling (Silver, 2016) for the documentation, preservation and study of the skulls. As artificially remodelled artefacts these human skulls carry evidence of unique cultural heritage to be preserved and may reveal new features through digital 3D imaging.

Palaeolithic and Mesolithic burials of humans in Europe and the Near East have contained evidence of removal of skulls (Orschiedt, 2018; Trinkaus, 1982). The practice of detaching and crafting skulls appears among the hunter-gatherers of the Neolithic site of Göbekli Tepe, a World Heritage Site situated in Turkey. Göbekli Tepe provides the earliest Neolithic evidence of postmortem crafted skulls in the Near East (Fig. 1). Drilled perforation, carvings and applied color with ochre have been detected on the detached skulls found at the site (Gresky et al., 2017).

Epipalaeolithic Natufians of the Levant, who were foragers practicing incipient cultivation along hunting and gathering, buried the deceased members of the community inside dwelling sites (Valla, 1991). Intramural burial practice continued in the Neolithic period at several sites in the Near East including in the Pre-Pottery Neolithic (PPN) Jericho, earlier situating in Jordan and Israel, presently in the Palestinian territories north of the Dead Sea (Kenyon, 1952–1953; Kenyon & Holland, 1981) as well as in another large PPN Neolithic center of Çatal Höyük in Turkey (Haddow and Knűsel, 2017). In Jericho the excavators noticed in the 1950s that burying the deceased for a secondary burial under house floors (Kenyon, 1952–1953) was reserved to some few members of the population (Kurth and Röhrer-Ertl, 1981, 433) as a special treatment.

Removed and cached human skulls dating to the earliest phases of the Neolithic period, namely to the Pre-Pottery Neolithic A phase PPNA (10,200– 8,800 cal BC) and B phase PPNB (8,800–6,900 cal BC), have been discovered in various sites in the Near East (Fletcher, 2020). A particular feature found among the deceased in PPNB intramural contexts consist of detached human skulls, without and with deforming *in vivo* or postmortem modelling by plastering. Such were found cached inside houses and under house floors in Tell es-Sultan of Jericho in the 1950s. Altogether 14 plastered human skulls were found in the tell of Jericho, and of them seven had remains of painting (Kurth and Röhrer-Ertl, 1981, 436–437).

Neolithic plastered skulls have since been discovered from other sites in Israel (see, e.g., Goring et al., 2001; Slon et al. 2014), Syria (see, e.g., Contenson, 2000), Jordan (Rollefson, 1986; Schmandt-Basserat, 2013) and Turkey (Bonogofsky, 2004; Haddow and Knűsel, 2017). Beside Pre-Pottery B Neolithic Jericho with walls and monumental tower (Kenyon and Holland, 1981) situated in the Palestinian territories the PPNB Çatal Höyűk in Turkey, another large urban type site, has provided such skulls (Haddow and Knűsel, 2017). The Neolithic practice occurring in the Levant and Anatolia has generally been called "skull cult" (Schmidt, 2012).

Among the PPNB communities, such as Jericho, a method of postmortem crafting included plastering (Figs 2, 4–6). Plaster containing lime, gypsum, ash and other sediments was a typical substance that was used for covering building surfaces, making vessels and beads during the PPNB period (Goren et al., 2001; Goren and Goring-Morris, 2008; Nilhamn et al., 2009), and it was used for plastering human skulls and sculpting statues

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(Kenyon, 1952–1953; Kurth and Röhrer-Ertl, 1981, 438; Rollefson 1986). Some remodeling of Neolithic skulls also included the use of clay, such as marl, beside lime plaster (Bonogofsky 2001; Bonogofsky 2004).

In the plastered skulls of Jericho mandibles had been often removed and features were applied with plaster, including in some cases ears and noses even with nostrils. There were examples that appeared to have traces of paint on the surface possibly imitating reddish skin colour, applying black stripes as hair or bandages and moustache. Inserted decoration using shells was executed for marking eyes, and some eyes have even eyelashes (Kenyon, 1952–1953; Kurth and Röhrer-Ertl, 1981, 436–438). "Cut marks" as well as "scratches" have also been observed on skulls discovered in PPN levels at 'Ain Ghazal in Jordan (Bonogofsky, 2001).

In their analyses Gottfried Kurth and Olav Röhrer-Ertl (1981, 445–447) observed that there was a balance of female and male remains in the skeletal finds from the Pre-Pottery Neolithic Jericho. The average height for the female examples was 158 cm and for the male examples 171 cm. The age expectation was ca. 20 years, but 50 % of children and young adults had died before the age of 20. In their craniological studies they found out that the dolichocephalic (long-headed) skull types were in majority, identified with the proto-Mediterranean type.

Apart from intentional postmortem remodeling of skulls with plaster (Kenyon, 1952–1953), the PPNB phase has also provided evidence of human skull modelling with asphalt or bitumen, the practice found in skulls (Fig. 3) from the cave of Nahal Hemar in the Judean mountains at the Dead Sea in Israel (Yakar and Hershkovits, 1988) and 'Ain Ghazal in Jordan (Bonogofsky, 2001).

A limestone mask was also found in the cave at Nahal Hemar. The eyes are round depressions, and there is a small protruding nose. Plaster was used in filling some incisions of the mask that did not utilize human skull as a basis. There was hair, even including lice, and it is possible that moustache or beard had been attached with asphalt around the mouth of the mask. Teeth had been sawn to the mouth to make them visible. The mask had been repainted which may indicate its use in magic and rituals. Similar stone masks have been found in the Judean hills but their exact provenance is unknown. (Bar-Yosef, 2003, 77– 79)

CT-scannings have revealed various features and the construction processes of plastered skulls (see Slon et al., 2014). CT-scannings and micro-focus radiography (MFR) had already been carried out on the PPNB skulls discovered from the site of Kfar HaHoresh in Galilee in Israel in the 1990s reavealing various consistences and densities of layers in the used plaster (Goren et al., 2001). Furthermore, CT-scanning has also been carried out for one of the Jericho skulls kept at the British Museum (BM 127414), and it shows the method of preparing a plastered skull by packing it first with clay. It also was realized that this particular skull had actually undergone intentional modification during the individual’s early childhood (Fletcher, 2020).

Already Eugen Strouhal (1973) studying some plastered skulls originating from the Jericho excavations also noticed that there might have been intentional cranial deformation of some individuals during childhood. Examples of such practice was encountered both in Pre-Pottery Neolithic A and B non-plastered skulls discovered from Jericho as well (Kurth and Röhrer-Ertl, 1981, 439).

The mentioned Jericho skull now at the British Museum (BM 127414) has also earlier been digitally modeled for facial reconstruction using forensic methods by adding tissue on the skull to create a proposed appearance of a Neolithic person (see Romey, 2017; Moraes et al., 2022). Surprisingly the results in the two separate works of the facial reconstruction became quite different in appearance from the same skull. Here we do not intend to proceed to the facial reconstruction but digitally model the existing skulls that had been crafted postmortem in ancient times.

2. DIGITAL RECONSTRUCTION OF SKULLS IN 3D

2.1 Digital visualization

For the present reconstruction earlier published documentation of some skulls from Göbekli Tepe, Köşk Höyük in Turkey and Nahal Hemar in the Judean mountains at the Dead Sea in Israel and from Jericho in the Palestinian territories provide information of measurements of the skulls to enable to construct digital models of them. The results of our digital reconstruction provide rich visual content for use in dissemination of research findings (Figs. 1–6).

By establishing to model, visualize, and reanimate skulls from millennia ago, it is hoped that this work helps to develop hybrid methodologies combing archaeology, anthropology and computer graphics further and provides a new synthesis process through an ongoing feedback loop. The three-dimensional visualization provides an approachable avenue for realizing natural modification as well as intentionally artificially crafted features in the skulls both while alive and postmortem.

Here the digital reconstruction and visualization of the Göbekli Tepe (Fig. 1), Köşk Höyük (Fig. 2) and Nahal Hemar (Fig. 3) crafted skulls are based on published drawings and images of the skulls. The documentation of the three plastered skulls from Jericho (Kenyon, 1953; Strouhal, 1973; Kenyon and Holland, 1981) offers photographs and detailed measurements for the basis for reconstruction and adding texture (Figs. 4–6). See the find locations of the chosen skulls for digital 3D modeling in Figure 7.

First we digitally modeled specimens that did not offer means for texturing. In the Göbekli Tepe specimen crafting had taken place by carving scars and red marks on the forehead (Gresky et al., 2017) on Fig. 1, but no plastering had been applied on surface. In the Köşk Höyük and Jericho examples plastering had been applied to surface (Figs. 2, 4–6), but in the Nahal Hemar skull the substance applied to surface to remodel the skull was asphalt. As visible in the Nahal Hemar skull a plastic pattern resembling braids or a net had also been executed on the skull with asphalt. (Yakar and Hershkovitz, 1988; Arensburg, and Hershkovitz 1989).

Two plastered skulls from Jericho studied by Strouhal (1973) (the National Museum in Amman J5757 and J5758) and presented here (Figs. 4–5) originally belonged to the group of seven skulls, like the British Museum skull (BM 127414), found in the PPNB layers in Jericho (reported by Kenyon and Holland, 1981, Pl. 50, Fig. b, excavation register numbers 529, 530, 532).

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The seven skulls in the group had been discovered in Trench I, DI, level xliii of the plastered floors and seemed to have been thrown away into a pit as unimportant for further use. One modeled skull of the group in our Fig. 6 (Reg. 532, J5738) is a well-preserved famous specimen often presenting the Jericho skulls in publications, but it also was found squeezed in earth without special reverence.

One skull (Reg. 3657) from Jericho that Strouhal also studied and that is digitally presented here (Fig. 4) did not belong to the group of seven skulls. It was stored in the Rockefeller Museum in Jerusalem in Israel and had been originally found in a fill of the PPNB layers in Jericho in much worse condition than those in the group of seven skulls.

2.2 Digitally Remodelling a Human Skull in 3D

The human skull is a multifaceted structure of hard tissue, formed by convolution of different pieces connected to each other with complex geometry. Digital skull models have been developed here, reaching high levels of detail, complexity, and precision.

These models make it possible to study spatially some of the deformations and disfiguring of the skulls and help us to develop head impact scenarios which may account for certain head injuries and deformations. Modelling a skull in 3D starting from 2D reference images (drawings or photographs) required several iterative stages. The stages of our modelling are summarized below (Table 1):

Stage 1: 2D image acquisition for modelling
Modelling the skull in 3D took a lot of studying the parts and forms of each skull from different views. We used reference drawings (Gresky et al. 2017, Skull 3) for digitally sculpting the skull in Figure 1. For 3D modelling of the remaining skulls we used photographs for Figure 2 (Bonogofsky, 2004, Figs 2–4), for Figure 3 drawings (Yakar and Hershkovitz, 1988, Pl. XXIV, Skull 1), and for Figures 4–6 photographs (Strouhal, 1973, Pls. 1–3; Kenyon and Holland, 1981, Pls. 50–57).

Stage 2: Setting the 3D reference frame
This means placing our reference images in the background on three orthogonal planes. Reference images show the same skull at right angles to each other.

Stage 3: 3D sculpting by dynamic topology
A dynamic tessellation sculpting method which is called dynamic topology was implemented in this stage. Through the Blender software this method allowed us to sculpt the complex shape of the skull out of a base mesh by adding details. The Blender software was chosen, because with its 20 different brushes which subdivide the base mesh during each stroke the software provided means to additional control over the topology in comparison to other 3D software, such as 3ds Max.

Stage 4: Texture mapping, shading and lighting
This is an important step to create a faithful and persuasive photographic reality to the skull topology we developed in the previous stages. The output of all surface and volume appearance were carried out by UV mapping (i.e. projecting a 3D model surface to a 2D image for texture mapping) of the texture imported from the reference images plus using shading and controlling lighting interactions on the surface.

Stage 5: Rendering
The 2D images presented in Figures 1 to 6 are the result of the Graphic Processing Unit (GPU) rendering by Nvidia graphics cards instead of the Central Processing Unit (CPU). GPU sped up rendering thanks to Nvidia graphics cards which are designed to do quite a lot of numbering crunching.

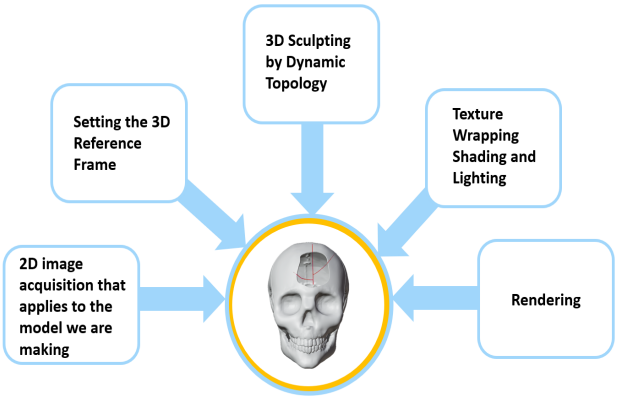

Table 1. The scheme of the applied procedure by digitally reconstructing crafted Neolithic skulls in 3D. constructed by A. Denker.The scheme

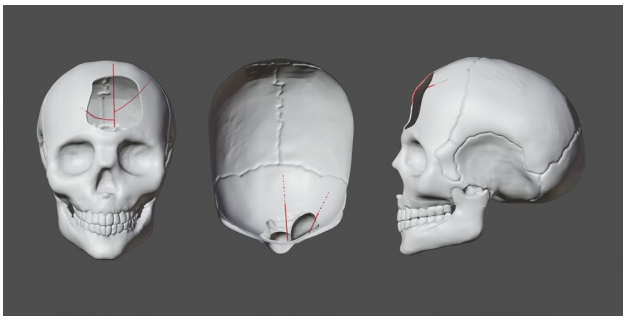

Figure 1. A digital 3D model of a Neolithic human skull from Göbekli Tepe, Turkey. The skull had been recrafted by incisions and painted with red stripes in the forehead of the skull (based on Gresky et al., 2017, Skull 3). Frontal, view of the skull. Digitally remodeled in 3D by A. Denker.

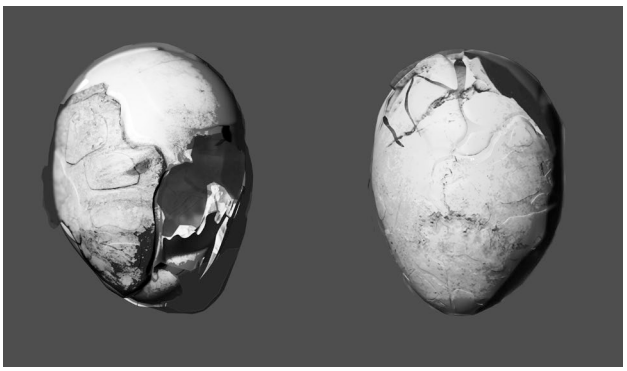

Figure 2. A digital 3D model of a Neolithic plastered human skull from Köşk Höyük, Turkey, based on Bonogofsky, 2004, Figs. 3–4. Posterior view on the right.Digitally remodelled in 3D by A. Denker.

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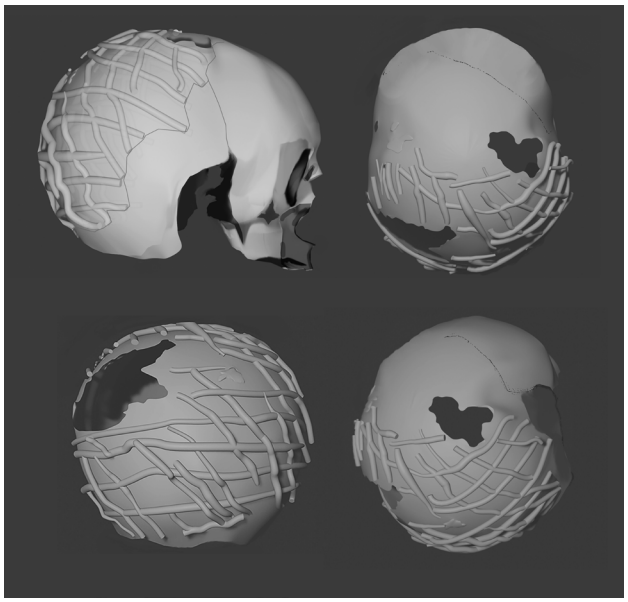

Figure 3. A digital 3D model of a Neolithic crafted human skull from the cave of Nahal Hemar in the Judean mountains at the Dead Sea in Israel covered with asphalt forming plastic crossing braid- or net-like pattern based on Yakar and Hershkovitz, 1988, Pl. XXIV, Skull 1. Views from the top left to the right: lateral view, superior view, posterior view, posterior-superior lateral view. Digitally remodelled in 3D by A Denker.

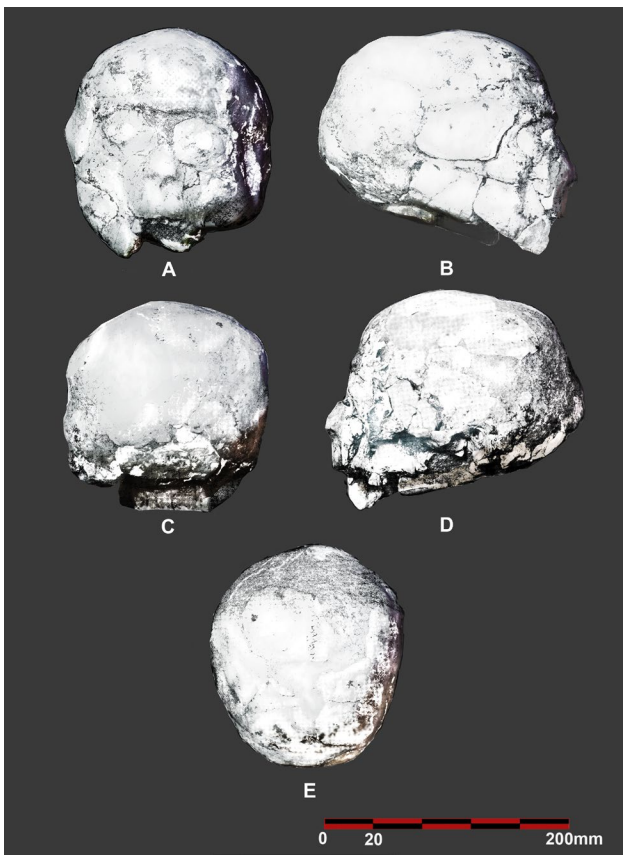

Figure 4. A digital 3D model of a Neolithic plastered human skull from Jericho with inserted shells for eyes based on Strouhal 1973, Pl. 1, and Kenyon and Holland 1981, Pl. 57. A) Norma frontalis, B) Norma lateralis dextra, C) Norma occipitalis, D) Norma lateralis sinistra, E) Norma verticalis. Digitally remodelled in 3D by A. Denker.

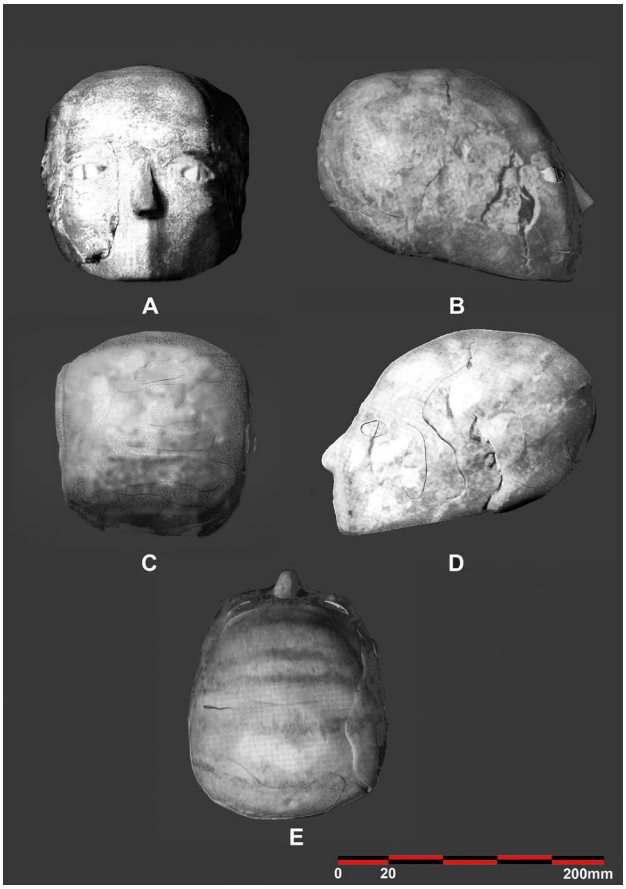

Figure 5. A digital 3D model of a Neolithic plastered human skull from Jericho with inserted shells for eyes and painted stripes on the head resembling bandages or hair based on Strouhal 1973, Pl. 2 and Kenyon and Holland 1981, Pls. 50, 52-53. A) Norma frontalis, B) Norma lateralis dextra, C) Norma occipitalis, D) Norma lateralis sinistra, E) Norma verticalis. Digitally remodelled in 3D by A. Denker.

As mentioned previously, in the case of reconstructing three Jericho plastered skulls digitally the texture was added based on the available photographic data. The texture provides a natural look for a specimen but may sometimes prevent from seeing the structural features of the skull.

3. CRANIAL DEFORMATION

3.1. Artificial deformation *in vivo*

We further wish to present some anthropological observations that are based on the earlier studies and our digitally performed visual reconstruction of the skulls in 3D. By artificial deformation. *in vivo*, i.e. alive is meant that the normal growth of the cranial bones is hindered in certain directions and directed to grow in others that give the desired shape to the head. The procedure usually begins around the age of one month and continues for about six months, sometimes longer.

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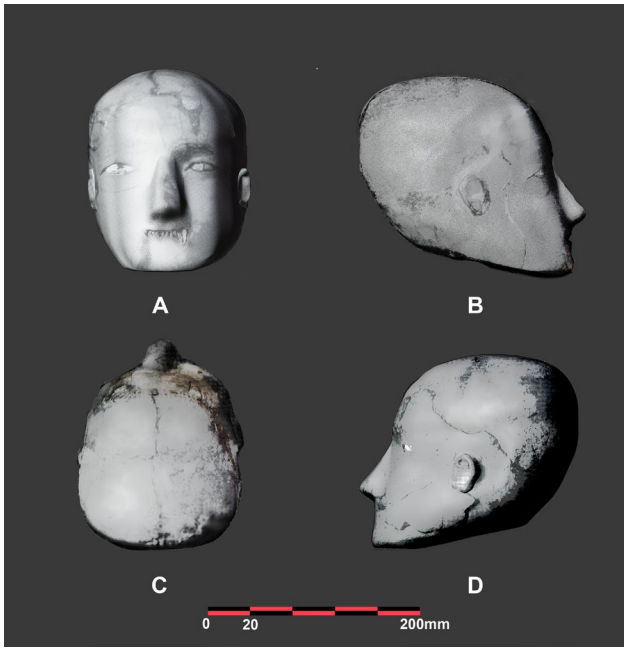

Figure 6. A digital 3D model of a Neolithic plastered human skull (J 5758, Amman) from Jericho with inserted shells for eyes based on Strouhal, 1973, Pl. 3 and Kenyon and Holland 1981, Pls. 50–52. A) Norma frontalis, B) Norma lateralis dextra, C) Norma occipitalis, D) Norma lateralis sinistra, E) Norma verticalis. Digitally remodelled in 3D by A. Denker.

Figure 7. The find locations of the digitally 3D modeled skulls presented in this article.

As mentioned previously, the Neolithic practices at Jericho were not confined to plastering of detached skulls only, but evidence also shows that the practice of deforming human skulls artificially *in vivo* was performed there for several individuals. Kurth and Röhrer-Ertl (1981, 438–458) found that Pre-Pottery Neolithic Jericho skulls had undergone intentional *in vivo* cranial deformation in 28 cases. Evidence of artificial deformation occurred both in male and female skulls, and in various age groups from adults to youngsters and children. In 17 cases the deformation took the form of *deformatio tabulae oblique* (tilted shaped) and in 10 cases *deformation tabulae erectae* (high crown shaped).

As pointed out, artificial cranial deformation *in vivo* (i.e. when individuals were alive) was also observed in the CT-scanned British Museum plastered skull belonging to the group of the seven plastered Jericho skulls. The Jericho example J3657 skull (our Fig. 4) stored in the Rockefeller Museum (now Israel Antiquities Authority) in Jerusalem, is a plastered head that Strouhal (1973, 235) also analyzed and concluded that the skull was deformed but the irregularity could have been caused of postmortal pressure by destruction of building layers. In any case, there is evidence that artificial deformation *in vivo* had already taken place for skulls that had been crafted postmortem by modeling with plaster.

Intentional artificial skull deformation while a person was alive has been practiced in various cultures from prehistoric times, even to modern times. A similar practice was indicated in two Neanderthal related skulls found in the Palaeolithic Mousterian levels in the Shanidar cave in Iraq (Trinkaus, 1982). Apart from the Near East, Southern America and Mesoamerica have brought prehistoric evidence of such practices (Dingwall, 1931; see, e.g., among the Taino people in the Caribbean in Núñez et al., 2023). Cases have even been found in Africa, Far East and Europe dating up to 19th century CE (Dingwall, 1931, see also, e.g., Gèlis, 1984, Pospišilová and Procházková, 2006).

The deformation of the skulls involved the applying certain constraining devices to the skulls of babies, usually from one to six months of age. In some countries a device was attached in a cradle to flatten a skull. Special bandages have also been used to compress the skull when flexible. (Dingwall, 1931). Hippocrates (ca. 400 BCE) mentions a folk called *Macrocephali* "large heads" that had elongated skulls and associates nobility to those who have the longest heads. The deformation took place for children with hands and bandages and suitable appliances when their skulls were tender. (Hippocrates, Introduction, Part 14).

In the Jericho Pre-Pottery A and B population the ratio of deformed skulls *in vivo* was 1 to 7 (Kurth and Röhrer-Ertl, 1981, 437) that would indicate intentional head deformation for a group bearing special social or ritual status.

In the digitally reconstructed Göbekli Tepe skull (Fig. 1) there seems to be a flattened area above the inion, encompassing the union of the sagittal and lambdoid sutures. The angle is not of the type normally seen in unintentional deformation from supine sleeping.

3.2. Metopic suture

Metopism is defined as a condition in which the two halves of the frontal skull bone fail to become obliterated in early childhood and persist into adulthood. Metopism has, for example, been encountered and studied both in ancient as well as among modern populations of Anatolia. However, the phenomenon seems to be more frequent among European populations. (Eroğlu, 2008).

In the Göbekli Tepe skull in the *calvarium* (top of the skull) the sutures are visible. What is interesting is the presence of full metopic suture in this adult individual. The same phenomenon appears in plastered Jericho skulls, for example, in our digitally modelled and textured skull (Fig. 6) identifiable with J5758

stored at the National Museum in Amman, Jordan (Strouhal, 1973, 238–240, Pl. 3, Reg. 532, Kenyon and Holland 1981, Pl. 52). Also, later Neolithic examples of plastered skulls from Köşk Höyük include signs of metopic suture.

The metopic suture normally fuses between 3 and 9 months of age and becomes obliterated by around 6–7 years of age. Metopism, the persistence of the metopic suture into adult age is a relatively rare non-metrical trait and is thought to be hereditary. It tends to be more frequent in females than in males, and its incidence varies from population to population. Metopism has been observed to have caused slightly larger skulls. It is intriguing to find such condition in minority of populations, and reasons for the phenomenon has been looked for. It is worth pointing out that metopism does not lead to visible deformities or disorders like the malformations caused by metopic synostosis, the premature closure of the metopic suture. (Eroğlu, 2008).

Interestingly, the studies of skeletal remains of Bedouin population of the Negev in Israel dating from ca. 200 BP showed exceptionally high percentage of metopic suture among the population of 170 individuals. Therefore, questions of impact of mobility and sedentism may be reviewed in this case, but the genetic inheritance need to be taken into account as well. In the case of the Negev Bedouin population inbreeding in small communities was practiced. (Arensburg et al., 1977). However, in the hunter-gatherer groups the mobility factor could be also studied as the Neolithic skull from Göbekli Tepe belongs to the stage of mobility at the site.

5. THE FUNCTION OF CRAFTED SKULLS

5.1. Art, Ritual or Magic

The plastered skulls have been generally understood as representations of the Neolithic "skull cult". The Jericho excavator Kathleen Kenyon interpreted the purpose of producing plastered skulls in various ways from portraiture to trophies gained in battles or as representations of ancestor cult (Kenyon 1953, 86–87; Kenyon 1957, 62). Some, like Eugen Strouhal (1973), early disagreed with the representation of the Jericho skulls as portraiture. Recently, such modelled skulls have, however, been used as a basis for studying iconographic development during the Neolithic period of the Near East (see Becker et al. eds. 2020).

Denise Schmandt-Basserat (2013) has also paid attention to the process of plastering skulls and fine modeling of them basing her studies on the finds of 'Ain Ghazal in Jordan. Beside human skulls, plaster heads (without human skulls as a basis) and lime plaster statues, have been found in Jericho (Kenyon 1953, 87) and in 'Ain Ghazal in Jordan (Rollefson 2000). Nevali Çori in Turkey has provided a large Neolithic statue, now visible at the Urfa Museum that, however, was executed in limestone (see also Denker and Gurbuz, forthcoming 2023).

One of the most popular explanation that Kenyon already launched was that the skulls were meant for veneration of ancestors. On the other hand, the studies by Kurth and Röhrer-Ertl (1981, 437) put the ancestor cult hypothesis concerning the plastered skulls of Jericho into a new light, when measurements and X-ray studies had been carried out showing that several of the skulls belonged to young adults. In his studies Ian Kuijt (2008) has suggested that the plastered skulls were used in mortuary rituals for communal memorizing and forgetting. One may also wonder whether the Göbekli Tepe skulls were used for ancestor veneration. Or did they represent cult of the dead in general? (cf. Slon et al., 2014). In the case of Göbekli Tepe the sanctuaries with human T-shaped stone pillars and animal symbols have been thought to indicate, not only to hunting rituals, but to the cult of the dead and the underworld (Peters & Schmidt, 2004).

The Jericho plastered skulls that were digitally modelled here were found under house floors which could have indicated to special ancestor veneration but were instead found thrown into fills no longer needed for any special use. Interestingly, the studies of PPNB cranial caches from Tell Qarassa North in Syria have revealed groups of cached plastered skulls with mutilated facial features indicating hostility rather than ancestor veneration (Santana et al., 2012). Were they then trophies? The disposal of a group of Jericho skulls may also indicate to such treatment. The skulls could have been venerated by the previous occupiers but became target of disposal for the following one.

It seems that the skulls were important representation of individuals, whether ancestors, important members or tribes of the society or enemies, so that they could have been used for various magical or ritual purposes depending on the case. That they represented some individuals can be seen in decorating them with special features, although not necessarily intended to be portraits.

5.2 Social denotation, mutilation, spiritual and medical enhancement

There is evidence around the world that artificial cranial deformation for individuals *in vivo* had at least in some cases social meaning, deformed skulls becoming group identifiers and/or status signifiers. In the royal families of Ancient Egypt (Dingwall, 1931) such deformation seems to express a social status and class. The crafted shape could also have been used as a signification of spiritual powers of an individual. Ethnic mutilation has also been suggested for cranial deformation in live individuals (Dingwall, 1931).

Artificial skull deformation *in vivo* has generally been understood as denoting social status of an individual belonging to a certain group or a class. However, we do not know the reason in every case, as some may have had spiritual or medical purposes. Interestingly trephination, surgical operation by a round or an angular incision in skulls of living individuals was used around the world from prehistoric times. Evidence has, for example, been found in Egypt, Sudan, Israel, Iran and Turkey. It has been used in other areas in Africa as well. (Dingwall, 1931; Arensburg and Hershkovitz, 1988).

A hole for one skull from Göbekli Tepe had been drilled, but instead of a trephination the hole was made to suspend the skull (Gresky et al., 2017). Evidence of trephination was, however, found in the Neolithic levels in the tell of Jericho and in the Early-Middle Bronze Age cemetery of the site (Arensburg and Hershkovitz, 1988). In trephination holes had been carved or drilled in skulls, possibly for removal of tumors, ease pressure or excessive pain, but also the intention to release evil spirits may have been one of the functions.

6. CONCLUSIONS

The digital modelling and visualization of Neolithic crafted skulls in 3D provides a way to document the skulls for their preservation and study. This also means preservation them as archaeological finds, part of valuable cultural heritage, and information that they entail for posterity.

We carried out two types of digital modeling: three skulls were modelled without texture based on drawings and photographs and three with texture based on photographs and detailed measurements. The Blender software allowed us to sculpt the complex shape of the skulls. GPU rendering sped up rendering thanks to Nvidia graphics cards. The output of all surface and volume appearance was carried out by UV mapping in applying the texture.

The visualization enabled us to make further anthropological observations. The CT-scannings and 3D reconstructions serve the observation of natural deformation, such as metopism, artificially deformed features *in vivo* or features executed artificially in postmortem, whether with added plastering or other ways of treatment of skulls. The deformation *in vivo* and postmortem treatments became much more visible in 3D than in 2D, but the texturing prevented from seeing some structural features. Therefore, compared to CT-scannings, the 3D imaging and remodelling did not reveal structure of layers or inner fillings.

However, the function of the skulls in each case may have varied. The treatment of the skulls and their find context is of essential importance for interpreting any kind of function. The skulls in public context (like in a temple) and in private sphere (like houses) may have had different kinds of uses. In Jericho several skulls were found abandoned in layers and fills not providing any clear association to the structures of the houses.

In any event, the manipulation of skulls both *in vivo* and postmortem had a special purpose that was confined to skulls. There must have been a thought that a skull was somehow a central part of an individual to produce and express different outlooks or treat it postmortem with a special practice.

The purposes for *in vivo* artificial deformation could have been intended to mark social status and particular spiritual power of an individual. The modelling of detached skulls represent artistic skills expressing individual features, but whether there had been any intention to express portraiture has been debated.

In any event, some ritual purposes such as veneration may be traced in caching skulls inside houses. That there is evidence of mutilation in some cases can indicate to magic performed towards enemies. In Jericho a group of skulls found in fills of buildings seemed to have been thrown away indicating that the disposal may have taken place by new occupiers or even conquerors.

It is now possible to recreate crafted human skulls digitally to visualize them and their particular features for studying the applied techniques and practices more in depth. That some crafted skulls comprised evidence that the persons had undergone artificial skull deformation *in vivo* broadens up the view that in those specific deceased persons or groups of the society, who already had a distinct skull, had been chosen for their skull to be postmortem detached and remodified .

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