Re-Presenting Qatari History: 3D Digitizing Human Remains of Neolithic Age from Wādī Ḍebayān

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Abstract

A program of systematic test pitting at Wādī Ḍebayān as part of the Qatar National Historic Environment Record Project (QNHER) in 2012 revealed the remains of a cemetery of Neolithic date. In 2013 one burial was subject to full excavation and analysis, however, the remains were found to be very poorly preserved, taking considerable time to excavate and careful consolidation prior to lifting. Given the fragile state of the remains, selected bones were subject to laser scanning during conservation and cleaning. This was undertaken in order to create a permanent record that would provide specialists with easy access to the digital archive, without the concern of further damage to the bone. However, such an archive has significantly more potential. By 3D printing laser scans of the skeleton it is possible to provide realistic, full-colour museums exhibits, while to some extent resolving the complex issues associated with the public exhibition of human bone. Such a record also has the potential to provide teaching aids and form the basis for future online digital archives. This research is a collaboration between the Qatar Museums, the University of Birmingham and Texas A&M University (Qatar) and was undertaken as part of the Qatar National Historic Environment Record Project.

Keywords: Laser scanning, Museum exhibits, digital archive, projection mapping

Project background

As the amount of archaeological work in Qatar has increased over recent years, a wealth of archaeological monuments has been revealed, spanning periods from the Palaeolithic to the later Islamic. Nevertheless, due in part to the hyperarid climate in Qatar, the survival of organic and environmental proxy data, including bone assemblages from the Neolithic period (*c*.7500-5,800BP), is extremely rare and its discovery fortuitous.

During 2012 metatarsals from a human skeleton were discovered during test pitting at *Wādī Ḍebayān*, in the north-west of Qatar, where extensive human occupation has been radiocarbon dated between *c*.7,500 and 4,500BP (Al Naimi, F. *et al*. 2011: Cuttler, R. *et al*. 2011). Further excavation in 2013 showed the remains were 60% complete and included the cranium and a suite of post cranial remains, and have tentatively been dated by the presence of ʿUbaid pottery within the grave fill and overlying stratigraphy to the fifth millennium BC (Zamora *et al*. forthcoming). The individual was identified as a female from the presence of a broad sciatic notch. The left clavicle appeared fused, and wear on the teeth suggested the individual was around 35-45 years old at the time of death (Figure 1). These remains are somewhat unique as excavation showed that the body was interred without the traditional presence of a burial cairn. These findings provide a rare opportunity to examine one of the most complete Neolithic skeletons yet discovered in Qatar.

Figure 1: Osteoarchaeologist Lawrence Owens inspects the maxilla insitu

Figure 2: The pelvis with surface concretions

Given the age of the remains and the environment in which they had been buried, the standard of preservation was relatively good; nonetheless the bones were extremely fragile. Manipulating and curating such rare and fragile material, whilst obtaining as much data from the remains proved to be challenging. In order that the remains could be lifted, paraloid resin and acetone was used to stabilise the the bones and ensure they remained complete (*Ibid*). Due to digenetic processes (a combined result of decomposition and later dissolution and recrystalisation of both the surrounding bedrock and similar activity associated with the bones themselves) the skeleton was encrusted with cemented gypsum, which required removal prior to comprehensive analysis (Figures 2 & 3). Given their fragility, removal of surface accretions and the subsequent analysis of the remains proved problematic. As a result the researchers considered alternative methodologies that would facilitate non-destructive analytical techniques and make the bone assemblage available to a wider range of specialists and researchers.

Together with specialists from Texas A&M the team from the Qatar Museums and the University of Birmingham digitized the skeletal assemblage under laboratory conditions. Whilst 3D laser scanning has been used previously to record *in situ* human burials and palaeopathology (Kuzminsky & Gardiner 2012:

2744-2751); the scanning of a complete/semi complete set of remains in order to produce an avatar or archive, has never been attempted on assemblages from the Arabian Peninsula. This digital assemblage not only provides a data set to facilitate further analysis of the remains, but offers an opportunity to explore how technologies such as 3D printing and augmented reality may be used to enhance the display and interpretation of human remains in museum environments.

Figure 3: The left humerus after cleaning and conservation

Aims and objectives

The aim of laser scanning the skeletal remains from *Wādī Ḍebayān* was to:

- Investigate the efficiency of laser scanning techniques in recording data during the excavation of fragile bone, and so record data that could otherwise be lost.
- To aid osteoarchaeological investigation of the remains.
- To investigate further techniques such as 3D printing, projection mapping and augmented reality for the display of skeletal remains in museums in Qatar.
- To develop a methodology for a full digital recording program of Qatar's prehistoric skeletal remains that could facilitate a future online archive.

Methodology

Laser scanning was undertaken at Texas A&M's Qatar campus using a Creaform C-Track 780 Scanner and handheld MetraSCAN 70. This equipment allowed for a greater freedom of movement and flexibility than table top scanners. The scanner also has an advantage over CCM 3D contact scanners in that there is no contact with the object being scanned. Importantly, this means there is no risk that the process of scanning the remains might modify or damage them. An internal coordinate system is used to reference and collect data, where the position of the scanner must be determined when the scanner is in motion. The MetraSCAN also features dynamic referencing, which automates the alignment of scans to each other based on the internal coordinate system. This vastly speeds up data processing, often considered a hindrance to complex, high resolution object scanning. Prior to the commencement of scanning, trial scans we made at different resolutions in order to determine the optimum scan settings. Higher resolutions produce more detailed information; however, the resulting dataset is exponentially larger. After testing it was decided the optimum scan resolution for the bone assemblage was 300 samples per inch. This resolution was found to give a sufficiently high data quality; allowing high preservation of detail with an acceptable collection time (Figure 4).

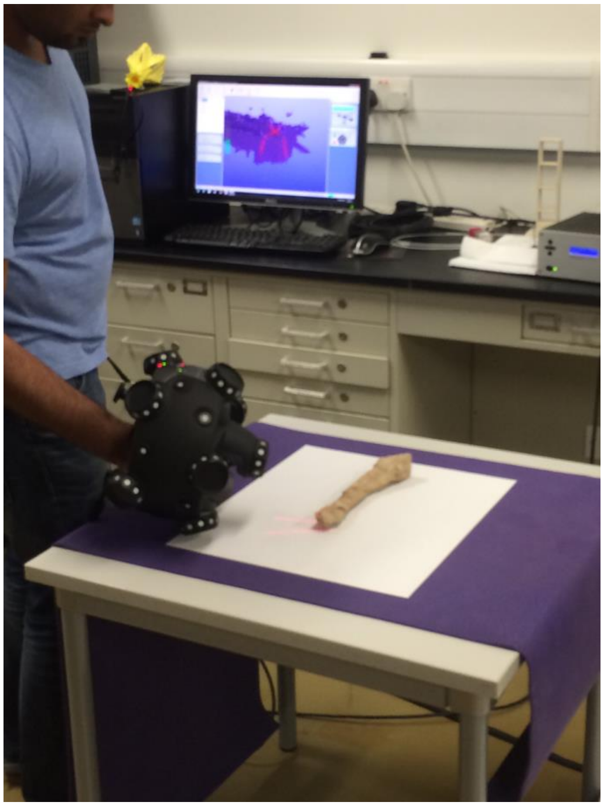

Figure 4: Scanning the bone using the handheld MetraSCAN 70

The remains had been subject to digenetic processes leaving very little of the original matrix. This fragility required the bones to be carefully lifted. In order to preserve as much of the integrity of the bone of possible, during excavation the bones were removed with the surrounding context still intact. Prior to scanning and within the laboratory environment, this additional material was carefully removed from each bone. Invasive 'cleaning' that might affect the integrity of the bone, was only undertaken on the rendered digital image, thus preventing further physical damage to the bone surface.

Three scans were taken for each for the long bones, including the clavicle, which had all survived in reasonable condition. However, the bones of the right side of the skeleton were much more heavily concreted with surface detritus than those from the left side. A single pass, inclusive of rendering time, took approximately 20 minutes, with the scan of each bone taking approximately one hour to complete. Due to their size and complexity, several more scans were required for the pelvis and cranium. A Canon 5D MKIII was then used to take high resolution photographs of each bone (4-5 of each) in order to add colour and to define the texture of the 3D render in SolidWorks.

Initial results

The scans produced were of a very superior quality and preserved a level of detail that was desirable for specialist analysis (Figure 5), with the preliminary (untextured) renders providing important information about the bone. Analysis of the model revealed a potential ante mortem fracture of the left humerus and allowed confirmation that the distal epiphyses of the clavicle was fused, further substantiating the previous age at death estimate.

However, these initial scans had varying levels of success. The registration of the scans by the software (VXElements), which normally would automatically produce a digital model, was not accurate enough to provide a suitable composite model from the separate scans. This meant the bones were not able to be fully compiled into the 3D model, even manually, as the degraded bones lacked appropriate, common registration points within the internal coordinate system. This means that bones may require scanning with reference markers (normally reflective tabs adhered to the object), or manual rectification, neither of which present an ideal solution to the scanning of large assemblages. Since the laboratory time available at Texas A&M was limited, automated registration was key to providing a compiled digital archive. Similar projects in the future might consider scanners with improved external referencing, such as a scanner linked to a mechanical arm allowing for automation of the model building process. This is an important issue since manual post processing and compilation of individual scans is particularly time consuming and will add considerably to a research project budget.

Figure 5: Three untextured renders of the left humerus (MetraSCAN 70)

Photogrammetry

While photogrammetry was not a main objective of the research, a small amount of time was given to the use of high quality photographs and the production of 3D photogrammetry models. Over the past few years photogrammetric software has undergone considerable development, and has become available in a variety of formats, from Iphone apps to fully professional editing suites. Photogrammetry allows for rapid data collection and automated registration, which means the cost of producing full colour 3D models has become quick and relatively inexpensive. High resolution images of each bone were taken using a Cannon 5D MKIII. These were then processed using Agisoft PhotoScan Professional Edition to produce a 3D model. While both laser scanning and photogrammetry have had significant success with large objects or buildings (Moulden *et al*. 2011), it was considered that the level of detail that was produced by photogrammetry is currently insufficient for the needs of specialists. Comparison between the two models would suggest the untextured model produced by the scan was a much more accurate product. However, the speed at which a model can be created by using photogrammetry means there is very little loss in terms of time, and such models create useful reference points (Figure 6). Given the recent advances in photogrammetry software it is not difficult to imagine that such software may be capable of producing 3D models of comparable quality to that produced by scanners in the near future.

Figure 6: A 3D photogrametric model produced using Agisoft PhotoScan

DISCUSSION AND CONCLUSIONS

The option to lift fragile artefacts and scan them in the laboratory during the removal of surface accretions, demonstrates the significant potential of laser scanners as a future tool for specialists undertaking laboratory conservation and cleaning. Laser scanning provides the option to review this delicate process, particularly where artefacts are in danger of fragmentation once they are moved from the laboratory. In addition by 3D printing the digital model it is possible for specialists to manipulate exact physical models without the risk of damaging rare and fragile material.

Digital scanning and excavation of bone presents problems when attempted on very cemented remains that cannot be excavated without damage to the integrity of the artefact. However, the burial from *Wādī Ḍebayān* was an interesting subject for this, as more concreted gypsum had adhered to the right side than the left. Since skeletal remains are largely symmetrical, this offers the opportunity to scan the bones along one side and mirror the digital model in order to provide the opposite side. Such a process would not aid analysis, but could be used for aspects such as facial reconstruction or museums displays. Such models also provide invaluable teaching tools and the basis for online digital archives and reference assemblages. The digital render may also form the basis of a 3D avatar, providing comment on stature, disease, trauma and cause of death.

Museums development

While the benefits of laser scanning technology for fragile artefacts is clear, the production of 3D models has much greater potential for the future development of interactive museum exhibits. The innovative Reykavík 871±2 museum in Iceland is an exceptional example of this and for a long time the Jorvik Viking Museum used these technologies very successfully. Archaeological features and reconstructions at these museums have been incorporated into state of the art digital and interactive exhibits which have included multimedia applications, projection mapping and augmented reality. The development of the new National Museum makes this a highly feasible application for Qatar.

3D printing, contextualisation and projection mapping

In Arabia (and many parts of the world) the display of human remains is a sensitive issue, and it is often a challenge to present prehistoric burials in regional museums in a way that is both informative and acceptable. Displays featuring a virtual or a physical 3D printed model is a way to respect sensitivities associated with burial archaeology while providing meaningful and engaging information. Within a museums environment replicas also have the added advantage of replacing fragile and friable artefacts that may not withstand long-term display. Future reconstructions could include dynamic, digital renders of the extrapolated environment and the wilder landscape from the time of burial. This would be an important opportunity to show the interaction between human groups, the landscape, their environment and their response to sea level change. From environmental proxy data the University of Birmingham and Texas A&M recreated the landscape around *Wādī Ḍebayān* as a 3D visualisation (Tetlow *et al*. 2012) that could easily form the basis for an interactive contextualised display.

Projection mapping onto large buildings has recently become very popular, however, the technique has the potential to be applied to 3D printed bone assemblages as a part of an interactive display. This offers the opportunity to provide textures to 3D prints and allow the visitor to interrogate the model for information about prehistoric burial practices. The results from a CT scan of the bones, and in particular the skull might also allow for more detailed projection mapping of the forensics or palaeopathology onto the untextured model.

Over the past six years the University of Birmingham have included investigation into prehistoric burial practices in Qatar as a part of the QNHER project research framework. The 2013-14 season has seen the discovery of inhumations from several different periods of prehistory (Izquierdo Zamora *et al*. 2014, this volume), all of which are in better condition than the one used for this research. This presents the possibility of refining the process, which should remove some of the difficulties encountered with scanning badly degraded remains. This work will therefore form part of a larger corpus of research which combines standard techniques with more innovative work such as isotopic and DNA analysis to determine geographic origin and diet.

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