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Facial reconstruction of a deformed skull from the Roman period of Juliopolis

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Abstract

The use of digital technologies in archaeological research has become considerably more widespread in recent years. While the earliest records of the use of electronic data in archaeology date from the 1950 and 1960s, the field has kept growing with the increasing interest in digital tools such as digital photography, three-dimensional imaging, GIS, virtual and artificial reality applications, CAD and facial reconstruction. Such digitization practices are used frequently for documenting, record keeping, and preserving and representing the data recovered from archaeological contexts, and are linked to other fields, such as cultural heritage studies and museology. Facial reconstruction is used to recreate the faces of individual from the past using their skeletal remains. It has been practiced for different reasons in the fields of forensics, anthropology, and archaeology. This study focuses on the facial reconstruction of a skull unearthed from Juliopolis. The reason for choosing this skull in this study is that it is the first and only known deformed skull dated to the Roman period in Anatolia. For the facial reconstruction application, authors created a 3D modelling of the skull by photogrammetry. Then, the missing parts of the skull are completed using the virtual donor library. The results are presented in different forms, as grayscale, in colour with eyes closed or open. Also, the type of deformation is demonstrated in the skull. This study adopts a digital process and is more strongly linked to data interpolation related to the external surface of the face. The prominent advantage of the methodology is being strongly supported by information obtained from computed tomography (CT) scans of living individuals, leaving a little room for the artistic issue in relation to the basic aspect resulting from the interpolation of data. The benefit of facial reconstruction is especially important since it is a way of preserving and presenting archaeological and anthropological data.

Keywords Facial reconstruction, Digital archaeology, Anthropology, Anatolia, Roman period

Introduction

The introduction of digital technologies to archaeological research has become considerably more essential. A rapidly growing amount of archaeological evidence is made up of digital data, which is used at vastly different proportions to record and show a diverse range of subjects [1]. While the earliest records of applications of electronic data on archaeological studies date from the late 1950s and early 1960s, the field has kept evolving, with increasing interest and experience in the application of digital technologies to archaeology and technical developments in digital tools [2]. The development of digital archaeology has affected almost all aspects of the work to varying degrees. Nowadays, tools such as digital photography, three-dimensional imaging, GIS, virtual and artificial reality applications, Computer-Aided Design (CAD) and facial reconstruction done by anthropological methodologies are used frequently as tools for documenting, record keeping, analysis, preserving and representing the data and materials recovered from archaeological

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contexts [1, 3]. Digitization practices in archaeology and also in anthropology are also closely linked to the application of technological developments in other fields, such as cultural heritage studies and museology [4].

Facial reconstruction, one of the digital tools, is a growing field with multiple applications in forensic sciences, archaeology and anthropology [5–7]. In archaeology, it is utilized to recreate the faces of individuals from the past using information from their skeletal remains, mummified or bog bodies [6, 8, 9]. Archaeological and anthropological research offer unique chances for reconstructing faces from the past, showcasing how these ancient people looked like to the public, and allowing comparison with modern faces [6]. Facial reconstruction is a multidisciplinary approach consisting of principles of anatomy, anthropology and archaeology and the process can include analyzing the shape of the skull and other bones to determine the size and placement of muscles and soft tissues, as well as using information about the individual's age-at-death, sex, and ethnicity to make educated guesses about their facial features [5]. Facial reconstruction is important in a way that the face represents a significant and defining part of the humans [5]. The human skull comprises of 14 facial and 8 cranial bones, 22 in total. Because of its intricate design and minute variances that occur during growth and development processes, along with the variations in soft tissue, the human population as a whole exhibit significant facial variation [6].

First examples of facial reconstruction dates to the Neolithic period. These included plastered skulls decorated with materials such as shells and beads for the eyes [10]. While the actual reason for skull plastering, practiced in Anatolia and the Levant region, is disputable, it can be said that the Neolithic people were the first known practitioners of facial reconstruction [11]. Throughout the time, from the Middle Ages to the Renaissance, 18th and 19th centuries and onwards, facial reconstruction has been practiced for different reasons in the fields of forensics, anthropology and archaeology. The practices of modern facial reconstruction that applied in the 19th century was started with the reconstruction of faces belonged to rich and famous people of that time [5]. In archaeological context, the main goal of facial reconstruction is mainly to recreate the most plausible depiction of an individual's face rather than establishing an identity, therefore, archaeologists and anthropologists may provide recommendations based on historical evidence for the most appropriate hair color, skin tone, eye color, hair style and clothing [6]. Moreover, archaeological facial reconstruction might be difficult as the skeletal remains may have pathological diseases, wounds and facial deformations, like the one in this study. In such cases, the facial reconstruction can be utilized for determining how facial appearance relates to such conditions [6].

The process of facial reconstruction can utilize different methods some of which are facial superimposition, imaging, radiography, 2D and 3D reconstructions and computer-based facial reconstruction which is used in this study. The computerized methods have gained importance in the late 1980s and necessitates expertise in both anthropological and computer modeling [5, 8]. However, it lessens the subjectivity of the practitioner while it produces several images of the same face with ease [8]. Nowadays, the practitioners frequently use digitally developed methods and the software for facial reconstruction, which have increased efficiency and speed of the process, as Verzé discusses [11].

This study focuses on the facial reconstruction of a skull unearthed from the archaeological excavation site of Juliopolis. Juliopolis is an ancient city located in Nallıhan, approximately 122 km northwest of Ankara, Turkey. Situated on the border of the Ancient Bithynia and Galatia regions, Juliopolis was the frontier town of Bithynia and had importance due to being located at the intersection of the Silk Road and Pilgrim's Road. While the ancient city is submerged under Sarıyar Dam Lake, built in the 1950s, the necropolis and remains of an Early Byzantine church dated to 5–6th AD and defense wall are located on the northern shore of the lake [12]. The salvage excavations, carried out in the necropolis since 2009 by the Museum of Anatolian Civilizations, have uncovered more than 750 tombs of various types [13]. Archaeological finds (e.g., precious and semi-precious jewellery, coins, metal, glass, ceramic and bone artefacts) recovered from these tombs have revealed that the necropolis was used from the Hellenistic period until the Roman and Byzantine Empire periods [14].

The skull sample is unearthed from chamber tomb 248 (Fig. 1). The chamber tomb, where the skeletal remains of 7 individuals were found, was dated to the Roman Period (3rd century AD) based on the finds of bronze coins and earrings [14]. While one is not certain, two individuals have artificial deformation marks on their skulls.

The sex and age at death estimations of the individual were made based on the morphological features of the skull due to the poor preservation of postcranial skeleton. The cranial suture closure degrees indicated that the individual was between 25 and 35 years old at death [15, 16]. While for the sex estimation, sex-related differences in the skull were used, which indicated a female gender [15, 16].

The reason for choosing this skull in this study is that it is the first and only known deformed skull dated to the Roman period in Anatolia [17]. The identification of deformation marks on the skull was made per Buikstra

Fig. 1 Chamber tomb 248 from Juliopolis

and Ubelaker [15]. The deformation observed in the skull reflects the circular–vertical deformation pattern described by Cocilovo et al. [18] (Fig. 2). In this type of deformation, there is a slight or distinct flattening of the frontal bone and a transverse, curved groove that continues along the frontal and parietal bones and ends around the lambda on the occipital bone. The growth in length and width is limited. The overall shape axis may be vertical or slightly inclined backwards by the Frankfurt horizontal plane. This deformation shape results from applying more flexible elements such as bandages, tapes or cross strips combined with other non-plastic materials on the back. Nevertheless, a second bandage mark was also found on the skull. The sclerotic structure along the coronal suture, especially the rostral part of the coronal suture, can be considered a sign that this area was subjected to long-term pressure. Therefore, the sclerotic structure appears more prominently at the junction of the first and second bandages. It is understood that two bandages, one of which is normally observed in the post-bregmatic area, were applied in the pre-bregmatic area. A narrower band was used compared to the second one. Moreover, it is thought that two hard objects of approximately 5 cm in diameter were used just above the tuber frontal areas of the frontal bone. Especially the presence of a slight hump in the frontal bone's midline and an observable depression on both sides of this hump emphasizes this thought. Likewise, this deformation shape resembles the Type A depicted by Molnar et al., one of the deformation types identified in the Carpathian region [19]. However, unlike this example, the second bandage on the skull is place in the pre-bregmatic area [19].

This study aims to create a facial reconstruction of a unique skull sample from an archaeological excavation site, Juliopolis. It also aims to demonstrate use of a digital application, facial reconstruction, for preserving and presenting this cultural heritage element. A 3D modelling of this skull was already displayed to the public as a part of a public archaeology event called the Faces of Juliopolis

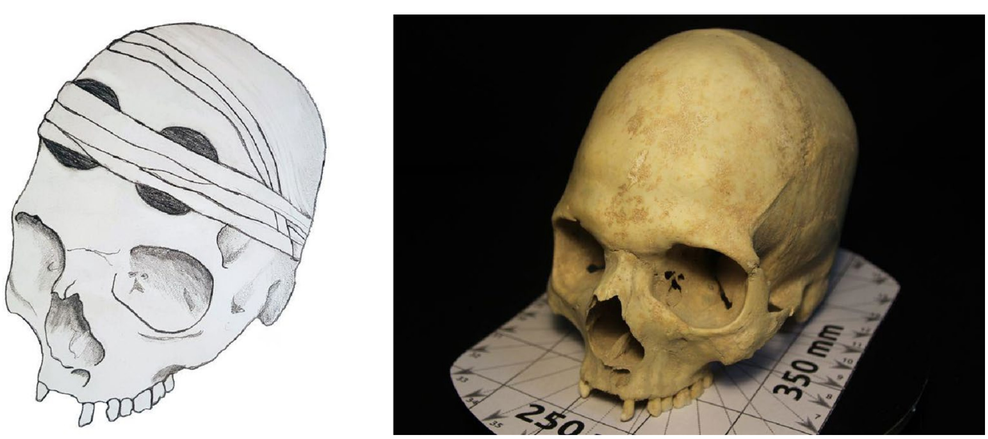

Fig. 2 Drawing and photo of the skull deformed skull

Exhibition. During the exhibition, it was observed that the skull attracted people's interest due to its unique features. By the facial reconstruction of this skull, the authors aim to further increase the visibility and recognition of this unique material.

Material and method

This study follows the step-by-step approach discussed by Abdullah et al. [20]. After the photogrammetry and 3D modelling processes, the missing parts of the skull are completed. Then, the projection and structure of the face were determined by data acquired from the skull measurements. Finally, the detailing of the face and hair was created, and the final images were generated. The Fig. 3 shows a systematic framework diagram for the used method in this study.

The bones of the skull lay the basis of facial appearance. They form a framework to which other structures forming the face are attached, such as muscle, fat and skin tissues. Therefore, first, the 3D model of the skull was created by photogrammetry method. Photogrammetry enables the creation of 3D models from digitized output data, such as 2D photographs, by identifying the spatial positions of features of an archaeological material [21]. The skull was placed on a rotating plate and photographed from different angles using Canon EOS 1200D and Sigma DC 1750 mm lens at the IDEA Lab at Hacettepe University. A total of 113 photographs were taken, and 95 were used by Blender to reconstruct a 3D model of the skull (Fig. 4). The photogrammetry process was carried out on a computer with the following characteristics: Intel® Core™ i7-47905 3.20 GHz processor, 8 GB of RAM with x64 Windows 10 operating system. The process took 16 min and 02 s.

As a result, the system created a 3D model of the skull with texture. However, the skull was missing the mandibula and several maxillary teeth, which caused a significant problem for facial reconstruction. Therefore, it had to be completed before the process. Before recovering the missing skull parts, several measurements were taken from the skull to choose proper virtual donors for the completion process. Proper donors were chosen from the author Moraes' virtual donor library (Fig. 5). A 3D mesh from an appropriate virtual donor was used to replace the missing mandibula and teeth of the individual (Fig. 6).

Assessing the possible ancestry group of the skull, measurements were taken between frontomalar points, glabella and nasion, and rhinion and the lateral edge of the orbit (Fig. 7). This skull represented a greater affinity with clusters represented in Fig. 8. However, it should be noted that this clustering is not direct evidence that the individual is from the mentioned ancestry groups. This simply suggests that the skull measurements are compatible with those from the groups.

The facial reconstruction was performed using OrtogOnBlender, an add-on in Blender software, and its submodule ForensicOnBlender. These tools, created by the author Moraes himself, provide additional features to Blender to carry out the digitalisation of 3D objects and to facilitate forensic facial approximation works [22].

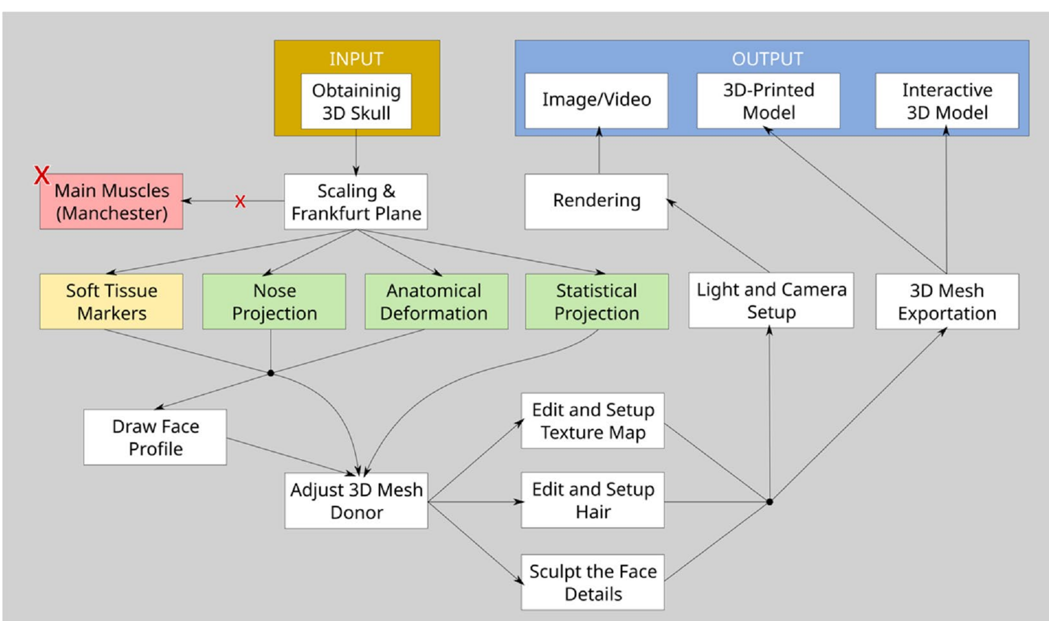

Fig. 3 A systematic framework diagram demonstrating the method used in the study

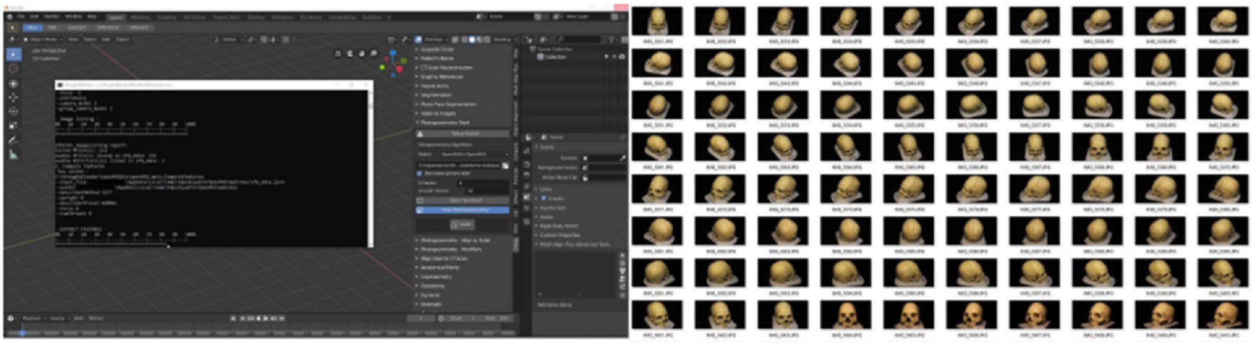

Fig. 4 Photogrammetry process on computer

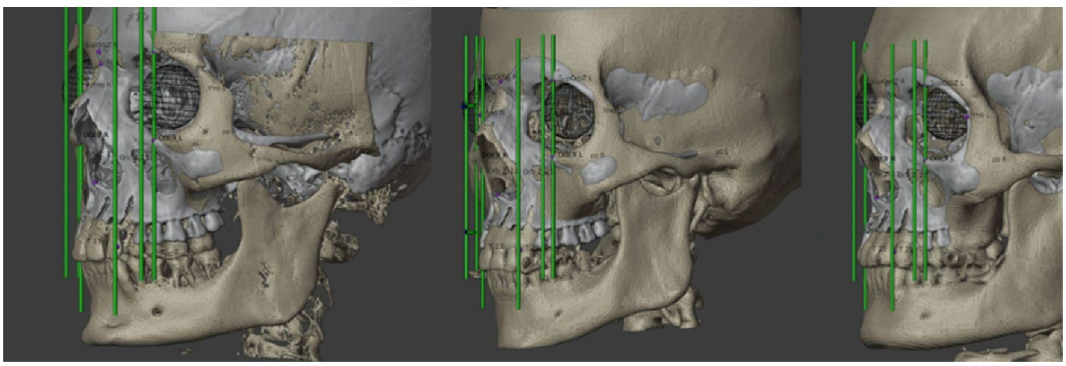

Fig. 5 Designation of appropriate mandible from the virtual donor library

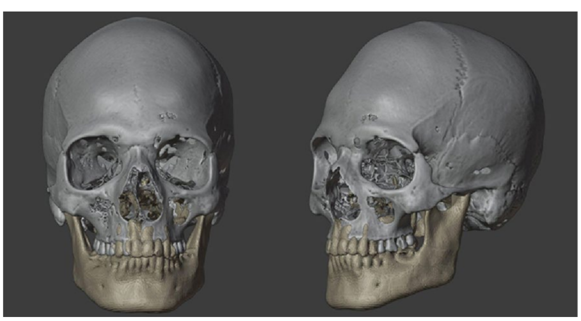

Fig. 6 Completion of the skull with the chosen mandible

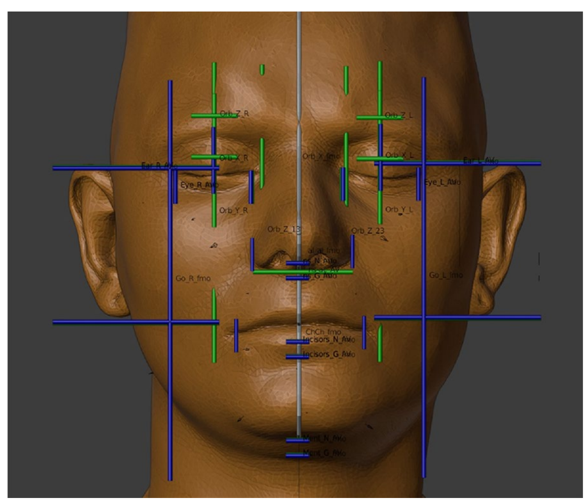

Fig. 7 Anatomical points used in facial reconstruction process

Following photogrammetry, the 3D model of the skull was positioned on the Frankfurt plane. Then, the soft tissue thickness markers were placed on the skull according to the sex and age-at-death of the individual. The facial measurements are essential to lay out a basis for the positioning of the eyes, nose and lips. Using standardised terms and methods to minimise measurement errors and increase reliability is important [23]. Therefore, the measurements were taken, and the anatomical points were determined in accordance with Caple and Stephan to be consistent with the author Moraes' previous study [20, 23].

The measurement of the distance between frontomalar (fmo) points is crucial to determining the place and projection of facial elements [20]. For the skull, the mean

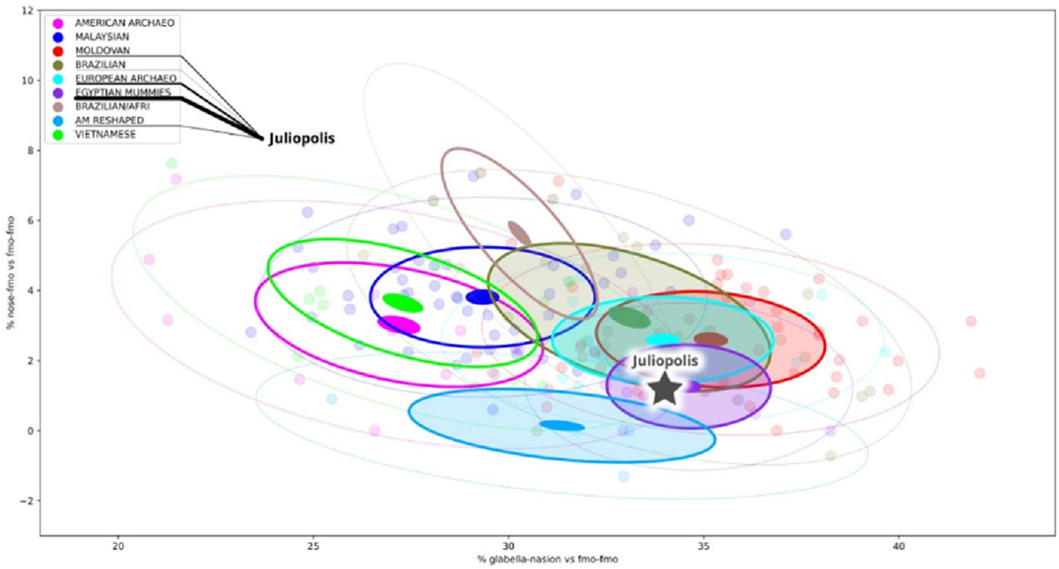

Fig. 8 Cluster of affinity for the skull

distance between fmo points of each side was measured as 95.35 mm. This mean distance is mainly used to determine the positioning of the eyeballs which is determined in accordance with the X, Y and Z axes due to the anatomical structure of eye orbits. The position on the X axis was projected from 16.5 mm from the fmo points on each side by using the mean distance between fmo points. A line was drawn on the Z axis, the mean distance of which is 15.5 mm to determine the height of the eyeballs. Concerning the position of the eyeballs in the Y axis, a mean distance was measured between a tangent to the infraorbital margin and p with a mean distance of 5.6 mm. The distance between al-al points is 37.72 mm.

Concerning the positioning of the mouth, the measurement of the distance between the cheilion (ch) points, which indicate the intersection of upper and lower vermilions in the outer corner of the mouth, is necessary [20, 23]. In this study, the mean distance between ch–ch was 49.76 mm. The size of the eyes was 28.39 mm and the height of the ears was 57.32 mm. To get all these distances, the authors used some commands on ForensicOnBlender, which are available on two video tutorials created by the author Moraes (link 1: https://www.youtube.com/watch?v=U6oYkEmfyWo. and link 2: https://www.youtube.com/watch?v=Vcz2e5uSFX8).

For the projection of the nose, the authors used an approach mixing statistical data with proportional projection, based on the measurements taken from the CT scans of live people [24]. An online video tutorial of this technique is available on https://www.youtube.com/watch?v=F205kLQ--Oo.

After all the statistical projections were done, a reconstructed CT scan of a virtual donor was imported on scene and the composed mesh of skull and soft tissue was deformed, until the two skulls match and the soft tissue followed this deformation. With the data of statistical projection and anatomical deformation, the basic structure of the approximation was done (Fig. 9). After this step, a final form of the face was generated by the digital sculpture of facial details, the pigmentation of the skin and the configuration of the hair.

Results and discussion

Final images of the facial reconstruction were generated using Blender 3D's Cycles renderer. As a result, four types of output were obtained. The first one shows the reconstruction in grayscale with eyes closed and without hair (Fig. 10). The second one shows an image in colour with eyes opened (Fig. 11). A third one also demonstrates an image in colour but also with hair (Fig. 12). By focusing on the facial projection and anatomical features, the grayscale version represents a more objective approach which could be considered more scientific. On the other hand, the versions in colour represent a more subjective and artistic approach since they provide various details such as colour, hair, eyebrow and eyelashes. In addition to these versions, the authors also created a facial reconstruction of the skull demonstrating the type of deformation (Fig. 13).

Facial reconstruction techniques have evolved over time and have been used for various purposes, including religious practices, teaching, forensics, anthropology, and

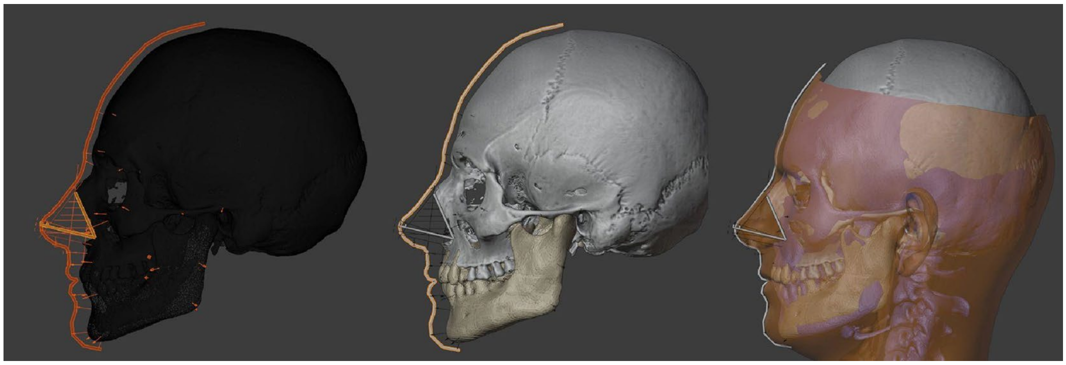

Fig. 9 Steps of facial reconstruction process

Fig. 10 Facial reconstruction in grayscale with eyes closed and without hair

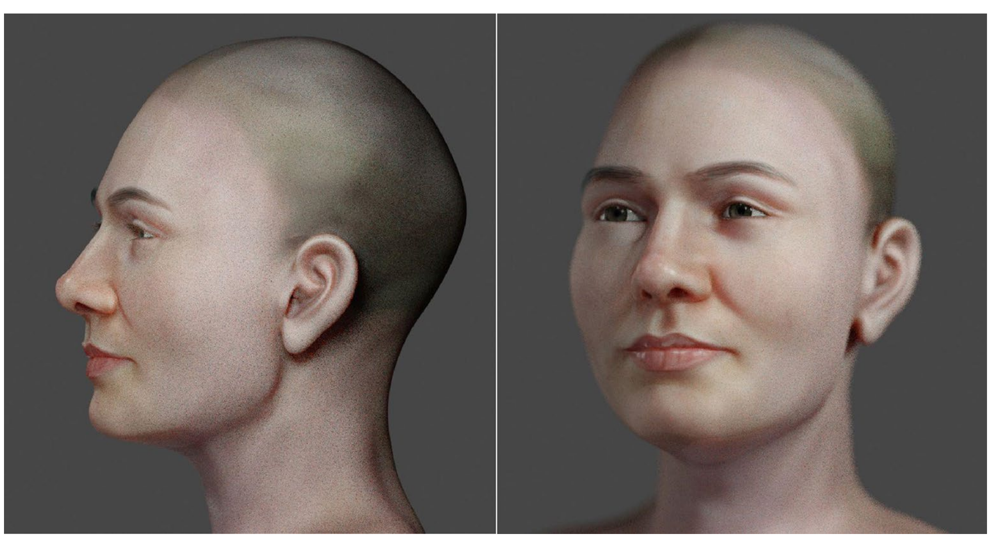

Fig. 11 Facial reconstruction in colour with eyes opened

Fig. 12 Facial reconstruction in colour with hair

archaeology [10, 25]. Early techniques of facial reconstruction, such as plaster skull reconstruction, relied on manually sculpting the soft tissues over the underlying bony structure to recreate the appearance of an individual's face [26]. These early methods often did not prioritize physical accuracy, but instead focused on symbolic representation [26]. However, with advancements in technology and scientific understanding, more reliable and accurate methods of facial reconstruction have been developed. One such method is the use of average soft tissue depths, which are based on studies of cadavers and provide a general guideline for the thickness of facial tissues at specific anatomical landmarks [27]. Another technique is the use of anthropometric measurements, which involve taking precise measurements of key facial features and using statistical analysis to estimate the soft tissue thickness in those areas [26]. Additionally, as mentioned before, computerized 3D facial reconstruction has become a valuable tool in facial reconstruction studies. This technique uses computer algorithms and medical imaging data, such as CT scans, to create a digital model of the skull and then overlays the estimated soft tissue depths to generate a virtual facial reconstruction. The advent of computerized 3D facial reconstruction has significantly advanced the field of facial reconstruction [8]. These computerized techniques allow for more precise and detailed reconstructions, taking into account factors such as facial asymmetry and individual variations. The field of archaeological facial reconstruction has also greatly benefited from these advanced techniques. Computerized 3D facial reconstruction has revolutionized the field of archaeology. It allows for meticulous and detailed reconstructions that can be studied and shared widely, contributing to a deeper understanding of ancient societies and cultures [8, 10]. These reconstructions not only provide a visual representation of individuals from the past but also aid in bringing their stories to life, enhancing public engagement and interest in archaeological endeavors.

Various studies regarding facial reconstruction mention the use of different methods, both manual and digital [see 5, 7–10]. Both methods are still adopted by researchers based on their study material. Kustar et al. [28] used a digital approach while creating a base for facial reconstruction and obtained 3D printing of the skull. Then, the researchers practiced the facial reconstruction manually

Fig. 13 Facial reconstruction of the skull demonstrating the type of deformation

on the 3D printing skull [28]. Another study lead by Wilkinson et al. [29] used the combination of Manchester Method, which is as mentioned one of the most used methods in this field, and digital techniques for the facial reconstruction of the Egyptian Pharaoh Ramesses II. Furthermore, a study conducted by Milani et al. [30] focused on the facial reconstruction of the famous Italian poet Dante Alighieri, whose mandible was missing as the case in this study. The researchers made a digital copy of the skull and created a 3D standard mandible model based on indexes [30]. However, this study adopts an approach different from the methods used in many facial reconstruction studies, especially from the Manchester Method. Unlike the Manchester Method, our approach has removed the positioning of the main muscles of the face (shown in red in Fig. 3) since they do not significantly affect the final depiction of the face. This approach is a digital process and is more strongly linked to data interpolation related to the external surface of the face. Hence, the soft tissue thickness markers have been kept (shown in yellow in Fig. 3). In addition, the lateral projection of the nose and the anatomical deformation and projection of other structures of the skull have been determined based on the statistical data. The prominent advantage of the methodology used in this study is that it is strongly supported by information obtained from computed tomography (CT) scans of living individuals, leaving a little room for the artistic issue in relation to the basic aspect resulting from the interpolation of data. When considering the newest approaches developed by the members of this team, the use of CT scans of living individuals (n = 110) stands out for the lateral projection of the nose and for other parts of the skull and soft tissue (ranging from n = 68 to n = 105, simplified table with all used data can be accessed here https://bit.ly/3NRw2KW, from [31]). The sample used in our approach comprises a group including people from different countries and ancestries, containing average and proportion data that allows a projection analyzing both parameters to deliver a statistically coherent approximation. In addition, such data obtained from the CT scans of living individuals also allows for a creation of the Virtual Donor Library from which the appropriate mandible was chosen to complete the skull in this study. Considering the study of Milani et al. [30], this method offers an alternative way to complete missing parts of the skull required for the facial reconstruction.

Conclusion

This study presents the facial reconstruction of a deformed skull from the archaeological site of Juliopolis. The authors chose this skull since it has the importance of being the only known deformed skull belonging to the Roman period in Anatolia. The 3D modelling of the skull was already displayed in a public archaeology event called the Faces of Juliopolis Exhibition, where it appealed to many visitors due to its unique feature. The facial reconstruction of this deformed female skull will demonstrate the way towards how the past people of Juliopolis may have looked like. Moreover, it provides an example for how to complete missing parts of a sample, such as the lower jaw (*mandibula*) in this case, using appropriate digital data which may serve as an example for future studies.

The benefit of facial reconstruction, as a digital tool used in archaeological and anthropological works, is especially important since it not only makes it possible to digitize the archaeological and/or anthropological data, but it also provides insight into how the people from the past looked. By reconstructing the faces of our ancestors, archaeologists and researchers are able to humanize history and connect us to those who lived long ago [10, 11, 26]. In addition, it is a way of preserving and presenting anthropological data come from archaeological context. It is important to note here that facial reconstruction is a speculative process, and the results should be considered as an approximation rather than an accurate representation of the subject. However, one should be aware of that in archaeological research identifying the face is rarely the main goal and recreating the most plausible depiction may be more crucial than establishing an individual's identity [6]. Yet, the reconstructions appeal to the audience and may somehow encourage them to seek more information and learn about the presented subject.

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Author contributions
ES, CM and EB wrote the main manuscript text. ES and CM prepared Figs. 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11 and 12. All authors reviewed the manuscript. All authors contributed to the study conception and design. Material preparation, data collection and analysis were performed by ES and CM. The first draft of the manuscript was written by ES, CM and EB and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

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Availability of data and materials
All data generated and analysed in this study are included in the article.

Declarations

Ethics approval and consent to participate
Not applicable.

Consent for publication
All authors have granted their consent for the publication of this paper.

Competing interests
The authors declare that they have no competing financial or personal interests that could have appeared to influence this paper.

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References

1. Shott M. Digitizing archaeology: a subtle revolution in analysis. World Archaeol. 2014;46:1–9. https://doi.org/10.1080/00438243.2013.879046.
2. Cowgill GL. Computer applications in archaeology. Comput Humanit. 1967;2:17–23.
3. Wrobel GD, Biggs JA, Hair AL. Digital modeling for bioarchaeologists. Adv Archaeol Pract. 2019;7:47–54. https://doi.org/10.1017/aap.2018.47.
4. Bruno F, Bruno S, De Sensi G, Luchi M, Mancuso S, Muzzupappa M. From 3D reconstruction to virtual reality: a complete methodology for digital archaeological exhibition. J Cult Herit. 2010;11:42–9. https://doi.org/10.1016/j.culher.2009.02.006.
5. Guleria A, Krishan K, Sharma V, Kanchan T. Methods of forensic facial reconstruction and human identification: historical background, significance, and limitations. Sci Nat. 2023;100:8. https://doi.org/10.1007/s00114-023-01838-9.
6. Wilkinson C. Facial reconstruction—anatomical art or artistic anatomy? J Anat. 2010;216:235–50. https://doi.org/10.1111/j.1469-7580.2009.01182.x.
7. Mesejo P, Martos R, Ibáñez Ó, Novo J, Ortega M. A survey on artificial intelligence techniques for biomedical image analysis in skeleton-based forensic human identification. Appl Sci. 2020;10:4703. https://doi.org/10.3390/app10144703.
8. Gupta S, Gupta V, Vij H, Vij R, Tyagi N. Forensic facial reconstruction: the final frontier. J Clin Diagn Res. 2015;9:26–8. https://doi.org/10.7860/JCDR/2015/14621.6568.
9. Balueva TS, Veselovskaya EV, Rasskazova AV. A comparison of the medieval and modern population of the Novgorod region, based on facial reconstruction. Archaeol Anthropol Eurasia. 2010;38:135–44. https://doi.org/10.1016/j.aeae.2010.10.013.
10. Stavrianos C, Stavrianou I, Zouloumis L, Mastagas D. An introduction to facial reconstruction. Balkan J Stomatol. 2007;11:76–83.
11. Verzé L. History of facial reconstruction. Acta Biomed. 2009;80:5–12.
12. Sağır E, Metin M, Cinemre O. Juliopolis necropolis 2012 excavation [Juliopolis Nekropolü 2012 Yılı Kazısı]. In: Özme A, editor. 23rd museum studies and salvage excavations symposium [23. Müze Çalışmaları ve Kurtarma Kazıları Sempozyumu]. Ankara: Merkez Repro Basım Yayın Ltd. 2015. p. 151–70. (**in Turkish**).
13. Büyükkarakaya AM, Alpagut A, Çubukçu E, Cavalli F. Juliopolis (Iuliopolis) anthropological research: preliminary results. J Ankara Stud. 2018;6:111–26. https://doi.org/10.5505/jas.2018.43433.
14. Arslan M, Metin M, Cinemre MO, Çelik T, Türkmen M. Juliopolis necropolis 2010 excavations [Juliopolis Nekropolü 2010 Yılı Kazı Çalışmaları]. In: Özme A, editor. 20th museum studies and salvage excavations symposium [20. Müze Çalışmaları ve Kurtarma Sempozyumu]. Ankara: İsmail Aygül Ofset Matbaacılık San. Tic. Ltd. 2012. p. 169–88. (**in Turkish**).
15. Buikstra JE, Ubelaker DH. Standards for data collection from human skeletal remains. Fayetville: Arkansas Archaeological Survey; 1994.
16. Nikita E. Osteoarchaeology: a guide to the macroscopic study of human skeletal remains. London: Academic Press; 2017.
17. Eroğlu S. An example of Roman deformation in Anatolia [Anadolu'Da Roma Dönemine Ait Bir Deformasyon Örneği (in Turkish)]. In: Büyükkarakaya AM, editor Julipolis band I. Ankara: Koç Üniversitesi Yayınları. (**in press**).
18. Cocilovo JA, Varela HH, O'Brien TG. Effects of artificial deformation on cranial morphogenesis in the South Central Andes. Int J Osteoarchaeol. 2016;21:300–12. https://doi.org/10.1002/oa.1141.
19. Molnar M, Janos I, Szucz L, Szatmary L. Artificially deformed crania from the Hun-Germanic period (5th–6th century AD) in Northeastern Hungary: historical and morphological analysis. NeuroSurg Focus. 2014;36:1–9. https://doi.org/10.3171/2014.1.focus13466.
20. Abdullah JY, Moraes C, Saidin M, Rajion ZA, Hadi H, Shahidan S, et al. Forensic approximation of 5000-year-old female skull from Shell Midden in Guar Kepah, Malaysia. Appl Sci. 2022;12(15): 7871. https://doi.org/10.3390/app12157871.
21. Lauria G, Sineo L, Ficarra S. A detailed method for creating digital 3D models of human crania: an example of close-range photogrammetry based on the use of structure-from-motion (SfM) in virtual anthropology. Archaeol Anthropol Sci. 2022;14:42. https://doi.org/10.1007/s12520-022-01502-9.
22. Moraes C, Sindelar J, Drbal K. The forensic facial approximation of Mladec skull 1. OrtogOnLineMag. 2022.
23. Caple JS, Stephan CN. A standardized nomenclature for craniofacial and facial anthropometry. Int J Legal Med. 2016. https://doi.org/10.1007/s00414-015-1292-1.
24. Moraes C, Bezzi L, Carrara N. The 3D digital facial approximation of Saint Anthony of Padua. Digit Appl Archaeol Cult Herit. 2022;28:1–6. https://doi.org/10.1016/j.daach.2022.e00255.
25. Stephan CN. Facial approximation: a review of the current state of play for archaeologists. Int J Osteoarchaeol. 2005;15(4):298–302. https://doi.org/10.1002/oa.787.
26. Sangkhro R, Sankhla MS, Sharma A, Kumar R. 3D forensic facial reconstruction: a review of the traditional sculpting methods and recent computerized developments. Int J Forensic Sci. 2018;3(1): 000134. https://doi.org/10.23880/ijfsc-16000134.
27. Hwang HS, Kim K, Moon DN, Kim JH, Wilkinson C. Reproducibility of facial soft tissue thickness for craniofacial reconstruction using cone-beam CT images. J Forensic Sci. 2012;57(2):443–8. https://doi.org/10.1111/j.1556-4029.2011.02007.x.
28. Kustar A, Gerber D, Fabian S, Köhler K, Mende BG, Szecenyi-Nagy A, Kiss V. Facial reconstruction of an early bronze age woman from Balatonkeresztur (West-Hungary). Antaeus: Communicationes Ex Instituto Archaeologico Academiae Scientiarum Hungaricae 38. Academie Scientarium Hungaricae; 2022.
29. Wilkinson CM, Saleem SN, Liu CY, Roughley M. Revealing the face of Ramesses II through computed tomography, digital 3D facial reconstruction and computer-generated imagery. J Archaeol Sci. 2023;160: 105884. https://doi.org/10.1016/j.jas.2023.105884.
30. Milani C, Zangari F, Cilli E, Gruppioni G. The facial reconstruction of Dante Alighieri using linear cranial measurements to predict his missing mandible. Digit Appl Archaeol Cult Herit. 2022. https://doi.org/10.1016/j.daach.2022.e00242.
31. Moraes C, Suharschi I. Mensuração de Dados Faciais Ortográficos em Moldavos e Comparação com Outras Populações (version 1). Figshare. 2022. https://doi.org/10.6084/m9.figshare.20089754.v1.

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