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CRANIA CANARIA 2.0: CONSTRUCTING A VIRTUAL SKULL COLLECTION

CRANIA CANARIA 2.0: CONSTRUYENDO UNA COLECCIÓN VIRTUAL DE CRÁNEOS

Alexia Serrano-Ramos *

Department Prehistory and Archaeology, University of Granada, Campus Universitario de Cartuja, 18071, Granada, España.
alexia.serrano.ramos@gmail.com

Highlights:

- "El Museo Canario" stores an exceptional human skull collection that has served as the basis for numerous studies seeking to reveal the origin and chronology of the indigenous population.
- This study presents an easy methodology for obtaining digital imagery using a 3D surface scanner, which allows constructing a virtual skull collection comprising more than 400 individuals.
- Virtual 3D models have numerous advantages and applications in anthropology and archaeology, not only improving research but also permitting the re-evaluation of old paradigms.

Abstract:

"El Museo Canario" stores a large collection of aboriginal skulls that have been essential to study the origin and chronology of the Canary archipelago population since the 19th century. Regrettably, research has been dominated by biased and *racial* interpretations of both bioarchaeological and cultural evidence. When scientific racism and craniometric studies were rejected, studies of the Canarian indigenous skulls variability ceased without replies. However, digital technologies and virtual sciences allow us to improve research and re-evaluate old paradigms. This paper presents a digitalisation project aiming to construct a virtual database of the indigenous Canarian skulls, using a simple method of digitalisation that is very suitable to deal with large collections- The procedure, involving a portable 3D structured light scanner, has allowed us to digitally reproduce more than 400 skulls stored at "El Museo Canario". This work offers a wide variety of possibilities for archaeology and anthropology. The versatility of 3D digital models enables the generation of interactive documentation, as well as educational material for digital conservation and dissemination purposes. Moreover, 3D models are easily shared and can be displayed over diverse web-based repositories and online platforms and so, creating virtual online museums. We have created a profile in Sketchfab (https://sketchfab.com/craniacanaria2.0) where we intend to gradually upload the complete virtual collection of skulls. It must be emphasized that digital skulls can serve as research objects. This paper discusses the advantages of studying 3D objects in a computerised environment, which includes traditional anthropometric studies (linear measurements and angles) but also 3D geometric morphometric approaches. In fact, in future studies, we will apply 3D geometric morphometrics for reassessing skull variation of ancient Canarians going beyond old paradigms and taking into account the latest advances in archaeology, anthropology and genetics in Canarian research.

Keywords: 3D scanning; virtual archaeology; virtual anthropology; aboriginal Canarian; digital skulls; museum collections

Resumen:

El Museo Canario conserva una extensa colección de cráneos de los antiguos canarios que ha sido esencial para el estudio del origen y la cronología del poblamiento temprano del archipiélago canario desde el siglo XIX. Lamentablemente, la investigación estuvo dominada por interpretaciones sesgadas y raciales tanto de las evidencias bioarqueológicas como culturales. Cuando los estudios raciológicos y craniométricos fueron rechazados, el estudio de la variabilidad craneal de los aborígenes canarios fue abandonado sin réplica. Sin embargo, las tecnologías digitales y las ciencias virtuales nos permiten implementar la investigación y re-evaluar antiguos paradigmas. En este trabajo se presenta un proyecto de digitalización que pretende construir una base de datos virtual a partir de una metodología de digitalización sencilla –muy adecuada para lidiar con grandes colecciones– con un escáner portátil 3D de luz estructurada, que nos ha permitido obtener más de 400 cráneos digitales alojados en El Museo Canario. Este trabajo de digitalización ofrece numerosas posibilidades dentro de la arqueología y la antropología. La versatilidad de los modelos digitales permite la generación de documentación más interactiva, material educativo, la conservación digital y la difusión. De hecho, los modelos 3D se pueden compartir fácilmente y existen diversos repositorios web y plataformas que permiten su visualización, permitiendo la creación de museos virtuales. Hemos creado un perfil en Sketchfab (https://sketchfab.com/craniacanaria2.0) donde iremos subiendo los modelos 3D obtenidos. Asimismo, los cráneos virtuales pueden emplearse como objeto de estudio. Se discuten las ventajas que ofrece el estudio de objetos 3D dentro

*Corresponding author: Alexia Serrano-Ramos, alexia.serrano.ramos@gmail.com

de un entorno computerizado, incluyendo estudios antropométricos tradicionales (medidas lineales y de ángulos) como de morfometría geométrica 3D. De hecho, en futuros proyectos se utilizará la morfometría geométrica 3D para re-evaluar los antiguos paradigmas sobre la variabilidad craneal de los antiguos canarios a la luz de los últimos avances en la investigación arqueológica, antropológica y genética canaria.

Palabras clave: escáner 3D; arqueología virtual; antropología virtual; aborígenes canarios; cráneos digitales; colecciones de museo

1. Introduction

1.1. The Canarian context

The Canary Islands are located off the northwest African coast (Figure 1). Although different hypotheses have been put forward for the early settlement of the archipelago, the most accepted one is that the islands were inhabited by Berber groups during the outset of the first millennium AD (Fregel et al., 2019 and references therein). Later on, at the end of the 15th century, the archipelago was conquered and colonised by Corona Castellana. The funerary customs of the ancient Canaries (mummification, tumuli and funerary caves) favoured the preservation of human remains and sparked further interest in research. Furthermore, controversy regarding the origins of indigenous Canarians, started after their similitudes with Cro-magnon 1 were remarked (Quatrefages & Hamy, 1874), thus turning the ancient Canaries remains into study objects of the new anthropological science.

El Museo Canario (EMC) (Las Palmas de Gran Canaria, Canary Islands, Spain) was created in 1879. It houses a large collection of indigenous skulls, assembled to preserve from plundering (Ortiz García, 2016) and to serve as a pivotal centre for studying the indigenous culture. The strong anthropological character of scientific research in the Canary Islands has been determinant for the preferential gathering of human remains (especially skulls). This is clearly demonstrated by the collections at the General Archive of EMC, where a great number of skulls dating to the late 19th century are registered (Santa Jubélls, 2003). A 1909 inventory reports a total of 991 skulls, 250 jawbones, several mummies and some complete skeletons (Herrera Piqué, 1979). In the 1960s, Schwidetzky (1963:25) was able to study 1231 skulls from Gran Canaria Island. The enormous bioanthropological collection of the EMC is kept mostly in storage rooms, although the museum maintains two halls dedicated to anthropological research, displaying shelves full of skulls and several mummies, in keeping the style of early museums. (Figure 2).

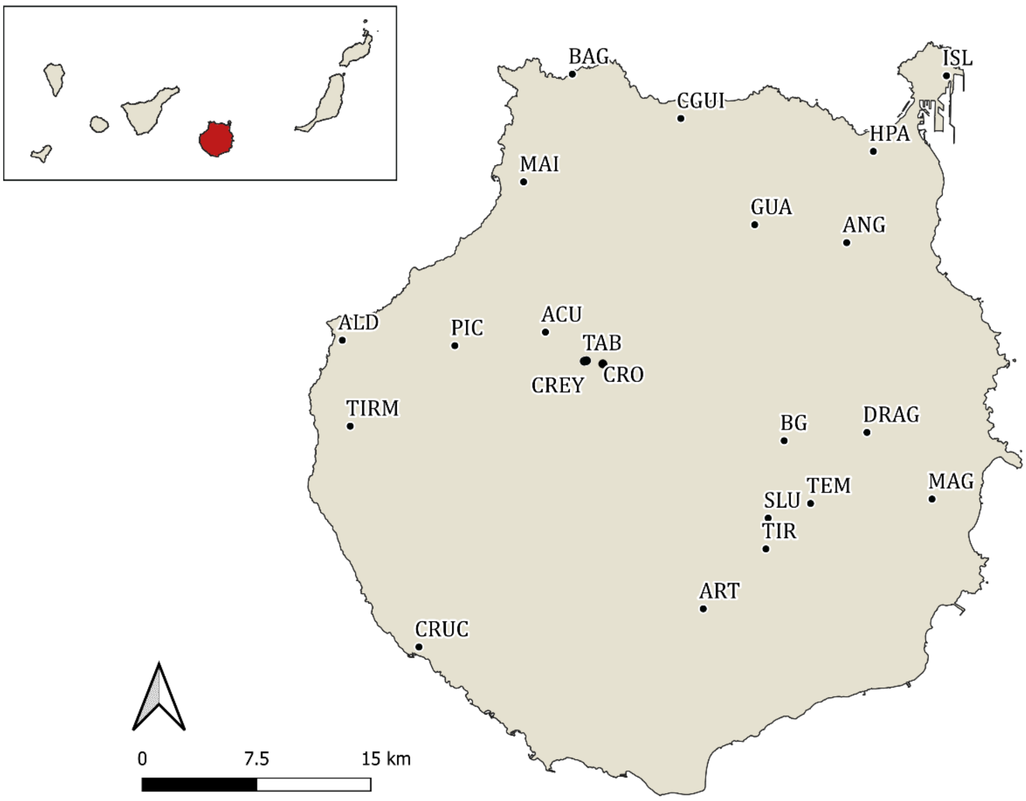

Figure 1: (Top left) Situation map of the Canarian archipelago; (Right) Situation map of the localisation of the main archaeological sites of Gran Canaria were the digitalised skulls come from. BAG: Bocabarranco-Agujero-La Guancha; CGUI: Cuevas de Guía; HPA: Hoya del Paso; ISL: La Isleta; MAI: Maipes de Agaete; GUA: Guanchía; ANG: Angostura; ALD: Aldea; PIC: Picachos; ACU: Acusa; TAB: Andén del Tabacalete; CREY: Cueva del Rey; CRO: Cueva del Roque; TIRM: Tirma; BG: Barranco Guayadeque; DRAG: EL Draguillo; SLU: Santa Lucía; TEM: Temisas; TIR: Cuevas de Tirajana; MAG: Montaña de Agüimes; ART: Artenara; CRUC: Las Crucesitas.

Figure 2: Screenshot of the virtual tour at EMC at one of the rooms dedicated to the anthropological research of aboriginal Canarian. https://mpembed.com/show/?m=3UcQkysU2eC&mpu=78 (Retrieved October 3rd, 2020).

The early configuration of the EMC has resulted in some limitations of the skull collection (Schwidetzky, 1963), the most relevant of which being the absence of a comprehensive archaeological context. In spite of this, an extensive group of anthropologists (see Farrujia de la Rosa, 2007) has studied the collection in order to elucidate the origin and chronology of the indigenous population of the Canary Islands. Regrettably, research has been dominated by biased and racial interpretations of both bioarchaeological and cultural evidence. Moreover, the binomial Race & Culture persisted as the principal argument to explain human variability in the archipelago, even in the second part of the 20th century. Specifically, Fusté (1958-59; 1959; 1960; 1961-62) and Schwidetzky (1957; 1963; 1980-81) concluded that two different races characterised the populations inhabiting Gran Canaria Island at different times, and that they had different cultural practices (tumuli vs funerary caves), site locations (inland vs coast), biogeographic area (southwest vs northeast) and different grades of “civilisation”. Notwithstanding the racist bias, research on the Canarian indigenous skulls variability was abandoned without responses. Rejecting scientific racism meant not only the end of craniometrical studies but also the abandonment of the population wave hypothesis and the rise of isolationist positions. Nevertheless, recent interdisciplinary research, involving both radiometric dating (Alberto, Delgado, Moreno & Velasco, 2019; Velasco-Vázquez, Alberto-Barroso, Delgado-Darias & Moreno-Benítez, 2021) and paleogenomics (Fregel et al., 2019) has caused some to take in account the population wave hypothesis once again.

1.2. Digital applications in archaeology and anthropology

Digital technologies are becoming common in museums, archaeological sites and cultural heritage projects. Digital objects are very easy to share through the Internet and effortlessly reach a massive audience, breaking the limitations of physical space linked to traditional exhibitions and turning them into “portable heritage” (e.g. Reinoso et al, 2020). Likewise, digitalisation allows us to transcend accessibility restrictions and overcomes the difficulty of interaction with the artefact that may be due to fragility, uniqueness, lack of physical space for exhibition (Kyriakou & Heremon, 2018) and problems relating to grant access for small collections and/or museums (Erolin, Jarron & Csetenyi, 2017; Rangel-de Lázaro, Martínez-Fernández, Rangel-Rivero, Benito-Calvo, 2021). In addition, we can create virtual teaching/learning environments (e.g. Craneoteca[1]; Serrano-Ramos, Jiménez Arenas & Esquivel, 2016).

Virtual imagery has become a commonly used tool in Physical Anthropology, particularly concerning the study of the shape of human skull and in fact, it has become a discipline in itself (Weber & Bookstein, 2011). Virtual anthropology begins with the acquisition of images (by means of photographs, surface scanning or 3D scanning). The obtained images are assembled to reconstruct a 3D virtual object in a computerised environment using specific software. From this point forward, a universe of possibilities opens up, diverging from “traditional approaches” since presenting significant advantages (e.g. Reinoso et al., 2020; Weber, 2014). One of the most evident possibilities is the transit from virtual reality to real virtuality (Zollikofer et al., 2005), which allows us to make almost perfect copies using stereolithography apparatus (3D printers). Depending on the method of image acquisition, it is even possible to access internal structures such as endocranium and osseous labyrinth (e.g. Conde-Valverde et al., 2021; Ponce de León et al., 2021). In addition, virtual restoration follows reversible procedures without compromising the physical integrity of the fossils (Bauer & Harvati, 2015; Zollikofer et al., 2005). Once the images have been appropriately obtained and stored, any destructive sampling that may be desired to increase different kinds of information (e.g. DNA, biogeochemistry, dating, etc.) becomes less problematic (see discussion in e.g. Ponce de León et al., 2018).

[1] Departamento de Prehistoria y Arqueología, Universidad de Granada. http://prehistoriayarqueologia.es/craneoteca

Obviously, digitization of skulls permits carrying out high-resolution morphometric analysis (see e.g. Cardini & Loy, 2013). Lastly, we can also move beyond Virtual Reality (VR) to attain Augmented Reality (AR), thus incorporating different layers (levels) of information (Kyriakou & Heremon, 2018).

1.3. Research goals

Taking into account the specificity of the skull collection housed at the EMC and the possibilities for the image acquisition and processing, the main goal of this project consists in the creation of a virtual database –*Crania Canaria* 2.0– that could serve as a digital catalogue. While its uses cover a range of conservation and dissemination purposes, it can also be used for research objectives; specifically regarding the re-evaluation of human variability outside scientific racism perspectives. Additionally, we present an easy to use methodology for digitalisation that is very suitable to deal with large collections; we show the results from the digitalisation process; and we discuss the possible uses for these virtual models in archaeology and anthropology in general, and Canarian research in particular.

2. Materials

One of the advantages of this skull collection is the large number of individuals held at the EMC, allowing us to select the best-preserved adult specimens. Most of the skulls are lacking their associated mandible, and so were digitalised in their partial state (only a few of the skulls have their mandibles attached with a spring system).

During a period of only 20 days of work at the EMC, 418 skulls were digitalised. Most of these skulls are attributed to Gran Canaria Island indigenous populations (N=350), while others derive from the rest of the archipelago (N=39) and a small heterogenic sample from around the world (N=29). The skulls from Gran Canaria (Figure 1 and Table 1) come from several different sites from all over the island. The rest of the archipelago specimens are represented by skulls from Tenerife (N=23), Fuerteventura (N=11), El Hierro (N=4) and La Gomera (N=1). The exogenous series held at the EMC belongs to individuals coming from current Guinea (N=6), Peru (N=4), Chile (N=2), USA (N=1), France (N=12) and the Basque region in Spain (N=4).

3. Methods: Digitalising with a 3D surface scanner

Acquisition and data registration was carried out at the EMC with a 3D scanner structured light MHT ARTEC (Figure 3), which provides a maximum error of ±0.5 mm. It is a portable scanner capable of capturing objects at a sample rate of 15 frames per second, assuring the superimposition between frames while moving the scanner around the object. Furthermore, it incorporates a photographic camera that acquires automatically referenced images, allowing the generation of a photorealistic texture of the object.

The scan files were processed with Artec Studio 10 Professional software, which enables the handling of both the point cloud acquisition process and the post-processing of the data (point cloud, solid mesh and

Table 1: Digitalised skulls from Gran Canaria.

Sites	*Skulls*
Barranco Guayadeque	168
Tirajana	26
Bocabarranco-Agujero-Guancha	23
Acusa	18
Santa Lucía	14
Túmulos La Isleta	13
Mogán	11
La Angostura	9
El Draguillo	8
La Aldea-Caserones	8
Temisas	6
Gáldar (indet)	6
Montaña Agüimes	6
Cuevas Guía	5
Andén del Tabacalete	4
Necrópolis del Maipez	4
Hoya del Paso	3
Necrópolis de Arteara	4
Los Picachos	2
Tirma	2
Cuevas del Roque	1
Cuevas del Rey	1
Tejeda (indet)	1
Fuente de Sao	1
Fuente Morales	1
Guanchía	1
Almogaren	1
Lomo San Pedro	1
Pago de la Angostura	1
Cueva Barranco Hornillo	1
TOTAL	350

Figure 3: View of the workspace at the EMC assigned for digitalising, some of the skulls and the scanner used in this project.

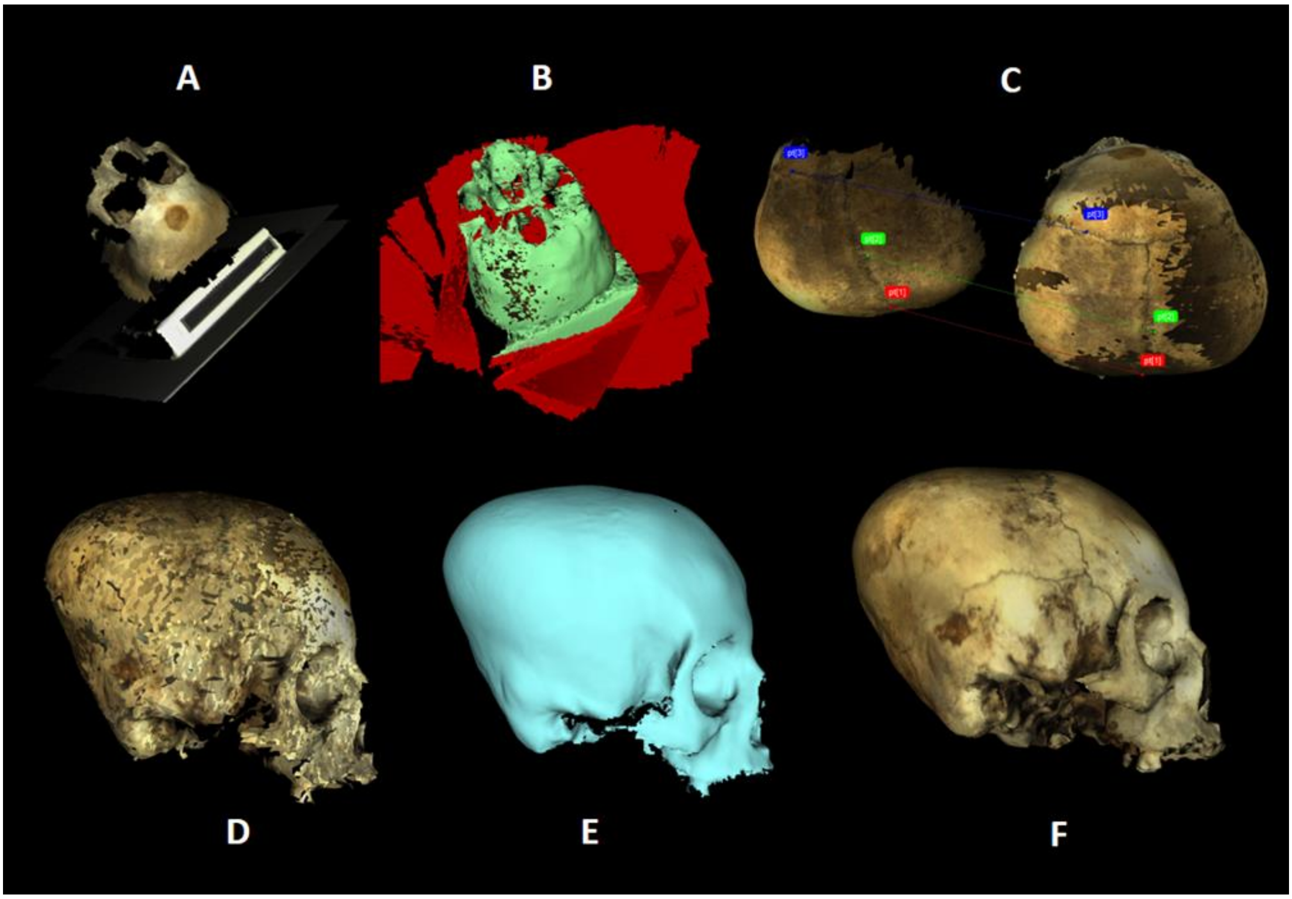

Figure 4: Digitalising process of an artificially deformed skull from Pachacamac (Peru) hosted at EMC: a) Raw data; b) Cleaning unneeded data; c) Alignment of the different scans; d) Point cloud aligned; e) Fusion into solid mesh; f) Solid mesh texturized.

texturing) as well as other optimization operations and metric and geometric analysis. The PC was a Windows 7 operating system, x-6 based processor and 64-bit operating system processor, with 8 GB of RAM, 512 GM of internal disk and NVIDIA graphic card.

Homogeneous and accurate results require the development of work protocols for data acquisition. In this sense, we carried out several tests involving light conditions, scanner movements (speed, directions), and the number of scans per object –between 6 and 8– to set up working guidelines that allowed us to obtain both quality scans and an optimised workflow. Particularities in some skulls required some alteration of the working guidelines for better results.

The scan files are composed of point clouds (Figure 4a) that also include the information of the space surrounding the object, and thus this data has to be removed (Figure 4b). The next step is aligning the different scans through homologous points in a single coordinate system (Figure 4c). The global optimisation of frame positions algorithm selects a group of geometric unique points in each frame and optimizes the position of all the frames, correcting errors and alignment anomalies (Figure 4d). Following this, the scans are integrated into a geometric model via a geometric algorithm –fusion– that interpolates multiple views and generates a solid mesh based on triangles (Figure 4e). During the process, it is possible to reconfigure the resolution/size of the triangulation of the grid in millimetres. Then, the mesh can be checked for small defects: outliers, filling small holes and surface smoothing. Finally, we can texturize the solid mesh (Figure 4f). In this work, we have used the “generate textures atlas” method, which cuts the surface into pieces, unfolds and nests them on a flat plane and fits them into an image of a specified size. The textures were generated with 8192 x 8192 pixels.

4. Results

We have been able to digitalise 418 skulls hosted in the EMC. The data acquisition (scans) took less than five minutes per skull. Full 3D modelling with texturisation required around 25 minutes per model. Thus, the construction of the virtual skull collection was achieved after 210 h of work.

Our digital skulls present very accurate mesh, even when digitalising some delicate items such as those with pathologies and alterations, for example those with cranium trepanation (Figure 5a), evidence of sutures, and varying stages of dental disease. Nevertheless, skulls present a complicated topography due to concavities, foramen, fossae and processes. All of this may naturally result in lower quality, especially affecting the texture but sometimes even parts of the mesh, in some areas of the skull (e.g. nasal and ocular cavities, base of the cranium), or for very thin elements of the skull, such as the temporal styloid processes, which are indeed rarely preserved in ancient skulls. We have not been able to digitise these former features (Figure 5b).

We have created 2D charts from the 3D virtual skulls including frontal, left and right lateral, occipital, basilar

Figure 5: A) Photography – left – and rendering of the digital model – right – of the skull 1826, which shows an example of skull trepanation, successfully digitalised; B) Photography – left – and rendering of the digital model – right – of the skull 1488 showing the temporal styloid process, which was not successfully digitalised.

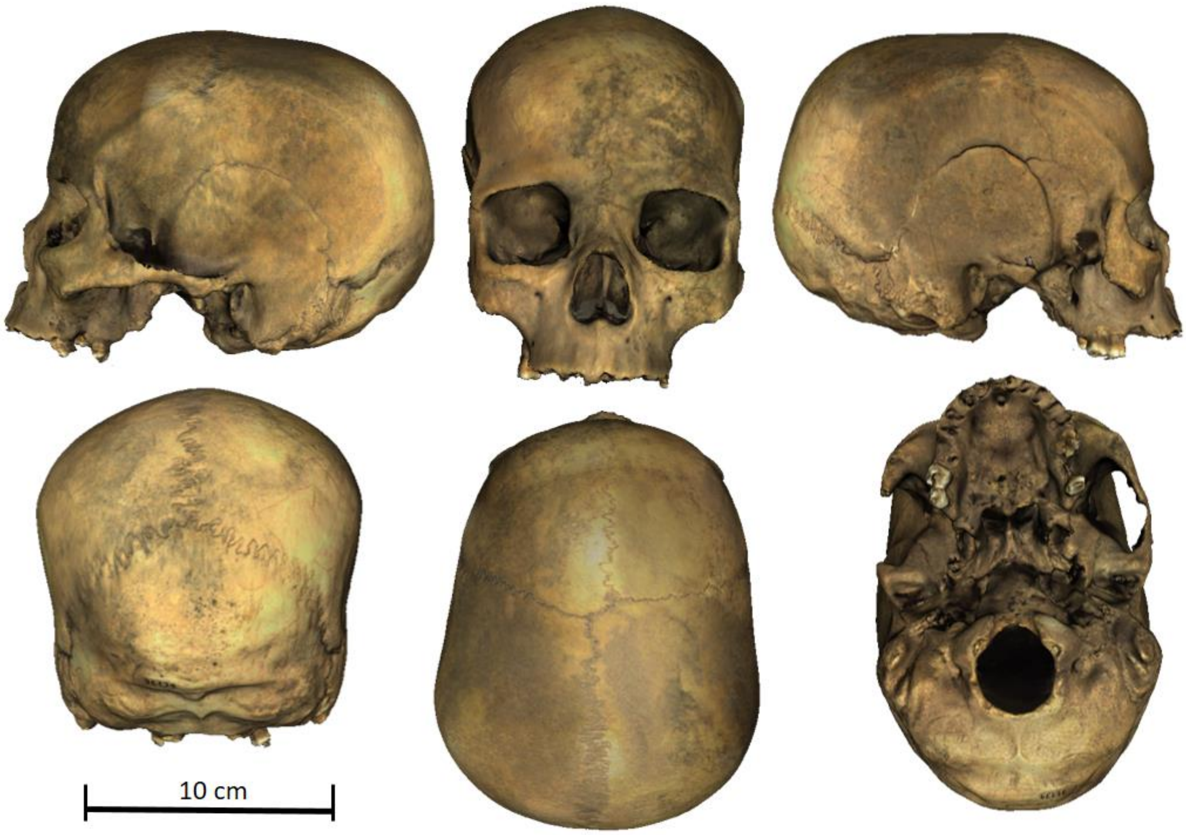

Figure 6: Chart with the main views of the skull 31139, from Tirma (Gran Canarias, Spain).

and parietal views of each skull (Figure 6). Additionally, we have created a profile in Sketchfab (https://sketchfab.com/craniacanaria2.0) as a way to share part of the virtual 3D skulls. We intend to upload gradually the complete virtual collection of indigenous Canarian skulls we have achieved. So far, 10 virtual skulls can already be accessed providing a good representation of important topics in Canarian research: skull variation, diverse types of a necropolis and their geographic locations, as well as a range of different health issues, such as traumatisms, trepanation, suture alterations and several stages of dental disease.

5. Discussion

The use of 3D scans and other technologies has improved bioarchaeological data collection, making the process faster and more versatile. In our project, after a well-designed workflow, both for data acquisition as for the post-processing of the files, we were able to digitalise a large number of skulls in a short period of time, with very basic equipment (neither the scanner, the software nor the PC is the newest and/or high-end technology).

From our point of view, Structure from Motion (SfM) photogrammetry, which is a very widespread technic for digitalising objects, is very time-consuming, both the data acquisition and the post-processing for comparison stages.

Regarding the constraints encountered while digitalising the skulls (difficult areas of texturisation, parts with lower mesh quality or even missing elements), these affect insofar how the 3D models are going to be used. In our case, this virtual skull collection will provide the basis for re-evaluating skull variability in Gran Canaria, so those virtual skulls presenting failed digitalisation that affects skull morphology will not be taken under consideration for future analyses.

Paradoxically, one of the basic by-products that can be obtained from the 3D models is 2D renderings, which allows generating accurate and quality graphic documentation. In this way, digital models in archaeology are used to generate graphic documentation, charts, computer graphics, and orthophotos of archaeological sites even when these lack constructive structures (Reinoso et al, 2020). They are additionally used to generate digital drawings for pottery (Esquivel, Alarcón-Moreno, Esquivel & Fernández-García, 2019).

Nowadays there are many options for the visualisation and sharing of three-dimensional (3D) models. Some format files allow displaying 3D models, such as PDF3D. Through the internet, there are a growing number of web-based repositories and online platforms (non-profit and commercial) focused on hosting and displaying 3D models (for an analysis of features and options, see Champion & Rahaman, 2020). Sketchfab is one of the most popular platforms, especially regarding archaeology and other related sciences, such as virtual museum showcases: almost 500 cultural institutions have joined the platform, turning Sketchfab into one of the biggest virtual museums online (Erolin et al., 2017). Besides, Sketchfab is also used to host 3D models linked to scientific publications (Champion & Rahaman, 2020).

The widening use of digitalising technologies has generated a great deal of large-scale and individual cultural heritage digitalisation projects with dissemination purposes (Nishanbaev, 2020). Massive digital projects can be accessed online: regarding cultural heritage of the world (https://www.cyark.org/), museum content of Europe (3D-ICONS, Barsanti & Guidi, 2013), or the large collections hosted at the 3D Smithsonian Institute (https://3d.si.edu/?utm_source=siedu&utm_medium=referral&utm_campaign=promo). In addition, we can find similar digitalisation projects aiming to grant access to small collections and/or museums (Erolin et al., 2017; Rangel-de Lázaro et al., 2021) and to create teaching/learning environments (Serrano-Ramos et al. 2016). And although there can be a conflict of interest between open-access data and data curator which restrains its access (as debated in Hublin, 2013), even 3D open-access data is increasingly available for scientific research, for example at the MPI-EVA Human Evolution Microtomographic Archive (http://paleo.eva.mpg.de/), now being part of a newly expanded site (https://human-fossil-record.org/).

One of the most valuable advantages of 3D objects is that they allow us to study the digitalised elements outside of their physical, and possibly restricted, space and thus enabling us to overcome some impediments to research. We may also note that collecting data from digital objects ensure that no harm comes to them through manipulating the actual bioarchaeological remains, a crucial consideration in terms of conservation. Another obvious advantage is that it is not strictly necessary to travel physically to the institution where the materials are stored, which is crucial in times of pandemics.

Currently, there are numerous computer applications and software that allow us to obtain accurate and versatile raw data from a wide variety of digital materials and media. In our case, the Artec Studio 10 Professional software allows multiple kinds of metric and geometric analysis. We have explored this option by taking the traditional craniometric measurements used in anthropology (Figure 7).

Metric digital studies are becoming common in anthropology and related fields. As a result, there are many studies concerning the accuracy and validation of measurements in a digital environment (Reynolds et al., 2017); comparing physical vs. digital measurements (Lee & Gerdau-Radonic, 2020) with variable results. These metrical analyses are commonly used to study human skulls and bones (Guyomarc'h et al., 2017; Reynolds et al., 2017), but are being applied to other kinds of artefacts, such as lithic industries (Morales, Lorenzo & Vergès, 2013; Titton et al., 2020),

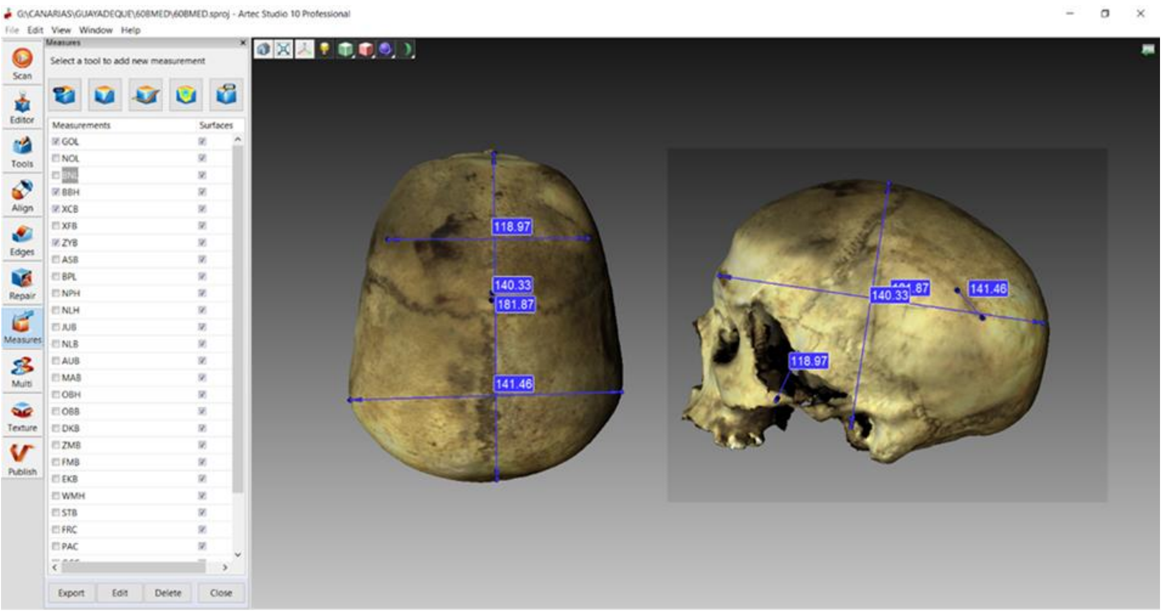

Figure 7: View of the measurement tool workspace in Artec Studio 10 Professional.

pottery (Esquivel et al., 2019) and prehistoric rock art (Jalandoni, Domingo & Taçon, 2018). Furthermore, new digital technologies present another great advantage: the virtual computerised environment permits resolving problems that affect the form and shape of the objects. Taphonomic processes, excavation and/or manipulation of these objects may result in different alterations in the form of the objects (Weber & Bookstein, 2011). Virtual reconstructions may allow the updated reconstructions of subject skulls to vary significantly from the physically restored specimens of past centuries. Indeed, re-measurements can lead to new interpretations or reinforce previous assessments (e.g. Jiménez-Arenas, Bienvenu, Toro-Moyano, Ponce de León & Zollikofer, 2019; Mafart, Guipert, Alliez-Philip & Brau, 2007).

3D Geometric Morphometrics (3D-GM) comprises the study of form and shape in a three-dimensional space through a set of statistics and graphical methods (Weber, 2014) that allow the retention of all of the 3D information. Moreover, 3D models are perfectly suited for this kind of study. In GM approach, landmarks are homologous points that might be repeatedly and reliably located in all specimens under study (Bookstein, 1991; O'Higgins, 2000). The landmark acquisition can be done in a "direct" way, from the physical object by the means of contact scanners – coordinated measuring machines (CMM) and joint arms –whose functioning is based on the acquisition of the coordinates of the points by touching with the tip the surface to be digitised. Besides, there are "indirect" ways of achieving the landmarks, both over the digital image (2D) or digital objects (3D). There are several software packages (2D: tpsDIG, ImageJ, ScionImage; 3D: IDAV Landmark Editor –although no longer available to download– Morphodig, TINA landmarking Tool…) that allow the colocation of the landmarks and the export of the coordinate information. This last option presents several advantages with respect to the contact scanners, especially when the study collections are neither easily available nor located near the researchers. The landmarks acquisition can be done several times and/or by multiple researchers; the number of landmarks in a study can be modified, and the acquisition process can be stored (both graphically and numerally), thus allowing the information to be available for consultation (Figure 8). In addition, it is even possible to correct misplacement landmarks. Moreover, all of this benefits the reproducibility of the study, a key factor in scientific approaches. The discrepancies between the two landmarks acquisition methods have been analysed with acceptable results (Simon & Marroig, 2015). Above and beyond all of this, these software packages allow the user to identify semi-landmarks, which enables the study of curved morphologies and surfaces.

The widening of virtual environments and growing interest in shape studies have led to an important increase of 3D-GM analyses, especially within the realm of human variation (Badawi-Fayad & Cabanis, 2007; Cui & Wu, 2015; Günz et al., 2009; Martínez-Abadías et al., 2009). Further, 3D-GM can be applied to lithic materials (García-Medrano, Maldonado-Garrido, Ashton & Ollé, 2020) and archaeozoological material, helping to identify taphonomic processes (Yravedra, Aramendi, Maté-González, Courtenay & González-Aguilera, 2018), even in combination with deep learning methods (Courtenay et al., 2019).

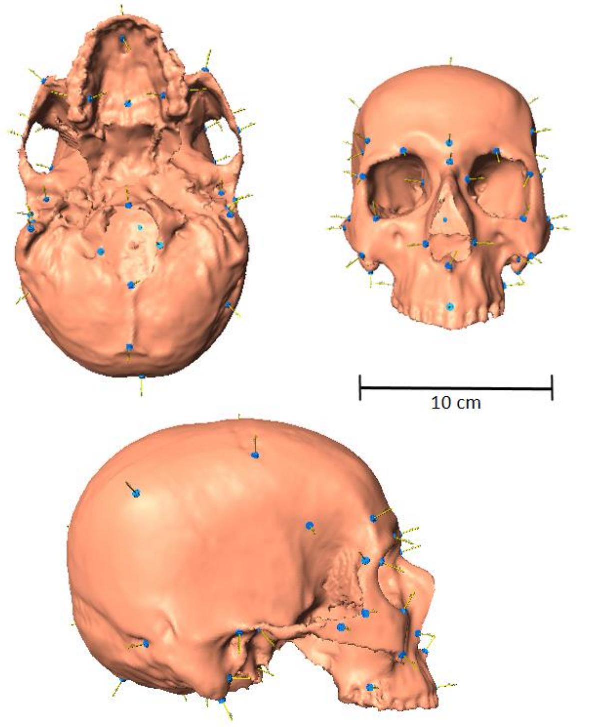

Figure 8: Example of landmark acquisition with IDAV Landmark Editor (v. 3.0).

Regarding Canarian research, human variation in indigenous skulls has been widely studied but mostly under racist perspectives. One of the advantages of expressing form and shape by numbers instead of words is that it reduces the almost inevitable subjectivity (Weber, 2014). Thus, the skull collection held at the EMC, as much for the collection itself as for the history of the investigations, is perfectly suited for 3D-GM approaches. We have already conducted a preliminary study (Serrano-Ramos, Jiménez-Arenas & Esquivel, 2018) applying 3D-GM to test human variability in Gran Canaria over a small sample of skulls (N=86) with interesting results. The increase of the digital skull sample would allow us to undertake a more solid study of the ancient Canarian skull variation, going beyond old paradigms and taking into account the latest progress in Canarian research.

Early anthropology is linked to scientific racism. It was during this period that most of the great skull collections were gathered and studied. However, we cannot discard all the data collected in these times just because biased scientists lead those studies, as seen in Lewis et al (2011). This study puts an end to a historical controversy that started when Steven J. Gould (1941–2002), in *The Mismeasure of Man* (1981) turned Samuel G. Morton (1799–1851) into a canonical example of scientific misconduct due to preconceptions about human variation. The re-evaluation of Morton's measurements led Lewis et al (2011) to conclude that Morton did not manipulate data to support his preconceptions. Besides, the scientific method can shield results from cultural biases. Nevertheless, there is no debate regarding whether Morton's interpretations fall into the racialism paradigm and even border racism. In this context, we prefer to re-evaluate this early anthropological data in order to check (*biased data or biased interpretations*) and verify its potential uses in new approaches. Moreover, digitalisation and open access to the data may help to assure reproducibility and reliability of the results, especially when study topics have been embroiled in controversy.

6. Conclusions

The skull collection held at the EMC is exceptional and comparable to other huge contemporary skull collections. In spite of the limitations that are present, these skulls have taken their place at international scientific circuits and foundational debates in Anthropology and Prehistory in Europe. They have thus become a basic study element in key issues of main insular research: the origins and the chronology of the indigenous population of the Canary Archipelago.

The use of a 3D surface scan has allowed us to obtain a virtual collection of an important part (> 400) of the skulls hosted at the EMC. This work offers a wide variety of possibilities. First, we have configured a digital database, which will be the foundation for the creation of 3D catalogues, allowing more interactive, accurate and accessible documentation. Moreover, the digital skulls will be very useful in dissemination, and will provide a basis for interactive activities, for example in the creation of digital educational material.

Furthermore, virtual skulls can be key elements in research as they provide several advantages over solely studying the physical specimens. They allow research to be carried out from any part of the world, opening the way to new perspectives and positing new questions to investigate. Thanks to these models, there is no need to manipulate or alter the physical specimens, optimizing thus the conservation of the bioarchaeological remains. Additionally, virtual models can be used to consider virtual reconstructions of fragmented materials and even to outline facial reconstructions. Above and beyond, these virtual skulls can be used to reassess human variation in the archipelago and increase the understanding of how the islands were populated. Enabling both the revaluating old data linked to raciologic perspectives and offering new interpretations that can be considered, without fear of engaging scientific racist interpretations, for multidisciplinary approaches to the study of the indigenous populations of the Canarian archipelago and its history.

New technologies applied to anthropology and archaeology are a very useful tool that implements all phases of research: documentation, data acquisition, data analysis, and its interpretations and results dissemination. An additional advantage is that virtual reality makes sampling less harmful by being non-invasive. Doubtlessly, the versatility of virtual models has given impetus to the rise in the use of these technologies and their applications in the sciences and so has become essential to archaeological and anthropological projects. Not only can this technology improve research with the newest approaches and methodologies, but also it can be used to revaluate old paradigms.

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