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# Digitising the past, preserving the future: creating a digital collection of pre-Columbian crania excavated one hundred-twenty-one years ago by Alfredo Jahn in Lake Valencia, Venezuela

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**ABSTRACT**
In 1903, the Berlin Museum of Ethnology commissioned Alfredo Jahn Hartman to conduct archaeological excavations in the Lake Valencia basin in Venezuela. Jahn explored two sites, Camburito and El Zamuro, where he unearthed pre-Columbian artefacts and human burials and subsequently sent them to Berlin. More than a century later, we digitised this collection following a detailed protocol to obtain scans with submillimetre accuracy reproducing the geometry and textures of the physical crania. The significance of this work extends beyond the technical digitisation of bioarchaeological samples. These three-dimensional models offer a rare opportunity to revisit and recontextualise this collection. It enables in-depth studies of intentional cranial modification in pre-Columbian societies, enhancing our understanding of the prehistory of the region. Furthermore, it helps preserve these fragile physical samples for future generations. To continue fostering open access and collaboration among specialists, a selection of the digitised collection is available in an online repository.

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## 1. Introduction

The nineteenth century witnessed the idea of a twofold new museum. One side focused on educating and entertaining the public, while the other functioned as an instrument for the research and documentation of testimonies from the past (Coleman Sellers 1980; Renfrew and Bahn 1996; Schultz 1990). During this time, museums were oriented towards a deeper understanding of nature, including humanity, history, and culture. Rooted in a nationalist and colonial perspective, these institutions used disciplines like anthropology and archaeology to highlight and promote a sense of local identity. They also focused on studying the "other", as societies considered "stuck in time" and on the so-called "primitive stages" within the progressive cultural "evolution" (Todorov 1991; White 1949). This trend was followed in Latin America and the Caribbean by an academic elite largely influenced by theoretical currents from Europe and North America.

On one side, this colonial paradigm influenced how the metropolises defined the narrative of reconstructing local prehistory, including collections of natural history, anthropology, and archaeology in the region. On the other, it promoted the rise of relevant intellectuals, professionals, and amateurs interested in the past of native populations and also drawn to palaeontology, botany, zoology, and other natural sciences in the region (Curet 2011).

Alfredo Jahn Hartman (1867–1940) stands out among this elite of local multidisciplinary intellectuals. Born in Venezuela with German roots, he made significant contributions to civil engineering, botany, geography, history, geology, anthropology, and archaeology in the region (Díaz Casanova 2007). His work in Venezuela and his personal and scientific link with Germany were fundamental in promoting professionalism in the archaeology of the region. As evidenced in 1903, the Museum of Ethnology (Museum für Völkerkunde) in Berlin commissioned him to carry out systematic explorations and archaeological excavations in the basin of Lake Valencia in Venezuela. In the report published in 1932, Jahn details the investigations carried out at the Ceramic Age[1] (Hofman 2013; Hofman and Hoogland 2011; Keegan and Hofman 2017) sites of El Zamuro and Camburito.

One hundred twenty years after the excavations of Alfredo Jahn, we present the digitisation of the pre-Columbian crania recovered in Lake Valencia sites and currently deposited in the Museum of Prehistory and Early History in Berlin. This study aims to revisit and digitally recontextualise this historically significant collection. By doing so, it has the potential to contribute to multiple fields. First, the digitised models enable advanced research into pre-Columbian societies in topics such as intentional cranial modification (ICM), enriching our understanding of

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biocultural practices of the past. Second, it helps to digitally preserve these fragile bioarchaeological remains by mitigating the risks of physical deterioration. Third, it ensures long-term access to this collection through open resources and subsequently creates new research exchanges. Fourth, it contributes to ethical and decolonial discussions by promoting equitable access to the collection. Finally, it reiterates the continuous effectiveness of 3D digitisation technologies for bioarchaeological documentation.

## 2. From the Lake Valencia Basin to Berlin

The Camburito site was located on the left bank of the Turmero River, approximately three kilometres east of Lake Valencia (Figure 1). It encompassed a series of 50–60 mounds, each with a diameter ranging from 10 to 25 metres (Jahn 1932; Von den Steinen 1904). After assessing 13 mounds, Jahn selected two for thorough excavation. In the central sectors, he found ceramics, necklaces, and stone and shell beads. Likewise, the presence of hearths suggests that these structures were likely used as dwellings.

Two types of burials were also found. One included funerary urns with human remains and the other skulls without urns or covers, indicating the convergence of practices similar to those observed in other cemeteries near Lake Valencia (Jahn 1932; Von den Steinen 1904). From Camburito, Jahn studied two skulls, as described in his unpublished 1903 report (Jahn 1903). Regrettably, the original assigned numbering has been misplaced, making it challenging to connect these specimens to the contexts outlined in the report. Nevertheless, in his accounts, Jahn references a child burial, suggesting a potential link with one of the infant skulls documented in the Museum of Prehistory and Early History in Berlin (Museum für Vor- und Frühgeschichte) from Camburito. Regarding the other skull, tentatively identified as that of an adult woman, the context remains uncertain based on the information available in current records (van Duijvenbode 2017).

The other site excavated by Alfredo Jahn in 1903 was El Zamuro (also known as La Mata; Figure 1). The site is located on the right bank of the Aragua River, approximately 2.5–3 kilometres east of Lake Valencia. According to the report drafted by Jahn, the 22 mounds found were randomly distributed and mostly ranged between 20 and 40 metres in diameter, except for number 4, which measured 130 metres in length and 63 metres in width (Jahn 1932; Von den Steinen 1904). In the central area of mound 2, Jahn found around 50 urns at a relatively shallow depth, distributed in groups of 8–10 sets. Meanwhile, he estimated that mound number 4 contained between 200 and 300 urns. The material collected from the 18 urns opened by Jahn included human and faunal bone remains, stone artefacts, and shell necklaces (Antczak, Antczak, and Falci 2019; Jahn 1932; Von den Steinen 1904). Like in Camburito, Jahn identified evidence of hearths and food remains, suggesting that humans inhabited these mounds. Once the archaeological excavations were completed, the materials found were transferred to the Berlin Museum of Ethnology in 1903.

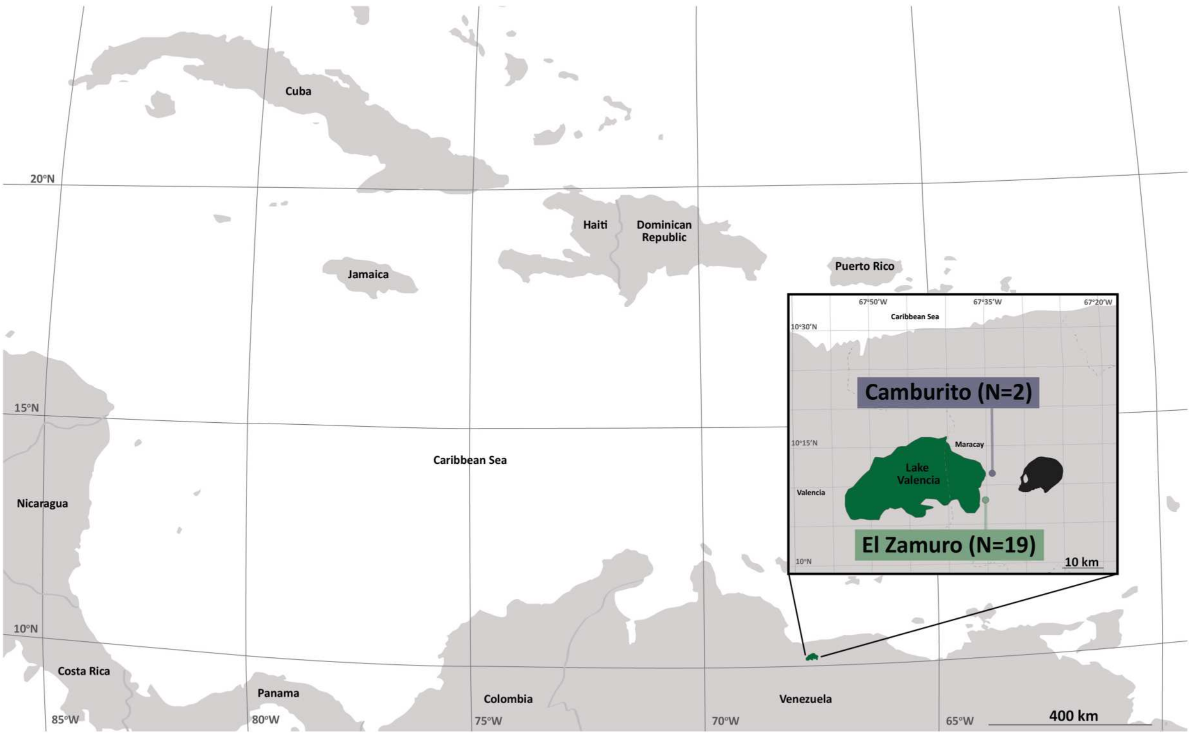


**Figure 1.** Map depicting the Caribbean region (scale 400 km), with a close-up view of the archaeological sites of El Zamuro and Camburito near Lake Valencia in Venezuela. Scale: 10 km.

## 3. Digitisation of the collection. Data acquisition and post-processing

Twenty-one specimens from El Zamuro ($N = 19$) and Camburito ($N = 2$) were scanned using the structured light scanner Artec Space Spider (Table 1), following the protocol presented by Rangel-de Lázaro et al. (Rangel-de Lázaro et al. 2021). This equipment can achieve submillimeter 3D resolution and point accuracy (up to 100 and 50 µm, respectively) in the final model.

**Table 1.** Digitised samples of pre-Columbian human crania from El Zamuro and Camburito (Bolivarian Republic of Venezuela) deposited in the Museum of Prehistory and Early History of Berlin.

| ID | Site | Age group | Modification |
|---|---|---|---|
| S 4928 | El Zamuro | adult | present |
| S 4929 | El Zamuro | adult | present |
| S 4930 | El Zamuro | adult | absent |
| S 4931 | El Zamuro | adult | present |
| S 4933 | Camburito | infant | present |
| S 4934 | El Zamuro | adult | present |
| S 4935a | Camburito | adult | absent |
| S 4936 | El Zamuro | adult | absent |
| S 4937 | El Zamuro | infant | absent |
| S 4938 | El Zamuro | adult | absent |
| S 4939 | El Zamuro | adult | present |
| S 4940 | El Zamuro | adult | absent |
| S 4942 | El Zamuro | adult | present |
| S 4943 | El Zamuro | juvenil | present |
| S 4944 | El Zamuro | adult | present |
| S 4945 | El Zamuro | adult | absent |
| S 4946 | El Zamuro | adult | absent |
| S 4947 | El Zamuro | adult | absent |
| S 4948 | El Zamuro | adult | present |
| S 4949 | El Zamuro | adult | present |
| S 4950 | El Zamuro | adult | absent |

All samples were digitised following the same procedure. Each specimen was placed on a rotating platform and scanned in different positions to capture the complete geometry and texture of the skull. Scans were processed using Artec Studio 17 (Artec3D 2022). First, fine registration was performed to align pairs of sequential frames in the three to four scans captured on each specimen (Figure 2(a)). In this step, the rotating platform was removed from the scene.

The auto-alignment tool was then used to reposition the overlapped scans in the same 3D space (Figure 2(b)). Once aligned, they were globally registered to compare and optimise the frame positions across all scans.

After completing the global registration of all scans, a maximum registration error of 100 µm was obtained, indicating the high quality of the acquisition performed (Figure 2(c)). Subsequently, in the final model, values that could introduce noise at the edges were removed (Figure 3(c)). A threshold value equal to 2, recommended for noisy surfaces, and a resolution equal to the maximum registration error (i.e. 100 µm) were applied for better results. Then, all scans were merged, creating a single sharp simplified mesh (with a resolution of 100 µm) with the small-object filter applied (Figure 2(d)).

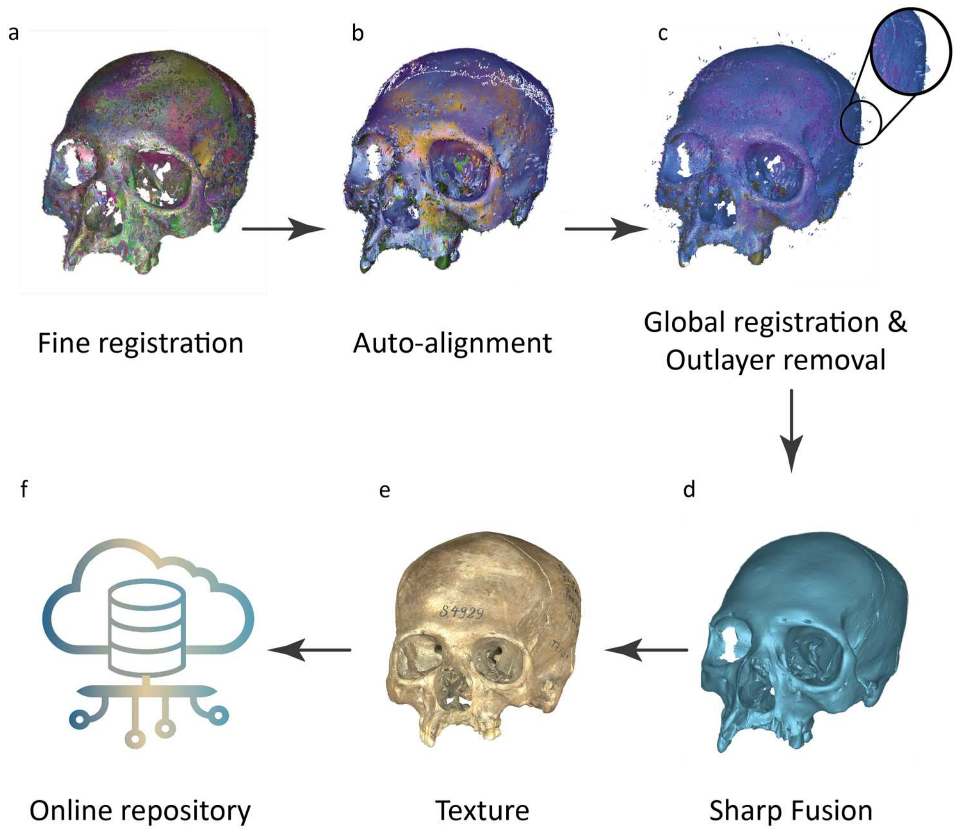


**Figure 2.** Workflow used for processing the scanned data in Artec Studio 17 (Modified after [Rangel-de Lázaro et al. 2021]).


**Figure 3.** Representation of scanned samples. a. Specimen S4936 from El Zamuro. b. Specimen S4933 from Camburito is displaying ICM. c. Specimen S4943 from El Zamuro with ICM. Scale: 5 cm.

The texture was applied to the models to achieve a realistic appearance (Figure 2(e)). A texture atlas was combined with structure interpolation and normalisation to obtain an output size 8192×8192. Texture parameters such as brightness, gamma correction, and contrast were adjusted to resemble the physical specimen. Finally, a curated selection of the scanned crania was uploaded to Figshare, an accessible online repository to facilitate the storing, sharing, and dissemination of these valuable specimens by professionals (Figure 2(f)).

## 4. From bones to digital model

A selection of three of the 21 3D models of pre-Columbian crania is illustrated in Figure 3. As can be observed in the image, two of these skulls from El Zamuro (Figure 3(b)) and Camburito (Figure 3(c)) exhibit fronto-occipital ICM (Dembo and Imbelloni 1938; Hrdlicka 1919). From the analysed sample, eleven individuals with these characteristics have been identified. ICM was a biocultural practice widespread in the region before contact between colonisers and the native population (Tiesler 2014).

In the case of fronto-occipital modification, the head was tightly bound with bandages and secured between two compression forces, one on the occipital bone and the other on the frontal bone. Both elements exerted an anteroposterior mechanical force to create a flattened parallel orientation and a backward inclination (Dembo and Imbelloni 1938; Hrdlicka 1919).

The Spanish Chronicles of the Indies reported that ICM was performed after birth and maintained until the early years of life (de la Vega 1826). At this stage, cranial bones are still flexible and easy to manipulate because sutures and fontanelles, which play a critical role in cranial expansion, act as growth and contact zones (Scheuer and Black 2000). The pressure and tension exerted during ICM induced functional and structural changes between soft and hard tissues (i.e. bone, brain, and vascular system) that grew towards uncompressed regions without affecting neurocranial size (Moss 1958; Rangel-de Lázaro et al. 2021; Tiesler 2014).

The intensity of the changes caused by cranial modification can vary from mild to severe or extreme. The extent of morphological alterations resulting from compression forces depends on the age at which modification began, the duration of compression application, the degree of pressure exerted, and the materials used. Nevertheless, every approach has its limitations. Ethnohistorical accounts (Dingwall 1931) and recent research refers to the potential health hazards of ICM (Lekovic et al. 2007; Mendonça de Souza, Reinhard, and Lessa 2008). Side effects, including secondary cranial asymmetry, circulatory issues, necrosis, and infections, could result from the mechanical pressure applied during head shaping and inadequate hygiene, blood, and air circulation (Boman, Froment, and Charlier 2016; Torres-Rouff 2020).

Over time, ICM has garnered interest from ethnohistorians, bioarchaeologists, and bioanthropologists, particularly in the study of Mesoamerican and South American samples and, to a lesser extent, those from the Caribbean (island and mainland). Early studies involved metric evaluations of intentionally modelled skulls using the Klaatsch polygon[2] (Klaatsch 1908) to analyse the displacement of cranial points by comparing their positions and angles with those of unmodified skulls (Imbelloni 1924–1925). Other approaches considered the vertical and horizontal angles of the foraminal clivus as convenient classifying parameters to distinguish different forms of tabular and annular modification (Dembo and Imbelloni 1938). Likewise, the angle between the basion-nasion was considered a measure to establish the degree of backward inclination of the vault and, therefore, the type of head modification (Romano 1965). Recently, the application of three-dimensional methods and geometric morphometrics has shifted the focus beyond classification and traditional metrics to offer a more comprehensive interpretation of what is evidence of culture imposed on biology (Kuzminsky et al. 2016; Püschel, Friess, and Manríquez 2020).

## 5. Exchange networks and cranial modification in pre-Columbian Venezuela and the Caribbean

The digitised skulls provide new information to help contextualise the archaeological landscape of Venezuela and the Caribbean in pre-Columbian periods. Recent research indicates the Caribbean was central to local, regional, and pan-regional exchange networks (Hofman and Hoogland 2011; Valera and González Muñoz 2017). Evidence suggests that during the early ceramic period, Saladoide artefacts were transported by communities from the Lower Orinoco to the Venezuelan coast, providing a means to reach the islands of the Caribbean (Boomert 2013; Keegan and Hofman 2017). Consequently, the sociocultural boundaries of these communities may have extended beyond the immediate coastal regions of the South American continent. This is supported by the presence of cranial modification practices in communities with Huecoid and Saladoide ceramics in the Antilles (Crespo-Torres 2005; Curet and Stringer 2010; van Duijvenbode 2017).

The pre-Columbian crania presented in this study come from the Lake Valencia Basin, a region projected as a centre of local interaction and exchange networks, connecting communities in Venezuela and Suriname, the Caribbean archipelago, and the coastal and inland territories of South America with the material culture associated with the Valencioide ceramic tradition (Brites 1995; Hofman et al. 2007; Zamakona de Arechavaleta and Lagrange de Castillo 2007). This blend of cultures exposed the inhabitants of the Lake Coast to new ideas resulting from migrations. The mobility and exchange networks created led to the extension of Valencioide beyond the Lake Valencia Basin to the Caribbean coast and the islands of Los Roques and La Orchila prior to the sixteenth century. However, future studies should provide a more comprehensive understanding of the preceding intersocial interactions that paved the way for this expansion. It is also pertinent to explore, if any, the potential impact of modification practices within the local populations and to elucidate the role of northern Venezuela as a hub for population movements to and from the Caribbean.

## 6. Discussion and conclusions

In this study, 3D structured light scanning proved to be an effective method to create reality-based models that accurately reproduce the original geometry and textures of the crania. The importance of digitising this pre-Columbian collection excavated by Alfredo Jahn in the early twentieth century in Venezuela goes beyond creating a virtual replica. It constitutes a further step in the search for answers to the previously raised questions.

In recent years, three-dimensional methods to document archaeological and anthropological objects have been widely validated (Martínez-Fernández 2020; Rangel-de Lázaro et al. 2021; Robson et al. 2012). These approaches have become a necessary resource for many institutions interested in safeguarding cultural heritage and facilitating future reconstructions based on reliable data sets.

The growing use of techniques like photogrammetry (Pierdicca 2018), computed tomography (Charlier et al. 2020), and 3D scanning (Kuzminsky and Gardiner 2012) to digitise museum collections has proven beneficial in improving preservation, access, management, exchange of geometric information, research, and knowledge transfer to the general public. Furthermore, using 3D models has become instrumental in many museums in reestablishing connections between exhibitions and visitors by allowing them to explore collections without interacting with the physical objects (Cassidy et al. 2018; Gimeno et al. 2017; Shehade and Stylianou-Lambert 2023; Younan and Treadaway 2015).

The digitisation of natural and cultural heritage offers a potential solution to bring to light collections that remain unpublished and largely unexplored (Kuzminsky and Gardiner 2012; Popov et al. 2021; Rangel-de Lázaro et al. 2021; Voglino 2023). Digital repositories host a decolonial domain for museums and facilitate remote access to collections. More locally, in the Caribbean context, it can raise awareness of ancestral communities, share knowledge, and connect local stakeholders, academics, and general audiences (Françozo and Strecker 2017). Although digitising museum collections automatically does not solve the lack of information about origin and acquisition methods, it does promote virtual documentation, open access to information-based catalogues, and community-engaged collaboration on those collections to which provenance information is known (Silverman 2015). This is a promising first step towards raising awareness and reconnecting Indigenous communities with their heritage.

Nonetheless, the issues of ethical dissemination and access to museum collections are not resolved by granting online availability to artefacts. Beyond this, many museums still face challenges related to the existence of colonial-era narratives associated with the objects and how different audiences interact with digital repositories (Françozo and Strecker 2017; Newell 2012).

Online catalogues are indispensable tools to disseminate information about objects housed in museums, promote equitable access, and preserve them virtually and physically. In this context, the development of online databases emerges as a critical focal point for accessing digital data from numerous museums. This endeavour facilitates the exchange of best practices and protocols among institutions with a colonialist legacy and ensures the perpetuity and value of collections.

Projects like the one presented here also contribute to the digital democratisation of science by promoting the exchange of 3D data. However, it is essential to consider the ethical implications of digitising human remains. In these cases, the process must be approached respectfully and ensure that the data used agrees with the values of the communities and institutions involved (Robbins Schug et al. 2021). Furthermore, it is critical to ensure their responsible use of 3D models for research, education, and museum exhibitions. It implies avoiding sensationalism, commodification, and objectification of human remains (Hassett 2018).

Research on the ethical digitisation and 3D display of skeletal collections in Venezuela is limited (Pérez Ramírez 2023). However, studies focused on ethnographic collections of Indigenous communities (Grimme and Nowak 2022) explore themes of cultural preservation and representation using digitalisation to promote permanent access to the collection and create an opportunity for collaborative research. In the Latin American context, key issues on this topic centre on concerns about ownership (Ballestero 2021), community-led digitisation efforts (Scholz and Guzmán Ocampo 2021), and the ethical implications surrounding the digitisation of ancestral remains (Ochoa Jiménez 2024; Ordoñez Alvarez 2019).

In recent years, there has been increasing awareness among specialists working with human remains regarding the ethical implications of digitising human remains. The central themes around this focus on consent and respectful representation, considering who has access to 3D models of skeletal material and for what purposes (e.g. academic, research, and museum outreach), and avoiding the potential misuse of digitised data by sharing the information through professional platforms (e.g. Figshare, Morphomuseum, Morphosource, among others). These activities must adhere to ethical guidelines and include proper referencing for the models used. Researchers and institutions must be aware of the potential exploitation of such images and strive for the use of their data to foster understanding, respect, and ethical engagement with history.

The 3D models created from the 21 pre-Columbian crania of El Zamuro and Camburito will expand the recognition of this anthropological collection and facilitate open access for study and dissemination among specialists and the general audience. It also implies that a commitment to decolonisation drives the accessibility, preservation, and contextualisation of such a collection.

## Notes

1. This period is categorised into two phases: Early Ceramic Age (400 BC-AD 600) and the Late Ceramic Age (AD600-1492). These divisions correspond to significant socio-political transformations experienced by Ceramic Age groups during this time.
2. The German anatomist Hermann Klaatsch defined a sequence of measurements that arranged cranial polygons into quadrilateral configurations.

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## Author contributions

CRediT: **Gizéh Rangel-de Lázaro:** Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Resources, Software, Visualization, Writing – original draft, Writing – review & editing; **Marcelo R. Sánchez-Villagra:** Conceptualization, Funding acquisition, Investigation, Methodology, Project administration, Resources, Writing – original draft, Writing – review & editing.

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## Data availability statement

A selection of the data that support the findings of this study is openly available in figshare at 10.6084/m9.figshare.27629901. Further data are available from the corresponding author.

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